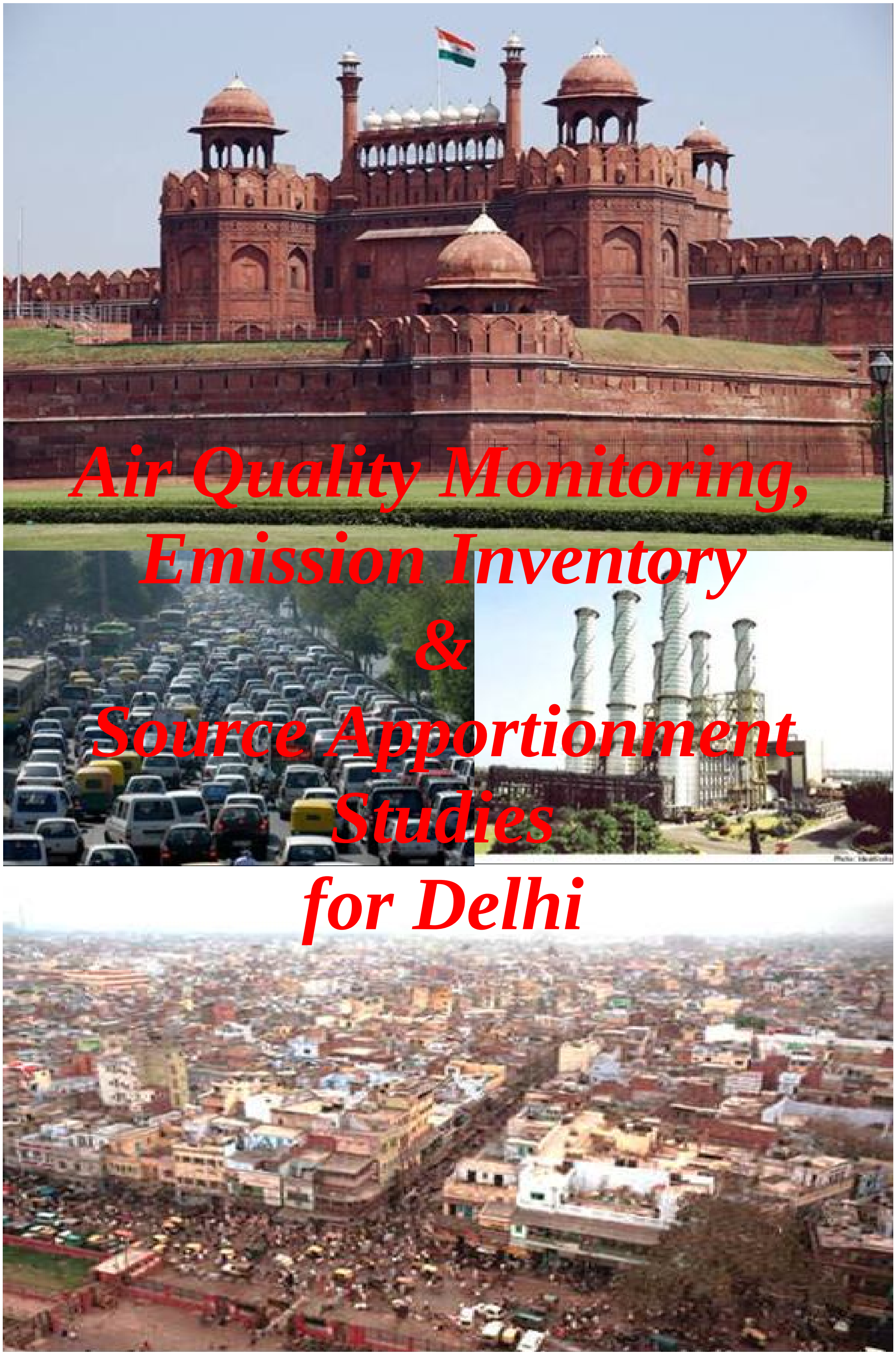


Air Quality Monitoring, Emission Inventory & Source Apportionment Studies for Delhi

NEERI, Nagpur

CONTENTS

No.	Title	Pages
Executive Summary		
Chapter 1 : Introduction		
1.1	Background of the Study	1.1
1.2	Description of the Study Region (Delhi)	1.1
1.3	Ambient Air Quality Status : Other Monitoring Progammes	1.2
1.4	Need for the Study	1.8
1.5	Objectives	1.9
1.6	Approach to the Study	1.9
1.6.1	Ambient Air Quality Monitoring	1.11
1.6.2	Emission Inventory	1.11
1.6.3	Dispersion Modeling	1.13
1.6.4	Source Apportionment Analysis	1.13
1.6.4.1	Based on Emission Load	1.13
1.6.4.2	Based on Air Quality	1.14
1.7	Deliverables	1.16
1.8	Report Structure	1.17
Chapter 2 : Air Quality Status – Delhi		
2.1	Introduction	2.1
2.2	Methodology	2.1
2.2.1	Sampling Sites	2.1
2.2.2	Monitoring Parameters	2.3
2.3	Ambient Air Quality Monitoring	2.6
2.3.1	Prahladpur (Reference/Background)	2.7
2.3.2	Pitampura	2.16
2.3.3	Naraina (Mixed Use)	2.25
2.3.4	SSI-GTK (Industrial)	2.35
2.3.5	Ashram Chowk	2.44
2.3.6	Dhulakuan	2.54
2.3.7	Mayapuri (Lajwanti Garden Chowk)	2.63
2.3.8	Anand Vihar	2.73
2.3.9	ISBT	2.82
2.3.10	Loni Road (Kerb Site)	2.91
2.3.11	Correlation Matrix of Sources	2.100
2.3.12	Comparison of Ten Sites	2.110
2.3.13	Mass Closure at Ten Sites	2.112
2.3.	Molecular Marker Analysis	2.114
Chapter 3 ; Emission Inventory		
3.0	Introduction	3.1
3.1	Emission Inventory of 2 km x 2 km Study Zones	3.2
3.1.1	Emission Inventory: Area Sources	3.2
3.1.1.1	Approach and Methodology	3.2

3.1.1.2 Collection of Secondary Data 3.3
3.1.1.3 Collection of Primary Data 3.3
3.1.1.4 Data Analysis and Emission Load Estimation 3.4
3.1.1.5 Emission Factors 3.4
3.1.1.6 Data Analysis 3.5
3.1.1.7 Emission Load Estimation 3.6
3.1.2 Emission Inventory: Industrial Sources 3.23
3.1.2.1 Approach/Methodology 3.24
3.1.2.2 Collection of Primary and Secondary Data and Data Analysis 3.24
3.1.2.3 Emissions Estimations 3.29
3.1.3 Emission Inventory: Vehicular Sources 3.37
3.1.3.1 Vehicular Growth and Present Population 3.38
3.1.3.2 Primary Data Collection Elements and Methodology 3.39
3.1.3.3 Survey of Passenger and Goods Vehicles 3.44
3.1.3.4 Approach for Analysis of Data and Emission Load Estimation 3.45
3.1.3.5 Applicable Emission Factors 3.46
3.1.3.6 Analysis of Primary Data 3.46
3.1.3.7 Emission Load Estimation in 2 km x 2 km Study Zone 3.52
3.1.3.8 Vehicular Emission Load 3.57
3.1.4 Contribution of Paved Road Dust Due to Traffic Movement 3.62
3.2 Vehicle Emissions Status for Ten Study Zones 3.64
3.3 City Level Emission Inventory 3.67
3.3.1 Emission Inventory: Area Source 3.67
3.3.1.1 Approach and Methodology 3.67
3.3.1.2 Emission Estimates 3.70
3.3.2 Emission Inventory: Industrial Sources 3.83
3.3.2.1 Approach and Methodology 3.83
3.3.2.2 Data Analysis 3.84
3.3.2.3 Data Constraints and Assumptions 3.98
3.3.3 City Level Emission Inventory: Vehicular Sources 3.98
3.3.3.1 Approach and Methodology 3.98
3.3.3.2 Summary of Emission Loads 3.102
3.4 Summary of Contribution of Various Sources to Total City Emissions 3.105
3.4.1 Study Zone-wise 3.105
3.4.2 Delhi City 3.106

Chapter 4 : Receptor Modeling

4.0 Introduction 4.1
4.1 Source Apportionment 4.1
4.1.1 Factor Analysis: Introduction & Methodology 4.2
4.1.1 Factor Analysis 4.5
4.1.2 Chemical Mass Balance (CMB 8.2) Modeling : Introduction & Methodology 4.5

4.1.2.1 CMB Application to PM 10 source apportionment 4.7
4.1.2.2 CMB Result 4.7
4.2 Summary and Conclusions 4.14

Chapter 5 : Dispersion Modeling: Existing Scenario

5.1 Introduction 5.1
5.1.1 Model Description 5.1
5.1.2 Modeling Domain 5.2
5.2 Emission Loads 5.4
5.3 Meteorological Data 5.4
5.4 Model Output – Concentration Profiles 5.6
5.4.1 Model Results for 2 km x 2 km Study Zones 5.6
5.4.2 Comparison of Predicted and Measured Concentrations (2 km x 2 km Modeling) 5.7
5.4.3 Influence of Other Emission Sources (beyond 2 km x 2 km) on Predicted Values 5.9
5.5 City Level Modeling 5.12
5.6 Conclusions 5.17
5.6.1 2 km x 2 km Study Zones (10 locations) 5.17

Chapter 6 : Future Projections and Evaluation of Control Options

6.1 Introduction 6.1
6.2 Emission Load Projections under BAU (2012 & 2017) Scenarios 6.1
6.2.1 Emission Load Projections: Area Sources 6.1
6.2.2 Emission Load Projections: Industrial Sources 6.6
6.2.3 Emission Load Projections: Vehicular Sources and Road Dust Re-suspension 6.10
6.3 Air Quality Projections under Business as usual (2012 & 2017) Scenarios 6.12
6.3.1 Model Results – Occurrence of Maximum GLC in the city and at Ten sites 6.12
6.3.2 Model Results - Iso-concentration Plots 6.16
6.4 Emission Control Options and Analysis 6.30
6.4.1 Area Sources 6.30
6.4.1.1 Methodology, Assumptions and Control Options 6.30
6.4.1.2 Emission Load Projection for 2012 and 2017 under Control Option Scenario 6.33
6.4.1.3 Air Quality Modeling under Control Scenarios (2012 & 2017) – Area Sources 6.37
6.4.2 Point Sources 6.38
6.4.2.1 Emission Load Projection for 2012 and 2017 6.39
6.4.2.2 Air Quality Modeling under Control Scenarios – Point Sources 6.46
6.4.3 Vehicular Sources and Road dust Re-suspension 6.49
6.4.3.1 Vehicular Pollution Control Measures: Current Scenario 6.49
6.4.3.2 Various Control Options Considered in the Present Study 6.50

6.4.3.3 Evaluation of Vehicular Control Options 6.53
6.4.3.4 Suggested Measures for Control of Vehicular Pollution 6.58
6.4.3.5 Suggested Measures for Control of Road Dust Re-suspension 6.60
6.4.3.6 Anticipated Benefits of Suggested Control Measures: Air Quality Modeling 6.61
6.5 Conclusions 6.66
6.5.1 Area Sources 6.66
6.5.2 Industrial Sources 6.66
6.5.3 Vehicular Sources (including Road Dust Re-suspension) 6.67

Chapter 7 : Prioritization of Management/Control Options
7.0 Introduction 7.1
7.1 Control Options : Future Scenarios 7.2
7.1.1 Area Sources 7.3
7.1.2 Industrial Sources 7.4
7.1.3 Vehicular Sources 7.4
7.2 Prioritized List of Management/ Control Options 7.12
7.3 Anticipated Benefits 7.26
7.4 Additional Measures for Sustainable Delhi Air Quality Plans 7.28
7.4.1 Industrial 7.29
7.4.2 Vehicular 7.30
7.4.3 Area Source 7.32
7.5 Major Recommendations 7.33
7.5.1 Recommended Action for Vehicular Sector 7.33
7.5.1.1 Fuel Issues 7.34
7.5.1.2 Fuel Adulteration 7.34
7.5.1.3 Fuel Alternatives 7.35
7.5.1.4 Engine Technology 7.36
7.5.1.5 Fitment of Emission Control Technology 7.37
7.5.1.6 Phasing out of the Vehicles 7.38
7.5.1.7 Inspection and Maintenance/ Certification 7.39
7.5.1.8 Roads and Pavement 7.39
7.5.1.9 Transportation Planning and New Roads 7.40
7.5.1.10 Traffic Management 7.40
7.5.1.11 Policy Level Instruments 7.41
7.5.1.12 Prioritization of Public Transport on Roads 7.41
7.5.1.13 Incentive/ Subsidy for Better Compliance towards I&M 7.42
7.5.1.14 Drivers & Mechanics Training Programme 7.43
7.5.2 Recommendations for Industrial Sector 7.43
7.5.3 Recommendations for Area Sector 7.43
7.6 Summary 7.45

Chapter 8 : Highlights and Recommendations
8.1 Need for the study 8.1
8.2 Objectives 8.2
8.3 Approach to the Study 8.2
8.4 Ambient Air Quality Status in Delhi 8.5

8.5 Emission Inventory 8.7
8.6 Receptor Modeling 8.9
8.7 Dispersion Modeling: Existing Scenario 8.11
8.8 Future Projections under BAU Scenarios for 2012 and 2017 8.15
8.8.1 Prominent Sources of Air Pollution 8.15
8.8.1.1 Area Sources 8.15
8.8.1.2 Industrial Sources 8.15
8.8.1.3 Vehicular Sources 8.15
8.9 Evaluation of Control options for 2012 and 2017 8.19
8.10 Preferred Scenario 8.22
8.10.1 Dispersion Modeling for Select Control Options for Preferred Scenarios 8.22
8.11 Anticipated Benefits of Preferred Scenario 8.23
8.12 Action Plan –Prioritized list of Management/Control options 8.25
8.13 Recommendations 8.26

Annexures

Ann_2.1 Correlation Matrix of Fine Particulate Matter at Different Sites A2.1.1
Ann_2.2 Observed Concentrations of Ambient Air Quality A2.2.1
Ann_2.3 Average Concentration of Molecular Markers at Ten Different Sites during Three Seasons A2.3.1
Ann_3.1 Emission Factors A3.1
Ann_3.2 Grid-wise Emission Load A3.4
Ann_3.3 Questionnaire for Survey A3.22
Ann_4.1.1a Factor loading matrix A4.1
Ann_4.1.1b Factor analysis results A4.28
Ann_4.1.2a Statistical measures of CMB model performance for PM10 A4.33
Ann_4.1.2b Daily source contribution estimates using CMB 8.2 for PM10 A4.40
Ann_5.1 Emission Loads/Rates for 2 km x 2 km Study Zones: Existing Scenario A5.1
Ann_5.2 Emission Loads for Delhi City - Existing Scenario A5.5
Ann_5.3 Wind rose Diagrams during Different Seasons for 10 Study Zones A5.20
Ann_5.4 Modeling Results – Predicted Highest Ten GLCs for 2km x 2km Study Zones A5.29
Ann_5.5 Modeling Results – Predicted First 10 Highest GLC for Delhi – Existing Scenario A5.56
Ann_6.1 Modeling Results – Predicted Highest Ten GLCs under BAU Scenarios A6.1
Ann_6.2 Model Results – Evaluation of Control Options A6.10

LIST OF FIGURES

1.1	Trends in Annual Average Concentration of RSPM in Residential Areas of Delhi and Vehicle Growth During 2001 -2006	1.3
1.2	Monthly variation in RSPM levels monitored by NEERI during 2006	1.3
1.3	Trends in Annual Average Concentration of SO_2 in Residential areas and Percent Sulphur Reduction in Diesel from 1995-2006	1.4
1.4	Monthly variation in SO_2 levels monitored by NEERI during 2006	1.4
1.5	Trends in Annual Average Concentration of NO_2 in Residential Areas of Delhi	1.5
1.6	Levels of NO_2 in Delhi for the Year 2006	1.5
1.7	Monitoring Results at CPCB's Sites	1.6
1.8	Framework for Air Quality Monitoring and Emission Source Apportionment Studies	1.10
1.9	Approach to Emission Inventory	1.12
1.10	Approach to Scheme of Source Apportionment	1.15
2.1	Location of sampling sites in the city	2.2
2.2	Study Zone (2 km x 2 km): Prahladpur	2.7
2.3	Observed Concentration of SPM, RSPM and PM_{10} at Prahladpur in all three seasons	2.9
2.4	Observed Concentration of SO_2 and NO_2 at Prahladpur in all three seasons	2.10
2.5	Concentration of $PM_{2.5}$ at Prahladpur	2.11
2.6	Observed CO concentration at Prahladpur in all three season	2.11
2.7	Observed CH_4, NMHC and THC concentration at Prahladpur in all three seasons	2.12
2.8	Diurnal Variation in NO_2 and Ozone at Prahladpur	2.13
2.9	24 hourly trends of OC, EC and TC at Prahladpur	2.14
2.10	Percent Mass Closure of PM_{10} at Prahladpur in three seasons	2.15
2.11	Study Zone (2 km x 2 km): Pitampura	2.16
2.12	Observed Concentration of SPM, RSPM and PM_{10} at Pitampura in all three seasons	2.18
2.13	Observed Concentration of SO_2 and NO_2 at Pitampura in all three seasons	2.19
2.14	Concentration of $PM_{2.5}$ at Pitampura	2.20
2.15	Observed CO concentration at Pitampura in all three seasons	2.20
2.16	Observed CH_4, NMHC and THC concentration at Pitampura in all three seasons	2.21
2.17	Diurnal Variation in NO_2 and Ozone at Pitampura	2.22
2.18	24 hourly trends of OC, EC and TC at Pitampura	2.23
2.19	Percent Mass Closure of PM_{10} at Pitampura in three seasons	2.24
2.20	Study Zone (2 km x 2 km): Naraina	2.25
2.21	Observed Concentration of SPM, RSPM and PM_{10} at Naraina in all three seasons	2.27
2.22	Observed Concentration of SO_2 and NO_2 at Naraina in all three seasons	2.28
2.23	Concentration of $PM_{2.5}$ at Naraina Site	2.29
2.24	Observed CO concentration at Naraina in all three seasons	2.30

2.25 Observed CH_4, NMHC and THC concentration at Naraina in all three seasons 2.30
2.26 Diurnal Variation in NO_2 and Ozone at Naraina 2.31
2.27 24 hourly trends of OC, EC and TC at Naraina 2.32
2.28 Percent Mass Closure of PM_{10} at Naraina in three seasons 2.34
2.29 Study Zone (2 km x 2 km): SSI-GTK 2.35
2.30 Observed Concentration of SPM, RSPM and PM_{10} at Pitampura in all three seasons 2.37
2.31 Observed Concentration of SO_2 and NO_2 at SSI – GTK in all three seasons 2.38
2.32 Concentration of $PM_{2.5}$ at SSI -GTK 2.39
2.33 Observed CO concentration at SSI –GTK in all three seasons 2.39
2.34 Observed CH_4, NMHC and THC concentration at SSI- GTK in all three seasons 2.40
2.35 Diurnal Variation in NO_2 and Ozone at SSI-GTK 2.41
2.36 24 hourly trends of OC, EC and TC at SSI-GTK 2.42
2.37 Percent Mass Closure of PM_{10} at SSI –GTK in three seasons 2.43
2.38 Study Zone (2 km x 2 km): Ashram Chowk 2.44
2.39 Observed Concentration of SPM, RSPM and PM_{10} at Ashram Chowk in all three seasons 2.46
2.40 Observed Concentration of SO_2 and NO_2 at Ashram Chowk in all three seasons 2.47
2.41 Concentration of $PM_{2.5}$ at Ashram Chowk 2.48
2.42 Observed CO concentration at Ashram Chowk in all three seasons 2.49
2.43 Observed CH_4, NMHC and THC concentration at Ashram Chowk in all three seasons 2.49
2.44 Diurnal Variation in NO_2 and Ozone at Ashram Chowk 2.50
2.45 24 hourly trends of OC, EC and TC at Ashram Chowk 2.51
2.46 Percent Mass of PM_{10} at Ashram Chowk 2.53
2.47 Study Zone (2 km x 2 km): Dhaula Kuan 2.54
2.48 Observed Concentration of SPM, RSPM and PM_{10} at Dhaula Kuan in all three seasons 2.56
2.49 Observed Concentration of SO_2 and NO_2 at Dhaula Kuan in all three seasons 2.57
2.50 Concentration of PM2.5 at Dhaula Kuan 2.58
2.51 Observed CO concentration at Dhaula Kuan in all three seasons 2.59
2.52 Observed CH_4, NMHC and THC concentration at Dhaula Kuan in all three seasons 2.59
2.53 Diurnal Variation in NO_2 and Ozone at Dhaula Kuan 2.60
2.54 24 hourly trends of OC, EC and TC at Dhaula Kuan 2.61
2.55 Percent Mass of PM_{10} at Dhaula Kuan 2.62
2.56 2 km x 2 km Study Zone: Mayapuri 2.63
2.57 Observed Concentration of SPM, RSPM and PM_{10} at Mayapuri in all three seasons 2.65
2.58 Observed Concentration of SO_2 and NO_2 at Mayapuri in all three seasons 2.66

2.59	Concentration of $PM_{2.5}$ at Mayapuri Site	2.67
2.60	Observed CO concentration at Maypauri in all three seasons	2.68
2.61	Observed CH_4, NMHC and THC concentration at Maypuri in all three seasons	2.68
2.62	Diurnal Variation in NO_2 and Ozone at Mayapuri	2.70
2.63	24 hourly trends of OC, EC and TC at Mayapuri	2.71
2.64	Percent Mass of PM_{10} at Mayapuri	2.72
2.65	2 km x 2 km Study Zone: Anand Vihar	2.73
2.66	Observed Concentration of SPM, RSPM and PM_{10} at Anand Vihar in all three seasons	2.75
2.67	Observed Concentration of SO_2 and NO_2 at Anand Vihar in all three seasons	2.76
2.68	Concentration of $PM_{2.5}$ at Anand Vihar	2.77
2.69	Observed CO concentration at Anand Vihar in all three seasons	2.78
2.70	Observed CH_4, NMHC and THC concentration at Anand Vihar in all three seasons	2.78
2.71	Diurnal Variation in NO_2 and Ozone at Anand Vihar	2.79
2.72	24 hourly trends of OC, EC and TC at Anand Vihar	2.81
2.73	Percent Mass of PM_{10} at Anand Vihar	2.81
2.74	Study Zone (2 km x 2 km): ISBT	2.82
2.75	Observed Concentration of SPM, RSPM and PM_{10} at ISBT in all three seasons	2.84
2.76	Observed Concentration of SO_2 and NO_2 at ISBT in all three seasons	2.85
2.77	Concentration of $PM_{2.5}$ at ISBT Site	2.86
2.78	Observed CO concentration at ISBT in all three seasons	2.87
2.79	Observed CH_4, NMHC and THC concentration at ISBT in all three seasons	2.87
2.80	Diurnal Variation in NO_2 and Ozone at ISBT	2.88
2.81	24 hourly trends of OC, EC and TC at ISBT	2.90
2.82	Percent Mass of PM_{10} at ISBT	2.90
2.83	Study Zone (2 km x 2 km): Loni Road	2.91
2.84	Observed Concentration of SPM, RSPM and PM_{10} at Loni Road in all three seasons	2.94
2.85	Observed Concentration of SO_2 and NO_2 at Loni Road in all three seasons	2.94
2.86	Concentration of $PM_{2.5}$ at Loni Road	2.95
2.87	Observed CO concentration at Loni Road in all three seasons	2.95
2.88	Observed CH_4, NMHC and THC concentration at Loni Road in all three seasons	2.96
2.89	Diurnal Variation in NO_2 and Ozone at Loni Road	2.97
2.90	24 hourly trends of OC, EC and TC at Loni Road	2.98
2.91	Percent mass of PM_{10} at Loni Road	2.99
2.92	Average Concentration of Particulate and Gaseous Pollutants at Ten Sites	2.110

2.93	Average Concentration of Carbonaceous Species in PM_{10}	2.111
2.94	Molecular Markers Concentrations at all Sites in Delhi	2.115
3.1	Contribution of Emissions from various Area Source Activities: Ashram Chowk	3.13
3.2	Contribution of Emissions from various Area Source Activities: ISBT	3.14
3.3	Contribution of Emissions from various Area Source Activities: Dhaula Kuan	3.15
3.4	Contribution of Emissions from various Area Source Activities: Mayapuri	3.16
3.5	Contribution of Emissions from various Area Source Activities: Anand Vihar	3.17
3.6	Contribution of Emissions from various Area Source Activities: Loni Road	3.18
3.7	Contribution of Emissions from various Area Source Activities: Pitampura	3.19
3.8	Contribution of Emissions from various Area Source Activities: SSI-GTK	3.20
3.9	Contribution of Emissions from various Area Source Activities: Naraina	3.21
3.10	Contribution of Emissions from various Area Source Activities: Prahladpur	3.22
3.11	Map Showing Location of Power Plants and Medium Scale Industries in Delhi	3.27
3.12	Map Showing Industrial Estates (SSI) in Delhi	3.28
3.13	Percentage Emission Contribution from Industries: Anand Vihar	3.33
3.14	Percentage Emission Contribution from Industries: SSI - GTK	3.34
3.15	Percentage Emission Contribution from Industries: Mayapuri (Lajwanti Garden)	3.35
3.16	Percentage Emission Contribution from Industries: Naraina	3.36
3.17	Share of Different Categories of Registered Vehicles: March 2007	3.39
3.18	Traffic Count Locations within 2km x 2 km Representative Study Zones	3.43
3.19	Average Fleet Composition of Different Types of Roads	3.53
3.20	Road category-wise Percent Share of VKT in each Study Zone	3.56
3.21	Vehicle Category-wise Emission Contribution: Overall Average of all sites	3.61
3.22	Site-wise and Road Category-wise Contribution of Re-suspended Road Dust: PM10 Emissions	3.63
3.23	Site-wise and Road Category-wise Contribution of Re-suspended Road Dust: PM2.5 Emissions	3.63
3.24	Road Category-wise Average Contribution of Re-suspended Road Dust: PM10 & PM2.5 (Average of 10 Sites)	3.64
3.25	Decadal Population Growth in Delhi	3.67
3.26	Ward-wise Map of Delhi	3.68
3.27	Annual Fuel Consumption in Delhi	3.69
3.28	Contribution of Emissions from various Area Source Activities in Delhi	3.79
3.29	Contribution of various Fuels to Area Source Emissions	3.80
3.30	Grid-wise PM Emission Load (kg/d) in Delhi: Area Sources	3.81
3.31	Grid-wise SO_2 Emission Load (kg/d) in Delhi: Area Sources	3.81

3.32	Grid-wise NO_2 Emission Load (kg/d) in Delhi: Area Sources	3.82
3.33	Grid-wise CO Emission Load (kg/d) in Delhi: Area Sources	3.82
3.34	Grid-wise HC Emission Load (kg/d) in Delhi: Area Sources	3.83
3.35	Pollutant-wise % Emissions Contribution of Power Plants: Delhi	3.85
3.36	Emissions Contribution of Medium Scale Industries	3.86
3.37	Pollutant -wise % Emissions contribution from SSI Units: North Zone	3.89
3.38	Pollutant -wise % Emissions contribution from SSI Units: East Zone	3.90
3.39	Pollutant-wise % Emissions contribution from SSI Units: South Zone	3.91
3.40	Pollutant-wise % Emissions contribution from SSI Units: West Zone	3.92
3.41	Pollutant and Category wise % Emissions Contribution of SSI Units	3.93
3.42	Percentage Contribution of Pollutants from Large, Medium and Small Scale Industries for PM10, SO_2, NOx, HC and CO	3.94
3.43	Grid-wise PM10 Emission Load (kg/d) in Delhi: Industrial Sources	3.95
3.44	Grid-wise SO_2 Emission Load (kg/d) in Delhi: Industrial Sources	3.96
3.45	Grid-wise NO_2 Emission Load (kg/d) in Delhi: Industrial Sources	3.96
3.46	Grid-wise HC Emission Load (kg/d) in Delhi: Industrial Sources	3.97
3.47	Grid-wise CO Emission Load (kg/d) in Delhi: Industrial Sources	3.97
3.48	Grid-wise PM Emission Load (kg/d) in Delhi: Vehicular Sources	3.99
3.49	Grid-wise CO Emission Load (kg/d) in Delhi: Vehicular Sources	3.99
3.50	Grid-wise HC Emission Load (kg/d) in Delhi: Vehicular Sources	3.100
3.51	Grid-wise NOx Emission Load (kg/d) in Delhi: Vehicular Sources	3.100
3.52	Grid-wise SO_2 Emission Load (kg/d) in Delhi: Vehicular Sources	3.101
3.53	Grid-wise Road Dust PM10 Emission Load (kg/d) in Delhi	3.101
3.54	Grid-wise Road Dust PM2.5 Emission Load (kg/d) in Delhi	3.102
3.55	Identified Hotspots (Highest Polluting Grids)	3.104
3.56	Percent Contribution of Different Source Categories to Total Emission Loads: Delhi	3.107
3.57	Percent Contribution of Different Sources in Total Pollution Load	3.108
4.1	Source contribution estimates using CMB model	4.8
4.2	Source contribution estimates using CMB model	4.9
4.3	Source contribution estimates using CMB model	4.9
4.4	Source contribution estimates using CMB model	4.11
4.5	Source contribution estimates using CMB model	4.12
5.1	Schematic Diagram showing Distribution of Grids along with Coordinates in a 2km x 2 km Study Zone	5.3
5.2	Distribution of Grids (as per Eicher Map) in Delhi with marked Study Zone and Grid Coordinates (in km)	5.4
5.3	Comparison of Predicted PM Concentrations from All the Sources in Different Seasons: Existing Scenario	5.6
5.4	Comparison of Predicted NOx Concentrations from All the Sources in Different Seasons: Existing Scenario	5.7
5.5	Comparison of Predicted and Measured PM and NOx GLCs at 10 AQM Sites during Summer, Post Monsoon and Winter: Existing Scenario	5.8
5.6	Comparison of Predicted GLCs with Measured Concentrations at 10 AQM Sites during Winter: PM (Existing Scenario)	5.9

5.7 Comparison of Predicted NOx GLCs and Measured NO_2 Concentrations at AQM Sites during Winter: NO_2 (Existing Scenario) 5.10
5.8 Site-wise Percent Variation in Predicted PM Concentrations with respect to Measured PM10 Values: Winter (Existing Scenario) 5.11
5.9 Site-wise Percent Variation in Predicted NOx Concentrations with respect to Measured NO_2 Values: Winter (Existing Scenario) 5.11
5.10 Iso-concentration Plots for PM from Area, Point, Line, Road Dust Re-suspension and their Cumulative Impact during Summer, Post Monsoon and Winter (Existing Scenario) 5.14
5.11 Iso-concentration Plots for NOx from Area, Point, Line and their Cumulative Impact during Summer, Post Monsoon and Winter (Existing Scenario) 5.15
5.12 Iso-concentration Plots for SO_2 from Area, Point, Line and their Cumulative Impact during Summer, Post Monsoon and Winter (Existing Scenario) 5.16
6.1 Percent Increase in Area Source Emissions in Delhi: BAU Scenario 2012 & 2017 6.3
6.2 Grid-wise Area Source PM10 Emission Load (kg/d): BAU Scenario 2012 6.3
6.3 Grid-wise Area Source PM10 Emission Load (kg/d): BAU Scenario 2017 6.4
6.4 Grid-wise Area Source SO_2 Emission Load (kg/d): BAU Scenario 2012 6.4
6.5 Grid-wise Area Source SO_2 Emission Load (kg/d): BAU Scenario 2017 6.5
6.6 Grid-wise Area Source NOx Emission Load (kg/d): BAU Scenario 2012 6.5
6.7 Grid-wise Area Source NOx Emission Load (kg/d): BAU Scenario 2017 6.6
6.8 Grid-wise Industrial Source PM10 Emission Load (kg/d): 2012 6.7
6.9 Grid-wise Industrial Source PM10 Emission Load (kg/d): 2017 6.8
6.10 Grid-wise Industrial Source SO_2 Emission Load (kg/d): 2012 6.8
6.11 Grid-wise Industrial Source SO_2 Emission Load (kg/d): 2017 6.9
6.12 Grid-wise Industrial Source NOx Emission Load (kg/d): 2012 6.9
6.13 Grid-wise Industrial NOx Source Emission Load (kg/d): 2017 6.10
6.14 Percentage Increase in Emission Loads (Vehicular & Road Dust): 2012 and 2017 6.12
6.15 Predicted Iso-concentration Plots for PM: 2012 & 2017 BAU Scenarios – Area Sources 6.17
6.16 Predicted Iso-concentration Plots for SO_2: 2012 & 2017 BAU Scenarios – Area Sources 6.18
6.17 Predicted Iso-concentration Plots for NOx: 2012 & 2017 BAU Scenarios – Area Sources 6.19
6.18 Predicted Iso-concentration Plots for PM: 2012 & 2017 BAU Scenarios - Industrial Sources 6.20
6.19 Predicted Iso-concentration Plots for SO_2: 2012 & 2017 BAU Scenarios - Industrial Sources 6.21
6.20 Predicted Iso-concentration Plots for NOx: 2012 & 2017 BAU Scenarios - Industrial Sources 6.22
6.21 Predicted Iso-concentration Plots for PM: 2012 & 2017 BAU Scenarios - Vehicular Sources 6.23
6.22 Predicted Iso-concentration Plots for SO_2: 2012 & 2017 BAU Scenarios – Vehicular Sources 6.24
6.23 Predicted Iso-concentration Plots for NOx: 2012 & 2017 BAU Scenarios - Vehicular Sources 6.25

6.24 Predicted Iso-concentration Plots for PM10: 2012 & 2017 BAU Scenarios – Road Dust Re-suspension 6.26
6.25 Predicted Iso-concentration Plots for PM during Different Seasons: 2012 & 2017 BAU Scenarios – Cumulative Impact of All Sources 6.27
6.26 Predicted Iso-concentration Plots for SO_2 during Different Seasons: 2012 & 2017 BAU Scenarios – Cumulative Impact of All Sources 6.28
6.27 Predicted Iso-concentration Plots for NOx during Different Seasons: 2012 & 2017 BAU Scenarios – Cumulative Impact of All Sources 6.29
6.28 Various Zones in Delhi 6.31
6.29 Grid wise PM10 Emissions Rate (kg/d): Area Sources Control Scenario 2012 6.34
6.30 Grid wise PM10 Emissions Rate (kg/d): Area Sources Control Scenario 2017 6.35
6.31 Grid wise SO_2 Emissions Rate (kg/d): Area Sources Control Scenario 2012 6.35
6.32 Grid wise SO_2 Emissions Rate (kg/d): Area Sources Control Scenario 2017 6.36
6.33 Grid wise NOx Emissions Rate (kg/d): Area Sources Control Scenario 2012 6.36
6.34 Grid wise NOx Emissions Rate (kg/d): Area Sources Control Scenario 2017 6.37
6.35 Iso- Concentration Plots for PM, SO_2 and NOx: 2012 & 2017 with Control Option Scenarios (Area Sources) 6.38
6.36 Grid wise PM10 Emissions Load (kg/d): 2012 (Control Equipment Scenario) 6.40
6.37 Grid wise PM10 Emissions Load (kg/d): 2017 (Control Equipment Scenario) 6.41
6.38 Grid wise SO_2 Emissions Load (kg/d): 2012 (Control Equipment Scenario) 6.41
6.39 Grid wise SO_2 Emissions Load (kg/d): 2017 (Control Equipment Scenario) 6.42
6.40 Grid wise NOx Emissions Load (kg/d): 2012 (Control Equipment Scenario) 6.42
6.41 Grid wise NOx Emissions Load (kg/d): 2017 (Control Equipment Scenario) 6.43
6.42 Grid wise PM10 Emissions Load (kg/d): 2012 (Industrial Fuel Change Scenario) 6.43
6.43 Grid wise PM10 Emissions Load (kg/d): 2017 (Industrial Fuel Change Scenario) 6.44
6.44 Grid wise SO_2 Emissions Load (kg/d): 2012 (Industrial Fuel Change Scenario) 6.44
6.45 Grid wise SO_2 Emissions Load (kg/d): 2017 (Industrial Fuel Change Scenario) 6.45
6.46 Grid wise NOx Emissions Load (kg/d): 2012 (Industrial Fuel Change Scenario) 6.45
6.47 Grid wise NOx Emissions Load (kg/d): 2017 (Industrial Fuel Change Scenario) 6.46
6.48 Iso-concentration Plots of Predicted PM, SO_2 & NOx in Delhi: 2012 & 2017 (Industrial Control Equipment Scenario) 6.47
6.49 Iso-concentration Plots of Predicted PM, SO_2 & NOx in Delhi: 2012 & 2017 (Industrial Fuel Change Scenario) 6.48
6.50 Predicted Iso-Concentration Plots in Different Seasons: Vehicular PM - 2012 & 2017 (Control Scenario) 6.62
6.51 Predicted Iso-Concentration Plots in Different Seasons: Vehicular NOx – 2012 & 2017 (Control Scenario) 6.63
6.52 Predicted Iso-Concentration Plots in Different Seasons: Road Dust Re-suspension - 2012 & 2017 (Control Scenario) 6.64

7.1	Predicted Iso-Concentration Plots: PM (All Sources), Preferred Scenarios (1, 2 & 3) – 2012 & 2017	7.10
7.2	Predicted Iso-concentration Plots: NOx (All Sources), Preferred Scenarios (1, 2 & 3) – 2012 & 2017	7.11
8.1	Air Quality Monitoring & Emission Source Apportionment Studies	8.3
8.2	Locations of Ambient Air Quality Monitoring Stations	8.4
8.3	Average Concentration of Particulate and Gaseous Pollutants at Ten Sites	8.5
8.4	Molecular Markers Concentrations at all Sites in Delhi	8.6
8.5	Percent Contribution of Different Source Categories to Total Emission Loads: Delhi	8.8
8.6	Iso-concentration Plots for PM from Area, point, Line, Road Dust Re-suspension and their Cumulative Impact during Summer, Post Monsoon and Winter (Existing Scenario-2007)	8.13
8.7	Iso-concentration Plots for NOx from Area, point, Line, Road Dust Re-suspension and heir Cumulative Impact during Summer, Post Monsoon and Winter (Existing Scenario -2007)	8.14
8.8	Predicted Iso-concentration Plots for PM during Different Seasons: 2012 & 2017 BAU scenarios – Cumulative impact of all sources	8.17
8.9	Predicted Iso-concentration Plots for NOx during Different Seasons: 2012 and 2017 BAU Scenarios – Cumulative Impact of All Sources	8.18

LIST OF TABLES

2.1	Air Quality Monitoring Stations	2.2
2.2	Sampling and Analytical Protocol used in the Study	2.4
2.3	Frequency of Air Pollutants Sampling in Delhi for SA Study	2.6
2.4 a	Air Quality Status at Prahladpur (Summer)	2.8
2.4 b	Air Quality Status at Prahladpur(Post Monsoon)	2.8
2.4 c	Air Quality Status at Prahladpur(Winter)	2.8
2.5	24 Hourly Concentrations of VOCs	2.12
2.6 a	Air Quality Status at Pitampura (Summer)	2.17
2.6 b	Air Quality Status at Pitampura(Post Monsoon)	2.17
2.6 c	Air Quality Status at Pitampura(Winter)	2.17
2.7	24 Hourly Concentrations of VOCs	2.21
2.8 a	Air Quality Status at Naraina (Summer)	2.26
2.8 b	Air Quality Status at Naraina(Post Monsoon)	2.26
2.8 c	Air Quality Status at Naraina(Winter)	2.26
2.9	24 Hourly Concentrations of VOCs	2.30
2.10a	Air Quality Status at SSI-GTK (Summer)	2.36
2.10b	Air Quality Status at SSI-GTK (Post Monsoon)	2.36
2.10c	Air Quality Status at SSI-GTK (Winter)	2.36
2.11	24 Hourly Concentrations of VOCs	2.40
2.12a	Air Quality Status at Ashram Chowk (Summer)	2.45
2.12b	Air Quality Status at Ashram Chowk (Post Monsoon)	2.45
2.12c	Air Quality Status at Ashram Chowk (Winter)	2.45
2.13	24 Hourly Average Concentrations of VOCs	2.49
2.14a	Air Quality Status at Dhaula Kuan (Summer)	2.55
2.14b	Air Quality Status at Dhaula Kuan (Post Monsoon)	2.55
2.14c	Air Quality Status at Dhaula Kuan (Winter)	2.55
2.15	24 Hourly Concentrations of VOCs	2.59
2.16a	Air Quality Status at Mayapuri (Summer)	2.64
2.16b	Air Quality Status at Mayapuri (Post Monsoon)	2.64
2.16c	Air Quality Status at Mayapuri (Winter)	2.64
2.17	24 Hourly Concentrations of VOCs	2.68
2.18a	Air Quality Status at Anand Vihar (Summer)	2.74
2.18b	Air Quality Status at Anand Vihar (Post Monsoon)	2.74
2.18c	Air Quality Status at Anand Vihar (Winter)	2.74
2.19	24 Hourly Concentrations of VOCs	2.78
2.20a	Air Quality Status at ISBT (Summer)	2.83
2.20b	Air Quality Status at ISBT (Post Monsoon)	2.83
2.20c	Air Quality Status at ISBT (Winter)	2.83
2.21	24 Hourly Concentrations of VOCs	2.87
2.22a	Air Quality Status at :Loni Road (Summer)	2.92
2.22b	Air Quality Status at :Loni Road (Post Monsoon)	2.92
2.22c	Air Quality Status at :Loni Road (Winter)	2.92
2.23	24 Hourly Concentrations of VOCs	2.96
2.24	Percent Mass Contribution at Ten Different Sites	2.112

2.25	Average Concentration of Molecular Marker (in ng/m^3) for all three seasons	2.114
2.26	Ratio of Markers and their Variation with reference Station Prahladpur	2.114
3.1	Source Categories and Types of Sources of Air Pollution	3.1
3.2	Type and Sources of Information for Area Source Emission Inventory	3.3
3.3	Various Types of Area Sources around AQM Locations	3.5
3.4	Emissions from Residential Fuel Combustion	3.7
3.5	Emissions from Fuel Combustion in Slums	3.7
3.6	Emissions from Hotel & Restaurants	3.8
3.7	Emissions from Bakeries	3.8
3.8	Emissions from Generator Sets	3.10
3.9	Emissions from Open Burning	3.10
3.10	PM10 Emissions from Construction Activities	3.11
3.11	Emission Load from Locomotives	3.11
3.12	Emission Load from Area Source Activities in the study zones	3.12
3.13	Type and Source of Information: Industrial Sources	3.24
3.14 a	Status of Total Polluting Industries in Delhi	3.25
3.14 b	Status of Air Polluting Industries in Delhi	3.25
3.15	Category wise Breakup of Air Polluting Industries in Delhi	3.26
3.16	Medium Scale Air Polluting Industries in Delhi	3.26
3.17	Study Zone-wise Details of Small Scale industries	3.29
3.18 a	Emissions from Different Small Scale Industries at Anand Vihar	3.30
3.18 b	Emissions from Different Small Scale Industries at SSI-GTK	3.30
3.18 c	Emissions from Different Industries Small Scale at Lajwanti Garden (Mayapuri)	3.31
3.18 d	Emissions from Different Small Scale Industries at Naraina	3.31
3.18 e	Emission Load of SSI Units in 2 km x 2 km Study Zones: Delhi, 2006-07	3.32
3.19	Total VKT and Estimated Pollution Load from Different Vehicles in Delhi	3.38
3.20	Identified Locations for Traffic Count around AQM Sites (Arterial/Ring Road/NH/SH/Major Roads)	3.40
3.21	Additional Traffic Count Locations: Main Roads and Feeder Roads	3.41
3.22	Traffic Classification used in Primary Data Collection	3.42
3.23	Matrix for Passenger and Goods Vehicles Survey	3.44
3.24	Total Motorized Traffic Volume on Different Major Roads in the Study Zone	3.47
3.25	Ten Major Roads with High Traffic Flow	3.48
3.26	Peak Hour Traffic Composition on Major Roads in the Study Zones (24 Hour Traffic Count)	3.49
3.27	Comparison of Peak Hour Traffic Composition on Working and Non-Working Days (Traffic Count on the Roads near AQM Sites)	3.51
3.28	Road Category-wise Total Daily Traffic and Fleet Composition	3.52
3.29	Road Category-wise Total Daily Traffic and Fleet Composition	3.53
3.30	Length of Different Categories of Roads in each Study Zone	3.54
3.31	Road Category-wise Total VKT with % Share of Different Categories of Vehicles	3.55

3.32	Year-wise Composition in Total Fleet	3.57
3.33	Road Category wise Vehicular Emission Load (kg/d) and Percent Share in all the Study Zones and Overall Average	3.58
3.34	Road Category wise Vehicular Emission Load (kg/d) and Percent Share in all the Study Zones and Overall Average	3.59
3.35	Summary of Total Emission Load in Each Study Zone	3.60
3.36	Study Zone and Road Category-wise Estimated Road Dust: PM10 Emissions	3.62
3.37	Study Zone and Road Category-wise Estimated Road Dust: PM2.5 Emissions	3.62
3.38	Pollutant-wise Identified Highest and Lowest Polluting Zones	3.65
3.39	Pollutant-wise Two Vehicle Categories Contributing to Highest Emissions	3.66
3.40	Population in different Types of Settlements	3.69
3.41	Emission Load from Residential Fuel Combustion	3.70
3.42	Emission Load from Slums Fuel Combustion	3.70
3.43	Emission Loads from Hotels & Restaurants	3.71
3.44	Emission Loads from Bakeries	3.71
3.45	Zone-wise Cremation Grounds	3.72
3.46	Registered Deaths in Delhi	3.72
3.47	Emission Load from Crematoria	3.73
3.48	Waste Incineration Facility at various Hospitals/ Private Agencies	3.73
3.49	Emission Load from Waste Incinerators	3.74
3.50	Power Generation in Delhi	3.74
3.51	DG Sets Supplied by Different Suppliers (Total for 10 Years)	3.75
3.52	Emission Load from Generator sets	3.75
3.53	Emission Load from Open Burning	3.76
3.54	PM10 Emission Load from Construction Activities	3.76
3.55	Total Number of Movements of Locomotives	3.77
3.56	Emission Load from Locomotives	3.77
3.57	Total Emission Load from Area Source Activities in Delhi	3.78
3.58	Total Emission Load from Various Fuels used in Delhi	3.78
3.59	Emissions from Power Plants: Delhi, 2006-07	3.84
3.60	Emission Inventory (Medium Scale Industries): Delhi- 2006-07	3.85
3.61	Emissions Inventory of SSI Units: Delhi- 2006-07	3.87
3.62	Zone-wise Emissions from Different Industries in Delhi	3.88
3.63	Category wise Emissions from Small Scale Industries at Delhi	3.89
3.64	Estimated Emission Load from all Industrial Sources: Delhi 2006-07	3.94
3.65	% Contribution of Emission Load from Industrial Sources: Delhi, 2006-07	3.94
3.66	Top Ten Vehicular Emission Loads and Affected Grids	3.102
3.67	Top Ten Re-suspended Road Dust Loads and Affected Grids	3.103
3.68	Identified Hotspots due to Vehicular Pollution and Re-suspended Road Dust Emission Loads	3.103
3.69	Emission Load from All the Sources in the Study Zones	3.105
3.70	Summary of Emission Loads from All the Sources in Delhi	3.106

4.1	Description of sampling sites	4.2
4.2	Summary of Factor Analysis Results-PM10 (Identified major factors)	4.4
4.3	Summary of CMB Results-PM10 Contribution of Major Sources	4.13
4.4	Major source contributions to PM10 at various sites during the three seasons	4.15
5.1	Salient Features of Modeling Exercise	5.3
5.2	Summary of Station-wise Wind Observation	5.5
5.3	Source Category and Season-wise Predicted Maximum GLCs: Delhi (Existing Scenario)	5.12
6.1	Projected Population of Delhi	6.1
6.2	Projected Pollutants Emission Load in 2012 & 2017	6.2
6.3	Projected Pollutants Emission Load in 2012 & 2017	6.7
6.4	Total Registered Vehicles in Delhi: 2002 and 2007	6.10
6.5	Projected growth of different Categories of vehicle in 2002 and 2007	6.11
6.6	Baseline and Projected Emission Loads: Vehicular and Road Dust	6.11
6.7	Pollutant and Season-wise Predicted MGLCs and their Occurrence in 2012 and 2017: BAU Scenario – Area Sources	6.13
6.8	Pollutant and Season-wise Predicted MGLCs and their Occurrence in 2012 and 2017: BAU Scenario – Industrial Sources	6.13
6.9	Pollutant and Season-wise Predicted MGLCs and their Occurrence in 2012 and 2017: BAU Scenario – Vehicular Sources	6.13
6.10	Pollutant and Season-wise Predicted MGLCs and their Occurrence in 2012 and 2017: BAU Scenario – Cumulative Impact of All Sources	6.14
6.11	Predicted Particulate Matter Concentrations (µg/m3) at ten AQM sites in Delhi: 2007 (Winter)	6.14
6.12	Predicted Particulate Matter concentration (µg/m3) at ten AQM sites in Delhi: 2012 (Winter)	6.14
6.13	Predicted Particulate Matter concentration (µg/m3) at ten AQM sites in Delhi: 2017 (Winter)	6.15
6.14	Predicted NO_2 Concentration ($\mu g/m^3$) at ten AQM sites in Delhi : 2007 (Winter)	6.15
6.15	Predicted NO_2 Concentration ($\mu g/m^3$) at ten AQM sites in Delhi : 2012 (Winter)	6.15
6.16	Predicted NO_2 Concentration ($\mu g/m^3$) at ten AQM sites in Delhi : 2017 (Winter)	6.16
6.17	Estimated Zone wise Population Holding Capacity	6.31
6.18	Area Source Control Option BAU Emission Scenario in 2012 and 2017	6.33
6.19	Emission Load and % Reduction- Area Sources Control Scenario 2012	6.33
6.20	Emission Load and % Reduction- Area Sources Control Scenario 2017	6.34
6.21	Emission Control Option Scenarios in 2012 and 2017 (industrial sources)	6.39
6.22	Emission Load and % Reduction under Control Scenario- 2012 and 2017 (industrial –Sources)	6.39
6.23	Vehicular Pollution Control Measures Taken in Delhi : 1996-2001	6.49
6.24	Technology based Vehicular Control Options, Expected Reduction and Achievable targets	6.50

6.25 Management based Vehicular Control Options 6.52
6.26 Evaluation of Technology based Options: Vehicular Sources 6.55
6.27 Evaluation of Management based Options: Vehicular Sources 6.56
6.28 Expected % Reduction in PM and NO_x Emissions by 2012 and 2017 6.61
6.29 Expected % Reduction in Road Dust Re-suspension by 2012 and 2017 6.61
6.30 Comparison of Range and interval of Iso-concentration Plots : Baseline, BAU and Control Scenarios for Different Vehicular Pollutants and Road Dust Re-suspension 6.65
7.1 Select Control Options and Expected Reductions (kg/day) in Emissions by 2012 and 2017 7.5
7.2 Improvement in Ambient Air quality in terms of PM and NOx (µg/m^3) under 2012 and 2017 Scenarios: Area Sources 7.6
7.3 Improvement in Ambient Air quality in terms of PM and NOx (µg/m^3) under 2012 and 2017 Scenarios: Industrial Sources 7.6
7.4 Improvement in Ambient Air quality in terms of PM, SO_2 and NOx (µg/m^3) under 2012 and 2017 Scenarios: Line Sources 7.6
7.5 Predicted PM and NOx Concentrations (µg/m^3) at ten AQM sites in Delhi : 2012 and 2017 (Winter) 7.7
7.6 Highest Ten Predicted Pollutant Concentrations –Preferred scenario: 2012 7.8
7.7 Highest Ten Predicted Pollutant Concentrations –Preferred scenario: 2017 7.9
7.8 Framework for Selecting Measures to Address Urban Air Pollution: Vehicles 7.12
7.9 Framework for Selecting Measures to Address Urban Air Pollution: Industries 7.14
7.10 Framework for Selecting Measures to Address Urban Air Pollution: Area Sources 7.15
7.11 Considerations in Prioritizing Technical Measures for Addressing Urban Air Pollution – Vehicles 7.16
7.12 Considerations in Prioritizing Technical Measures for Addressing Urban Air Pollution – Industries 7.21
7.13 Considerations in Prioritizing Technical Measures for Addressing Urban Air Pollution – Area Source 7.23
7.14 Prioritized List of Management / Control Options 7.25
7.15 Benefits associated with prioritized control /management options –Vehicular 7.27
7.16 Benefits associated with prioritized control / management options –Industrial 7.28

7.17	Benefits associated with prioritized control / management options –Area Source	7.28
8.1	Source Categories and Types of Sources of Air Pollution	8.7
8.2	Summary of Emission Loads from All the Sources in Delhi	8.8
8.3	Major source contributions to PM10 at different sites during three seasons	8.10
8.4	Salient Features of Modeling Exercise	8.11
8.5	Pollutant and Season-wise Predicted $MGLC_S$ and their Occurrence in 2012 and 2017: BAU Scenario – Cumulative Impact of All Sources	8.19
8.6	Emission Control Options Scenarios in 2012 and 2017- Point Sources	8.19
8.7	Area Source Control Options BAU Emission Scenario in 2012 and 2017	8.20
8.8	Evaluation of Technology based Options: Vehicular Sources	8.21
8.9	Improvement in Ambient Air quality in terms of PM and NOx ($\mu g/m^3$) under 2012 and 2017 Scenarios: Area Sources	8.23
8.10	Improvement in Ambient Air quality in terms of PM and NOx $\mu g/m^3$) under 2012 and 2017 Scenarios: Industrial Sources	8.23
8.11	Improvement in Ambient Air quality in terms of PM, and NOx ($\mu g/m^3$) under 2012 and 2017 Scenarios: Line Source	8.23
8.12	Select Control Options and Expected Reductions (kg/day) in Emissions by 2012 & 2017	8.24
8.13	Prioritized List of Management / Control Options	8.25

Executive Summary

E.1 Background

Air pollution is one of the major problems faced by many urban centers across the country. Delhi is no exception as it boasts of all the right mix of sources which can create an unacceptable urban air pollution scenario. The tremendous increase in the number of vehicles has contributed significantly to the increase in combustion of petroleum products. The vehicular pollution in Delhi has grown from 64% to 72% in the last decade (1990 – 2000) whereas petrol and diesel consumption have grown by 400% and 300% respectively in the last two decades. Other sources such as construction dust, biomass and refuse burning and other unregulated sources are becoming major inputs in some areas of high pollution levels.

In the present urban setting, the ever growing increase of motor vehicle emissions, as well as other anthropogenic sources gives rise to gaseous pollutants and smaller fractions of particulate matter along with carbonaceous and volatile organic compounds. Epidemiological studies conducted in many countries have demonstrated that there is an association between increase in morbidity and mortality due to increase in particulate matter (PM) specially the finer fraction. The main focus of this study is on characterization and source apportionment of $PM_{10.}$ Limited exercise on characterization and source apportionment of $PM_{2.5}$ – a relatively more hazardous particulate fraction, has also been included in order to have a better understanding and correlation between these two fractions. The smaller particles ($PM_{2.5}$) penetrate deep into the lung and can reach the alveolar region. These fine particles are important from health viewpoint because of their high number and large surface area which may absorb/adsorb toxic compounds such as heavy metals and PAHs.

The need for better air quality necessitates better knowledge about the sources and their strength in the urban centers. This fact was recognized through Auto-Fuel Policy Document of Government of India in the year 2002. The report suggested that these gaps in knowledge be addressed before we feel confident about the steps being planned for all sectors. With this in view, oil companies in India, in association with premier research institutions, joined together with the stewardship of CPCB and MOEF to initiate a detailed study for source apportionment of ambient air pollutants. NEERI in collaboration with IOCL, R&D Center, Faridabad and other oil companies (BPCL, HPCL, and RIL) initiated the study for Delhi.

The study was conducted based on a common methodology delineated by Central Pollution Control Board (CPCB), which was followed by all six cities participating under this programme. The composition of monitoring stations represented three major land-use types viz. residential, industrial, kerbside, and background. In all the cities, local stakeholders including State Pollution Control Boards were involved for selecting representative land-used based sites.

E.2 Objectives of the study

The study focus was aiming to address the Delhi air pollution sources through identifying, assessing their strength and finally establishing their levels and contributions in different parts of Delhi. This comprehensive study is based on an integrated approach involving all major factors influencing urban air quality management. Quantification of these sources would help in ranking them and formulating appropriate control strategies and management options. Although total control of air polluting sources would be certainly an ideal goal, but will not be practically feasible and therefore emission reduction based on exposure reduction by technology options and management techniques could be possible solutions. A comprehensive air quality management would need three basic requirements viz. assessment of ambient air quality levels, preparation of emission inventory and conducting source apportionment analysis. The major objectives of the study are:

- To measure baseline air pollutants and air toxic levels in different parts of Delhi, including "hot spots" near kerbside locations
- To inventories various air pollutants for projection analysis
- To conduct source apportionment studies for Particulate Matter
- To delineate an Urban Air Quality Management Plan for exposure reduction

E.3 Approach to the Study

The study approach has many components with each one of them having their own importance and interdependence as shown in **Fig E.1**. The ultimate objective is urban air quality management that primarily requires knowledge of ambient air quality status, sources and emission loads. These three objectives were achieved through monitoring of air pollutants at 10 locations depicted in **Fig E.2** using various instruments and multiple analyses. These locations were selected on the basis of land use and activity profile. All the six kerb sites are highly influenced by vehicles such as Mayapuri, Anand Vihar and Loni Road. These are different than sites with very high traffic density such as Dhaula Kuan, ISBT and Ashram Chowk. Pitampura is a residential area, whereas Naraina is a mixed use residential-industrial zone and SSI-GTK is an industrial site. Prahaladpur was taken as reference site as it has least activity compared to many other locations in Delhi. Air Monitoring was carried out using varied instruments and all attributes were analyzed using standards methodologies.

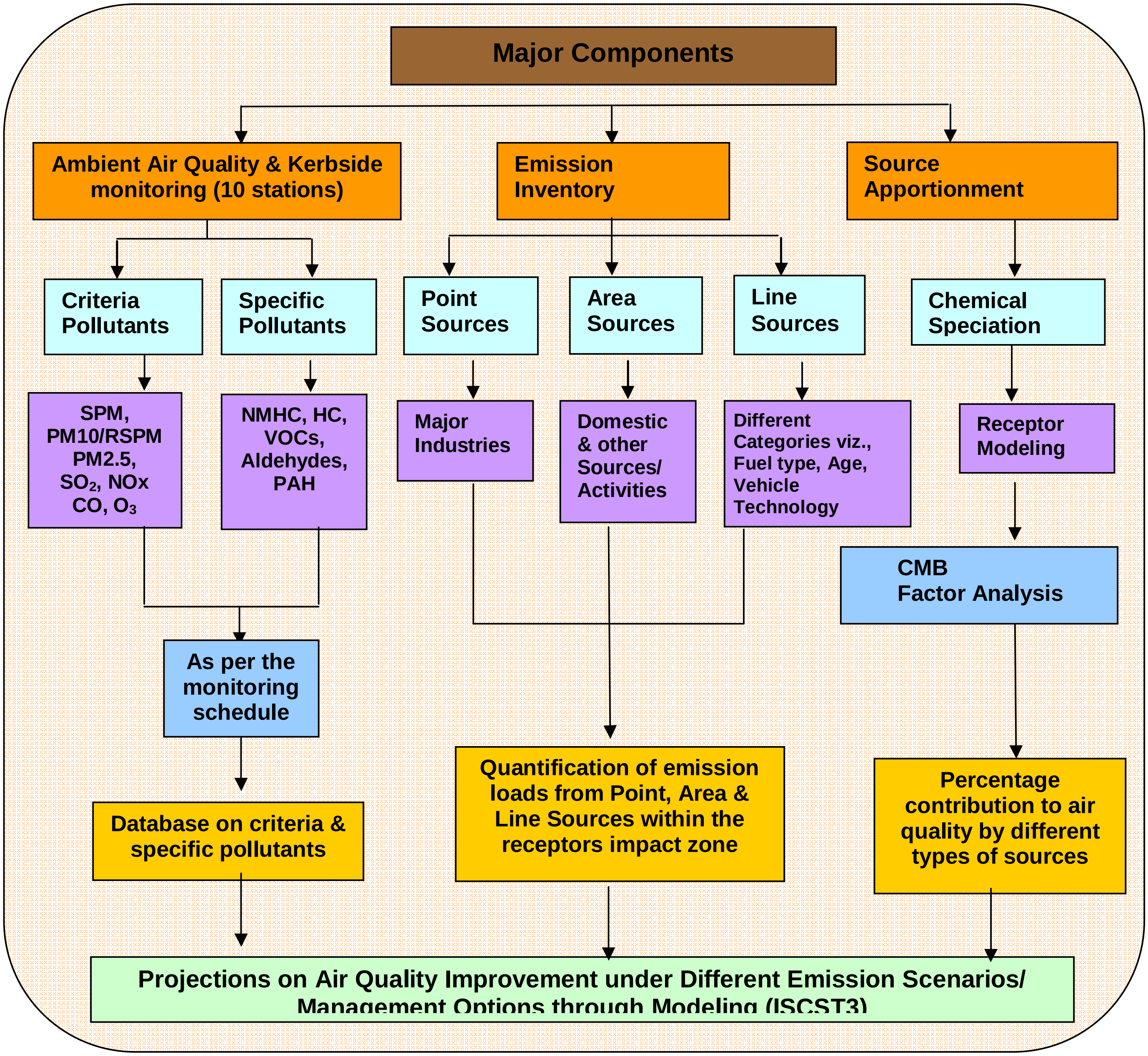


Fig E.1: Air Quality Monitoring & Emission Source Apportionment Studies

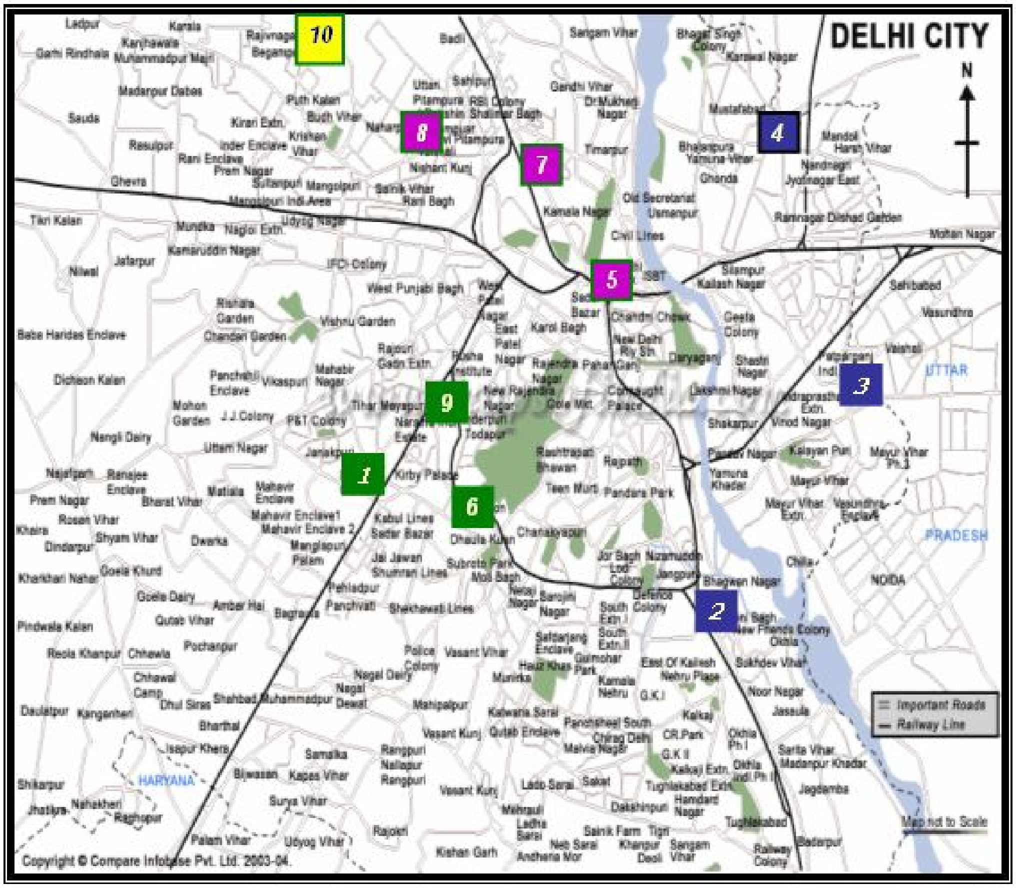


Fig E.2: Locations of Ambient Air Quality Monitoring Stations

The methodology of the study was divided into four parts namely ambient air quality monitoring, sources emission inventory, source apportionment analysis and finally delineating an urban air quality management plan based on the data collected during the study

E.4 Ambient Air Quality Status in Delhi

Ambient air quality monitoring includes both criteria pollutants monitoring as well as specific pollutants that are source specific. Some of the air pollutants attributed to vehicular emissions are not listed in National Air Quality Standards of India yet. However, these were included in the study and air quality standards from USEPA, WHO etc. were used to facilitate comparison. Some of the critical air pollutants that were covered in the study are CO, Benzene, 1-3 Butadiene, Aldehydes, Alkanes, NMHC, THC, Ozone, PAHs, SPM, PM_{10}, $PM_{2.5}$, SO_2 and NO_2. Ambient air quality status in Delhi with respect to average concentration of major pollutants is presented in **Fig E.3**

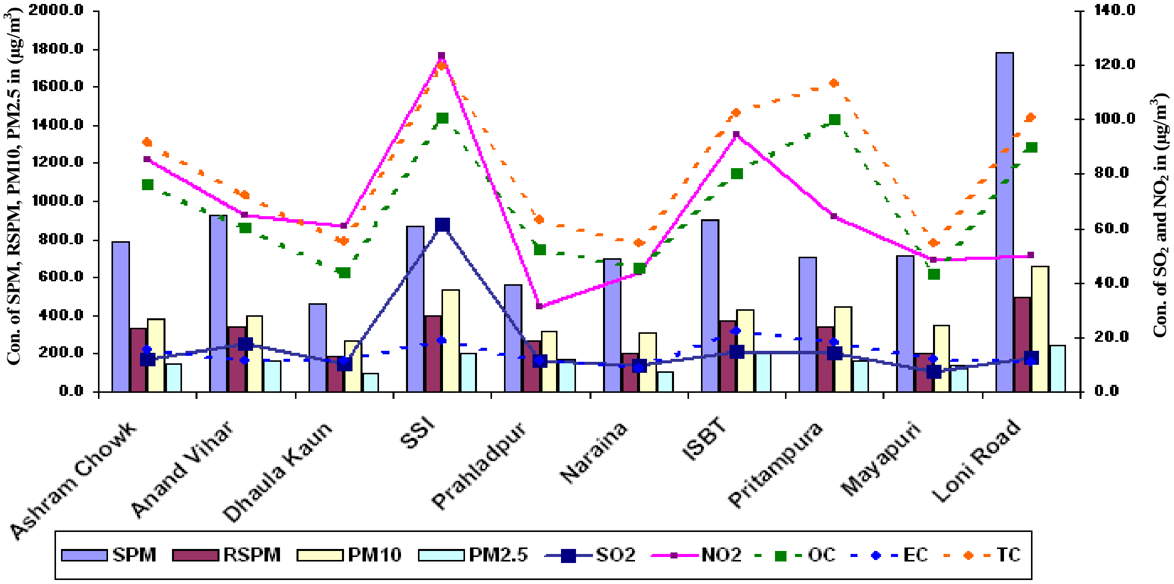


Fig E.3 : Average Concentration of Particulate and Gaseous Pollutants at Ten Sites

The background site at Prahladpur shows that the levels of coarse and fine particulate matter exceed the standard. Similarly in all remaining sites as well, same trend for particulate pollution has been noticed. SPM concentrations were highest in Loni, followed by Anand Vihar, ISBT, SSI, whereas RSPM concentration were higher at Loni, SSI-GTK and ISBT. Higher values at Loni Road is encountered due to poor road conditions as well as mixed use area with high biomass burning activities. The industrial site at SSI-GTK also shows high concentration of PM_{10} due to large scale industrial as well as construction activities. PM10 values at ISBT and Pitampura ranged between 200-400 $\mu g/m^3$. Dhaula Kuan shows lowest PM_{10} concentrations. At all sites $PM_{2.5}$ concentrations are exceeding the USEPA standard 35 $\mu g/m^3$.

The criteria pollutant NO_2 exceeded the CPCB standard value at Kerb sites of ISBT and Ashram Chowk, clearly indicating dominance of vehicular movement at these sites. Being an industrial site of SSI-GTK, NOx concentration is also high. Whereas, in remaining in all seven locations the levels of NO_2 & SO_2 are within the limit as per the CPCB norms.

The data also indicates that EC, OC values at ten sites correlate well with the local activities. As can be seen from the **Fig E.4,** that OC and TC value is highest at SSI-GTK site. Higher OC values at Pitampura indicates biomass burning, whereas it shows lower values at Mayapuri, Prahaladpur and Naraina. EC values variation in the city is not large, which indicates that most of the areas have similar impacts, except at high traffic density areas, it is slightly elevated such as ISBT, Ashram Chowk. It has enhanced values at industrial site as well due to high temperature combustion processes.

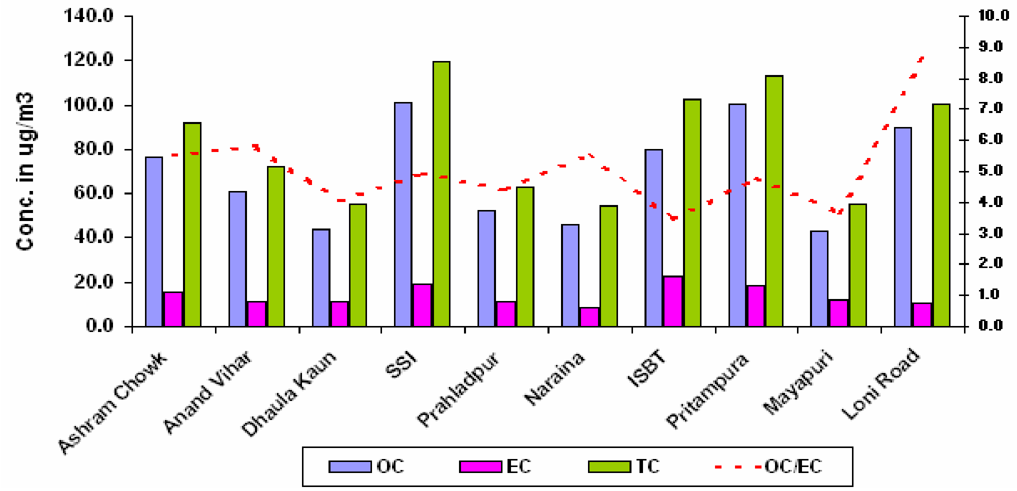


Fig E.4 : Average Concentration of Carbonaceous Species in PM_{10}

Higher OC concentrations observed at SSI followed by Pitrampura, ISBT, Loni Road and Ashram Chowk, whereas lower at Dhaula Kuan, Naraina and Mayapuri. Higher EC concentration were observed at ISBT, SSI and lowest at Naraina. The OC/EC ratio maximum at Loni followed by Naraina and Anand Vihar, lowest at ISBT and Mayapuri. The major sources of carbonaceous species are basically from refuse burning activities, vehicular movement resupension of dust, high temperature fuel oil combustion. The concentrations of carbonaceous species are higher in fine fractions.

E. 6 Mass Closure

Mass closure analysis has been performed for all sites with a view to understand the percent contributions from multiple sources. All around high PM values can not primarily be accounted for based on the anthropogenic sources. The mass closure data indicates highly variable percentage of crustal and unidentified portions as shown in **Fig E.5.**

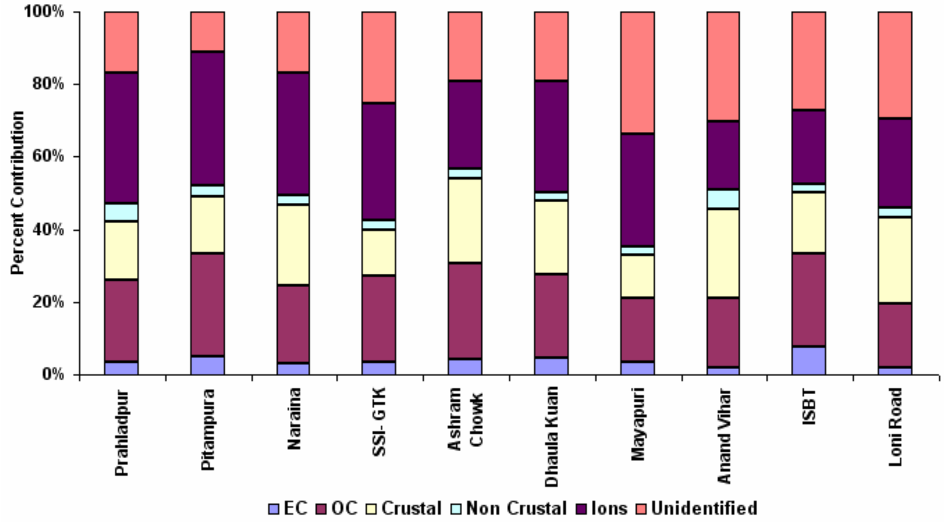


Fig E.5 : Chemical Composition of PM_{10} at Ten Sites

E.7 Molecular Marker Analysis

The PM samples of all sites were analyzed for molecular markers. These markers are signature molecules which indicate the sources based on their presence as also on their abundances. Their presence and absence indicates the impacts of sources close to the site or away. Representative samples from all 10 sites were analyzed at Desert Research Institute, Nevada. **Fig E.6** presents concentration of molecular marker at 10 sites.

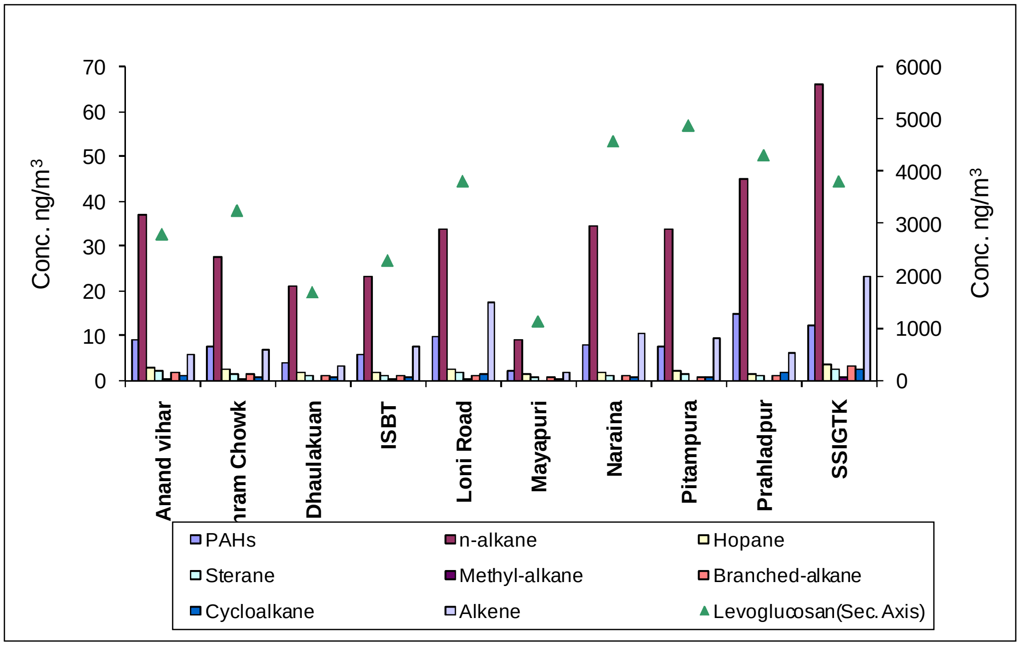


Fig. E.6 Molecular Markers Concentrations at all Sites in Delhi

It is evident that variation is random in most of the places. However, the presence of hopanes and steranes at all the sites in much higher quantities compared to Prahaladpur indicates that vehicles effect is prevalent at all sites of Delhi. Even residential location such as Pitampura shows much higher values of these vehicular markers compared to Naraina and ISBT. The marker for biomass burning “Levoglucosan” is found to be highest at residential site of Pitampura followed by Naraina, Prahaldpur and SSI-GTK. It clearly indicates that biomass burning is prevalent all across Delhi and adjoining areas. The lowest biomass burning is seen at Mayapuri. N-Alkane and Alkene values were highest at SSI-GTK which could be attributed to industrial processes present in the industrial area.

E.8 Emission Inventory

Emission inventory of different sources of air pollution has been prepared at two scales, one for the ten Study Zones of 2 km x 2 km around the air quality monitoring sites and then this emission inventory is used to estimate/extrapolate total emissions for the whole of the city. The very purpose of 2 km x 2 km study zones is to accurately identify and quantify emissions from different sources to be used to predict air quality in the study zones and compare the predicted air quality levels with the measured air quality levels. Emission inventory has been prepared in terms of five major pollutants, viz. PM_{10}, SO_2, NOx, CO and HC. Source categories and types of sources of air pollution in Delhi are presented in **Table E.1.**

Table E.1: Source Categories and Types of Sources of Air Pollution

Source Category	Types of Sources
Area Sources	• Domestic cooking • Bakeries • Crematoria • Hotels & Restaurants • Open eat outs • Open burning (refuse/biomass/tyre etc. burning) • Paved & unpaved roads • Construction/Demolition/Alteration activities for buildings, • roads, flyovers • Waste Incinerators • DG Sets
Point Sources	• Large scale industries and Power plants • Medium scale industries • Small scale industries (36 industrial estates)
Line Sources	• 2 Wheelers (Scooters, Motor Cycles, Mopeds) • 3 Wheelers (CNG) • 4 Wheelers (Gasoline, Diesel, CNG) • LCVs (Light Commercial Vehicles) • Trucks (Trucks, min-trucks, multi-axle trucks) • Buses (Diesel, CNG)

Total emissions from industries, area and vehicular sources in Delhi are presented in **Table E.2**. Estimated emission loads from all the sources are **PM**: 147.2 TPD, **SO_2**: 267.7 TPD, **NOx** : 460.1 TPD, **CO** : 374.1 TPD and **HC** : 131.4 TPD.

Table E.2: Summary of Emission Loads from All the Sources in Delhi

	Pollutant Emission Rate (kg/day)				
Source	**PM_{10}**	**SO_2**	**NOx**	**CO**	**HC**
Industrial	32479	264399	360526	23771	4765
Area	27730	2608	15332	132552	59968
Vehicular	9750	720	84200	217800	66700
Road Dust	77275	-	-	-	-
Total	147234	267727	460058	374123	131433

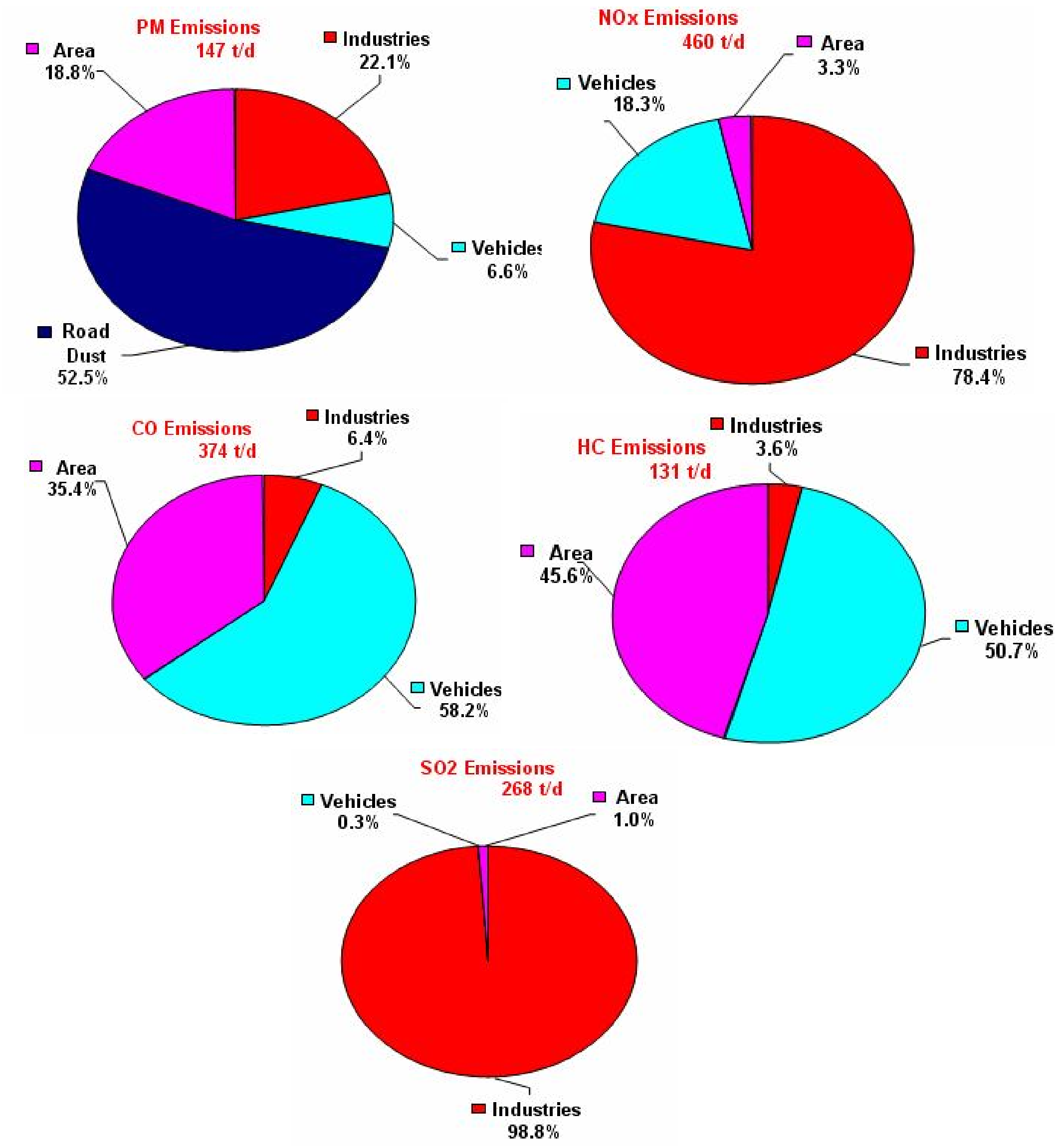


Fig. E.7: Percentage Contribution of Different Source Categories to Total Emission Loads: Delhi

It can be observed that PM_{10} is dominated by re-suspension of road dust to the extent of 52%. NOx is contributed by the industries (79%), mainly power plants, whereas vehicles contribute about 18%. CO and HC are primarily contributed by vehicular sources to the tune of 59% and 50% respectively. Area sources, mainly fuel combustion/open burning also contribute significantly to CO (35%) and HC (46%) emissions. SO_2 to the extent of about 99% is contributed by the industries, mainly power plants and some SSI units

E.9 Receptor Modeling

The modeling methodology used to derive the contribution of sources to a particular receptor is called receptor modeling. If the marker chemical species of pollution sources are known, statistical methodology called factor analysis can be used on the chemical species data collected at the receptor end. Chemical Mass Balance is another method which can be used.

In this study, receptor data includes chemical species concentration of particulate matter collected at 10 AAQ Monitoring stations within Delhi. Pollution sources in the 2 km x 2 km grids around the 10 monitoring stations were considered. Particulate matter collected from these sources was chemically analyzed for various species (ions, metals, carbons, molecular markers) so that signatures of sources were identified. The chemical species data generated for PM_{10} / $PM_{2.5}$ of pollution sources is called source signature profile. The source signature profile data generated by IIT Mumbai and ARAI, Pune under this project was provided to NEERI. Based on the receptor modeling studies carried out for Delhi, major sources contributing PM 10 emissions are presented in **Table E.3.**

Table E.3: Major source contributions to PM10 at different sites during three seasons

Site	Summer	Post monsoon	Winter
Prahladpur	Construction, industrial DG sets, kerosene generators, agricultural waste, **soil dust**, auto exhaust	Coal based power plant, unpaved road dust, solid waste burning, **soil dust**, industrial DG sets	**Soil dust**, solid waste burning, unpaved road dust, construction
Pitampura	Industrial DG sets, wood combustion, chullah, construction	Construction, tandoor combustion, solid waste burning, auto exhaust	Solid waste burning, paved road dust, industrial DG sets, solid waste burning, auto exhaust
SSI-GTK	**Construction**, paved road dust, auto exhaust, **solid waste burning**, wood combustion, soil dust	**Construction**, **solid waste burning**, kerosene generators	Soil dust, **construction**, **solid waste burning**, auto exhaust, paved road dust
Naraina	Paved road dust, kerosene generator, tandoor combustion, wood combustion, chullah, solid waste burning, auto exhaust	Construction, tandoor combustion, kerosene generators, soil dust, auto exhaust, paved road dust	Construction, solid waste burning, soil dust
Mayapuri	Industrial DG sets, paved road dust, kerosene generators, soil dust, fuel combustion, **auto exhaust**	Construction, coal based power plant, tandoor combustion, **auto exhaust,** solid waste burning, paved road dust	Soil dust, tandoor combustion, solid waste burning, construction, **auto exhaust**

Table E.3 (Contd..) :

Site	Summer	Post monsoon	Winter
Loni Road	**Soil dust**, coal based power plant, tandoor combustion, **construction**	**Construction**, **soil dust**, solid waste burning	**Construction**, **soil dust,** tandoor combustion, unpaved road dust, solid waste burning
ISBT	Soil dust, construction, **fuel combustion, auto exhaust**	Paved road dust, industrial DG sets, kerosene generator, **fuel combustion, auto exhaust**, solid waste burning	Construction, solid waste burning, **fuel combustion**, tandoor combustion, soil dust, **auto exhaust**
Ashram Chowk	Fuel combustion, industrial DG sets, **construction**, kerosene generators, **auto exhaust**, paved road dust, fuel combustion	Soil dust, **construction**, solid waste burning, **auto exhaust**	**Construction**, **auto exhaust**, soil dust, tandoor combustion, solid waste burning, coal based power plant
Anand Vihar	Solid waste burning, soil dust, kerosene generator, auto exhaust	Construction, solid waste burning, paved road dust, auto exhaust	
Dhaula kuan	--	Fuel combustion, industrial DG sets, chullah, tandoor combustion, auto exhaust, construction, paved road dust, wood combustion	Soil dust, fuel combustion, tandoor combustion, construction, auto exhaust, wood combustion, kerosene generator

Note: **Bold font** indicates the similar sources contributing in three seasons and underline indicates the similar sources contributing in two seasons

Overall, major sources in PM mass appears to be contributed by soil dust, fuel combustion, vehicular sources, solid waste burning and construction. Other sources are mixed such as DG sets, wood combustion, power plants, Kerosene burning etc.

E.8 Dispersion Modeling: Existing Scenario

Air quality dispersion modeling exercise has been undertaken with a view to delineate the important sources and their impact on ambient air quality in general, and specifically at measurement locations. Dispersion modeling tool has been also used for the whole city air quality scenario generation for different emission loads. The existing scenario model runs are to establish the dispersion pattern of pollutants due to local meteorology and emissions from all possible sources. Model runs also provide an idea about missing sources or additional sources which may have not been accounted earlier. Scenarios covering different seasons, locations and sources have been generated to assess the impacts of contributions and variations. The comparison of concentrations for the existing scenario has been carried out by considering the highest ten concentrations. Air quality modeling was carried out for three seasons viz., summer, post monsoon and winter. The USEPA developed/validated ISCST-3 air quality model was used to predict spatial distribution of PM_{10} and NO_2 concentrations in ambient air (USEPA, 1995) Salient features of the dispersion modeling studies conducted for Delhi city are presented in **Table E.4** For dispersion modeling within each site grid, the site-specific local meteorology was used to see the impact of low height emission sources.

Table E.4: Salient Features of Modeling Exercise

Parameter	10 Study Zones (2 km x 2 km)	Delhi City
Sources considered	Area, Industrial, Vehicular, Road dust and all sources together	Area, Industrial, Vehicular, Road dust and all sources together
Pollutants modeled	PM, NOx & RD-PM_{10}	PM, SO_2, Nox & RD-PM_{10}
Emission rate	Hourly variations	Hourly variations
Sources grids	0.5 km x 0.5 km	2 km x 2 km
Surface Met data	Site specific	IMD
Upper air Met data	CPCB document on mixing height	CPCB document on mixing height
Seasons	Summer, Post Monsoon, Winter	Summer, Post Monsoon, Winter
Model used	ISCST3	ISCST3
Receptors grids	50 m x 50 m	500 m x 500 m
Model Output		
GLC prediction at	1600 receptor locations	3840 receptor locations
Ranked GLCs	First 10 highest values	First 10 highest values
Iso-concentration plots	--	For each pollutant in each season using Surfer 32 graphical software

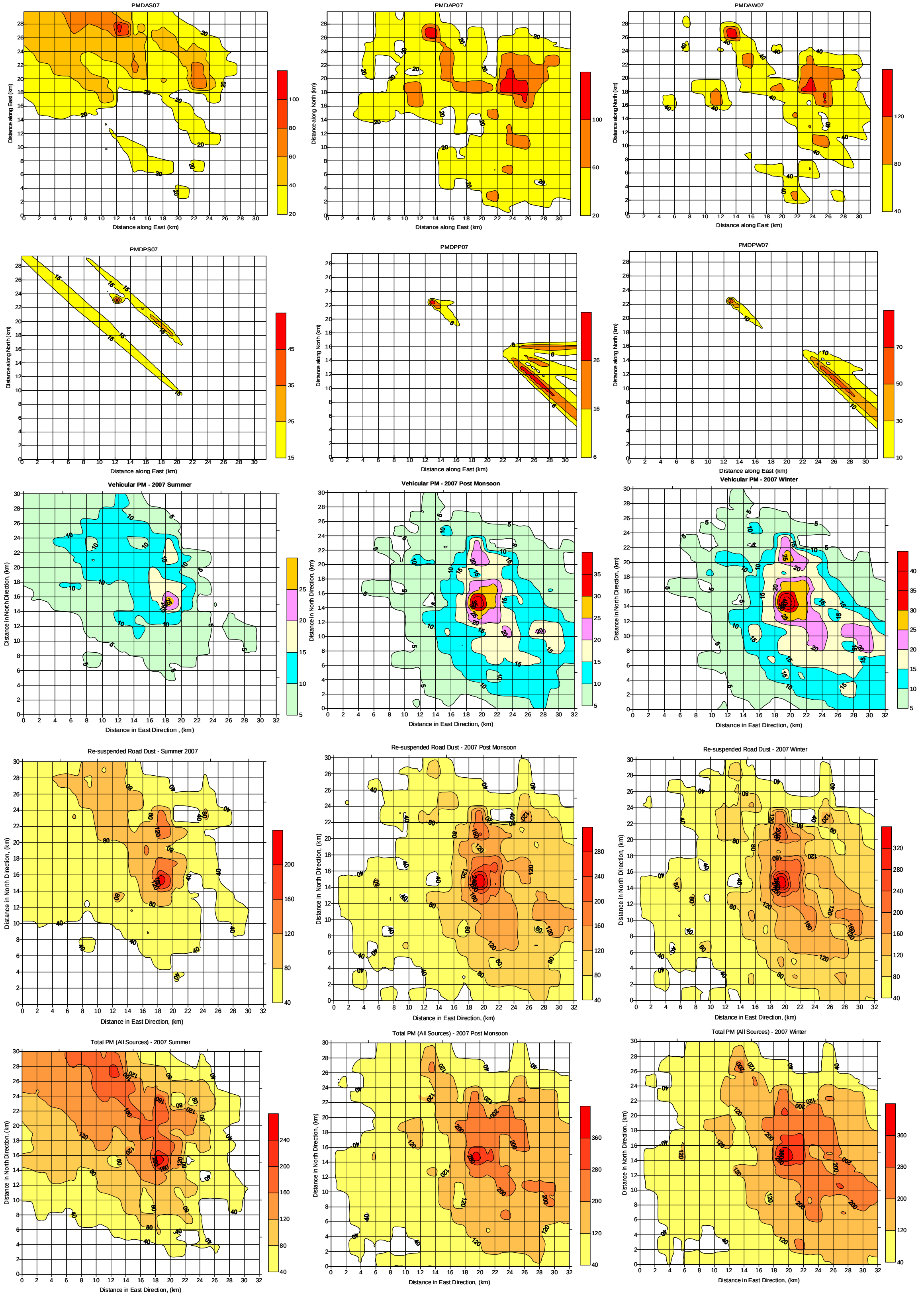
Maximum GLCs of PM (total of all sources) during summer, post-monsoon and winter are observed to be 260, 387 and 438 µg/m^3 respectively, occurring in Connaught Place-India Gate-ITO area. Higher PM concentration levels are due to the fact that contribution of road dust is also included in the total PM.

Maximum GLCs of NOx during summer, post-monsoon and winter are predicted to be 735, 732 and 1297 µg/m^3 respectively, occurring in Chandni Chowk-Chawri Bazar area (during summer) and in Mayur Vihar-Patparganj area (during post monsoon and winter). The predicted maximum concentration levels of NOx are found to be about 9 to 15 times higher than the CPCB standard (80 µg/m^3) for mixed area category. These maximum concentrations are the values which may occur at a particular location. Average values shall be much lower.

Iso-concentration plots drawn for total PM (as PM_{10}), NOx and SO_2 for summer, post-monsoon and winter seasons indicate that concentration of PM is well distributed through out the Delhi, with higher levels confining to the area between ISBT and Ashram Chowk. A good spread of high levels of NOx (40 μg/m^3) was observed in all the three seasons, but highest levels are following the trend of dispersion from point sources, mainly power plants. Similarly, spread of SO_2 is confined to a few grids and it also follows the dispersion pattern of power plants. Higher levels of SO_2 are predicted in Mayur Vihar area during post monsoon and winter, whereas in summer, its spread is more along the Chandni Chowk-Chawri Bazar-Ashok Vihar-SSI-GTK-Pitampura area.

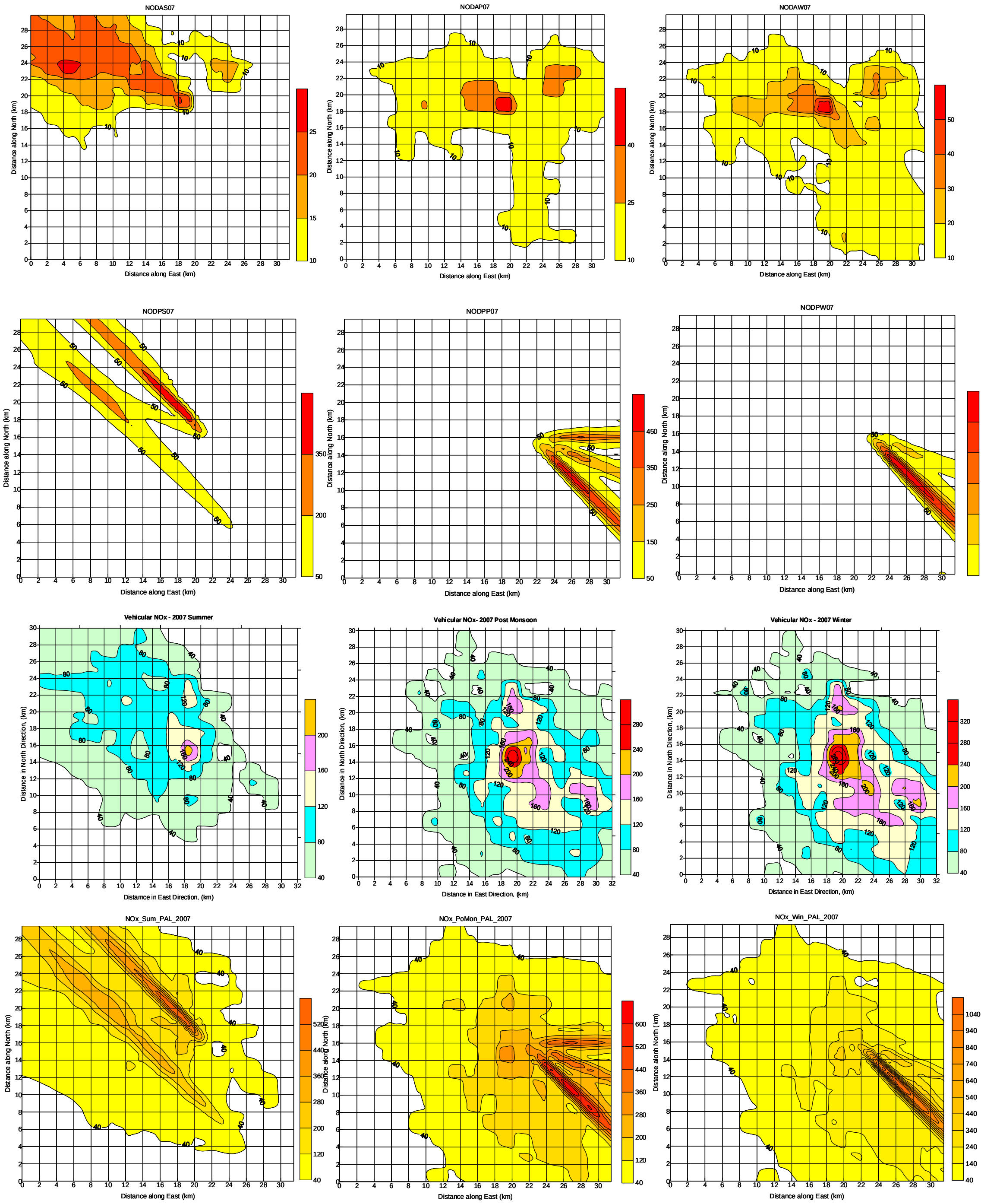
Fig E.8 and E.9 shows Iso-concentration Plots for PM and NOx from Area, point, Line, Road Dust Re-suspension and their Cumulative Impact during three seasons for 2007. The observed and predicted concentrations of PM and NOx indicate that former varies considerably from site to site. One of the prominent reason for its large variation from observed values is that model does not take into account wind blown dust as also emission loads from many distributed infrequent sources such as refuse burning, construction activities etc. NOx values, however, are close to the observed values in most of the locations. This could be attributed to the fact that NOx is mainly contributed through anthropogenic sources.

Site characteristics have very high influence on the emission estimates through inventory, actual observed values and finally simulated values obtained through the ISCST modeling. Reactivity of the pollutant also plays a role as some pollutants such as SO_2 and NO_2 can form secondary particulates in the form of sulphate and nitrate respectively.



Plots Sequence: 1st Row – Area Sources; 2nd Row – Point Sources, 3rd Row – Line Sources, 4th Row – Road dust re-suspension, 5th Row – Cumulative Impact

Fig E.8 : Iso-concentration Plots for PM from Area, point, Line, Road Dust Re-suspension and their Cumulative Impact during Summer, Post Monsoon and Winter (Existing Scenario-2007)



Plots Sequence: 1st Row – Area Sources; 2nd Row – Point Sources,
3rd Row – Line Sources, 4th Row –Cumulative Impact

Fig E.9 : Iso-concentration Plots for NOx from Area, point, Line, Road Dust Re-suspension and their Cumulative Impact during Summer, Post Monsoon and Winter (Existing Scenario -2007)

E.9 Future Projections under BAU Scenarios for 2012 and 2017

Delhi has multiple sources such as vehicles, industries both large and small scale, and diverse area sources, such as DG sets, domestic burning, biomass-refuse burning etc. The city has its own share of emissions which are not very area specific. These are construction activities, road paving, repairing, demolition etc. Business as usual scenarios have been generated for each source category based on major trends, which are likely to continue in the time frame of 5 & 10 years, viz. 2012 & 2017. Prominent sources under each category are:

Area Sources

- Due to power shortage, diesel generator sets continue to be the major source of air pollutant emissions in Delhi
- Delhi, due to its high population density and a high percentage of people living in the slums, the extent of usage of cooking fuel in the form of biomass including coal and kerosene is considerably high leading to high level of emissions. However, a change in this pattern is now being observed as there is rapid increase in the use of LPG as cooking fuel.
- Urban infrastructural development and related construction activities are contributing to particulate pollution in Delhi

Industrial Sources

- Coal based Power plants are the major source of PM and SO_2 emissions
- NG based Power plants are the major source of NO_2 emissions

Vehicular Sources

- PM emissions due to Re-suspension of road dust
- Trucks and LCVs are the two major sources of vehicular pollution.

Fig E.10 and E.11 show the predicted concentration of PM and NOx for BAU 2012 and 2017 for different seasons due to all Sources.

It can be observed that concentration of PM is well distributed through out Delhi with higher levels confining to the area between ISBT and Ashram Chowk. In general, a good spread of high levels of NOx (40 μg/m^3) can be seen in all the three seasons, but highest levels are following the trend of dispersion from the point sources, mainly power plants. Similarly, spread of SO_2 is limited to confined grids and follows mainly the dispersion pattern from point sources. Higher levels of SO_2 is predicted in Mayur Vihar area during post monsoon and winter, whereas in summer its spread is more and observed along the Chandini Chowk-Chawri Bazaar- Ashok Vihar-SSI-GTK-Pitampura.

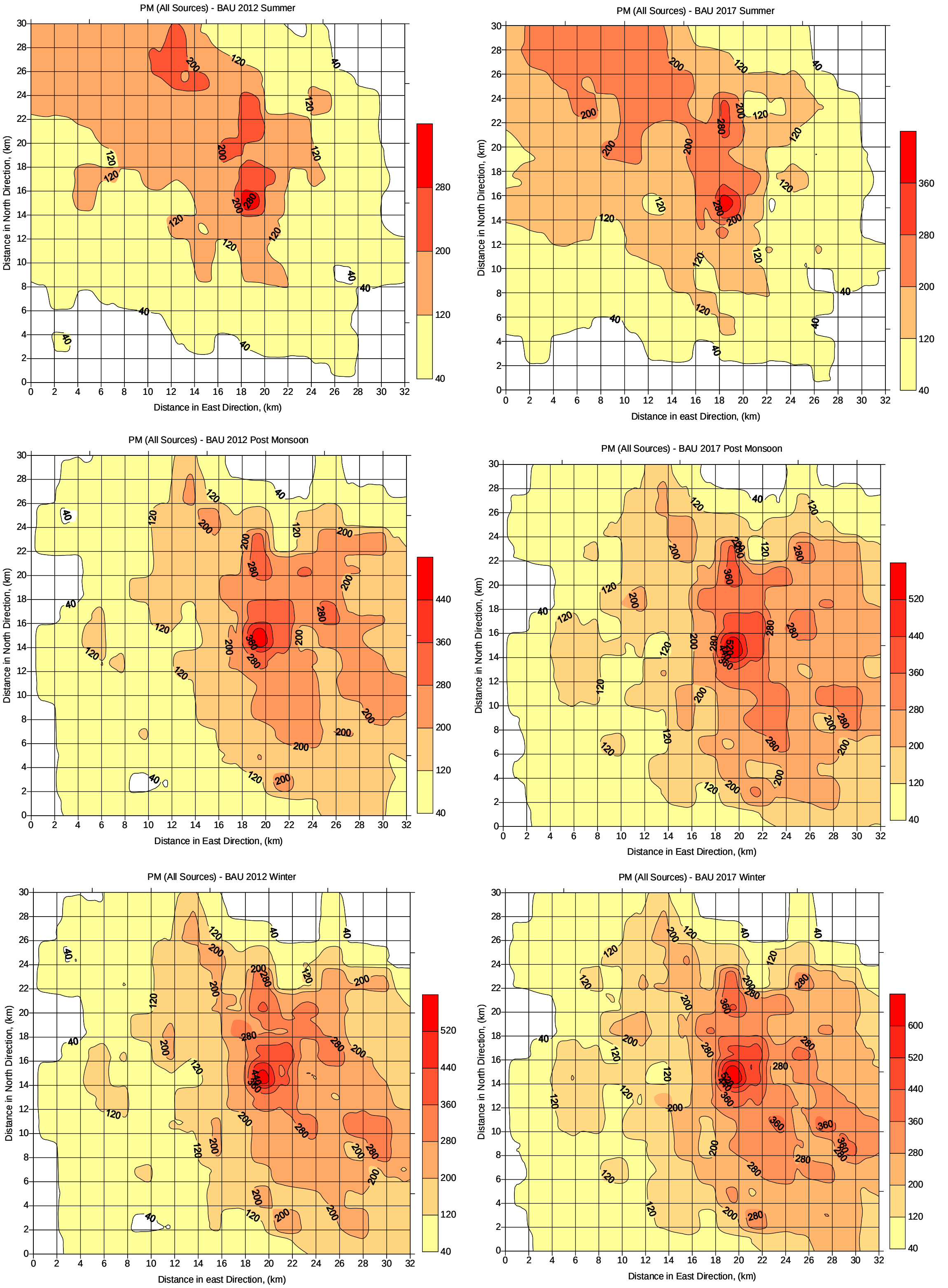
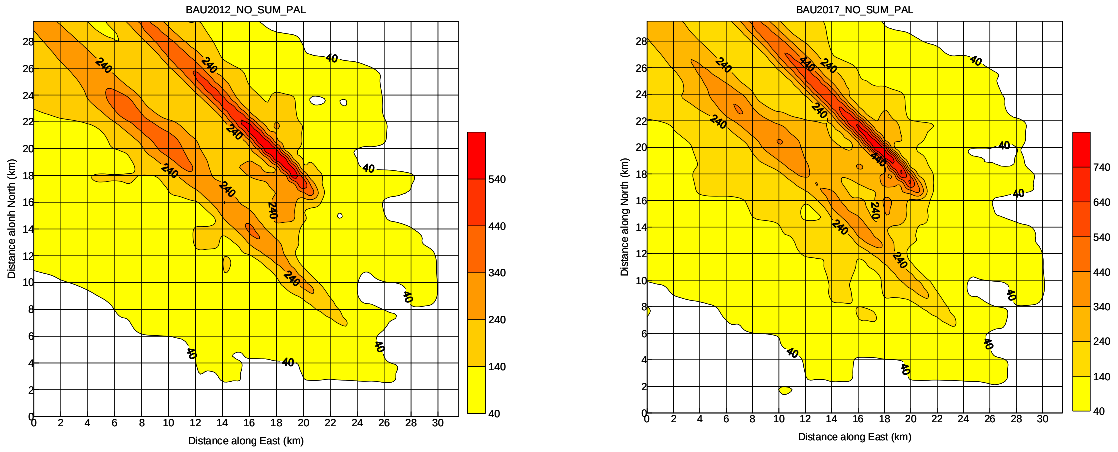
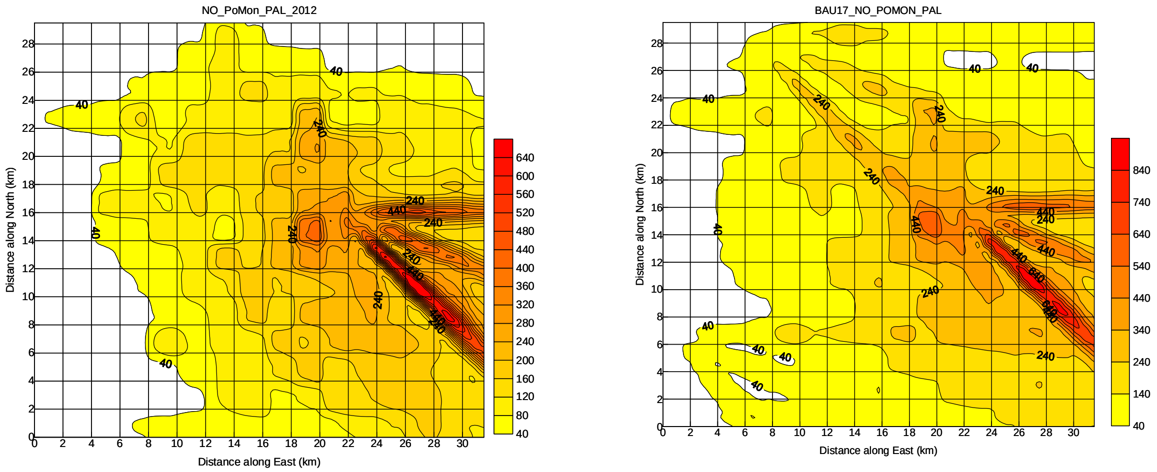


Fig E.10: Predicted Iso-concentration Plots for PM during Different Seasons: 2012 & 2017 BAU Scenarios – Cumulative Impact of All Sources



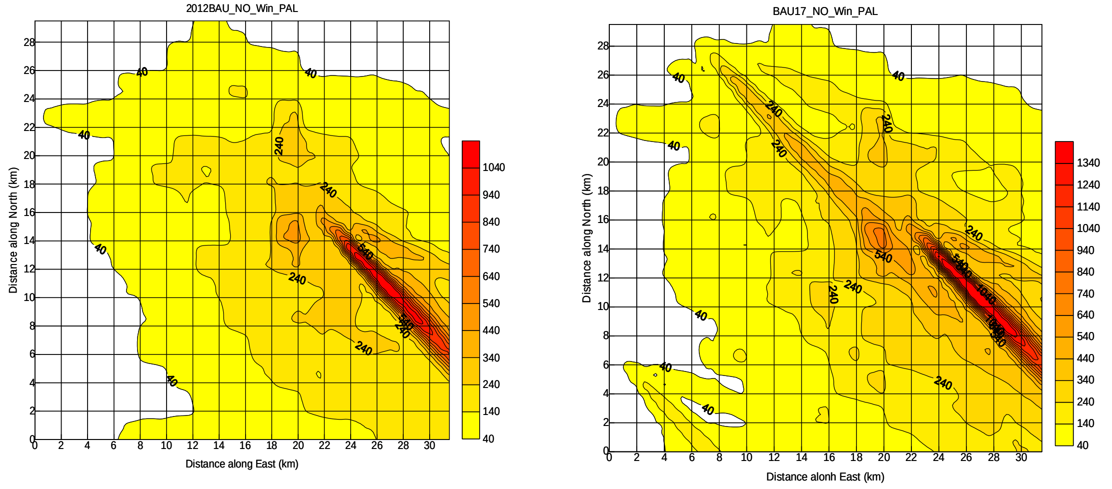
Summer 2012

Summer 2017



Post Monsoon 2012

Post Monsoon 2017



Winter 2012

Winter 2017

Fig E.11: Predicted Iso-concentration Plots for NOx during Different Seasons: 2012 and 2017 BAU Scenarios – Cumulative Impact of All Sources

E.10 Evaluation of Control options for 2012 and 2017

Major emission control options studied for 2012 and 2017 Scenarios are given in **Table E.6 through E.8** for point, area and vehicular sources, respectively. The evaluation process has been based on both technology as well as management options

Table E.6: Emission Control Options Scenarios in 2012 and 2017- Point Sources

Control Option	Type of Industries	Scenario for 2012	Scenario for 2017
Use of cleaner fuels viz. NG	Large scale (power plants)	All power plants to be shifted to NG	All power plants to be operated on NG
	Medium scale	100% to be shifted to NG	100% to be operated on NG
	Small scale	--	--
Installation of control equipment viz. FGD, wet scrubber	Large scale (power plants)	Improvement in ESP efficiency Installation of FGD	Upcoming power plants to be operated on NG
	Medium scale	Venturi scrubber to be installed in 100% industries	Venturi scrubber to be installed in 100% industries
	Small scale	Venturi scrubber to be installed in 50% industries.	Venturi scrubber to be installed in 100% industries
Shifting on Industries	Large scale (power plants)	Not applicable	Not applicable
	Medium scale	Not applicable	Not applicable
	Small scale	50% industries to be shifted	100% industries to be shifted

Table E.7: Area Source Control Options BAU Emission Scenario in 2012 and 2017

Control Option	Type of Industries	Scenario for 2012	Scenario for 2017
Domestic	Use of cleaner fuels viz. LPG/ NG	50% solid fuel, kerosene for domestic use to be shifted to LPG/NG	100% solid fuel, kerosene for domestic use to be shifted to LPG/NG
Hotels, Restaurants Bakeries	Use of cleaner fuels viz. LPG/ NG	100% to be shifted to LPG/NG	100% to be shifted to LPG/NG
Crematoria	Use of cleaner fuels viz. electricity	50% to be operated on electricity	100% to be operated on electricity
Incinerators	Installation of control equipment viz. wet scrubber	100% to be installed	100% to be installed
Generator sets	Adequate supply of grid power	Use of generator sets till adequate grid power available	No use of generator sets
Open burning	Strict compliance with ban on open burning	100% compliance	100% compliance
Locomotives	Use of cleaner fuels viz. electricity	100% to be operated on electricity	100% to be operated on electricity
Construction	Better construction practices viz. proper loading and unloading of materials, water spraying etc.	50% reduction from construction activities under BAU 2012	100% reduction from construction activities under BAU 2017

Table E.8: Evaluation of Technology based Options: Vehicular Sources

Sr.	Control Option/ Scenario	% Reduction with respect to Corresponding Year BAU Level	
		PM	NOx
	2007 Baseline Status	--	--
	2012 BAU Scenario	--	--
	2017 BAU Scenario	--	--
1. Implementation of Stringent Emission Norms			
a.	Implementation of BS-IV in 2012		
	2017 Scenario	-8.6	-4.5
b.	Implementation of BS-V in 2012		
	2017 Scenario	-11.5	-6.0
c.	Implementation of BS-VI in 2012		
	2017 Scenario	-11.5	-6.9
d.	Implementation of BS-IV in 2007		
	2012 Scenario	-12.1	-6.8
	2017 Scenario	-18.5	-10.0
e.	Implementation of BS-V in 2007		
	2012 Scenario	-18.0	-12.0
	2017 Scenario	-27.7	-17.8
f.	Implementation of BS-VI in 2007		
	2012 Scenario	-19.0	-15.9
	2017 Scenario	-29.1	-23.6
2. Introduction of Hybrid Electric Vehicles (HEVs)			
a.	**Electric Vehicles**		
	2012 Scenario	-0.5	-0.9
	2017 Scenario	-0.8	-1.7
b.	**Hybrid Vehicles**		
	2012 Scenario	0.01	-0.1
	2017 Scenario	0.06	-0.2
3.	**Fuel Blending: Ethanol (E10), Bio-Diesel (B10) and Hydrogen (H10)**		
	2012 Scenario	-7.9	-1.5
	2017 Scenario	-7.8	-1.6
4.	**Retro-fitment of DPF**		
	2012 Scenario	-19.5	0.0
	2017 Scenario	-39.9	0.0
5. Improved I & M Practices			
	2012 Scenario	-3.0	-3.3
	2017 Scenario	-5.9	-6.6
6. Ban on 10 Years Old Commercial Vehicles			
	2012 Scenario	-18.7	-9.6
	2017 Scenario	-17.6	-8.1
7. Ban on 15 Years Old Private Vehicles			
	2012 Scenario	-0.2	-1.8
	2017 Scenario	-1.0	-3.9
8. Improvement in Public Transport - Shift in VKT			
	2012 Scenario	-1.6	-3.9
	2017 Scenario	-3.5	-8.0

Analysis of various technology and management based options for vehicular sources indicates that implementation of any of the above strategies would not be able to achieve even to the baseline status of 2007, by 2012 or 2017. However, the increase could be reduced to some extent. Significant reductions are not observed because several vehicular pollution control measures like introduction of BS-II for 2 Wheelers and BS-III for all other vehicles, introduction of CNG for 3 Wheelers, taxis and buses, less sulfur content in diesel, ban on more than 8 years old buses etc. have already been implemented in Delhi during the last decade. To get further incremental reductions, the efforts required would be much more, whereas the expected benefits would not be commensurate with the efforts towards technology based pollution control systems. Therefore, the control scenario of vehicular sector particularly must look at managerial options, which can provide the right reductions and supports the city sustainability.

The control scenario for vehicular emissions includes implementation of next stage emission norms for new vehicles, retro-fitment of diesel particulate filter for in-use commercial diesel vehicles, mandatory inspection and maintenance in automobile manufacture company owned service centers, improvement in public transport system, synchronization of traffic signals, introduction of hybrid vehicles with improvement in fuel quality (no adulteration) is expected to yield about 47% reduction by 2012 and 82% reduction in PM emissions by 2017 as compared to estimated emissions under BAU for those years. Reduction in NOx emissions is expected to the tune of 30% by 2012 and 42.5% by 2017, as compared to respective years BAU scenario emission levels.

E. 11 Preferred Scenario

Preferred scenario delineation involves critical examination of the constraints (technical, fiscal, administrative and others) with a view to understand the applicability of the solution for the city. It also examines the benefits and co-benefits of each of the actions. These have been delineated for each of the sources viz., vehicles, industries and area sources as given in **Table E.9 to E.11**:

Table E.9 : Considerations in Prioritizing Technical Measures for Addressing Urban Air Pollution – Vehicles

Actions	Technical Issue	Effectiveness for PM reduction	Barriers to implementation	Administrative /regulatory	Qualifiers	Local/ National Stakeholders
Strategy : Vehicles: Emission Reduction per unit Fuel Used						
S reduction in diesel	Technically feasible and being implemented	Moderate. Reported elsewhere 2000-300 ppm reduction in S leads to 2.5 – 13 % reduction in PM [#]	High cost. Being planned by Refineries as per the Auto Fuel Policy. The cost is in the range of 15000/35000 crore based on the levels of S	Improvement in emission standards as well as legislation for stringent fuel standards for S, Phasing out the subsidies on diesel. Bringing diesel cost at par in a state/centre	The S reduction will not only reduce the PM but also lead to correspondingly lower SO_2 emission leading to lower ambient SO_2 and sulphate. It will also allow exhaust after treatment devices.	Oil companies, Ministry of Petroleum, vehicle manufacturer
Reduce fuel adulteration	Better quality fuel by adopting stricter fuel supply and dispensing system (e.g. Pure for Sure etc.) Chemical marker system	Reduced adulteration will lead to reduced PM (difficult to quantify). Effectiveness is moderate as marker system has not been seen as a primary means to reduce PM	Present system of Anti Adulteration cell function needs major improvement in terms of higher manpower and spread. Success of marker system shall be highly dependent upon the joint working relation with Oil companies and AAC.	The current fuel specifications are too broad and therefore checking of conventional parameters such as density etc. does not reflect the adulteration. Finer fuel specifications are needed for implementation. Oil companies themselves can be proactive in proposing these values, which can be checked easily in any laboratory. They can suggest their own norms.	One of biggest advantage of non-adulteration shall be longer engine life besides the emission reduction for PM as well as CO and HC. The catalytic converter shall be active for its lifetime.	Anti-Adulteration cell, Oil Companies, Vehicle owners

Source (Air pollution from motor vehicles, Faiz Asif, Weaver C.S. and Walsh M.P., The World Bank, Washington, D.C., 1996)

Table E.9 : Considerations in Prioritizing Technical Measures for Addressing Urban Air Pollution - Vehicles

Actions	Technical Issue	Effectiveness for PM reduction	Barriers to implementation	Administrative /regulatory	Qualifiers	Local/ National Stakeholders
Strategy : Vehicles: Emission Reduction per unit Fuel Used						
Alternative fuels	- Technical infrastructure in Mumbai for dispensing CNG/LPG is fairly good and is improving	High, more than 90% reduction in PM can be achieved compared to diesel #	Can be applicable mainly for vehicles, which are supposed to ply within the city. Applicable to only local public transport, taxies etc.	Incentive by the government authorities to private vehicle owners to shift to CNG/LPG.	Will lead to substantial reduction in CO and HC emission, however, NOx values may go up	Gas, Oil Companies marketing LPG
	- Biofuels can be used up to 5-10% without any major technical issue.	Similar to diesel but low SO_2 and low PM	Can be easily implemented	Regulatory system allows	Low SO_2 emission	Ministry of Petroleum
Phase out of grossly polluting vehicles	No major technical problem	High, Estimate suggest 25% of these vehicle may contribute 75% of total emission $	Poor Inspection system both for emission as well as vehicle. New legislation may require changes in Motor Vehicles Act	New legislation needed for improved Inspection certification system, better testing facility.	Better compliance will lead to reduction of other pollutants as well. It will also lead to less pressure on complying vehicles	Transport Commissioner office, Ministry of Road Transport and Highway

Source (Air pollution from motor vehicles, Faiz Asif, Weaver C.S. and Walsh M.P., The World Bank, Washington, D.C., 1996)

$ Source (Impact of Better Traffic Management, South Asia Urban Air Quality Management, Briefing Note No. 5, ESMAP, The World Bank, 2002)

Table E.9 : Considerations in Prioritizing Technical Measures for Addressing Urban Air Pollution - Vehicles

Actions	Technical Issue	Effectiveness for PM reduction	Barriers to implementation	Administrative /regulatory	Qualifiers	Local/ National Stakeholders
Strategy : Vehicles: Emission Reduction per unit Fuel Used						
Congestion reduction	Improvement of roads, new roads, scientifically planned traffic management, mass transit systems, parking on roads	High emission due to fuel burning at idle or slow moving traffic	Road quality improvement is a matter of technology and quality of work carried out. Concretization of road may be the solution. New road planning and Traffic management are being taken as integral part of the road and flyovers construction.	Better planning and training in traffic management. Mass Rapid Transit System (Metro and High Capacity Bus system) Road construction norms to be evolved and implemented	It will reduce traffic junction hotspot of all the pollutants It will also reduce continuous source of dust	Delhi Government, MCD, NCR Board, Transport police, other utilities.
Strategy : Vehicles: Emission Reduction per unit distance travelled						
Standards for new and In-use vehicles	No technical issue with new vehicles. For in use old vehicles, technical feasibility needs to be established	Marginal improvement from newer vehicles except when implementation is for Euro V & VI In-use vehicles emission reduction can be substantial	The process of in-use vehicles standards may take time as they need to be revised at central level. Inadequate infrastructure and manpower at local; levels could other major barriers.	After the legislation is in place, provision of strict penalty leading to cancellation of vehicle registration.	As the old vehicle population is substantial, the standards will bring in the much needed control on emissions of all types	MoRTH, Transport Office Govt.of Delhi
Introduction of new technology vehicles	New technology based vehicles emit less per unit distance travelled Electric vehicles	High compared to grossly polluting, moderate with respect to in use vehicles	Emphasis to allow only a type of technology to be permitted may meet with resistance from manufacturer as well as buyer. (e.g. rule to allow only 4 stroke vehicle to be registered)	This needs to be backed with proper legislation. Else charge higher registration fee or subject them to carry out more frequent I&C test. Electric vehicles for grossly polluting high VKT vehicles are a good option. It needs regulatory push	It will lead to better compliance from on-road emission test and overall improvement in emission of all the pollutants. Electric vehicles provide localized benefits of no air pollution	MoRTH, Transport Office Govt. of Delhi, MNRE

TableE.9 (Contd..) : Considerations in Prioritizing Technical Measures for Addressing Urban Air Pollution - Vehicles

Actions	Technical Issue	Effectiveness for PM reduction	Barriers to implementation	Administrative /regulatory	Qualifiers	Local/ National Stakeholders
Strategy : Vehicles: Emission Reduction per unit distance travelled						
Retrofitment of new engine/ Emission control device	Experience of other countries suggests that it can be feasible. However, in Indian scenario, a pilot retrofit programme to evaluate the efficacy needs to be undertaken. A small pilot project is on in Pune with USEPA, USTDA and NEERI	Engine replacement could lead to major reduction of PM. Emission control devices available (DPF, DOC) can remove PM upto 90%	Availability of new engines for retrofit. Vehicle manufacturers need to come forward. For Emission control devices, there are innumerable agencies.	Presently no legislation. Need to frame one including a mechanism by which the system can be evaluated by an appropriate agency.	Short time frame, high levels of compliance expected for all the in-use older vehicles.	MoRTH, Transport Office Govt. of Delhi, vehicle manufacturer, vehicle fleet owners
Higher usage of Public Transport	Dedicated bus lane, better buses, low cost of travel, faster travel etc.	Effectiveness is high as less and less road space will be occupied by private vehicles, faster movement of public transport in comfort shall lead to low emissions	Feasibility to be established for bus lane. Finances for better buses. Measures to reduce the cost of travel by way of cross subsidizing.	Local level planning in coordination with all the authorities involved in transport infrastructure related to metro, roads and flyovers.	Future growth of the city will entirely depend upon the levels of public transport availability. Cheaper and faster mode of public transport will lead to higher per capita efficiency.	MCD, NCR Board, Metro Rail and public transport companies DTC etc.
Decrease Private vehicles on Road		Less private vehicles on road, high road space utilization	Awareness matched with better public transport. Need for barriers for buying a car	Higher parking charges, high registration fees, higher car user charges	Private vehicles owners should must own their own garages, less parking on the roads, less congestion	MCD, Govt of Delhi, RTO
Strategy : Vehicles: Emission Reduction per unit distance travelled						
Training and Awareness programme car owners, public transport operators, drivers and mechanics	On use of alternative fuel, Inspection and certification, adulteration of fuels, use of public transport, less usage of private vehicles	May lead to 5-10% reduction of emission.	Resources for awareness and training, bringing the different groups together	Support from local and national institutions with finances as well as manpower.	Savings by way of improved vehicle maintenance and operation	MCD, Govt of Delhi, Central Govt, Transport Department, Other institutions involved in awareness campaign

Table E.10: Considerations in Prioritizing Technical Measures for Addressing Urban Air Pollution - Industries

Actions	Technical Issue	Effectiveness for PM reduction	Barriers to implementation	Administrative /regulatory	Qualifiers	Local/ National Stakeholders
Strategy : Industries: Emission Reduction per unit Fuel Used						
Combustion Processes	Change in combustion technology will be needed for shifting from coal/oil to natural gas	Moderate	Finances to change the process technology	No regulatory issue	It will lead to lower emission of CO and HC	DPCC, CPCB, Power companies and Industries
Alternate Fuel	Large no of industries are using NG and LPG	The higher percentage of use of cleaner fuel has already resulted in better air quality in the city		More allocation of NG/LPG to the industrial sector by Govt. of India	Better air quality in terms of SO_2, CO and HC will be achieved.	Govt of India and DPCC
Strategy : Industries: Emission Reduction by Industrial Policy and Standards						
Promoting Cleaner Industries	Use of cleaner production processes	Large scale shift shall result in major PM reduction	Finances to carry out these changes	MoEF can provide incentives to carry out the necessary change	It will lead to sustainable existence of industries within the city. Also lead to other pollutants reduction	MoEF, CPCB, CII
Location Specific emission Reduction	Control technologies change to cleaner	Medium	Higher allocation of NG/LNG at lower cost is needed	State as well as central government can provide the necessary incentive on use of cleaner fuel by the power plant and other industries	High level emission shall have lower PM and other gaseous pollutants	Govt of Delhi, DPCC, CPCB and GoI
Fugitive Emission control	Industrial process improvement better operation and maintenance	For localized region, effective. Particularly for industries with fine particles raw material or products. High efficiencies can be achieved for quarries.	Monitored data is scarce and therefore how and where to undertake the action will be limited	DPCC and CPCB can work on the standards for fugitive emission and develop compliance system	Local area air quality improvement could be highly effective.	DPCC, CPCB, Industries

Table E.11 : Considerations in Prioritizing Technical Measures for Addressing Urban Air Pollution – Area Source

Actions	Technical Issue	Effectiveness for PM reduction	Barriers to implementation	Administrative /regulatory	Qualifiers	Local/ National Stakeholders
Strategy : Area Sources: Mixed sources and varied strategies						
Improve fuel used for domestic purposes	LPG/PNG major domestic fuel, however kerosene is still a major source in low income group/ better stoves or change in fuel to LPG	Likely to improve indoor air quality	Lack of finance to low income group, particularly in slums	Administrative mechanism to be evolved to provide low cost clean fuel to slum dwellers	It would alleviate large section of population with high indoor pollution of other sources leading to lower disease burden and better quality of life	Central and State Govt., MoPNG
Bakeries /crematoria	Electric/LPG source based bakeries needing changes in design Many crematoria have electric system, but need to convert all the other into electric system	Local grid based PM can be reduced.	Awareness to bakeries that the quality can still be maintained with electric or LPG ovens. Similarly, despite electric crematoria being available, people prefer using wood based pyres	Strict monitoring of emissions from bakeries and crematoria	Reduction in PM as well as odour will take place and is likely to improve the local air quality	MCD, DPCC
Biomass/trash burning, landfill waste burning	Better control on collection and disposal at the respective sites. Landfill waste burning needs proper technology driven site management	Local area can have substantial reduction in PM. Very high effectiveness to adjoining grids	Awareness and local control. Apathy to take urgent action. No burning day vow to be taken by BMC	DPCC needs to address this issues	High level improvement in local area ambient air quality not only for PM but other pollutants	MCD, DPCC

Table E.11 (Contd..) : Considerations in Prioritizing Technical Measures for Addressing Urban Air Pollution – Area Source

Actions	Technical Issue	Effectiveness for PM reduction	Barriers to implementation	Administrative /regulatory	Qualifiers	Local/ National Stakeholders
Strategy : Area Sources: Mixed sources and varied strategies						
Resuspension	Vehicle movement related resuspension can be reduced by having better paved roads, regular sweeping and spray of water.	Highly effective for kerb-side air quality	Awareness and will to implement	Norms for road construction to be framed and implemented	Roadside as well population within the distance of about 200-300 m from the road will have low exposure of PM leading to better sense of well being	MCD, DPCC
Illegal SSI	Level of problem not well known. Need to understand what are the levels of operation and their contribution in each of the grids in the city	Local area improvement can be moderately good	Knowledge of the problem	Need for strict rules of such units and identification by DPCC/DIC and MCD	It will lead to large scale reduction of fire accidents as well as minimization of wastewater problem	MCD, DPCC, DIC
Construction	Construction activities which involve demolition, digging, construction, vehicle movement etc.	Large scale improvement in local area is expected.	Emphasis on better construction practices and management plan for air emission and its control by the implementing agencies	Fine system to be employed by the local authorities for violating the best construction practices for air pollution control.	Spillage on road and further re-suspension of dust can be minimized	MCD, DPCC, Builders Association

E.12 Dispersion Modeling for Select Control Options for Preferred Scenarios

Impact of control options in the improvement of air quality was assessed using three types of scenario generation. The first scenario is for only PM emissions reduction, whereas the second scenario is formulated for NOx emissions reduction. However, the final scenario considered is for the reduction of both PM and NOx emissions.

Expected ambient air quality with regard to PM and NO_2 under 2012 and 2017 Scenarios for vehicular, industrial and area sources are given in **Table E.12 through E.14** respectively.

Table E.12: Improvement in Ambient Air quality in terms of PM, and NOx (µg/m^3) under 2012 and 2017 Scenarios: Line Sources

Year	Pollutant	BAU	All Scenarios
2012	**PM_{10}**	58	31
	NOx	461	325
	Road Dust	476	119
2017	**PM_{10}**	71	13
	NOx	568	327
	Road Dust	590	59

Table E.13 : Improvement in Ambient Air quality in terms of PM and NOx (µg/m^3) under 2012 and 2017 Scenarios: Industrial Sources

Year	Pollutant	BAU	Combined Scenarios
2012	**PM_{10}**	115	111.3
	NOx	1153	691
2017	**PM_{10}**	115	110
	NOx	1505	688

Table E.14: Improvement in Ambient Air quality in terms of PM and NOx (µg/m^3) under 2012 and 2017 Scenarios: Area Sources

Year	Pollutant	BAU	Combined Scenario
2012	**PM_{10}**	146.4	67.4
	NOx	65.4	37.1
2017	**PM_{10}**	146	56.0
	NOx	75.6	43.6

E.13 Anticipated Benefits of Preferred Scenario

Percentage reductions in emissions of PM, SO_2 and NOx have been estimated for different control options with respect to the corresponding year BAUs (2012 and 2017) emission loads as shown in **Table E.15**. Area coverage for PM and NOx reduces substantially by 2012 and continues till 2017 as compared to the respective year BAU scenarios. With the suggested management plans, road dust re-suspension is expected to be reduced to a large extent by 2012 and 2017.

Table E.15: Select Control Options and Expected Reductions (kg/day) in Emissions by 2012 & 2017

Sr.	Control/Management Option	2012 Scenario		2017 Scenario	
		PM	NOx	PM	NOx
A. Industrial Sources					
A1	**Power Plants (Fuel shift: Coal to NG) All Plants by 2012**	5.4	39851.27	17.95	132269.6
A2	**Medium Scale industries (Fuel shift)**	0.65	23.99	0.65	23.99
A3	**Any other**				
	Total Industrial Sources (A)	**6.05**	**39875.26**	**18.6**	**132293.6**
B. Area Sources					
B1	All Construction related emissions control adopted in 100 % of the activities by 2012 and 2017	4777.3	--	3645.0	--
B2	Domestic (including slums) emissions control options adopted in 50% of the activities by 2012 and 2017 (fuel shift SF to LPG)	12790.7	1296.9	14615.1	661.1
B3	DG Sets replaced due to power availability by 2012	613.7	8678.4	706.5	9990.0
	Total Area Sources (B)	**18181.7**	**9975.3**	**18966.6**	**10651.1**
C. Vehicular Sources					
C1.	Implementation of next stage emission norms for new vehicles (BS-III for 2 and 3 Wheelers and BS-IV for 4 Wheelers, LCVs, Trucks & Buses) by April 2010	126	556	1327	6214
C2.	Retro-fitment of DPF in all commercial diesel vehicles (Trucks and LCVs) including inter-state vehicles by January 2010	2454	0	6170	0
C3.	Improved I&M in AMCOSC	2517	22225	3085	27619
C4.	Improvement in public transport	189	4445	540	11048
C5.	Others (electric/ hybrid vehicles, Synchronization of traffic signals etc.)	629	5556	1543	13810
	Total Vehicular Sources (C)	**5916**	**32782**	**12664**	**58691**
D. Road Dust					
D1.	Implementation of Road Dust Management/Option 2010 (Arterial & Main Roads)	76684	0		
D2.	Implementation of Road Dust Management/Option 2015 (Feeder Roads)			114873	
	Total Road Dust (D)	**76684**	**0**	**114873**	**0**

Though the I&M will provide a small percentage reduction in Vehicles PM$_{10}$ emission, its impact on toxic fine particles will be very high as vehicles PM are in mainly in finer sizes.

E.14 Action Plan –Prioritized list of Management/Control options

Based on series of evaluation as presented above aiming at load reduction leading to better air quality, a list of most important options have been prepared as given **Table E.15.**

Table E.15 : Prioritized List of Management / Control Options

Source Category	Control/Management Option	Implementation and regulatory agencies
Industrial		
I.1	Power Plants (Fuel shift - coal to NG)	Power companies, Govt of Delhi, GOI
I.2	Medium Scale industries (Fuel shift)	Industries, DPCC
I.3	Technology up-gradation, fugitive emission control	Industries, DPCC
1.4	Illegal industries shifting	Govt of Delhi, DPCC
Area		
A.1	All construction demolition related emissions control	MCD, DPCC
A.2	Road Construction/repair Practices	MCD, PWD
A.3	All domestic (including slums) emission control through clean fuel	MCD, Govt of Delhi, GOI
A.4	DG Sets replacement by making power available	Power companies, Gas company, Govt of Delhi and GOI
A.5	Biomass and Refuse burning	MCD, DPCC
A.6	Public Awareness on local area air pollution problems	DPCC, MCD
Vehicular		
V.1	Augmentation of city public transport system	Govt of Delhi, GOI
V.2	Traffic restrain, and congestion related taxes – Financial aid to public transport	SIAM, MORTH,CPCB
V.3	Development of fuel economy based emission norms for all category of vehicles	Vehicle manufacturer, CPCB
V.4	Fuel Quality Improvement	Oil companies, GOI
V.5	Emission Norms for New Vehicles	GOI, CPCB, SIAM, MORTH
V.6	Inspection and Maintenance (I&M) System for all category of vehicles in Automobile Manufacture Company Owned Service Centers (AMCOSC)	DPCC, CPCB
V.7	Performance evaluation of Catalytic Converter and periodic performance evaluation	DPCC, CPCB
V.8	Conversion of private vehicles to clean fuel	Govt of Delhi, Gas companies
V.9	Retro-fitment of DPF in LCVs, Trucks and Diesel-Buses	DPCC, SIAM
V.10	Phase out of older grossly polluting vehicles	MORTH, DPCC, CPCB
V.11	Stringent system for checking for adulteration in fuels	Oil Companies, Anti Adulteration Cell

Table E.15 (Contd..) : Prioritized List of Management / Control Options

Source Category	Control/Management Option	Implementation and regulatory agencies
Road Dust		
RD.1	Collection and proper disposal of road side dumped material (dust, garbage, leaves, refuse material etc.) and continue road cleaning regularly	MCD
RD.2	Repair/maintenance of all types of roads (arterial, main and feeder roads) for pot holes etc.	MCD
RD.3	Removal of encroachment of roads	MCD
RD.4	Conversion of unpaved road to paved roads	MCD
RD.5	Wall to wall paving of roads (with proper provision for water percolation)	MCD

E.15 Conclusions and Recommendations

The air quality sustainability goal of Delhi aims at addressing mainly two pollutants such as PM_{10} and NOx. Though, there are other related air pollutants such as finer particles which may have very high toxic components, hydrocarbons of varied origin (VOCs), Ozone and others, however, PM and NOx dominate the current goals of sustainable air quality. The sustainability goal of Delhi is linked with overall environmental quality, of which Clean Urban Air Goal is one of the most important areas.

The city boasts of many cleaner areas and regions of better visibility and air quality, however, large tracts of Delhi region has been witnessing severe air pollution problems. Many steps have been undertaken in the past to address air pollution issue. Of those initiatives, majority of measures were taken for vehicle sector. Actions pertaining to other sectors, which are more distributed and wide spread, have been limited.

The analyses of situation and the development taking place in Delhi need multiple pronged approaches to arrive at better and sustainable air quality goals. The apparent problems of PM and NOx control for the overall city (which also includes other areas within NCR for control option implementation) can be addressed by prioritizing the following sectors in following ways.

A: Industrial

The contributions of industries (particularly power plants) for PM and NOx are very high [1854.7 TPD PM and 131591.8 TPD NOx]. Though the tall chimneys associated with these industries provide high dilution and dispersion, however, in stable atmospheric conditions (inversion combined with high wind related calm conditions) in some part of the year, these can add substantial quantities of pollutants in urban air. The options of fuel shift which mainly involves opting for gas based operation of power plants, will only yield PM reduction. However, NOx levels would continue to get added with increased capacity. These additional loads shall create situation of frequent and longer duration of violation of ambient air quality norms in select regions of Delhi city.

Industrial NOx control options will need to be looked at as priority options, in addition to measures suggested above. Possible NOx control technologies include selective catalytic reduction (SCR), non catalytic reduction (NSCR), lean burn technologies etc. Many of these are proven technologies and can be adopted. For older coal based power plant as well, retrofitting of NOx control technologies can be attempted.

B: Area Sources

Area sources such as DG sets, use of biomass and kerosene for domestic cooking, refuse burning, crematoria, bakeries etc create local air quality problems. Some of these sources are located in a particular area and therefore any control as discussed earlier shall bring the immediate improvement in local area quality. However, there are many options which need wide ranging policy and management intervention. Some of these are:

DG sets Air Quality Management : Emissions reductions at the household levels can not be easily controlled. Its elimination by way of electricity supply is the only workable solution. The implementation of additional power supply for Delhi shall provide wide ranging improvement in overall Delhi air quality.

Bakeries and Crematoria: These sources impact a limited region or locality. Local issue of air pollution can be substantially improved through their control by shift in fuel types. Benefits accrued would be in terms of local area hot spot air quality improvements.

Dust sources: The air quality monitoring and analysis clearly indicates the following: Delhi particulate problems can be ascribed to four different sources, viz; 1- wind blown natural dust (sometime getting transported from a longer distance), 2- road dust resuspension (dust lying on the roads due to inadequate sweeping gets resuspended due to vehicles movement), 3- construction dust (due to poor quality of road construction and repair, large scale construction/ demolition and movement of construction material), and the last, 4- particles generated from all combustion sources including vehicles.

The dust components which can be controlled through measures suggested above in prioritized list are mainly from combustion sources, construction of roads/buildings, and road side dust. A large amount of dust emission due to wind blown dust as also the dust storm related contributions can not be controlled. Biomass and refuse burning activities are also not easy to control. In future, ambient PM targets in Delhi need to be specified on the basis of background crustal dust contribution. These background dust levels will not provide the necessary standards of PM (SPM, RSPM). Even fine a particulate (PM2.5) standard, which is closer to the anthropogenic sources of emissions, needs to be addressed from the point of view of crustal contributions.

The controllable options need implementation of better code of construction for road and buildings as also for repair and demolition etc. These codes will need to be framed and integrated into the contractual system of all agencies including private agencies engaged in construction and demolition. This will bring about large scale improvement in whole of Delhi. Distributed sources based burning will need a serious attempt of educating and creating awareness about such combustion practices.

C: Vehicular

The concepts of control scenario for vehicles provide umpteen options. Many technologies mentioned earlier have yielded large scale benefits for the city air quality besides improving the quality of life. However, all these technology measures and improved fuel quality alone do not lead to sustainable air quality solution. These options are able to reduce the PM and NOx levels to a limited extent. As our vehicles population is rapidly rising, all these benefits get nullified in a limited period. The personalized mode of transport has taken over the public transport which is leading to high congestion.

The vehicular pollution in coming years will not be driven by technology of the engine and types of the fuel but by the congestion related air emission. It means fuel burnt per unit distance will continue to increase.

The problem of PM from vehicles will remain to be addressed only for fine fraction, however, as the technology of engine improves along with fuel quality, this issue will also get addressed to a great extent. The biggest challenge remaining for this sector will be NOx emissions despite improvement in engine out emission.

One of the most workable solutions emerging for high growth Delhi is to develop mass rapid transport system comprising of road as well as railway options. Benefits of MRTS operations have been clearly felt elsewhere in the emerging cities of many countries. Delhi also has started experiencing its benefits not only in terms of better mobility but also in urban air quality improvement of the region.

This solution however, will make an impact on NOx and PM only when its coverage is far and wide, across Delhi as well as to its nearby growth centers. This option in combination with traffic restraints system, congestion charges, parking restrictions etc will bring the sustainability of the air quality on a better platform.

Reach of these solutions

> ***These development needs of Delhi are not limited to its boundary alone but all of these options will need to be integrated to all the urban centers and growth centers around Delhi (NCR). The benefits accrued due to these options based on technology and management of air polluting sources will be limited if they are not only aligned with nearby urban centers (which will include area, point and vehicular sources) but also with the neighboring states and finally country***

The prioritization of various options in all three categories have addressed mostly all the major reduction in the overall pollutants load reduction combined with ambient air quality improvement. However, many of these measures still may not lead to resolving very small area high concentration points which could be due to short term but high emission or high activity for a limited period and limited area. Such hot spots in the city of Delhi could exist when a local road is dug up and/or being repaired, construction and demolition of buildings, biomass and refuse burning, industries short term emissions etc. All of such activities can be controlled and regulated through local efforts and constant vigil on the part of citizen, pollution control agency and respective responsible implementing agency.

The benefits computed in the process described above will not only yield PM and NOx related pollution reduction but also co benefit of other pollutants (SO_2, VOCs, HC, CO etc) reductions as well. One of the other major co-benefits of these options (adoption of mass transport, use of cleaner fuel, efficient combustion etc) will provide large scale green house gas reduction. As a city of Delhi, it will provide the impetus of overall mitigation of GHG. The benefits of air quality improvement plan suggested and delineated above again will not yield desired results if the adjoining urban centers and states do not adopt measures suggested for Delhi as the objectives of clean air can not be kept limited to the political boundary of Delhi.

---------------------------------- xxxx ----------------------------------

Chapter 1

Introduction

1.1 Background of the Study

Urbanization coupled with industries and related ancillary activities have resulted in growth of urban centers in India. Increasing population and consequent increase in the number of vehicles have further led to deterioration of air quality, leading to adverse impact on public health. Taking cognizance of the public concern for improvement in air quality, the Government of India constituted a Committee of Experts under the chairmanship of Dr. R.A. Mashelkar, Director General, Council of Scientific and Industrial Research (CSIR), 2001 and entrusted it with the task of recommending an Auto Fuel Policy for the country together with a road map for its implementation. The committee submitted its report to the Government of India in August 2002.

The committee identified knowledge gaps in some areas of air pollution like source contribution. This knowledge gap can be bridged by a detailed study for source apportionment in urban areas. Keeping this in view, oil companies in India, in association with premier research institutions, initiated a detailed study for source apportionment of ambient air pollutants. NEERI in collaboration with IOCL, R&D Center, and other oil companies (BPCL, HPCL, RIL) initiated the study in Delhi in 2004 for achieving this objective. While the work was in progress, it was construed that the study which was methodology focused mainly on source apportionment of vehicular pollution may not provide a holistic view of the air pollution sources in an urban area as urban air pollution also includes road side dust, fugitive emissions from area sources as well as point sources emissions. Considering the above aspects in 2006, Central Pollution Control Board (CPCB) suggested certain modifications in the existing study framework for Delhi. As a result, a standard methodology was followed for conducting source apportionment studies which was deliberated in detail with the experts and other concerned agencies carrying out study for each of the cities. This methodology is the guiding document for conducting this study as well as five other cities viz. Banglore, Kanpur, Pune, Chennai and Mumbai.

1.2 Description of the Study Region (Delhi)

Delhi, the Capital of India is situated between latitudes 28°24' 17" and 28°53'00 N and longitudes 76°50'24" and 77°20'37" E at 216 meters above the mean sea level (MSL). It is spread over an area of approximately 1500 sq. km. The Delhi Development Authority (DDA) is responsible for planning and implementation of various development plans for the city. The city is surrounded by other major growth centers of adjoining states such as Haryana and Uttar Pradesh.

Delhi has experienced a phenomenal population growth rate of about 4.5 % during 1991-2001 as compared to the national average rate of 2.1%. As per 2001 census the population of Delhi is about 1.38 million. The climate of the region ranges between arid and semi-arid. Both summer and winter are severe with June being the hottest month and January, the coldest. The annual rainfall is around 700 mm. Maximum rain occurs during July to August.

Air pollution is one of the major environmental problems faced by Delhi today. The tremendous increase in the number of vehicles has contributed significantly to the increase in combustion of petroleum products. The vehicular pollution in Delhi has grown from 64% to 72% in the last decade (1990 – 2000) whereas petroleum and diesel consumption have grown up by 400% and 300% respectively in the last two decades.

Diesel generator sets are very common in household as well as for commercial purposes due to perennial power shortage, more pronounced in summer. Slums use wood, kerosene, biomass, refuse for cooking. Biomass burning for heating is very high during winter months. The city has mix of many types of industries starting from SSI to large industries such as power plants. Industrial use of fuel is mixed and many of them operate in non-conforming zones.

1.3 Ambient Air Quality Status : Other Monitoring Programme

Ambient air quality of in Delhi is mainly monitored by CPCB (7 Sites), NEERI (three sites) and DPCC. These stations have been located at various places and time series information of few sites for a longer period is available. For many other sites, last few years data have been analyzed with a view to understand the ranges of air quality observed in Delhi.

Status of RSPM

The monitoring results of period 2001-2006 indicate that RSPM levels exceed the prescribed National Ambient Air Quality Standards (NAAQS) in residential areas in Delhi most of the time except during monsoon months. Though many attempts have been made to regulate industries, implementation of Bharat Stage-III norms and others, however, ambient RSPM levels have not shown corresponding decline. One of the reasons could be exponential rise in number of vehicles. The reason for high particulate matter levels may be vehicles, engine gensets, small scale industries, biomass burning, resuspension of road dust due to traffic movement, commercial and domestic use of fuels, etc. **Figure 1.1** below indicates that the trends of annual averages of RSPM in residential areas, as well as vehicle growth of Delhi during 2001-2006. Monthly variation in RSPM levels monitored by NEERI in three activity zones (Industrial, Commercial and Residential) are presented in **Figure 1.2**, which indicates that RSPM values dip during the monsoon months. The difference between commercial/mixed use and residential zones are not very distinct as most of the residential zones have started to be commercial activities as well.

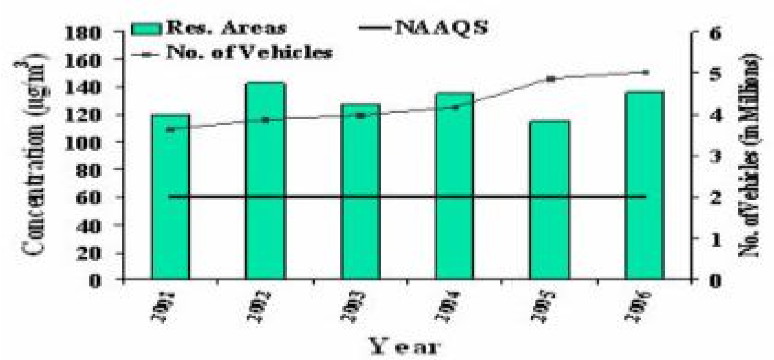


Fig. 1.1 : Trends in Annual Average Concentration of RSPM in Residential areas of Delhi and Vehicle Growth During 2001 -2006

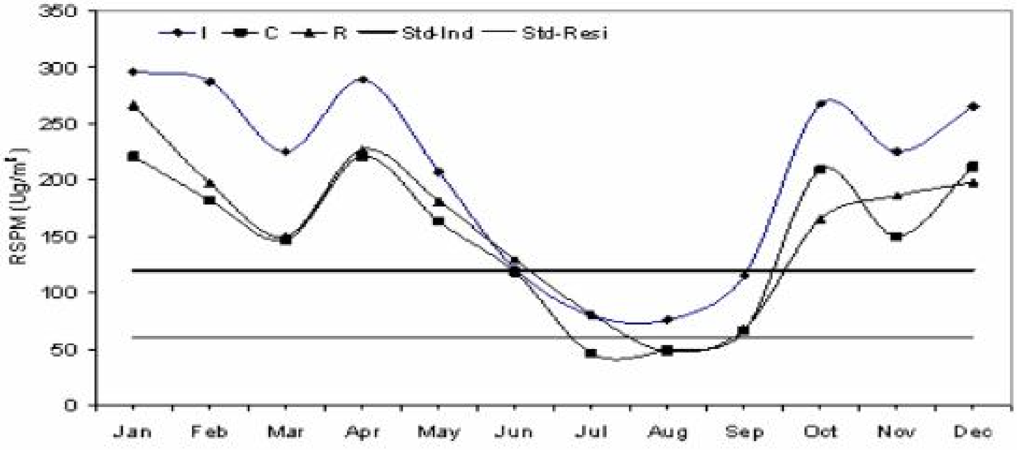


Fig 1.2 : Monthly variation in RSPM levels monitored by NEERI during 2006

Status of SO_2

Status of SO_2 on the other hand shows, levels are within the prescribed NAAQM in residential areas of Delhi. Overall a decreasing trend has been observed in SO_2 levels. This reduction can be attributed to reduced 'S' levels in fuel as also use of cleaner fuel such as CNG. Other measures include implementation of Bharat Stage-III emission norms for new vehicles as also appropriate fuel quality. Overall, the use of LPG for cooking has also increased, which has reduced SO_2 emissions from biomass and other solid fuel burning sources. **Figures 1.3** below indicate the levels of SO_2 prevalence in Delhi for different years with sulphur reduction and **Figure 1.4** presents the monthly variation of SO2 monitored by NEERI during 2006.

There has been a change in domestic fuel used from coal to LPG, which may have also contributed to reduction in ambient levels of SO_2.

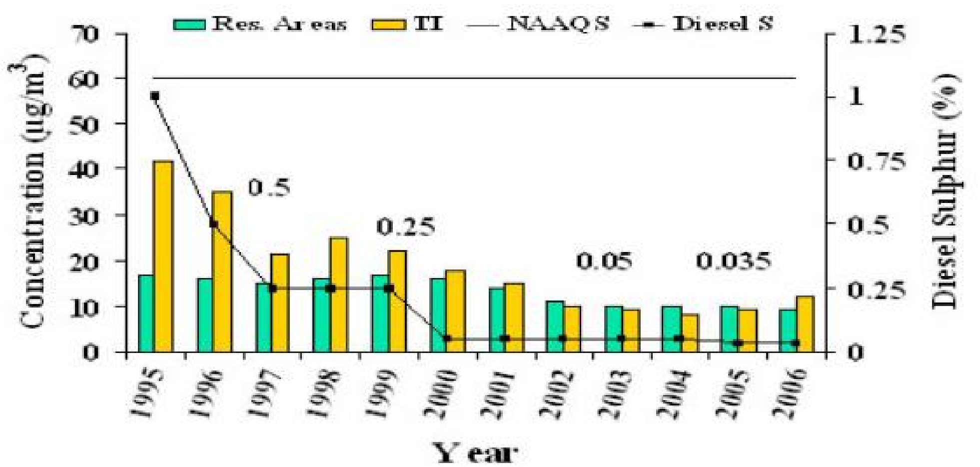


Fig. 1.3 : Trends in Annual Average Concentration of SO_2 in Residential areas and Percent Sulphur Reduction in Diesel from 1995-2006

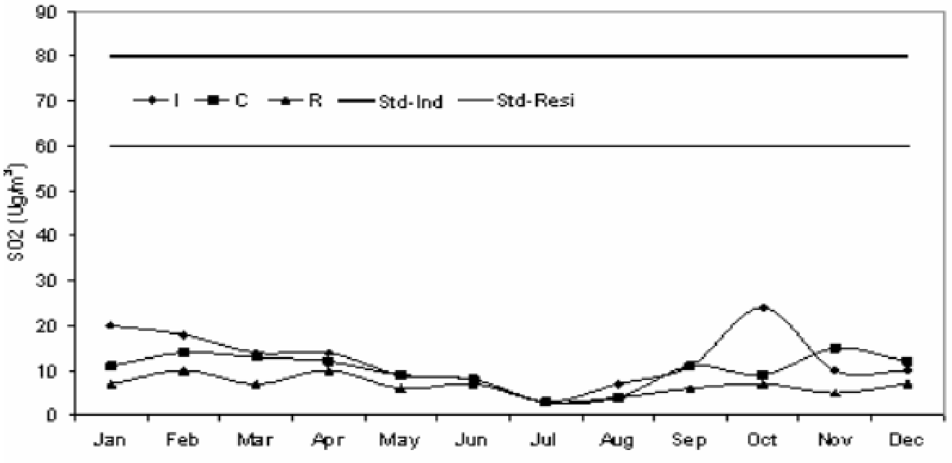


Fig 1.4 : Monthly variation in SO_2 levels monitored by NEERI during 2006

Status of NO_2

Though NO_2 values are mostly meeting the standards, however in some areas it exceeds the standards on few occasions. Also, on some places where standard is not exceeded, increase has been noticed owing to vehicular emissions. The overall rapid increase has not been seen as various measures have been taken such as banning of old vehicles, better traffic management etc. Fluctuating trends have been observed in NO_2 levels in recent times, wherein though the technology has been playing a role to reduce the same but it gets negated by exponential increase in vehicles population. Annual averages of NO_2 concentration from 1995-2006 at residential areas and monthly averages of NO_2 monitored by NEERI during 2006 is presented in **Figures 1.5 and 1.6**.

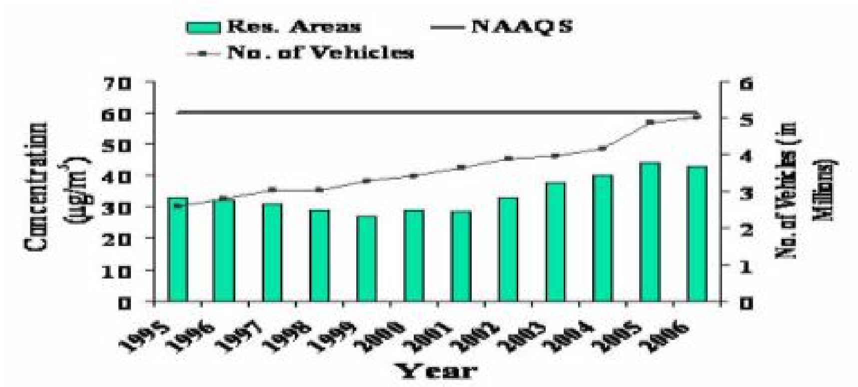


Figure 1.5 : Trends in Annual Average Concentrations of NO_2 in residential areas of Delhi

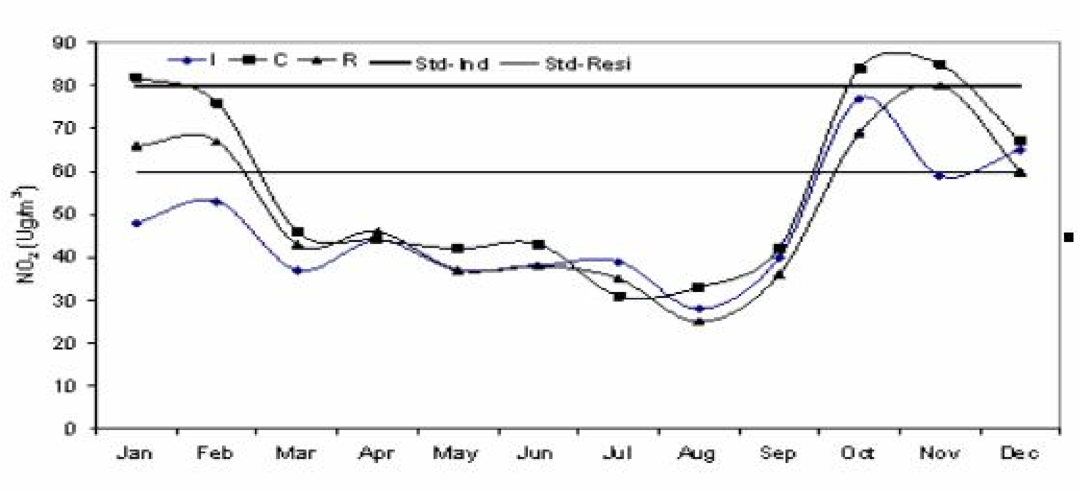


Figure 1.6 : Monthly Averages of NO_2 in Delhi for the year 2006

The other major gaseous emission, Carbon monoxide (CO) shows varying levels at many places. It can be attributed to increase in vehicular population of all types, mainly passenger cars and two wheelers in Delhi. Despite an increase in number of vehicles, CO levels have reduced during last few years. The decrease may be attributed to measures such as conversion of three wheelers to **CNG** as well as fuel efficient engines.

Recent monitoring results at CPCB stations

Some recent data of main three pollutants such as SPM, RSPM and NO_2 have been analysed for the city of Delhi. **Figures 1.7** present these values for different areas of Delhi. As can be seen from these figures, SPM values fluctuate much more widely than RSPM and NO_2. NO_2 values are consistently lower, however their values go up during more calm conditions of atmosphere. Some of these conditions are frequently encountered in Post monsoon and Winter seasons.

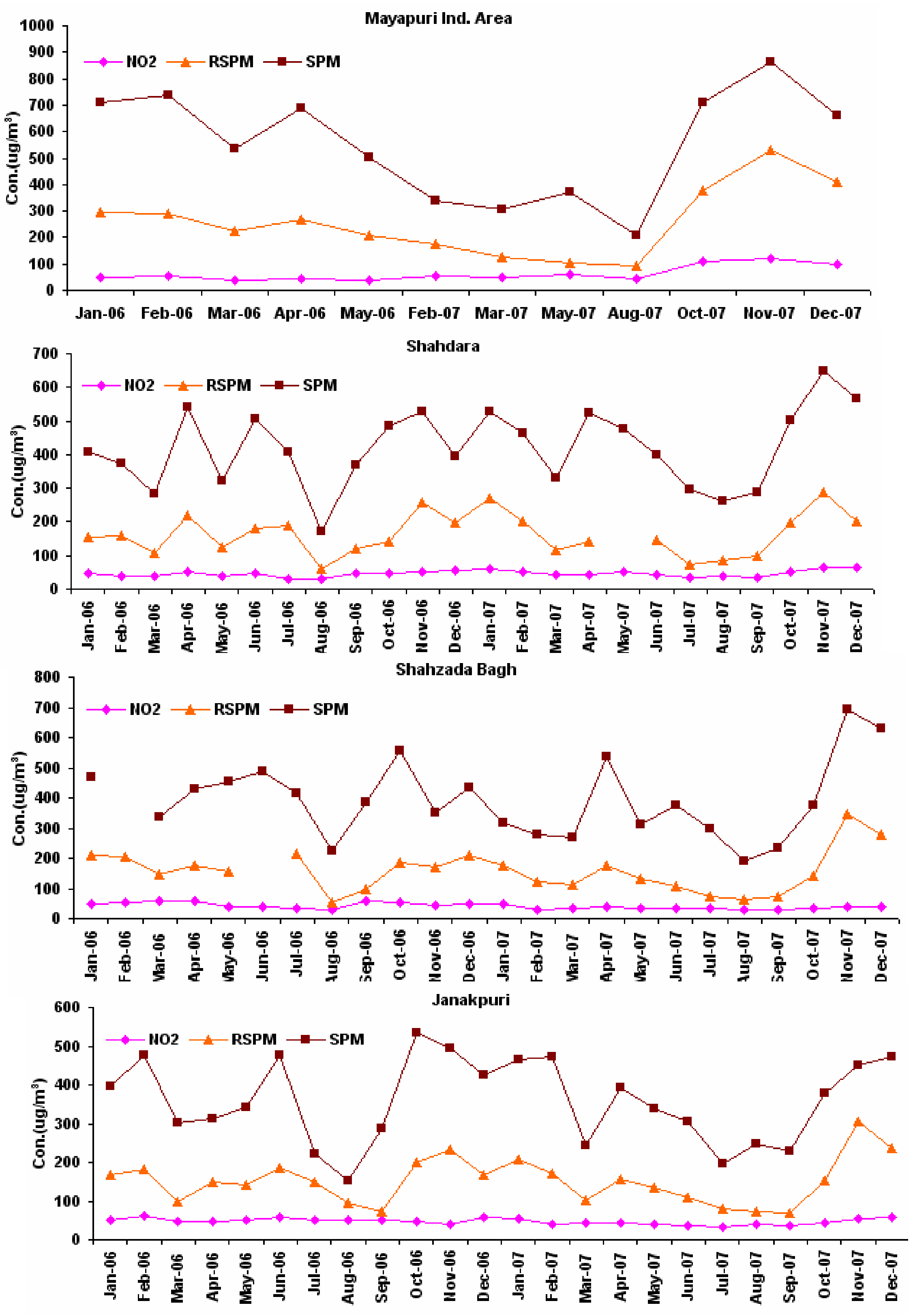


Figure 1.7 : Monitoring Results at CPCB's Sites

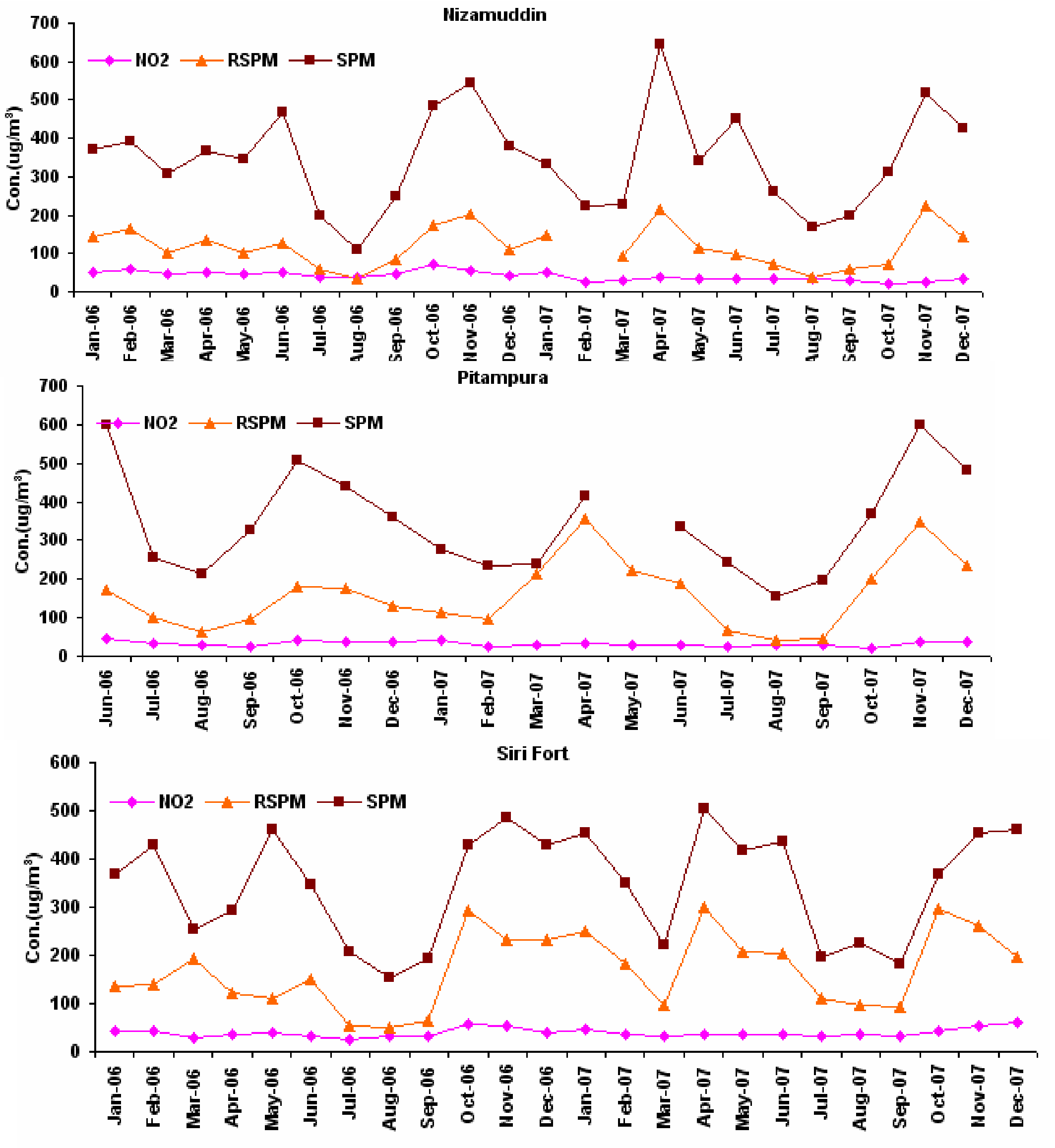


Figure 1.7 : Monitoring Results at CPCB's Sites

These values also indicate that Post monsoon (October- November) and Winter (December-January) periods have higher accumulation of pollutants which shows up in terms of higher concentrations. IMD data also shows that Post monsoon period has higher calm conditions than winter and summer has the least. Mixing of pollutants are very high during summer due to heat wave conditions and also has more dusty days due to storm and gusty winds.

1.4 Need for the Study

In the present urban setting, industries, the ever increasing motor vehicle emissions, as well as other anthropogenic source such as biomass burning, combustion etc give rise to gaseous pollutants and smaller fraction of particulate matter comprising of inorganic and volatile organic compounds. Epidemiological studies conducted in the US and UK have demonstrated that there is an association between increase in morbidity & mortality with an increase in concentration of particulate matter (PM) specially the finer fraction. The effects caused by PM on humans as a result of short term exposure include lung inflammatory reactions, respiratory symptoms, adverse effects on the cardiovascular system, increase in medication usage, increase in hospital admissions, increase in mortality etc. Effects related to long term exposure usually encompass increase in lower respiratory symptoms, reduction in lung function in children and adults, increase in chronic obstructive pulmonary disease and reduction in life expectancy, mainly due to cardiopulmonary mortality. It also increases the probability of lung cancer in population exposed. The smaller particles (PM2.5) penetrate deep into the lung and can reach the alveolar region. These fine particles are important from health viewpoint because of their high number and large surface area which may absorb/adsorb toxic compounds such as heavy metals and PAHs.

On the other hand gaseous pollutants such as NOx, SO_2, CO and other hydrocarbons pose different kind of health impacts.

A comprehensive understanding of the above stated issues and other related issues on global, regional, and local scales require the ability to determine accurately the sources of natural and anthropogenic aerosols and their precursors. On the other hand, local sources when emitting in a limited region with low assimilative capacity, can cause severe air pollution problems. The present study examines the contribution of these sources to aerosol mass, which is an important factor in the development of effective strategies for the control of aerosol-associated problems.

Besides PM, other pollutants and their sources are needed to be inventorized with a view to ascertain the point of generation. The gaseous pollutants such as NOx, SO_2, Ozone and VOCs are also known to use PM as a surrogate to carry and deposit themselves. Pollutants of all origin should be considered in entirety for any implementing agency to formulate strategies and embark upon the action plan. The complexities of sources and their impact on receptors are interlinked with source, strength, meteorology, elevation of release, atmospheric transformations etc. Strategies for sector specific pollutants need to be drawn from scientific evidences which are concrete and clear. These facts can be derived from the use of multitude of techniques such as emission inventory, dispersion modeling, receptor modeling and finally cost effectiveness analysis of varied options. Therefore, a comprehensive study has been proposed for six cities in India of which NEERI has carried out this study two cities Delhi and Mumbai.

1.5 Objectives

Primarily, the project aims at identifying the urban air pollution sources and quantifying them. Quantification of these sources would help in ranking them and formulating appropriate control strategies and management options. Although total control of air polluting sources would be certainly an ideal goal, but will not be practically feasible and, therefore, emission reduction based on cost benefit analysis, and exposure reduction by management techniques are most suitable strategies. A comprehensive air quality management would, therefore, have three basic requirements: ambient air quality levels, emission inventory and source apportionment analysis. The objectives of the study are : To measure baseline Ground Level Concentration (GLC) of air pollutants and air toxic levels in different parts of the city including background, residential, commercial/mixed area and source specific “hot spots” viz. Kerbsides, industrial zones, etc.

- To prepare inventory for the various air pollutants, their emission rates and pollutant loads from various sources along with spatial and temporal distribution in Delhi.
- To conduct source apportionment analysis for PM_{10} and $PM_{2.5}$ and prioritize the source categories for evolving cost-effective air pollution mitigation strategies/plans.
- To assess the impact of sources on ambient air quality under different management/ interventions/ control options.
- Draw a roadmap of short term and long term measures as considered appropriate and cost effective to ensure “Cleaner air in urban areas”

1.6 Approach to the Study

Approach to the study was designed to comply with the multi-objective tasks as shown in **Figure 1.8**. The final objective was urban air quality management that primarily requires knowledge of ambient air quality status, sources and emission load. These three objectives were achieved through monitoring of air pollutants at 10 locations using variety of state-of-the-art instruments for different pollutants, identifying sources of emissions and carrying out emission inventory through primary and secondary data collection. The information about emissions was used to predict the ambient air quality levels using source dispersion models that facilitate forecasting long term air quality under different meteorological conditions and emission scenarios. In order to exercise the source control measures, it is necessary to

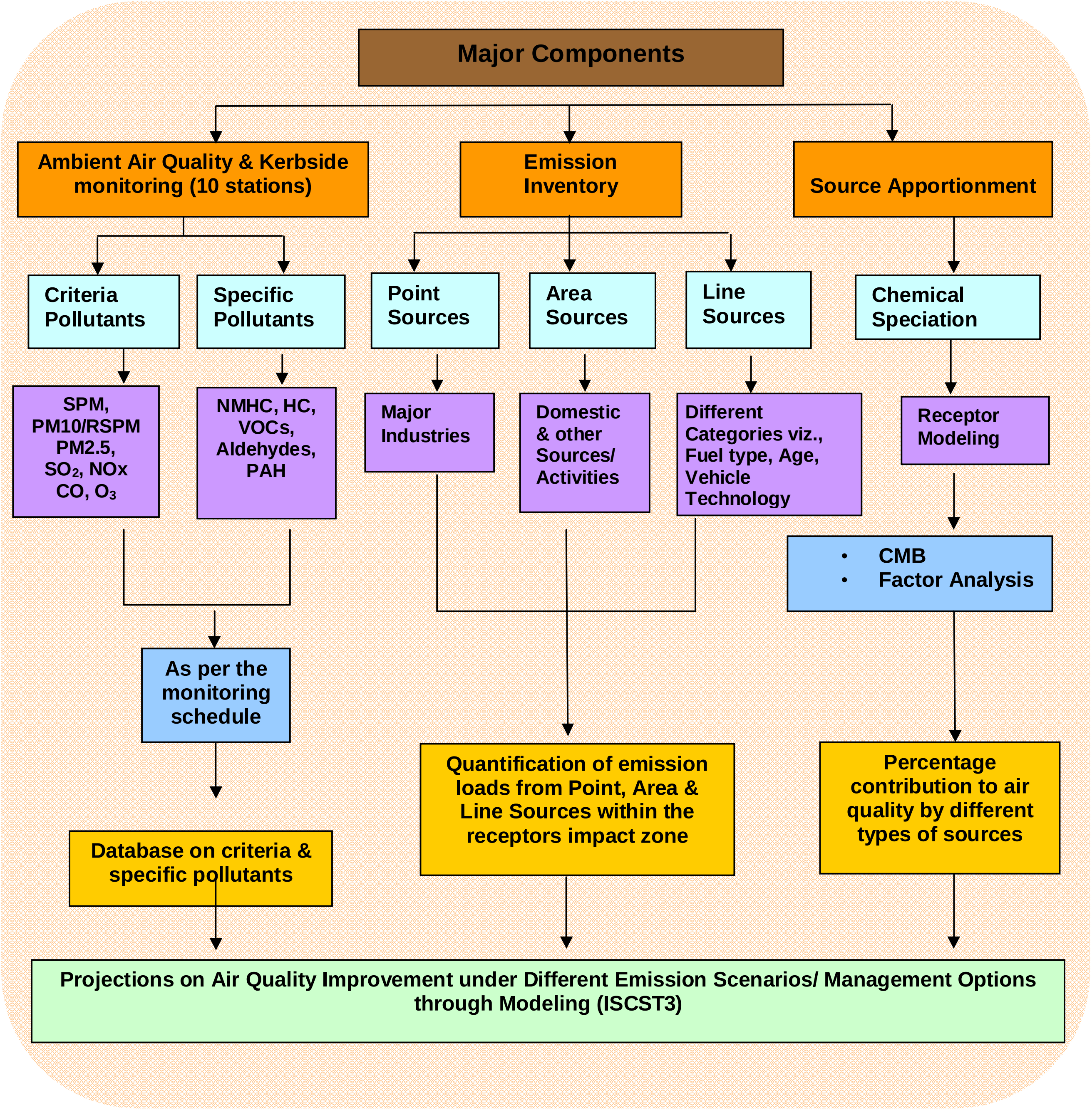


Figure 1.8 : Framework for Air Quality Monitoring & Emission Source Apportionment Studies

know the contribution from each type of source. This was carried out by receptor modeling using CMB8.2 (Chemical Mass Balance Model). Finally, all information have been collated and used for developing control options for better air quality in Delhi. The major components of the study are described briefly here.

1.6.1 Ambient Air Quality Monitoring

Ambient air quality monitoring included monitoring of criteria pollutants as well as source specific pollutants. Many of the source specific pollutants were included in the study and air quality standards from USEPA, WHO etc. were used to facilitate comparison. Some of the other critical air pollutants that were covered in the study are Benzene, 1-3 Butadiene, Aldehydes, Alkanes, NMHC, THC, Ozone, PAHs, and $PM_{2.5}$.

1.6.2 Emission Inventory

Emission inventory (EI) is a tool for identifying the sources of pollution and quantification of pollutants emissions. Emission inventories of industrial (point) source, area and vehicular (line) sources were prepared. Impact of pollution from these activities depends on many factors, viz. vicinity of emission sources, concentration of pollutants, temporal/spatial variations in emission patterns and receptor types etc. These data/information were collected from the credible sources as far as possible.

All the available sources of primary as well as secondary data were analysed. The limitations and constraints faced encountered in data collection were also identified. Concerted efforts were focused on the impact zone around the identified ten air quality monitoring sites. Emphasis was given to quality assurance and quality control of data and its documentation. The approach to preparing emission inventory is presented in **Figure 1.9** In order to facilitate the preparation of emission inventory, the study area of the Delhi metro was divided into small sectors with due consideration to prominent activities. The secondary data on the quantity and composition of these sources in different zones of Delhi were collected from various sources. Primary data were collected through questionnaires and specific surveys. Methodology used for inventory ensured high level of data handling and checks to establish its validity. Assumptions made in all cases have been mentioned and explained.

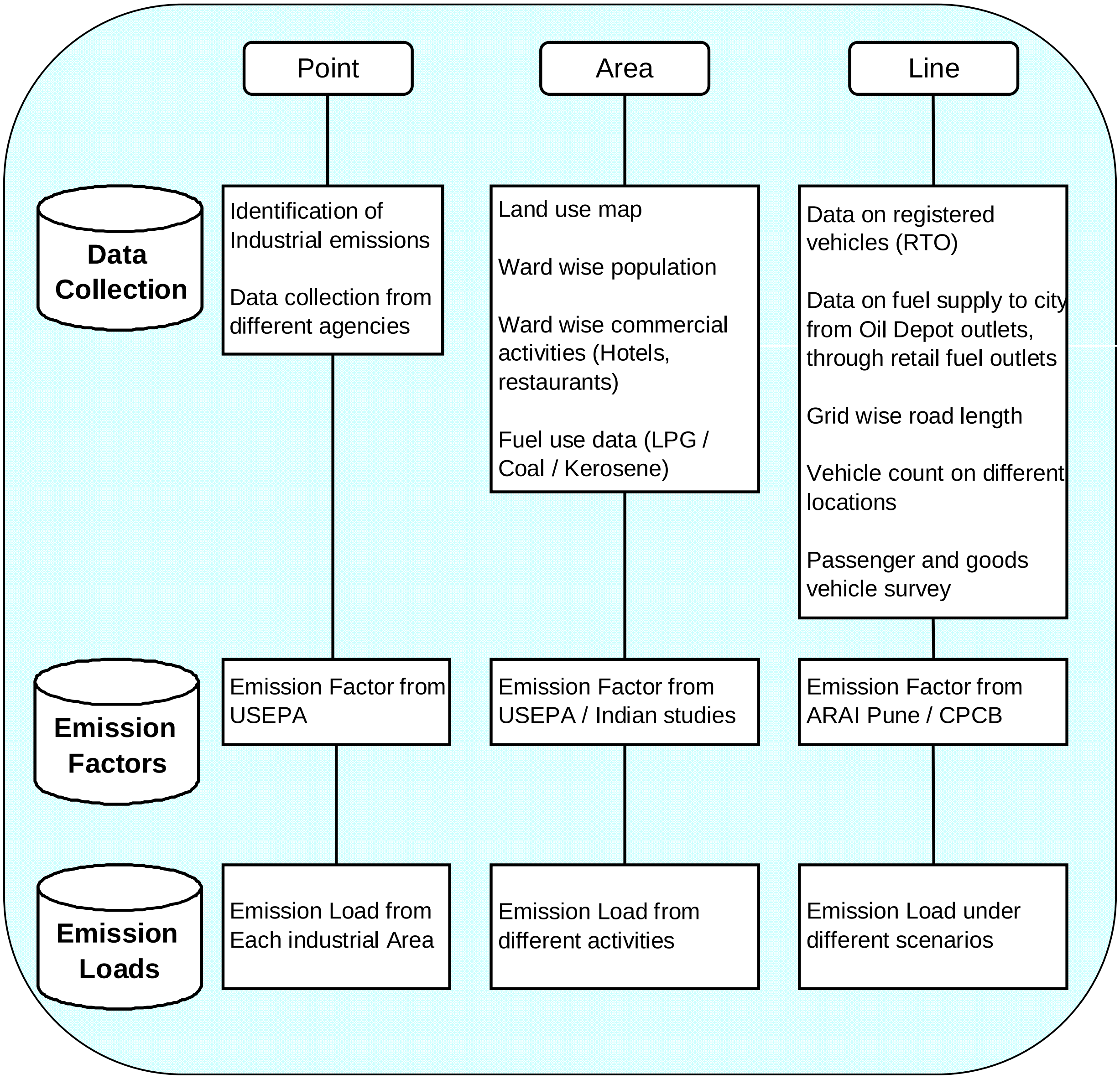


Figure 1.9 : Approach to Emission Inventory

1.6.3 Dispersion Modeling

ISCST3, air quality model, was used for dispersion modeling of particulate matter PM10 and NOx. Besides the overall city level emission inventory based on secondary data, the detailed micro-level emission inventory compiled through primary surveys at 10 locations was the input datasets to the model. Model runs were made to account for both the above inventories simultaneously. Iso-concentration plots were generated for the whole city. As a validation measure, dispersion model predicted concentrations for PM10 and NOx were compared with the measured concentrations. Future concentration estimates were drawn under different scenarios (BAU, Control options and Preferred Scenario) based on the developed correlations.

1.6.4 Source Apportionment Analysis

The contribution of pollutants by various sources and their respective share with respect to ambient air quality in any given area can be assessed in two ways. One is through the calculation of emissions from various activities or source categories using emission inventory data and the other is the estimation of percent fraction contributed by different source categories to ambient air using receptor modeling tools such as factor analysis and chemical mass balance.

1.6.4.1 Based on Emission Load

The estimate for source apportionment from emission load can be made from the emission inventory data. Emission inventory includes quantification of use of different types of fuels in a certain activity that results in air pollutant emissions. In addition, fuel supply in a region was also used as an estimate of the fuel used in energy conversion and the resultant pollutant emissions. Based on detailed emission inventory data, present as well as future emission source scenarios were generated. This helped in identifying hotspots based on the emission load. However, its distribution in the atmosphere depends upon the source characteristics like the velocity with which pollutant is emitted into the atmosphere, temperature of emissions, volumetric and mass emission rate. Besides the above, meteorology also plays a vital role in the dispersion of pollutants. Therefore, based on ranking of emission load alone, the pollutant distribution in the atmosphere and the impact on receptor can not be inferred unless, in such instances, ambient air pollutant source apportionment study has been carried out. As a first step the emission inventory data was grouped for further analysis in source apportionment studies:

- Emission inventory with respect to point sources/projections
- Emission inventory with respect to area sources/projections
- Emission inventory with respect to line sources/projections

1.6.4.2 Based on Air Quality

Distribution of pollutants in the ambient air can be approximated using source dispersion model, if the source characteristics and meteorology are known. For predicting the concentration of pollutants in the ambient air due to emissions from well defined industrial stacks, the source dispersion methodology with the assumption of Gaussian distribution of pollutants can be used. However, in an urban setting, the source characteristics are not well known. Besides the above, the urban roughness causes change in spatial wind vector in shorter distances. This does not allow the use of source dispersion modeling approach for pollution mapping. Decision making in air quality management requires control of pollutant sources that contribute more towards a particular receptor or ambient air. This can be done using another modeling approach wherein knowledge of the pollutant at receptor and the chemical composition of pollutant at the sources are known. Following are the possible major sources of PM in Delhi:

- Vehicular exhaust
- Coal burning
- Oil burning
- Re-suspended dust
- Construction activities
- Other site specific sources

The modeling methodology used to derive the contribution of sources to a particular receptor is called receptor modeling. If the marker chemical species of pollution sources are known, statistical methodology, termed as factor analysis, can be used on the chemical species data collected at the receptor end. If the composition of chemical species at the source as well as at the receptor are determined, mass balance can be worked out between source and receptor chemical species. The methodology is called chemical mass balance (CMB) method.

In this study, receptor data included chemical species concentration of particulate matter collected at 10 AAQ Monitoring stations within Delhi. Pollution sources in each of the 2km x 2km grids around the 10 monitoring stations were accounted for is modelling. Particulate matter collected from these sources was chemically analyzed for various species (ions, metals, carbons, molecular markers) and signatures of various sources were identified. The chemical species data generated for PM10 / PM2.5 pollution sources are called source signature profile. The source signature profile data generated by IIT Bombay and ARAI, Pune under this project were used as input to the CMB model. The overall approach to source apportionment analysis is presented in **Figure1.10**.

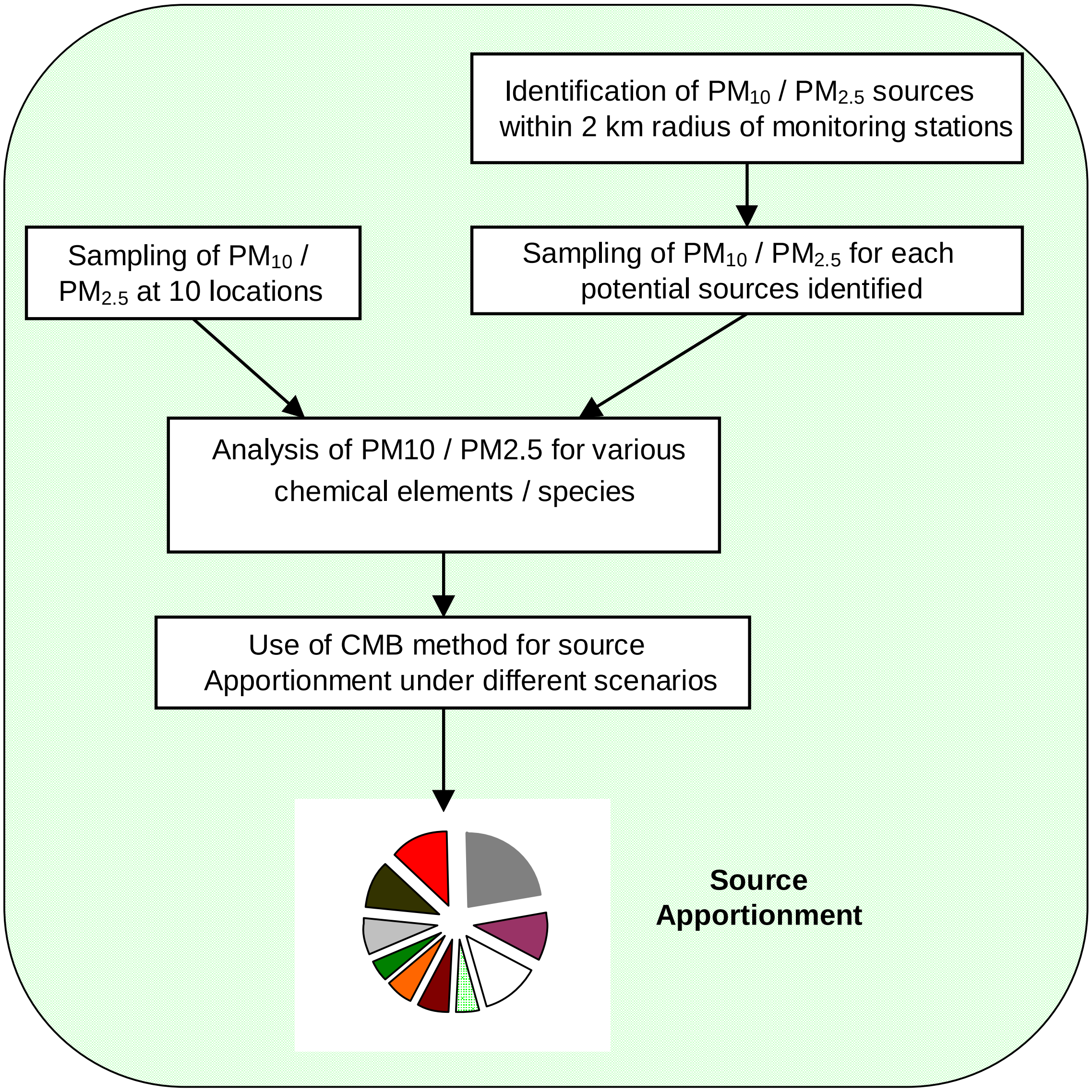


Fig 1.10 : Approach to Scheme of Source Apportionment

1.7 Deliverables

- Spatial and Temporal analysis of different air quality parameters along with corresponding emission rates of pertinent sources (obtained through emission inventory) after quantification of contribution (temporal and spatial profiling) of pollutants emitted from different sectors (transport, industrial, commercial, residential, etc).
- Percentage shares in air pollutant emissions of each source category at different receptors. (e.g. in case of vehicular sources, type of vehicles (2/3 wheelers, passenger cars, light duty vehicles, multi-utility vehicles, buses and trucks), each category of fuels (Gasoline, CNG/LPG and Diesel), sub-categorization in terms of technology of the vehicles within the aforesaid category, age of the vehicle and impact of inspection & maintenance practices, pre Euro-I or India 2000 vehicles, etc.)
- Projection of growth trends in emissions by 2012 and 2017 for various source categories and formulation of different impact scenarios (BAU and Control Options).
- Impact on ambient air pollution levels after the implementation of short/medium term interventions for the following:

  (i) Line Sources
    a) Better vehicle technology
    b) Better maintenance of vehicles
    c) Improved traffic management
    d) Better road conditions and pavements
    e) Improved tail pipe treatment / catalytic converter/ particulate filter
    f) Improved use of oxygenates/ performance additives
    g) Improved fuel quality.

  (ii) Point and area sources
    a) Control Technologies
    b) Fuel Change
    c) Other Management Options
- Preparation of a city specific air quality action plan after prioritizing control options.

1.8 Report Structure

Salient features of major study components presented in each chapter of this report are listed below

Chapter 1:

- Background and need for the present study
- Study area details and sources of pollution
- Objectives and deliverables
- Approach to the present study

Chapter 2:

- AAQM stations selection methodology and parameters
- Air quality monitoring and analysis techniques
- Seasonal variation in ambient air quality status
- Interpretation of results and discussion
- Summary of Delhi air quality status
- Chemical speciation of particulate matter

Chapter 3:

- Emission Inventory Methodology
- Point, Area and Line Sources of Pollution and Data collection Methods
- Emission Factors and emission loads estimation
- Secondary and primary data collection
- Emissions from different sources
- Contribution of different sources

Chapter 4:

- Factor Analysis methodology and apportionment of sources
- Chemical Mass Balance Model application and source contribution estimation
- Interpretation of results and percentage contribution of different sources

Chapter 5:

- Dispersion Modeling using ISCST3 Model
- Modeling of impact zones around ten air quality monitoring stations
- Interpretation of results
- Modeling of Delhi air quality based on projection of emission loads

Chapter 6:

- Projection of emission loads from Delhi under BAU scenarios, (2012 & 2017) and corresponding impact on air quality
- Evaluation of control options from point, area and line sources with respect to their impact on ambient air quality

Chapter 7:

- Preferred air quality scenario alternatives for 2012 and 2017 and impact on air quality
- Prioritization of management and control options
- Road Map for implementation

Chapter 8:

- Highlights and recommendations includes major outcome of the study

Annexure All related additional information for different chapters

Chapter 2

Air Quality Status – Delhi

2.1 Introduction

Establishment of ambient air quality status of an urban region demands air quality monitoring of various pollution parameters. It was planned to monitor criteria pollutants to examine the influence of anthropogenic sources. Air pollutants such as SPM, PM_{10}, $PM_{2.5}$, SO_2, NO_x, CO, $O_{3,}$ Benzene, 1, 3 - Butadiene, Aldehydes, NMHC and HC have been monitored. Further, PM_{10} and other fine particulate have been also analyzed for EC/OC, ions and PAH including molecular marker.

The purpose of monitoring is also to establish the levels of organic and inorganic elements, ions etc. present in the PM with a view to identify the sources. Chemical transformation in the atmosphere leading to secondary pollutants formation are also need to be accounted for while addressing the overall objectives of the study. Since the study at Delhi aims at source apportionment of pollutants, specific pollutants with recommended sampling and analysis protocol were monitored at 10 locations over a period of one year covering three different seasons viz., summer, post monsoon and winter. In the subsequent sections, sampling stations, pollutant parameters, frequency etc. are described. A detailed description is provided about the quantitative values of the pollution parameters and their comparison/correlation with regulatory levels and other parameters to define the air quality status. Air quality status around each AAQ monitoring station is presented along with the details of seasonal variations. Analysis of air pollution data sampled and analyzed for each station is discussed with a view to establish seasonal variation and comparison with other pollutants. An attempt was also made to establish correlation of pollutants in order to understand their sources. Elements, ions, EC-OC and molecular markers have been analyzed in PM to further establish the sources and their strengths.

2.2 Methodology

2.2.1 Sampling Sites

Monitoring was carried out at ten monitoring sites representing kerb side, industrial, residential, mixed zones and reference (background) zone activities. The locations of ambient air quality monitoring stations are shown in **Figure 2.1** and are listed in **Table 2.1** along with the details of categories. Six kerb side and one each representing Industrial, residential, mixed use and reference areas were shortlisted for comprehensive air quality monitoring as also for PM source apportionment after using adequate site assessment criteria .

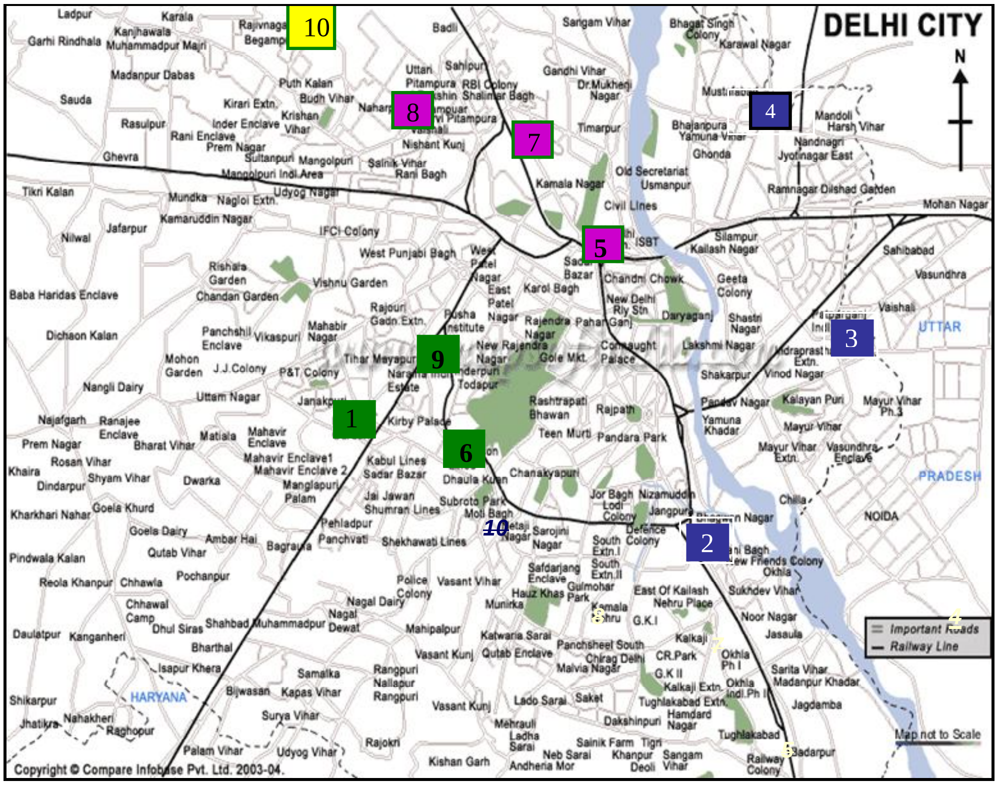


Figure- 2.1 : Location of sampling sites in the city

Table 2.1 Air Quality Monitoring Stations

Sr. No.	Monitoring Stations	Type	Site Description
1	Prahladpur	Reference /Background	Close to agricultural field, Main Bawana road about 800m from the site.
2	Pitampura	Residential	Residential area, commercial activity, Ring road at 600m distance from station
3	Naraina	Mixed Use	SSI units like electrical, electronics, hospital equipments, plastics, garments, printing press, engineering machinery etc. Fly over construction in progress, residential area, commercial activity, slum population
4	SSI- GTK Road	Industrial	National Highway and outer Ring Road, Jahangirpur Industrial area, High traffic volume, Slum population, construction work for Metro Rail
5	Ashram Chowk	Kerb Side	High traffic volume, Ring roads, National Highway, Residential, commercial activity
6	Dhaula kuan (DK)	Kerb Side	High traffic volume, Ring road and two National Highways, Cantonment area, Relatively less commercial and residential activity
7	Mayapuri	Kerb Side	Industries, Heavy traffic on Ring Road, Limited residential area, Tihar Jail area
8	Anand Vihar (Road No. 56)	Kerb Side	Proximity to ISBT, Sahibabad and Patparganj Industrial area, commercial activity
9	ISBT Ring Road	Kerb Side	Traffic connecting to Northern States, River Yamuna on east side, Metro rail station, Road side eateries and moderate commercial activities
10	Loni Road	Kerb Side	National and State highway, High traffic volume, residential and commercial activities

2.2.2 MONITORING PARAMETERS

Parameters of monitoring were decided based on the objectives of air pollution and source apportionment study. The source apportionment analysis required air quality monitoring for particulate matter (PM_{10} and limited $PM_{2.5}$) and its chemical speciation to develop signature profiles of pollution sources that can be used in chemical mass balance models. The analysis data could also be used to interpret the overall loading of different chemicals contributed varied sources. Monitoring included air quality attributes such as SPM, RSPM, SO_2, NOx to understand not only the regulatory compliance but also their inter-correlations with other species such as EC, OC, TC, nitrate, sulphate etc.

Since the objective of source apportionment study is to determine the contributions from various sources such as industries, vehicular and other area sources additional parameters were also monitored such as CO, Benzene, 1-3 Butadiene, Aldehydes, Alkanes, NMHC, THC, Ozone, PAHs. For chemical speciation of PM10, it was collected at medium flow rate on different media (teflon, quartz and nylon filter of 47mm diameter) using 4 channel speciation sampler (TSI-2300 four channel). For regulatory compliance assessment, SPM and RSPM were collected on glass fiber filter paper of 8x10” size in respective dust sampler. List of all the parameters, sampling instruments, sampling flow rate and analytical methods are provided in **Table 2.2**.

Monitoring Frequency

All pollutants exhibit diurnal and seasonal variations, which have been taken into account while determining the frequency of the sampling. In order to assess the impact of the diurnal variations in source contributions for a given meteorology of the day, 8 hourly monitoring plan was envisaged with the period between 06-14hrs, 14-22hrs and 22-06hrs. The field study was planned for a period of 20 days at each monitoring site in each season to represent the variation in air quality during the whole year. The sampling frequency details are presented in **Table 2.3**.

Table 2.2: Sampling and Analytical Protocol used in the Study

Particulars	**Parameters**						
	SPM	**PM_{10}**	**$PM_{2.5}$**	**NO_X**	**SO_2**	**CO**	**OC/EC**
Sampling Instrument	High Volume Sampler	Multichannel (4 channel) Speciation Sampler	FRM Partisol ($PM_{2.5}$) sampler Or Equivalent	Impingers attached to HVS	Impingers attached to HVS	Automatic analyser	PM_{10} Sampler Particulate collected on Quartz filter
Sampling Principle	Filtration of aerodynamic sizes	Filtration of aerodynamic sizes with a size cut by impaction	Filtration of aerodynamic sizes with a size cut by impaction followed by cyclone separation	Chemical absorption in suitable media	Chemical absorption in suitable media	Suction by Pump As per instrument specification	Filtration of aerodynamic sizes with a size cut by impaction
Flow rate	0.8-1.2 m^3/min	16.7 LPM	16.7 LPM	1.0 LPM	1.0 LPM	0.2 – 0.5 LPM	16.7 LPM
Sampling Period	8 change of filter, 24 Hourly Reporting	20 days 24 hourly and 10 days 8 Hourly filter change	24 hourly	4 Hourly change of absorbing media, 24 Hourly Reporting	4 Hourly change of absorbing media, 24 Hourly Reporting	Real time analysis and 8/24 hourly reporting	24 hourly Or 8 / 24 Hourly
Sampling frequency	30 Days continuous in each season, for three seasons	30 Days continuous in each season, for three seasons	One week continuous. First 2 days with Quartz, next 3 days with Teflon and next 2 days again with quartz filter	30 Days continuous in each season, for three seasons	30 Days continuous in each season, for three seasons	One week continuous during 30 days of monitoring in each season	30 Days continuous in each season, for three seasons
Analytical instrument	Electronic Balance	Electronic Balance	Electronic Micro Balance	Spectrophotometer	Spectrophotometer	GC - FID with Methaniser	OC/EC Analyser
Analytical method	Gravimetric	Gravimetric	Gravimetric	Colorimetric Improved West & Gaeke Method	Colorimetric Jacobs & Hochheiser Modified method	CO as Methane	TOR/TOT Method NIOSH 5040
Minimum Reportable value	5 µg/m^3	5 µg/m^3	5 µg/m^3	9 µg/m^3	4 µg/m^3	0.1 ppm	0.2 µg/ 0.5 cm^2 punch

Table 2.2 (Contd...): Sampling and Analytical Protocol used in the Study

Particulars	**Ions**	**VOC (Benzene and 1,3 Butadiene,)**	**O_3**	**Aldehyde**	**NMHC**	**HC**	**PAHs (Included in organic Markers)**
Sampling Instrument	PM10 Sampler Particulate collected on Teflon filter	Low volume sampling pump connected to Adsorption Tube	Automatic analyser	Impingers attached to HVS / RDS	Low volume sampling pump connected to Tedlar bags	Low volume sampling pump connected to Tedlar bags	PM_{10} Sampler
Sampling Principle	Filtration of aerodynamic sizes with a size cut by impaction	Active pressurised sampling / Adsorption	Suction by Pump	Chemical Absorption Or Active pressurised sampling	Suction by Pump	Auto suction by pump	Filtration of aerodynamic sizes
Flow rate	16.7 LPM	0.2 - 0.5 LPM	As per instrument specification	0.5 LPM	As per instrument specification	As per instrument specification	16.7 LPM
Sampling Period	24 hourly Or 8 / 24 Hourly	8 Hourly sampling and 24 Hourly Reporting	One week continuous Real time analysis and 8/24 hourly reporting	8 Hourly sampling and 24 Hourly Reporting	8 Hourly sampling and 24 Hourly Reporting	8 Hourly sampling and 24 Hourly Reporting	Weekly composite of left over Quartz filter after OC/Ec analysis
Sampling frequency	30 Days continuous in each season, for three seasons	Twice during 30 days of monitoring in each season	One week continuous during 20 days of monitoring in each season	Twice in 30 days of monitoring in each season	Once in every week during 30 days of monitoring in each season	Once in every week during 30 days of monitoring in each season	04 weekly composite samples per season
Analytical instrument	Ion Chromatograph	GC-ATD-FID / MS Or GC-FID / MS	Automatic analyser	Spectrophotometer	GC - FID with Methaniser	GC - FID with Methaniser	GC-MS
Analytical method	Ion Chromatography	USEPA method TO-1/ TO-2 / TO-4 / TO-10 / TO-14	UV-Photometry	Colorimetric (MBTH method)	FID Analysis	FID Analysis	GC-MS
Minimum Reportable value		0.1 ppb	2 ppb	µg/m^3	0.05 ppm	0.05 ppm	1 ng/m^3

Notes:
1. Benzene 1,3 Butadiene and Alkanes may be done by adsorption followed by GC-ATD-FID Analysis using selective Adsorption tubes.
2. Methodology for molecular marker has been provided separately

Table 2.3: Frequency of Air Pollutants Sampling in Delhi for SA Study

Parameter	Number of Days	Change of filter /absorbing media	Reporting
SPM	20	8 hourly	24 hourly
RSPM	20	8 hourly	24 hourly
PM_{10}	20	14 days-24 hourly 6 days-8 hourly	14 days-24 hourly 6 days-8 hourly
$PM_{2.5}$	7	2 days- Quartz 3 days- Teflon 2 days-Quartz	24 hourly
NO_2	20	4 hourly	4 & 24 hourly
SO_2	20	4 hourly	4 & 24 hourly
Aldehyde	1	8 hourly	24 hourly
CO	7	-	8 & 24 hourly
VOC	1	8 hourly	24 hourly
Ozone	7	1 hourly	1 & 24 hourly
NMHC	7	8 hourly	24 hourly
HC	7	8 hourly	24 hourly

2.3 Ambient Air Quality Monitoring

The air quality monitoring stations were chosen to represent the whole of Delhi and its varied characteristics. In the initial stages of the study design, wide spread traffic activities and dense road network were under focus. The final monitoring network of Delhi represented kerb side locations under different land-use types. Six stations were selected near road side, which are referred as kerb side stations with variable situation and location to represent the overall city traffic locations. One station was established in the industrial area to represent the industrial sources contribution. Another two stations were established in mixed and residential areas to understand the characteristic of such areas. All these nine stations were located within the core area of known sources of pollution within the city. However, to facilitate comparison of pollution from these sources with background levels, a station was also located at the outskirts of Delhi. Porta cabins were installed at the monitoring sites to house instruments and other necessary equipments.

2.3.1 Prahladpur (Reference/Background)

Site Description

It is considered as low activity zone, as it is away from the core area of Delhi. It is located near village with an estimated population of about 28,000. The sampling station is installed near a temple, which is located in open area and the nearby land is used for agricultural purposes as shown in **Fig. 2.2**. Main roads, Bhawana road and road from Rohini side are about 800 m away from the monitoring site.

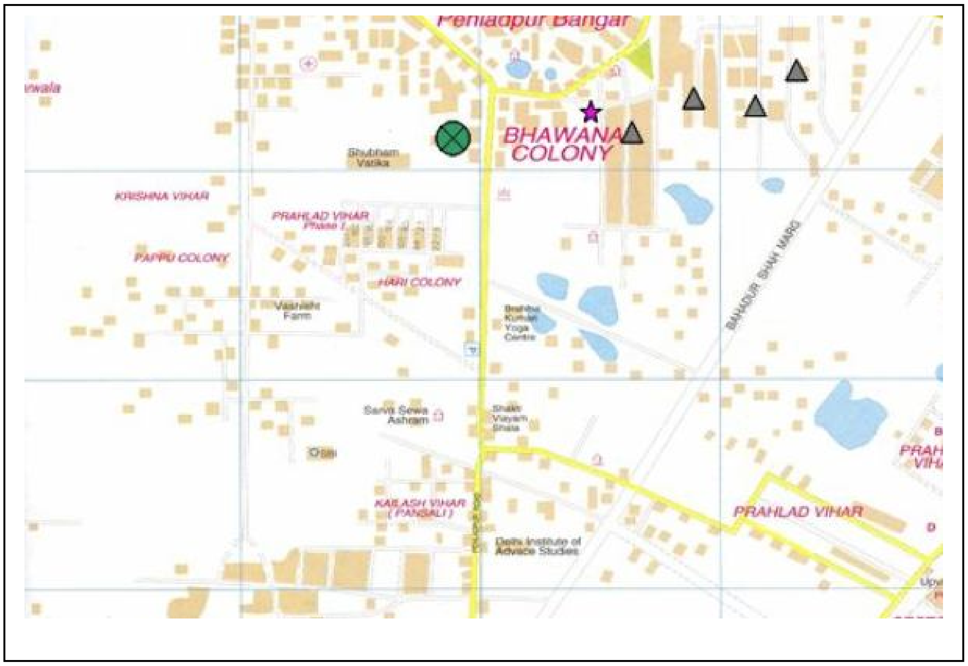


Fig. 2.2: Study Zone (2 km x 2 km): Prahladpur

Air Quality Monitoring

For ambient air quality monitoring, twelve major parameters were sampled at this station for all three seasons. No of observations, Maximum, Minimum, average, 98% standard deviation values, CV of pollutants concentrations are estimated as shown in **Table 2.4 a-b-c for** different seasons viz. summer, post monsoon and winter. All PM_{10} and limited number of $PM_{2.5}$ samples were analyzed for EC, OC, TC, elements, ions and molecular markers.

Trends of pollutants concentration has been plotted and represented in **Fig. 2.3 and 2.4.** These figures indicate that the seasonal variation is significant and varies from site to site. The plots have been drawn with the available data for all seasons. Some of the days when the data was highly variable and a valid sample was not possible, those have been considered as outliers and removed. Some other cases, where the data can still be derived from the average of earlier and next days due to limitation of sampling date, the average values have been used.

Table 2.4 a: Air Quality Status at Prahladpur(Summer)

	N	Min	Max	Average	Per98	Stdev	CV
SPM	21	251	967	558.4	935.8	219.6	0.393
RSPM	21	54.7	368	214.3	364.7	107.3	0.501
PM_{10}	21	108	479.5	253.4	465.9	106.8	0.421
$PM_{2.5}$	3	87	233	143.3	228.1	78.5	0.548
SO_2	21	4.7	21	8.9	20.3	4.8	0.539
NO_2	21	15	43	26.1	41	7.7	0.295
O_3	7	2.7	25.2	16.3	24.8	7.6	0.466
CO	7	0.6	0.9	0.7	0.9	0.1	0.143
CH_4	NA	NA	NA	NA	NA	NA	NA
NMHC	NA	NA	NA	NA	NA	NA	NA
THC	NA	NA	NA	NA	NA	NA	NA
HCHO	1			11			

Table 2.4 b: Air Quality Status at Prahladpur (Post Monsoon)

	N	Min	Max	Average	Per98	Stdev	CV
SPM	21	400	833	558.4	811.5	111.8	0.200
RSPM	21	194.1	459.2	277.4	448.7	70	0.252
PM_{10}	17	249	515.5	364.6	514.5	83.7	0.230
$PM_{2.5}$	3	170	205	187.7	204.3	17.5	0.093
SO_2	21	5	20	8.7	18	3.9	0.448
NO_2	21	14	53	33.1	52.6	11	0.332
O_3	7	26.9	50.8	41.8	50.7	13	0.311
CO	7	0.5	1.7	0.9	1.6	0.4	0.444
CH_4	7	2.2	2.7	2.5	2.7	0.2	0.080
NMHC	7	0.4	0.7	0.6	0.7	0.1	0.167
THC	7	2.7	3.4	3.1	3.4	0.3	0.097
HCHO	3			9.3			

Table 2.4c: Air Quality Status at Prahladpur (Winter)

	N	Min	Max	Average	Per98	Stdev	CV
SPM	21	284	888	574.4	876.8	178.1	0.31
RSPM	20	122	508	304.4	493	129.7	0.43
PM_{10}	21	156	571	333	568.4	151.2	0.45
$PM_{2.5}$	3	163	194	183.3	194	17.6	0.09
SO_2	21	5.9	32	16.7	31.2	8	0.48
NO_2	21	13.8	54	35.4	53.2	11.1	0.31
O_3	3	18.4	27.8	22.5	27.8	3.8	0.17
CO	7	1.2	2.1	1.6	2.1	0.3	0.19
CH_4	7	1.9	2.3	2.1	2.3	0.1	0.05
NMHC	7	0.7	1.2	1	1.2	0.1	0.1
THC		2.6	3.2	3.1	3.2	0.2	0.07
HCHO				10			NA

* PM_{10} values are based on speciation sampler

Particulate matter (SPM, RSPM and PM_{10}) levels of Prahladpur during all three seasons are presented in **Figures 2.3** along with regulatory standards of CPCB for SPM and RSPM. It can be seen that for the two criteria pollutants (SPM, RSPM) the monitored values exceed the regulatory limit on most of the days. In the case of PM_{10}, the levels are almost between SPM and RSPM during the monitoring period. Though it is not expected to get higher values of SPM and RSPM at background site, however, the background dust contribution dominates the mass. Subsequent chemical analysis presented later proves that it's a background site with comparatively minimum anthropogenic contribution.

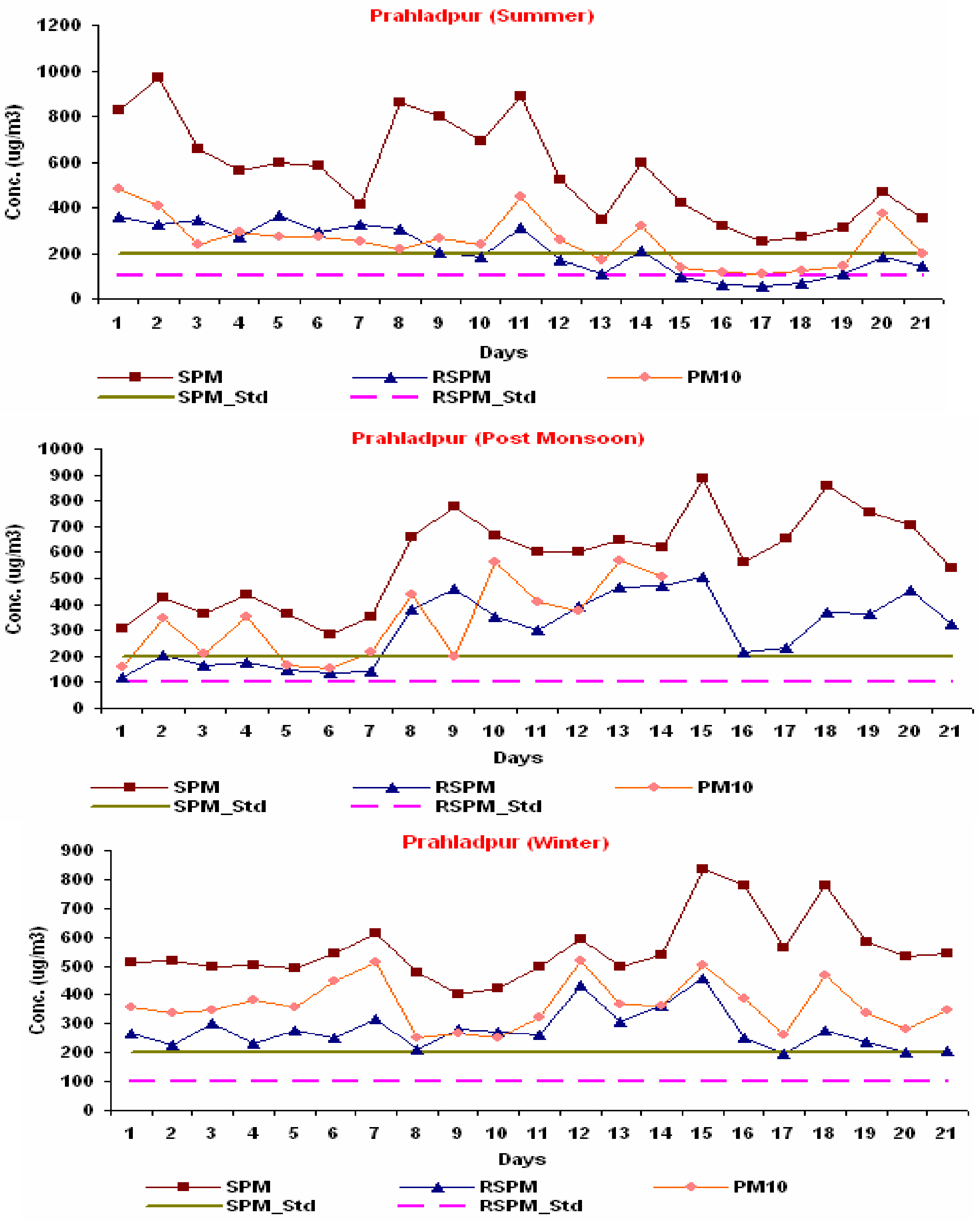


Fig 2.3 : Observed Concentration of SPM, RSPM and PM_{10} at Prahladpur in all three seasons

Gaseous criteria pollutants SO_2 and NO_2 are plotted for all the three seasons to examine regulatory compliance as shown in **Fig. 2.4** for all three seasons. It can be observed that the SO_2 concentration levels are below the NAAQM standard in all the days. The NO_2 concentration levels are also below standards.

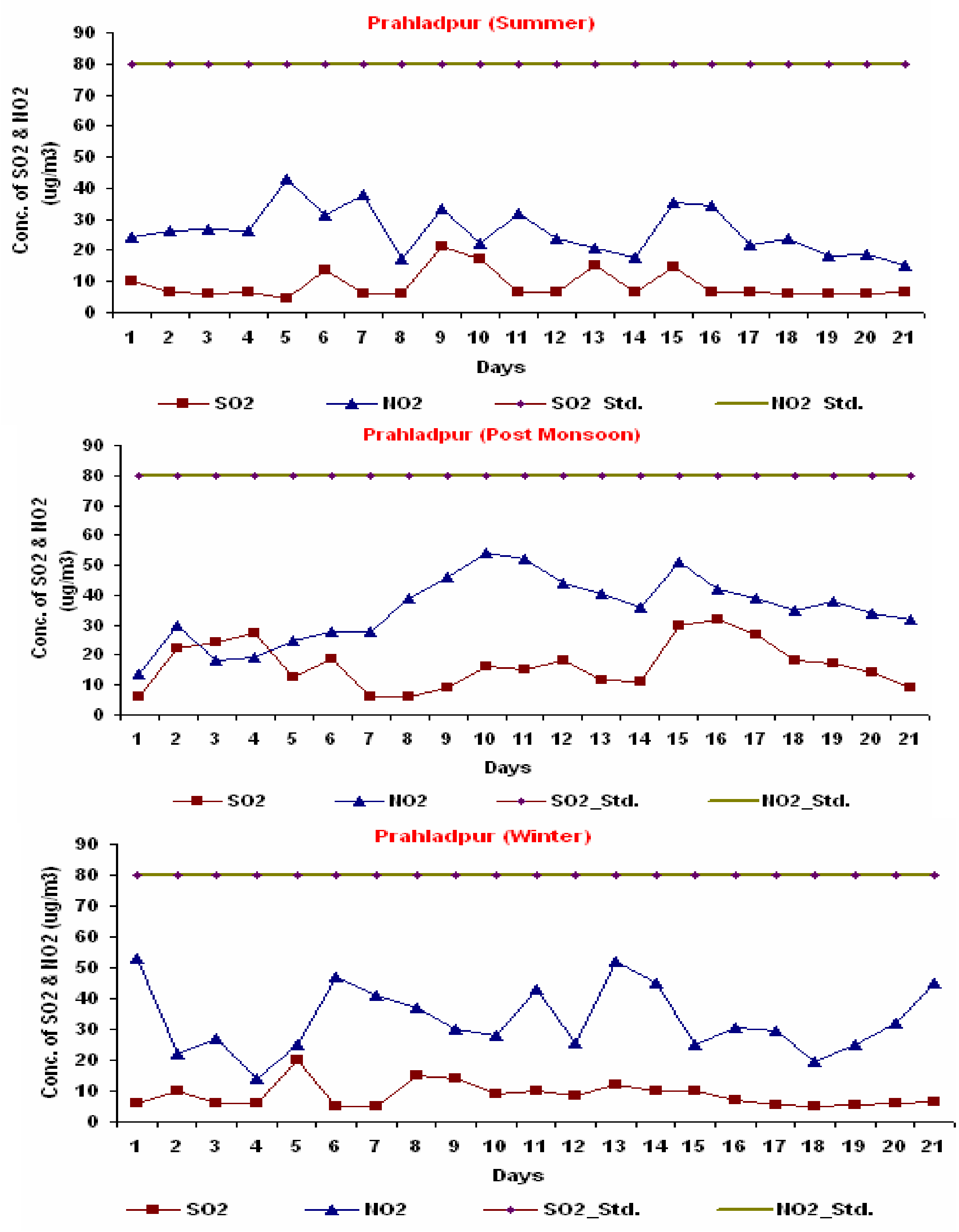


Fig 2.4 : Observed Concentration of SO_2 and NO_2 at Prahladpur in all three seasons

The concentrations of $PM_{2.5}$ for all three seasons are presented in **Fig 2.5**. The concentration of $PM_{2.5}$ exceeded the US EPA standard of 35 µg/m^3 in all three seasons.

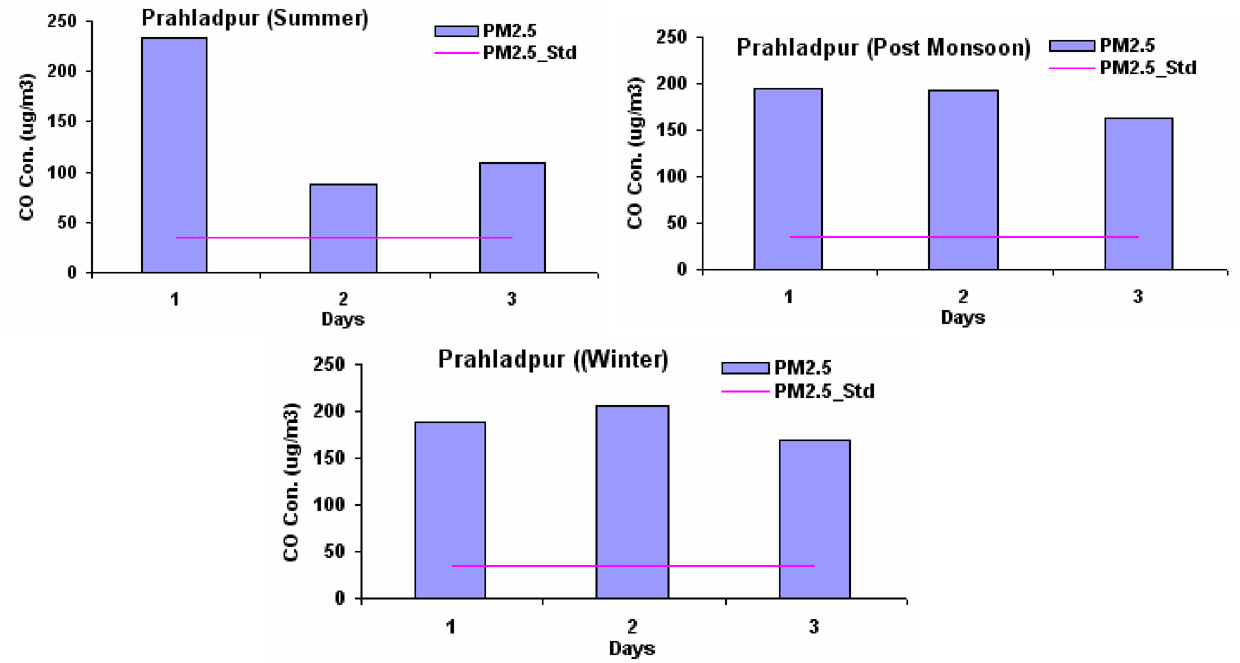


Fig 2.5 : Concentration of $PM_{2.5}$ at Prahladpur

Figure 2.6 and 2.7 present the levels of CO along with CH_4, NMHC & THC respectively in all three seasons. CO values are meeting the standards of 2 mg/m^3 all the time in all seasons, except once in post monsoon season it exceeds on one occasion marginally. CH_4, NMHC and THC values are low when compared with other places.

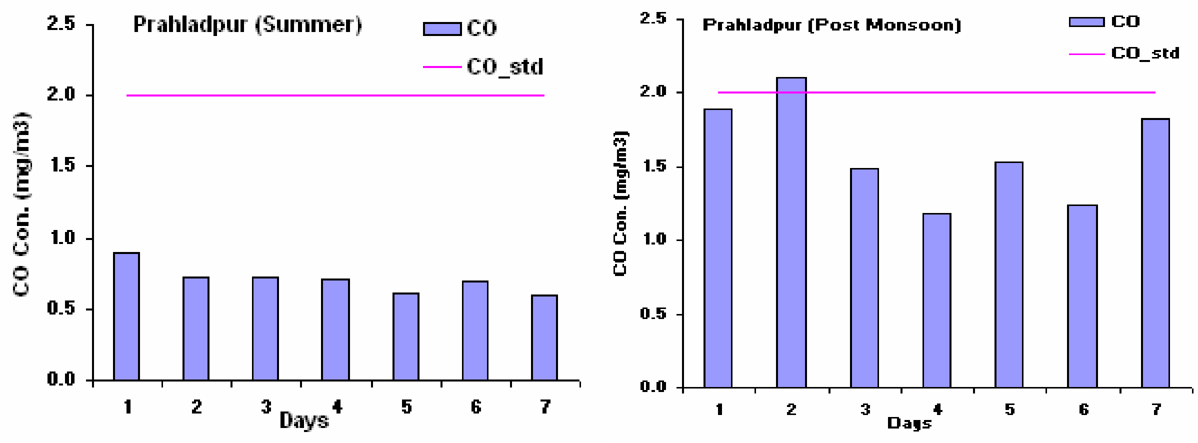


Fig 2.6 : Observed CO concentration at Prahladpur in all three seasons

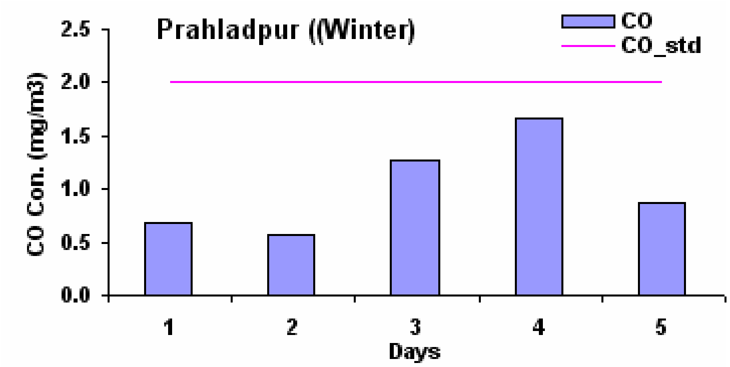


Fig 2.6 (Contd..) : Observed CO concentration at Prahladpur in all three seasons

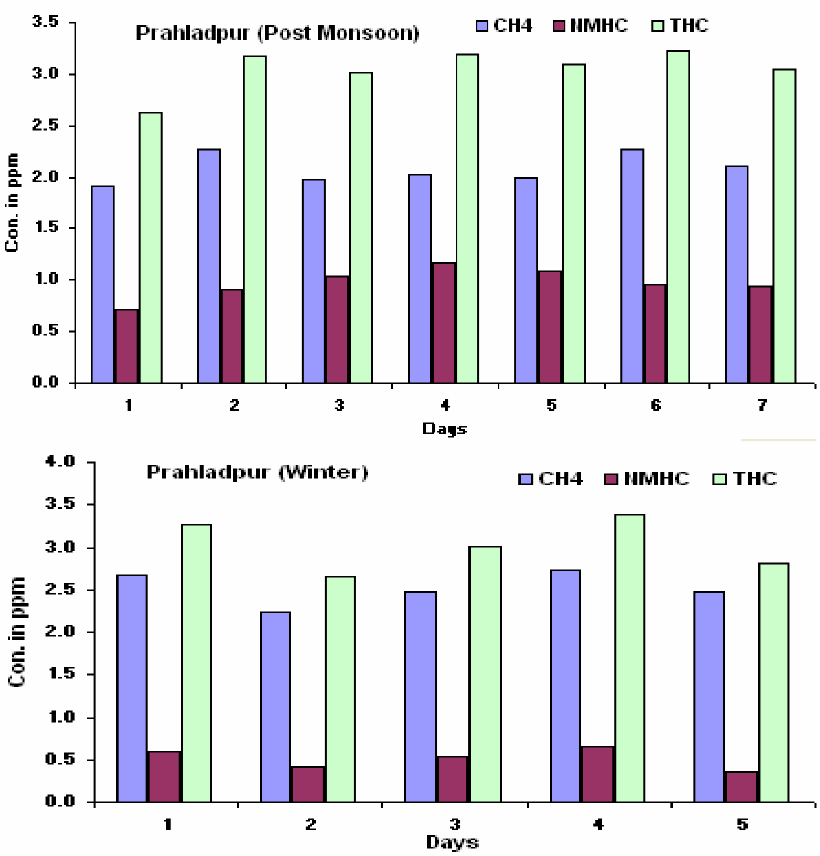


Fig 2.7 : Observed CH_4, NMHC and THC concentration at Prahladpur in all three seasons

Table: 2.5 shows the 24 hourly average Concentrations of VOCs for one day in all the three seasons. The variation is not significant except that the Benzene values are higher in winter compared to summer.

Table 2.5 : 24 Hourly Concentrations of VOCs

	1-3 Butadiene	Benzene
Summer	0.5	0.6
Post Monsoon	0.6	0.8
Winter	0.3	0.9

Diurnal variation in NO_2 and Ozone levels is plotted in **Figure 2.8**. It can be observed that the day time concentration of NO_2 is about 30 µg/m^3 and later it rises after sunset to about 40 µg/m^3 till 6 PM and then falls to 30 µg/m³. The monitored Ozone values are plotted and it can be observed that both NO_2 and Ozone follow a diurnal cyclic pattern.

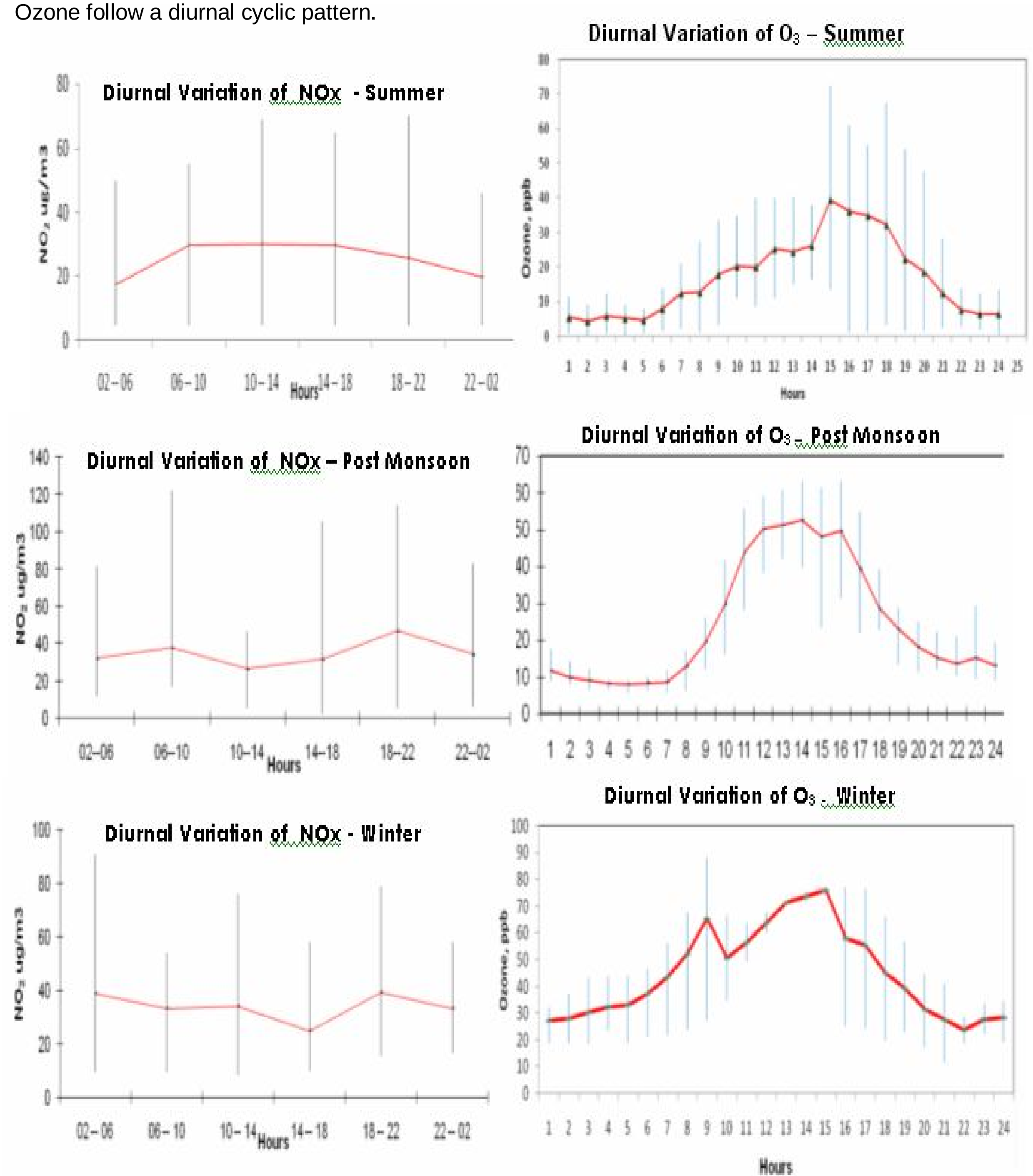


Fig 2.8 : Diurnal Variation in NO_2 and Ozone at Prahladpur

Estimation of EC/OC Ratio

EC and OC was determined for PM samples with a view to establish the sources of carbon. Many of these carbon in their different form can indicate their sources. For each season and for all stations EC and OC values have been determined and addressed. 24 hourly trends of OC, EC and TC with respect to their ratios are presented in **Fig 2.9.** High concentration of OC, EC is observed in winter season with OC/EC ration ranging from 2.5 to 7 indicating presence of organic carbon formation with biomass burning etc.

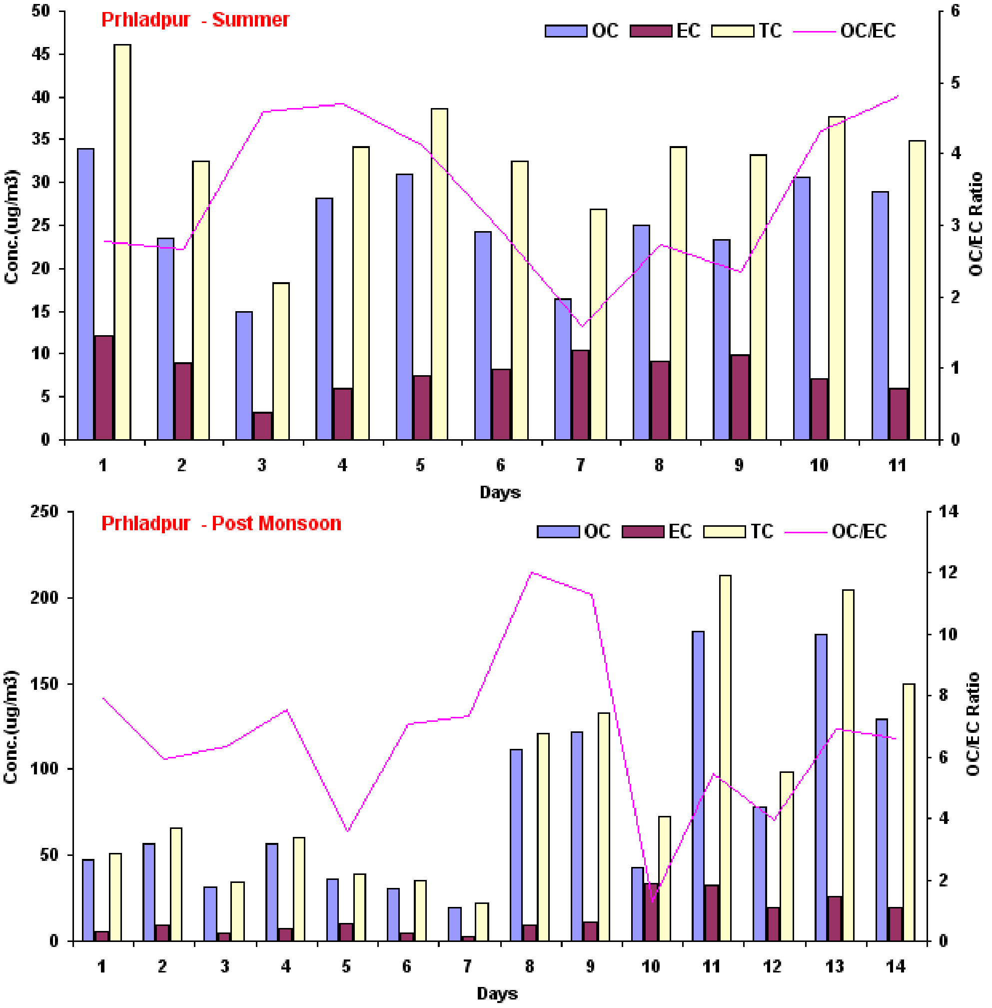


Fig 2.9: 24 hourly trends of OC, EC and TC at Prahladpur

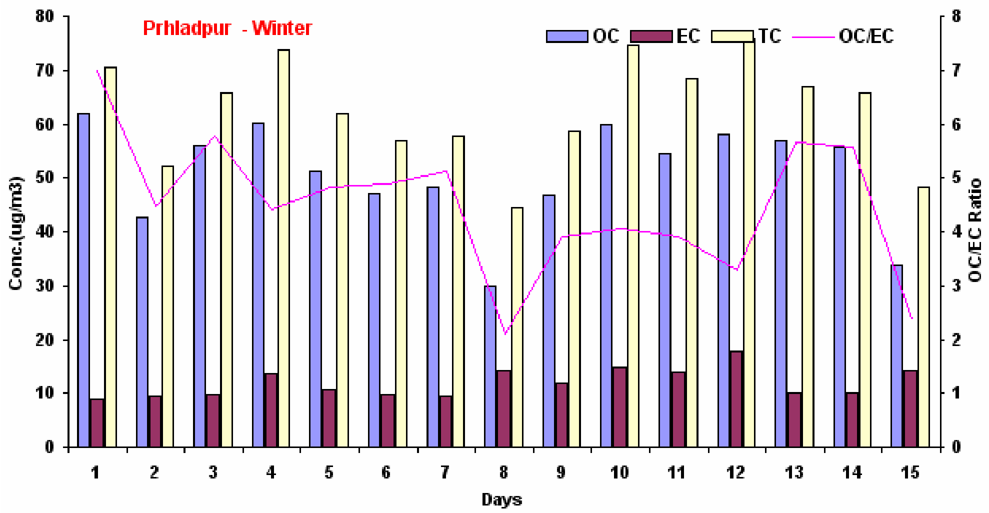


Fig 2.9 (Contd...): 24 hourly trends of OC, EC and TC at Prahladpur

Mass Closure

With a view to assess the extent of crustal, non-crustal, ionic, carbon and un-identified fractions, all the average mass of components were used and plotted to see the extent of each enrichment. As can be seen from **Figure 2.10,** at this site the crustal components are higher compared to other categories indicating higher contribution is from natural soil.

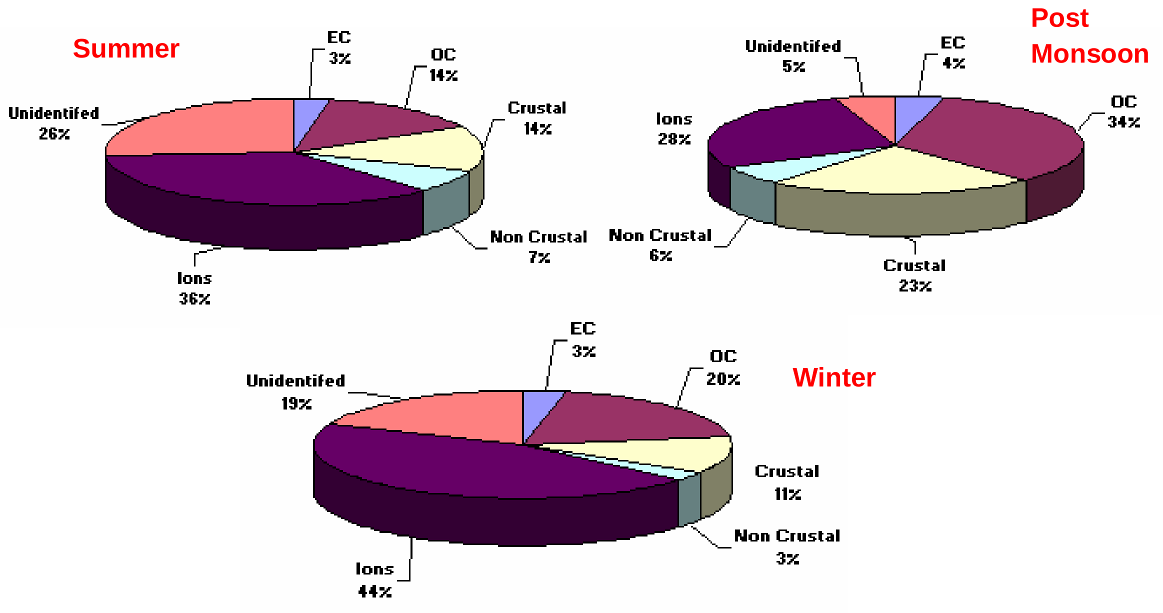


Fig 2.10: Percent Mass Closure of PM_{10} at Prahladpur in three seasons

2.3.2 Pitampura

Site Description

It represents a residential area. The total population of the study zone is estimated to be about 95,000, spread in relatively well organized colonies/areas like Uttari, Purvi & Dakshini Pitampura, Prashant Vihar, Rohini Sector 14 etc. Most of the people belong to HIG and MIG category. Ring road leading towards Madhuban Chowk passes through the study zone, and is about 600 m from the monitoring site **(Figure 2.11)**. Pitampura area is well encompassed between Outer and Inner ring roads, NH1 and Rohtak road. Over the years, Pitampura has shown significant growth. Two of the major attractions of the region are Pitampura TV tower and Delhi Development Authority (DDA) District Centre commercial complex. This complex is built on similar lines to Nehru Palace and Rajendra Palace and is also known as Netaji Subhash Palace. Several schools and vocational training institutes are growing in large number here. Students across the country come here for higher studies. With the advent of shopping malls and retail outlets of world renowned brands and designers, markets have developed really well. Overall, the study region can be characterized as residential area with some commercial activities.

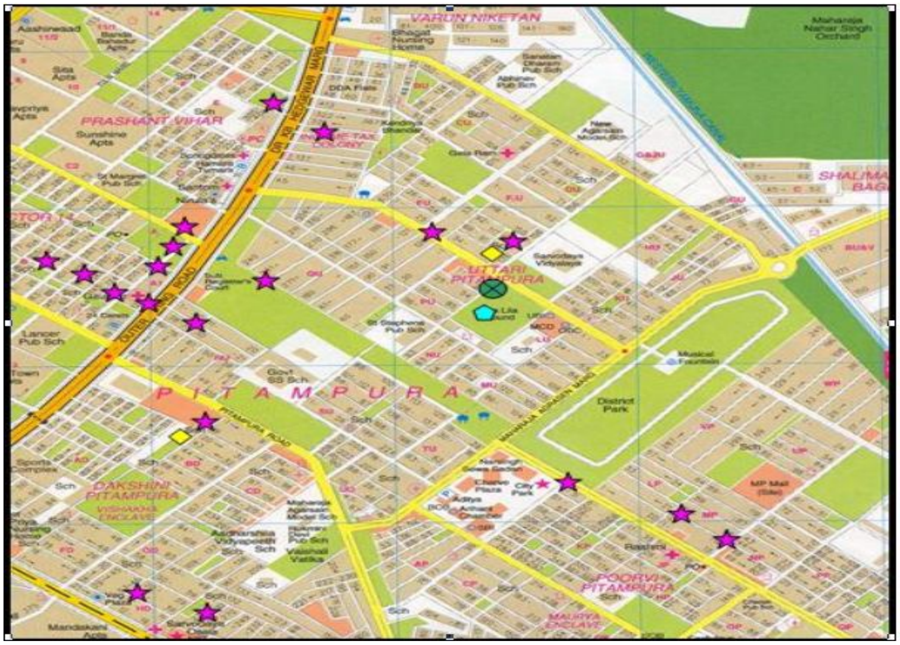


Figure 2.11 : Study Zone (2 km x 2 km): Pitampura

Air Quality Monitoring

Ambient air quality monitoring results at the site for all three seasons are presented in **Tables 2.6 a-b-c.** As can be seen from these tables, SPM values always exceed the CPCB standard in all three seasons however RSPM meets the requisite standards of 100 µg/m^3 in summer. The average SPM and RSPM trends indicate that the values in post monsoon and winter are higher. This is attributed to low mixing during these seasons and also due to many construction and road repair activities.

Table 2.6a : Air Quality Status at Pitampura (Summer)

	N	Min	Max	Average	Per98	Stdev	CV
SPM	20	173.7	358	288.7	353.1	48.9	0.2
RSPM	20	34	128	75.1	127.9	29.7	0.4
PM_{10}	20	25.5	230.5	91.8	212.8	52.5	0.6
$PM_{2.5}$	3	30	30	30	30	0	0.0
SO2	20	3	11.3	7.8	11	2.1	0.3
NO2	20	18.7	43.7	29.5	42.1	7	0.2
O3	7	6.9	16	11.9	15.9	3.2	0.3
CO	7	0.5	0.9	0.7	0.9	0.1	0.1
CH4	NA	NA	NA	NA	NA	NA	NA
NMHC	NA	NA	NA	NA	NA	NA	NA
THC	NA	NA	NA	NA	NA	NA	NA
HCHO	1	NA	NA	12	NA	NA	0.0

Table 2.6 b : Air Quality Status at Pitampura (Post Monsoon)

	N	Min	Max	Average	Per98	Stdev	CV
SPM	20	640	1427	989.8	1374.4	215.7	0.22
RSPM	20	226.3	703.4	506.8	692.2	131.5	0.26
PM_{10}	20	308	1119	718.7	1063.5	232	0.32
$PM_{2.5}$	NA	NA	NA	NA	NA	NA	NA
SO2	20	9.9	34.4	19.3	33.2	6.9	0.36
NO2	20	59.3	120.3	90.1	118.9	18.1	0.20
O3	6	9.7	26.8	18.3	26.7	7.1	0.39
CO	7	1.1	2.1	1.7	2.1	0.3	0.18
CH4	7	2.8	3.7	3.1	3.7	0.3	0.10
NMHC	7	0.3	1.1	0.7	1.1	0.3	0.43
THC	7	3.4	4.9	3.8	4.8	0.5	0.13
HCHO	1			9			0.00

Table 2.6 c: Air Quality Status at Pitampura (Winter)

	N	Min	Max	Average	Per98	Stdev	CV
SPM	20	653.7	1133	839.1	1113.3	146.3	0.17
RSPM	20	350.3	648	445.9	622.4	83.5	0.19
PM_{10}	20	284.5	901.3	527	857.7	172.3	0.33
$PM_{2.5}$	3	297	303.6	300.3	303.5	4.7	0.02
SO2	20	3.2	24	14.8	23.2	5.1	0.34
NO2	20	57	94	74.1	93.6	11.8	0.16
O3	4	17.9	56.9	37	56.6	20.9	0.56
CO	NA	0.8	1.6	1.2	1.6	0.3	0.25
CH4	7	2.9	3.5	3.2	3.5	0.2	0.06
NMHC	7	0.6	0.8	0.7	0.8	0.1	0.14
THC	7	3.6	4.2	3.9	4.2	0.2	0.05
HCHO	NA	NA	NA	NA	NA	NA	NA

Particulate matter (SPM, RSPM, and PM_{10}) levels of Pitampura for all three seasons are presented in **Figures 2.12** along with regulatory standards of CPCB for SPM and RSPM. **Figures 2.13** presents the variation of SO_2 and NO_2 at the site for all the three seasons. It is evident from the figures that SO_2 values meet the standards in all seasons, whereas NO_2 values exceed the standards in post monsoon and winter.

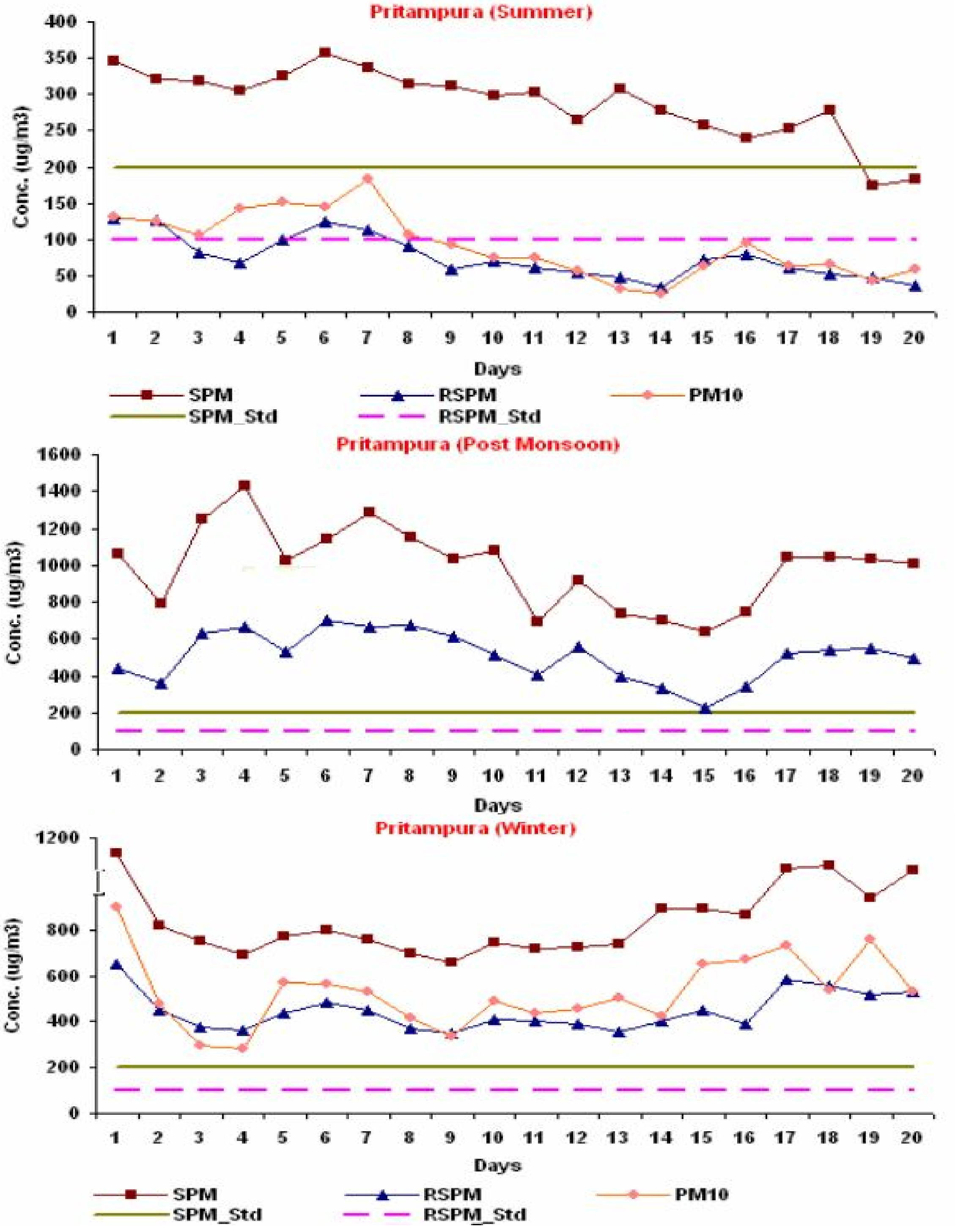


Fig 2.12 : Observed Concentration of SPM, RSPM and PM_{10} at Pitampura in all three seasons

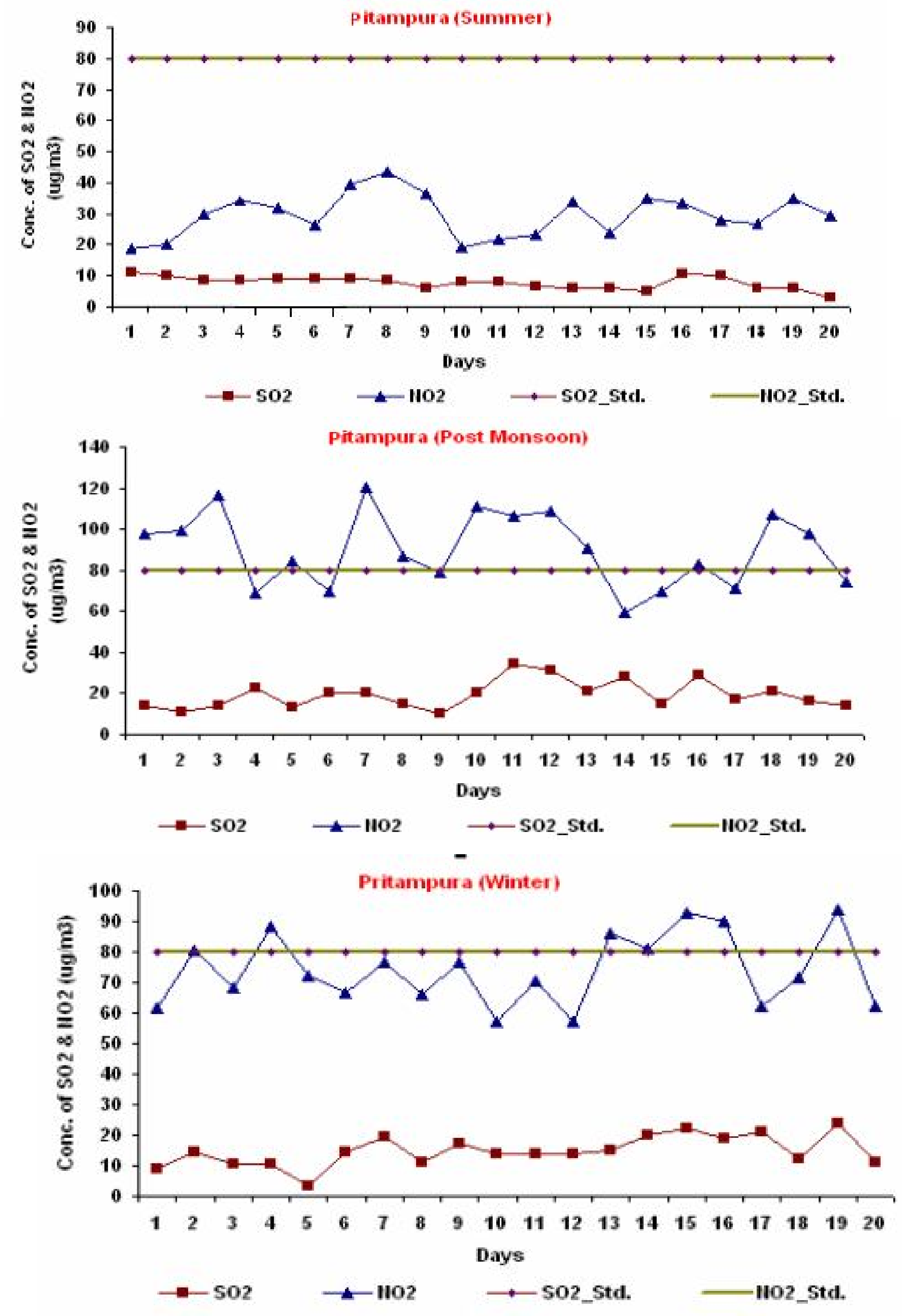


Fig 2.13 : Observed Concentration of SO_2 and NO_2 at Pitampura in all three seasons

The concentrations of $PM_{2.5}$ for all three seasons are presented in **Fig 2.14**. The concentration of $PM_{2.5}$ is within limit in summer whereas it is exceeding in winter the US EPA standard of 35 µg/m^3.

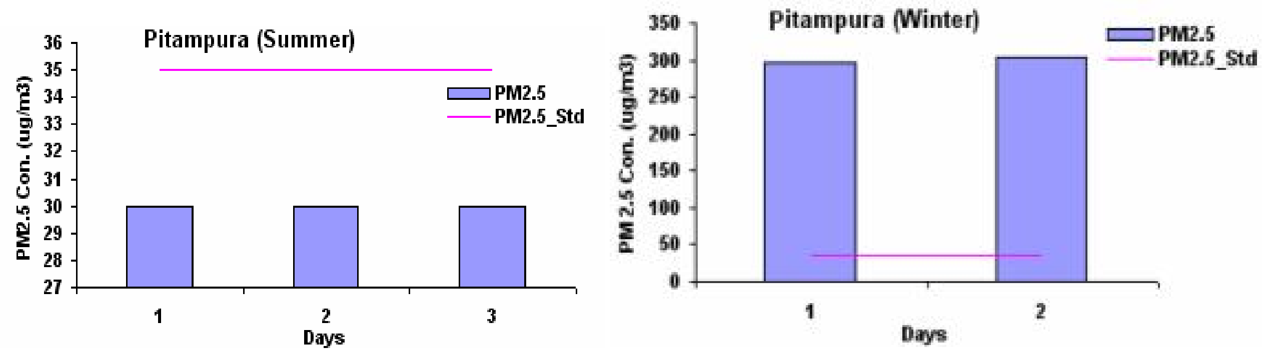


Fig 2.14 : Concentration of $PM_{2.5}$ at Pitampura

Figure 2.15 shows the concentration of CO for all three seasons. Apart from 4th and 5th day of Post Monsoon, the concentration of CO is below the CPCB standard 2 mg/m^3 on most of the days in all three seasons. **Figure 2.16** shows the concentration of Methane, Non Methane and Total Hydrocarbons, ambient air quality monitoring could not be done for summer season for these parameters. **Table 2.7** shows the 24 hourly average concentrations of VOCs for one day of all three seasons.

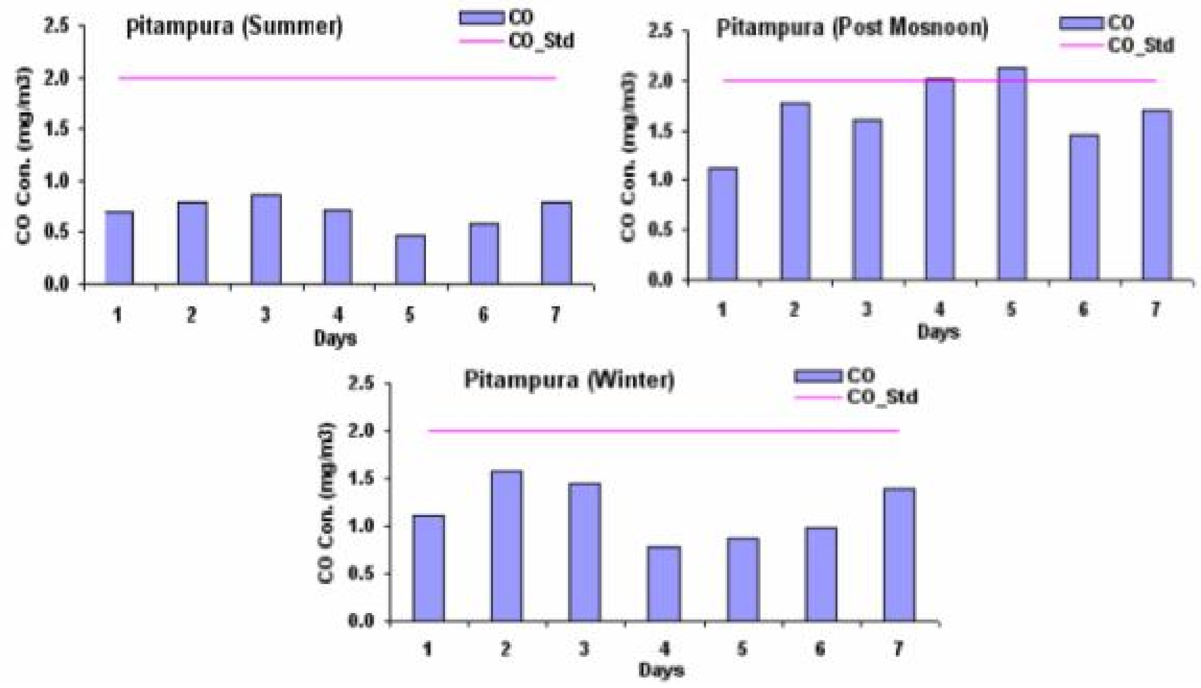


Fig 2.15 : Observed CO concentration at Pitampura in all three seasons

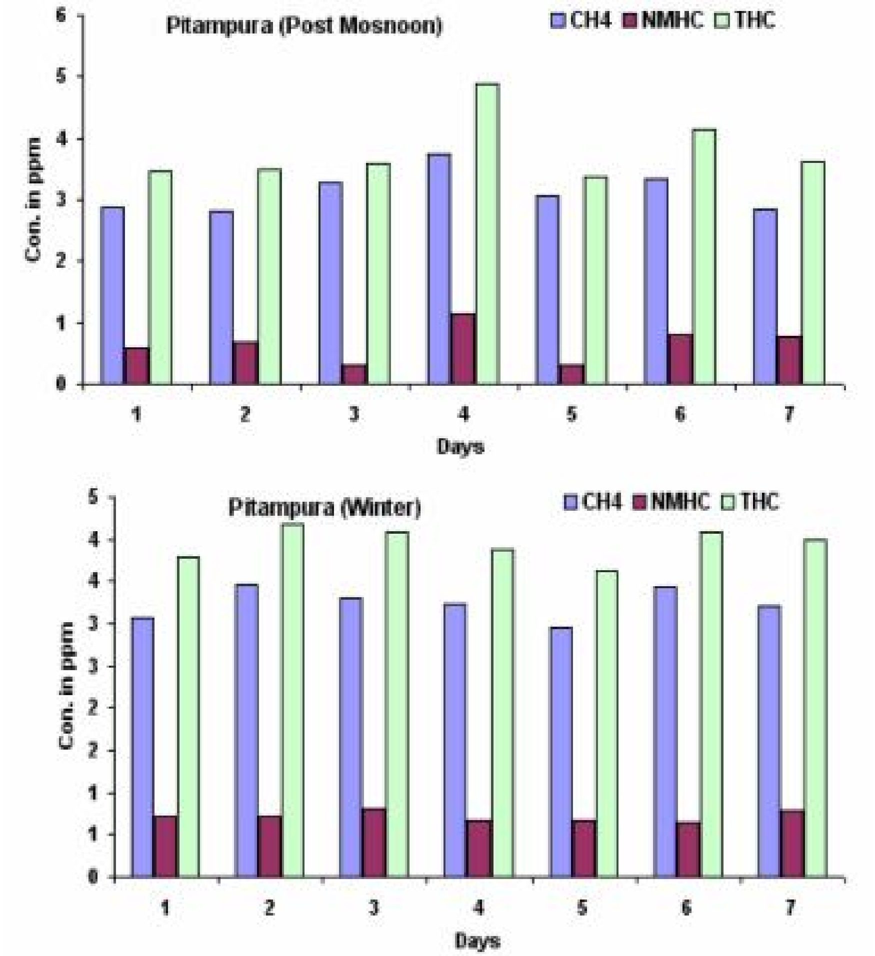


Fig 2.16 : Observed CH_4, NMHC and THC concentration at Pitampura in all three seasons

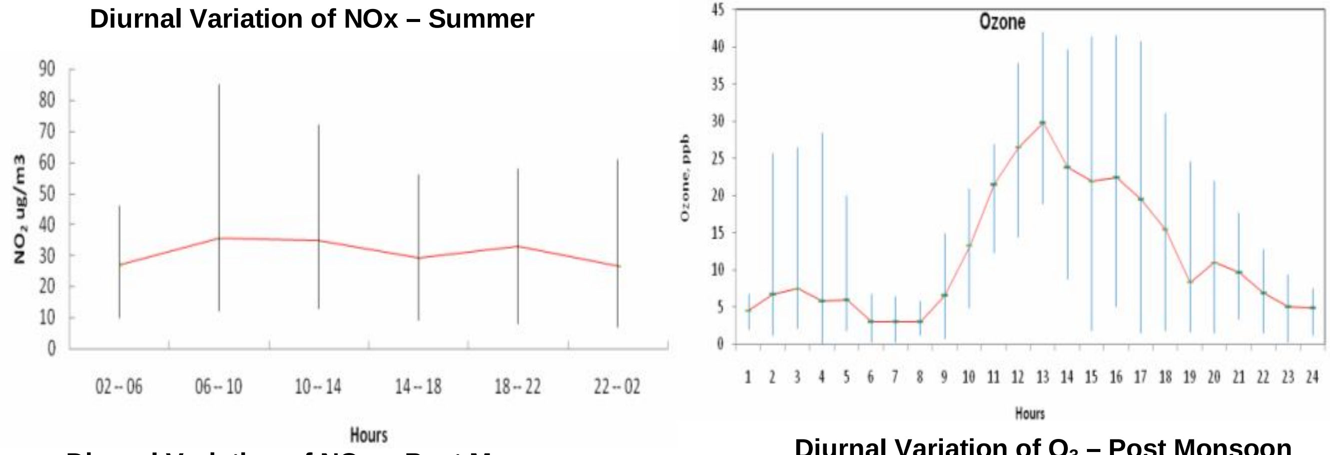
Table 2.7 : 24 Hourly Concentrations of VOCs

	1-3 Butadiene	**Benzene**
Summer	1.4	0.6
Post Monsoon	0.8	1.6
Winter	0.4	0.8

Diurnal variation in NO_2 and Ozone levels is plotted in **Figure 2.17**. It can be observed that for the summer season the day time concentration of NO_2 is about 35 µg/m^3 which falls to about 30 µg/m^3 till 6 PM and it increases after sunset to about 35 µg/m^3 till 10 PM and then falls down to 30 µg/m^3. The monitored Ozone values are plotted and it can be observed that both NO_2 and Ozone follow a diurnal cyclic pattern. In Post Monsoon the day time concentration of NO_2 is about 80 µg/m^3 which increases after sunset to about 100 µg /m^3 till 10 PM and later reduces to 80 µg/m^3. The monitored Ozone values are plotted and it can be observed that both NO_2 and Ozone follow a diurnal cyclic pattern. In Winter season the day time concentration of NO_2 is about 100 µg/m^3 it falls down about 60 µg /m^3 after 2 PM. The monitored Ozone values in winter show high variability. Ozone concentration peak in summer is experience is at about 12-1 pm, whereas in post monsoon it shifts to the period of 3-4 pm.

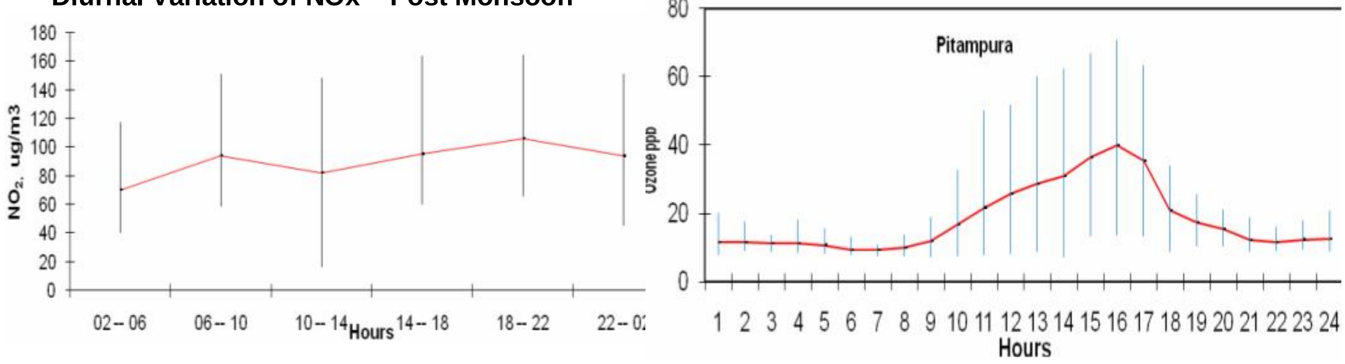
Diurnal Variation of NOx – Summer

Diurnal Variation of O_3 – Summer



Diurnal Variation of NOx – Post Monsoon

Diurnal Variation of O_3 – Post Monsoon



Diurnal Variation of NOx – Winter

Diurnal Variation of O_3 – Winter

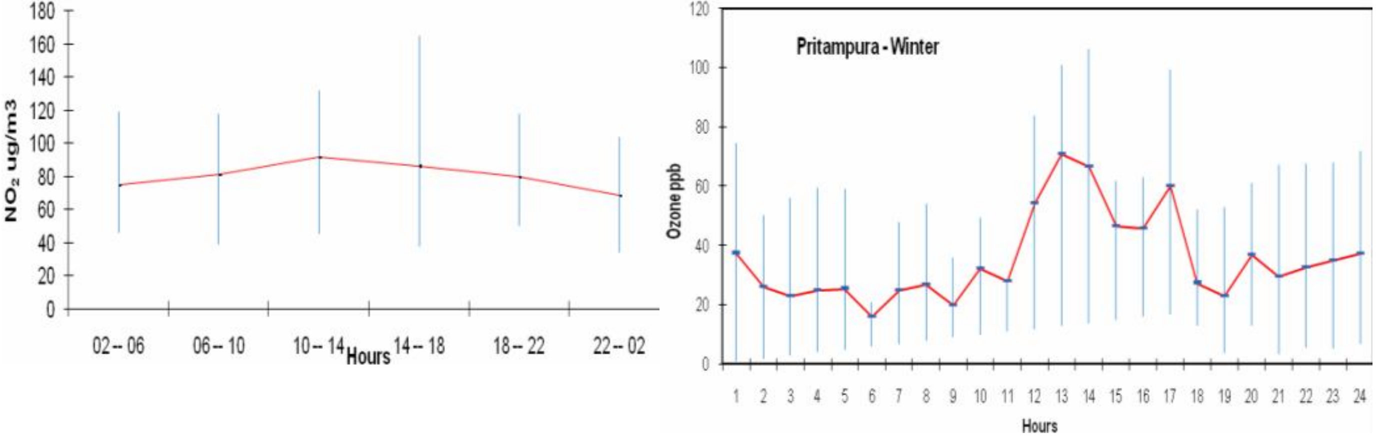


Fig 2.17 : Diurnal Variation in NO_2 and Ozone at Pitampura

Estimation of EC/OC Ratio

EC and OC was determined for PM samples with a view to establish the sources of carbon. 24 hourly trends of OC, EC and TC with respect to their ratios are presented in **Fig 2.18.** The ratio of OC to EC indicates that in post monsoon, it ranges between 6-18 which is higher than winter and summer. This could be attributed to high biomass burning combined with more calm condition.

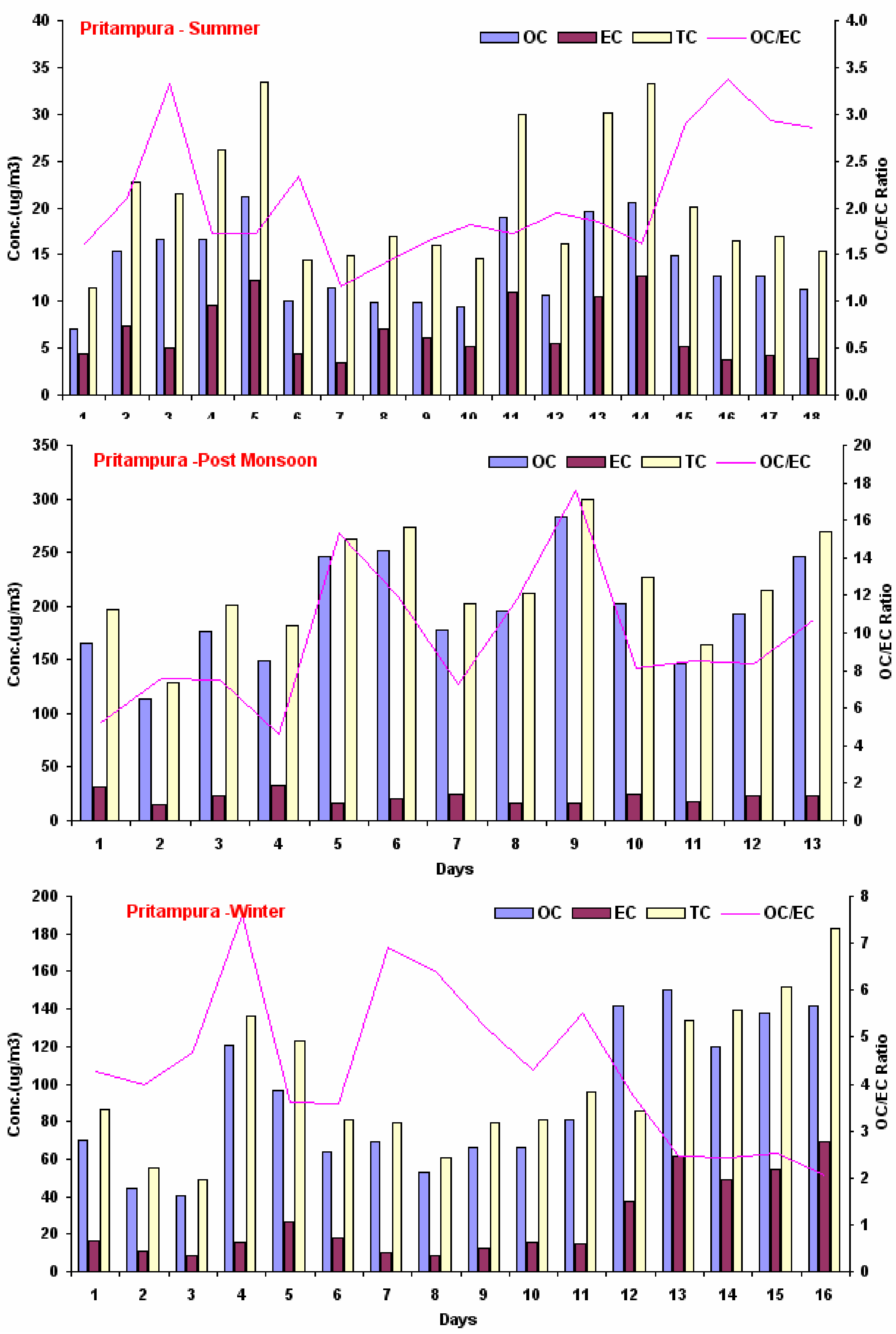


Fig 2.18 : 24 hourly trends of OC, EC and TC at Pitampura

Mass Closure

Mass fraction of elements, ions and carbons in terms of percentage in PM_{10} is shown in **Fig 2.19.** High percent of OC is due biomass burning and vehicles. Ions also contribute significantly to PM mass in all the seasons. The ions and TC together form the highest mass percentage, indicating anthropogenic sources.

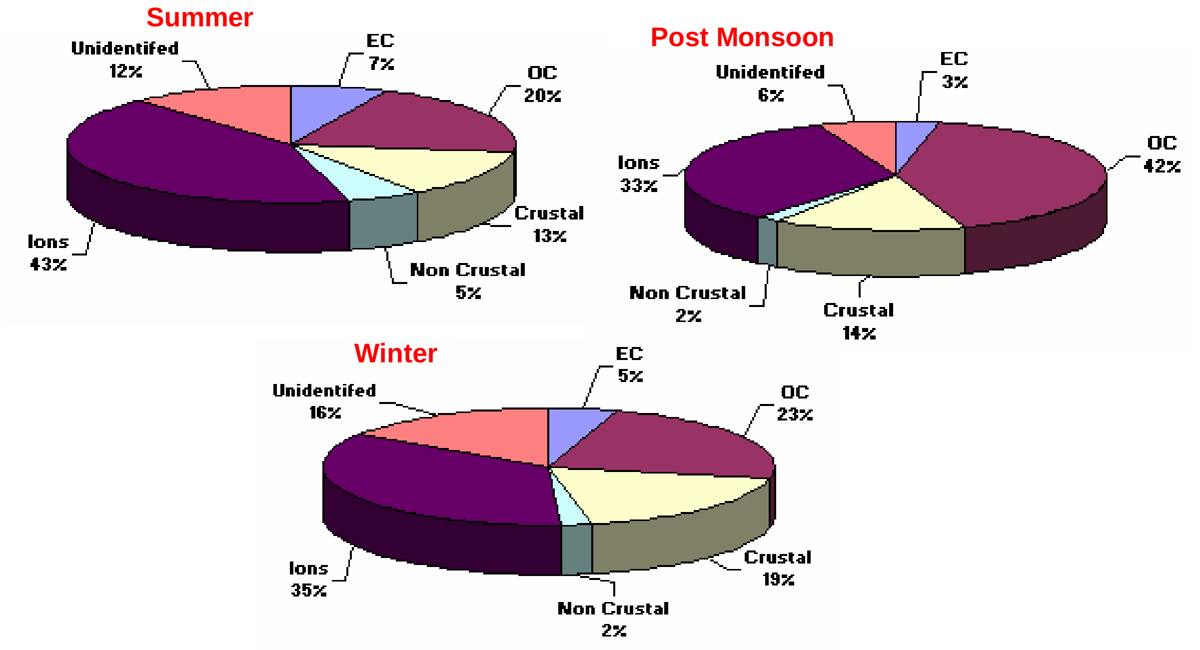


Fig 2.19 : Percent Mass Closure of PM_{10} at Pitampura in three seasons

2.3.3 Naraina (Mixed Use)

Site Description

It represents Industrial/ Mixed activities area. The Naraina Industrial Area has over 1,200 units comprising of generally small units, which manufacture products ranging from electrical, electronics and import substitutes, to hospital equipment and garments for exports. The area also has modern printing press and units which manufacture plastic industrial components and plastic processing machinery. Some of the bigger industries in the area are Pearlpet, British Plastic and Engineering Works and British Plastic and Stationery Works, Bentex-Linger Switchgear Company, Narula Udyog (I) Private Limited and Archies.

The ring road from Dhaula Kuan to Mayapuri passes through the study zone and is about 800m (aerially) away from the monitoring site. The other main road is Naraina road connecting Loha mandi to Ring road **(Figure 2.20)**. The study zone has an estimated population of about 75,000, spread in the areas like Loha mandi, Budh Nagar, Naraina Vihar, Rajaouri Garden, Ramesh Nagar etc. Of the total population, nearly 40% population live in slum areas. A railway line passes through the study zone. Construction work of flyover on ring road was under progress during the study period. Overall, the study zone can be characterized as industrial-cum residential area with some commercial activities like PVR, hotels & restaurants etc.

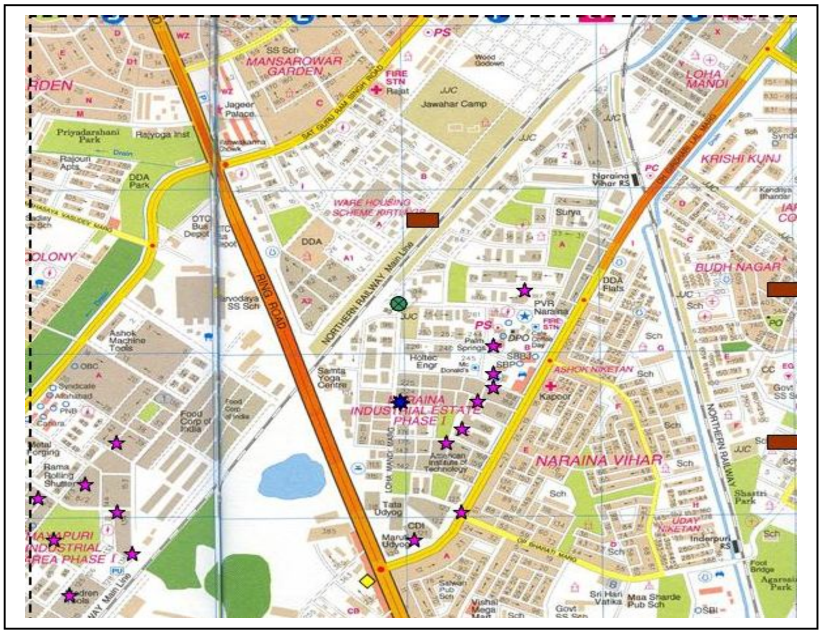


Fig. 2.20 : Study Zone (2 km x 2 km): Naraina

Air Quality Monitoring

Ambient air quality monitoring results at the site for all three seasons are presented in **Table 2.8 a-b-c**. As can be seen from these tables, SPM values always exceed the CPCB standard in all three seasons; however RSPM meets the requisite standards of 100 µg/m^3 most of the times. The average SPM and RSPM trends indicate that the values in summer and winter are higher.

Table 2.8a : Air Quality Status at Naraina (Summer)

	N	Min	Max	Average	Per98	Stdev	CV
SPM	20	385	972.3	637.1	954.7	185.8	0.29
RSPM	20	102	209.3	141.9	208.4	33	0.23
PM_{10}	20	124	358.7	216.3	344	59.1	0.27
$PM_{2.5}$	3	50	53	51.5	52.9	2.1	0.04
SO_2	20	3.5	22.7	10.2	21.1	5	0.49
NO_2	20	23.3	62.3	41.1	61.4	11.6	0.28
O_3	7	40.5	57	47.1	56.9	7.6	0.16
CO	7	1.1	1.8	1.5	1.8	0.3	0.20
CH_4	NA	NA	NA	NA	NA	NA	NA
NMHC	NA	NA	NA	NA	NA	NA	NA
THC	NA	NA	NA	NA	NA	NA	NA
HCHO	1			9			NA

Table 2.8b : Air Quality Status at Naraina (Post Monsoon)

	N	Min	Max	Average	Per98	Stdev	CV
SPM	19	268	823.9	481.4	816.3	155.6	0.32
RSPM	19	37.1	307	150	289.8	72	0.48
PM_{10}	19	172.5	492.2	268.5	489.4	97.5	0.36
$PM_{2.5}$	3	56	89	75.3	88.7	17.2	0.23
SO_2	19	3.2	12	6.6	11.2	2.3	0.35
NO_2	19	13	42.8	31.1	41	7.1	0.23
O_3	7	5.8	11.1	8.3	11	2.1	0.25
CO	7	0.9	1.4	1.1	1.4	0.2	0.18
CH_4	7	2.5	3.5	3.1	3.4	0.3	0.10
NMHC	7	0.6	1.5	0.9	1.5	0.3	0.33
THC	7	3.6	5	4	4.9	0.5	0.13
HCHO	1			12			0.00

Table 2.8c : Air Quality Status at Naraina (Winter)

	N	Min	Max	Average	Per98	Stdev	CV
SPM	20	709.8	1463	990.4	1427.4	234.9	0.24
RSPM	20	146.5	489.8	309.8	489.8	104.6	0.34
PM_{10}	20	279.5	725	445.9	714	141.9	0.32
$PM_{2.5}$	2	185.9	209.4	197.6	208.9	16.6	0.08
SO_2	20	4.5	21.4	12.1	20.7	5.1	0.42
NO_2	20	36	97.3	59.8	90.6	16.3	0.27
O_3	7	7.6	29.4	13	27.6	8.1	0.62
CO		1.2	2	1.6	2	0.3	0.19
CH_4	7	2.9	3.6	3.3	3.6	0.3	0.09
NMHC	7	0.9	1.6	1.3	1.6	0.3	0.23
THC	7	3.9	5.3	4.6	5.2	0.6	0.13

HCHO				7.8			0

Particulate matter (SPM, RSPM, and PM_{10}) levels of Naraina for all three seasons are presented in **Figures 2.21** along with regulatory standards of CPCB for SPM and RSPM.

Figures 2.22 presents the variation of SO_2 and NO_2 at the site for all the three seasons. It is evident from the figures that SO_2 and NO_2 values meet the standards in all seasons and higher concentration is observed in winter due to refuse burning activities, industries in that area and meteorological conditions.

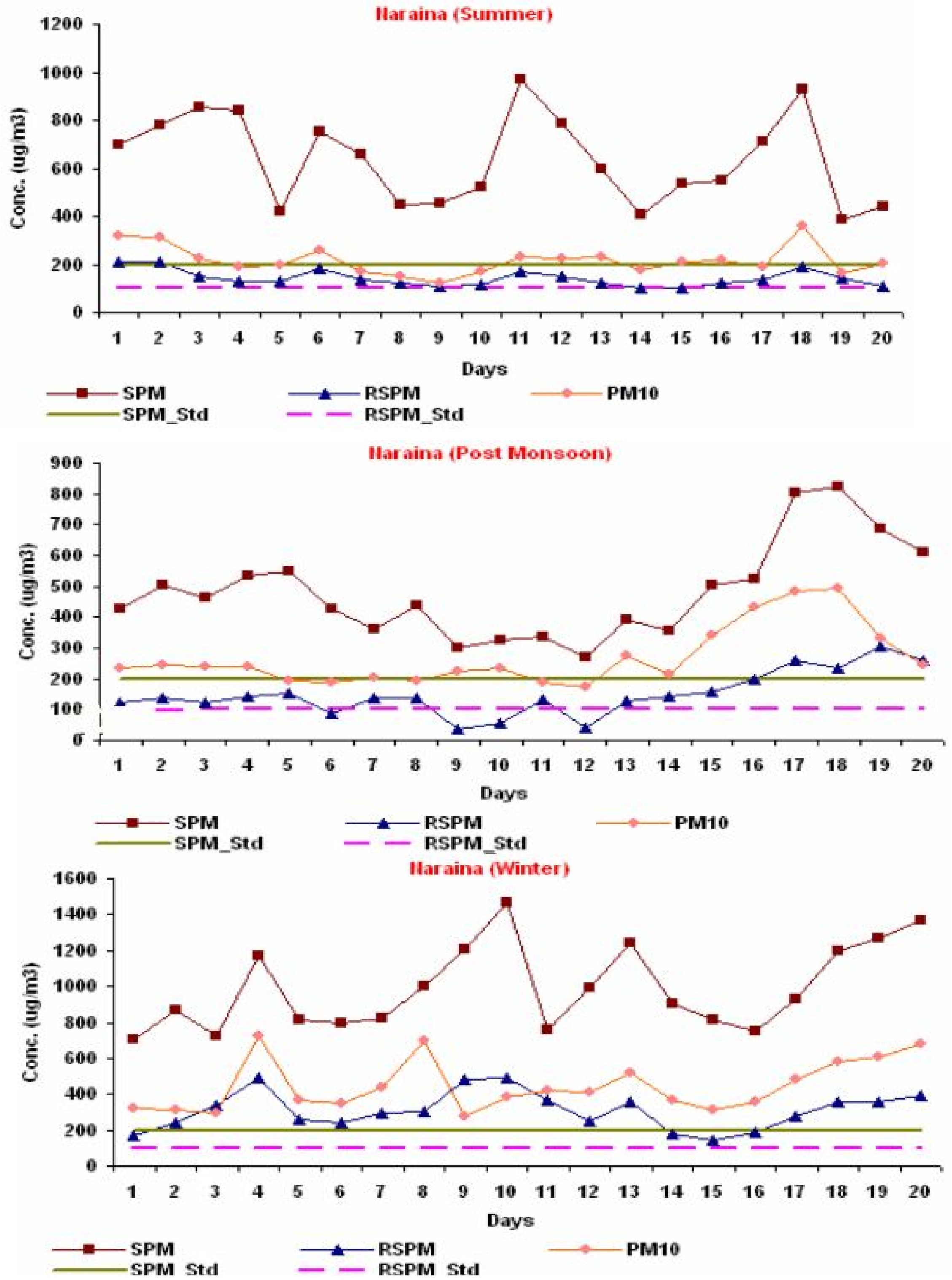


Fig 2.21 : Observed Concentration of SPM, RSPM and PM_{10} at Naraina in all three seasons

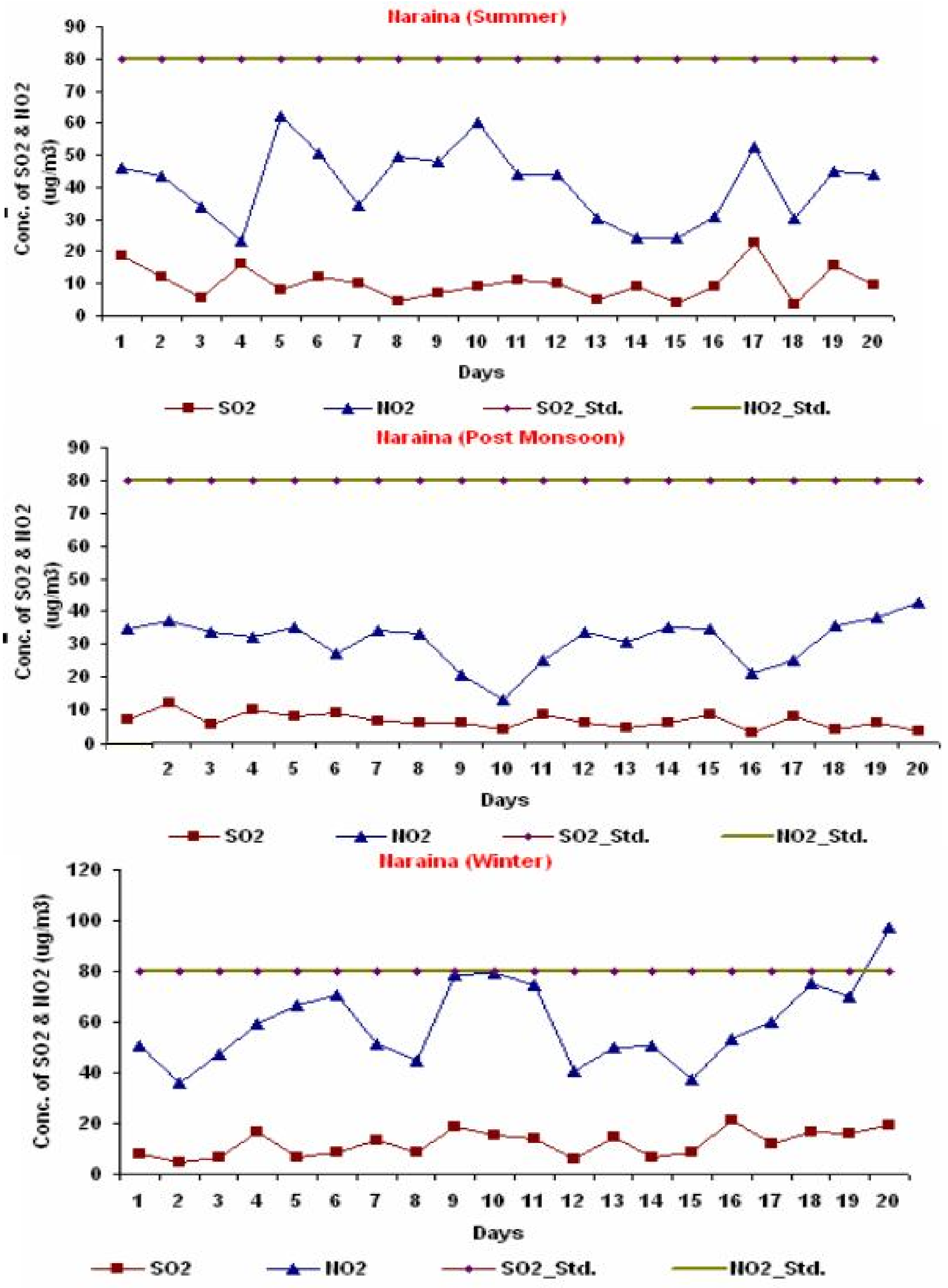


Fig 2.22 : Observed Concentration of SO_2 and NO_2 at Naraina in all three seasons

The concentrations of $PM_{2.5}$ for all three seasons are presented in **Fig 2.23**. The concentration of $PM_{2.5}$ is exceeding the limit of US EPA standard of 35 µg/m^3 in all seasons due to industries and fuel oil combustion which contribute to high load of fine particulate matter.

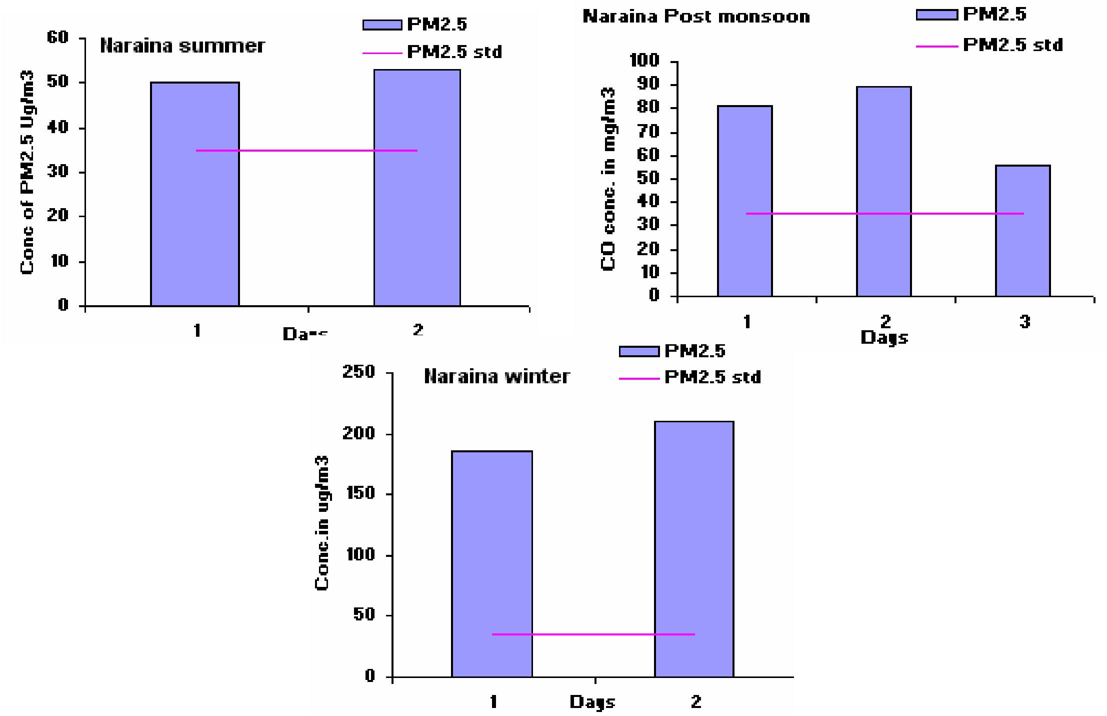
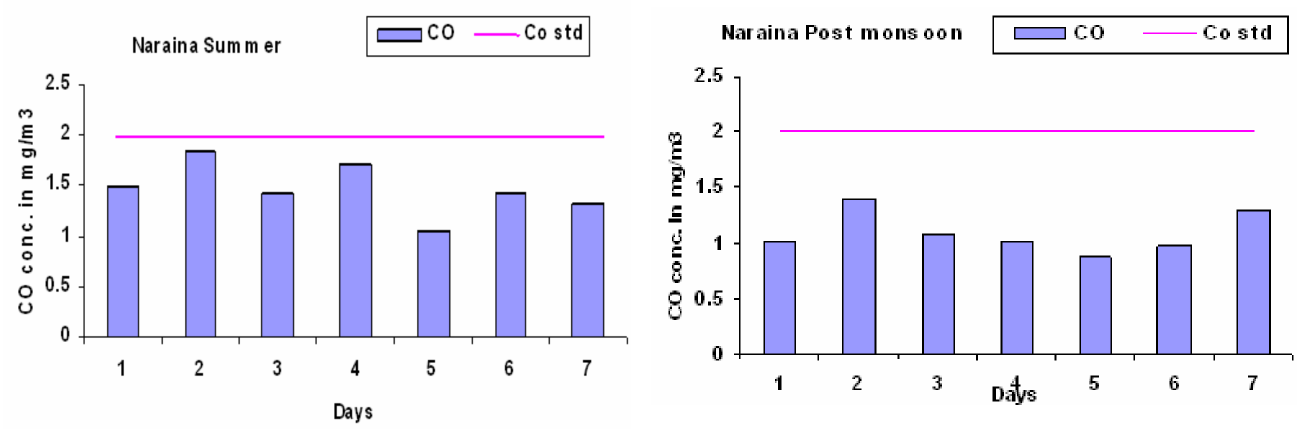


Fig 2.23 : Concentration of $PM_{2.5}$ at Naraina Site

Figure 2.24 shows the concentration of CO for all three seasons. The concentration of CO is below the CPCB standard 2 mg/m^3 in all three seasons. **Figure 2.25** shows the concentration of Methane, Non Methane and Total Hydrocarbons.. **Table 2.9** shows the 24 hourly average Concentrations of VOCs for one day of all three seasons. Benzene values are higher than Prahladpur and Pitampura.



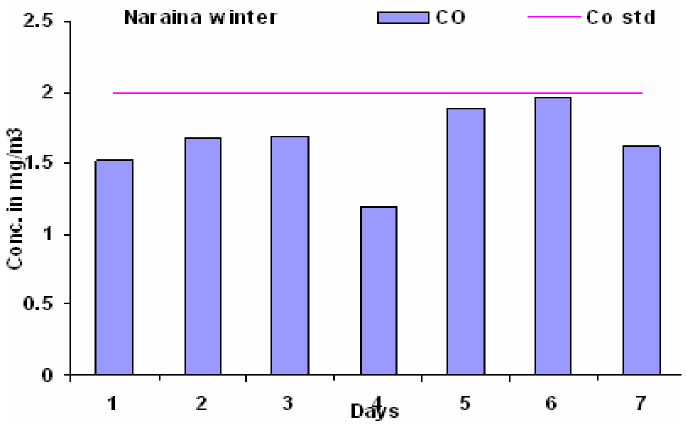


Fig 2.24 : Observed CO concentration at Naraina in all three seasons

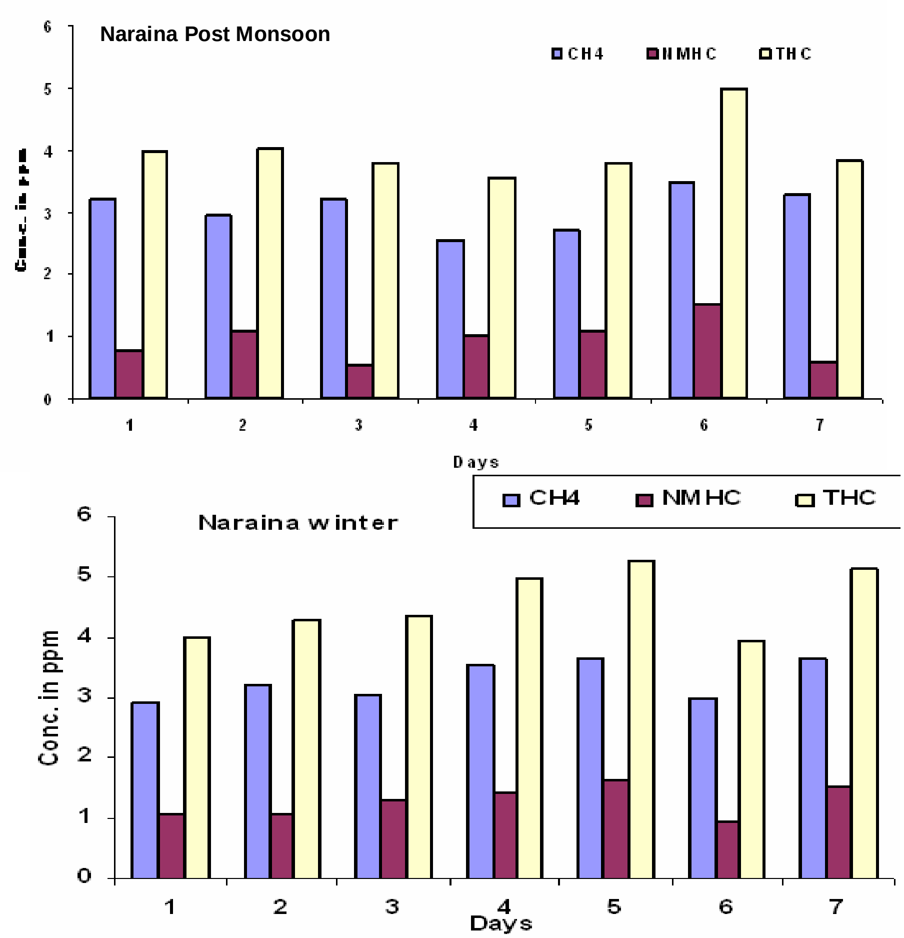


Fig 2.25 : Observed CH_4, NMHC and THC concentration at Naraina in all three seasons

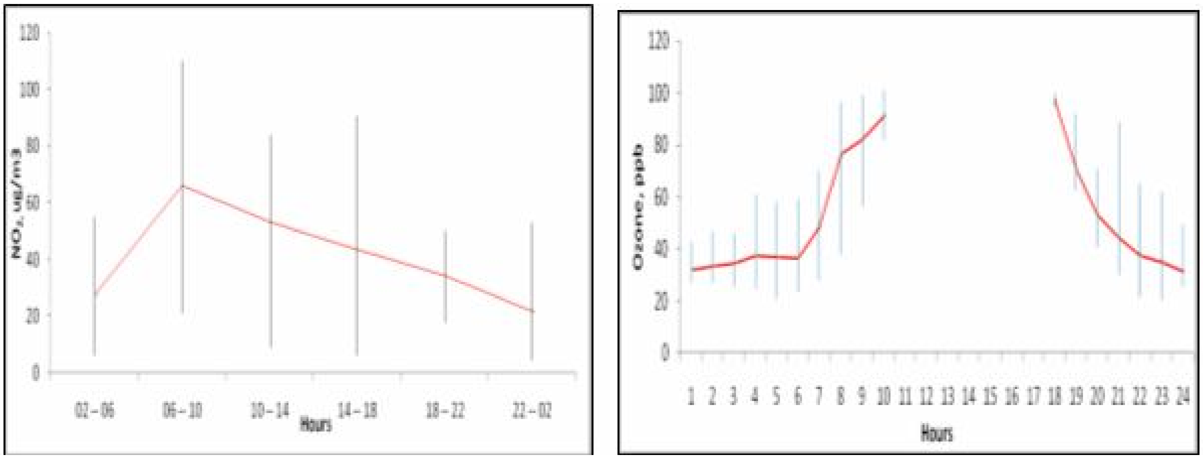
Table 2.9 : 24 Hourly Concentrations of VOCs

	1-3 Butadiene	Benzene
Summer	0.7	3.5
Post Monsoon	1.6	0.8
Winter	0.8	3.5

Diurnal variation in NO_2 and Ozone levels is plotted in **Fig 2.26**. It can be observed that for the Summer season the day time concentration of NO_2 is about 70 µg/m^3 till 10 AM and then it falls continuously to about 20 µg/m^3 till 10 PM. In Post Monsoon the day time concentration of NO_2 is about 25-30 µg/m^3 till 2 PM then it increases to about 40 µg/m^3 till 10 PM and remains constant later. The monitored Ozone values are plotted and it can be observed that Ozone concentration increases to about 13 ppb by 2 PM and it falls to about 6 ppb by 9 PM. In Winter season the concentration of NO_2 is much higher than summer. Ozone concentration increases to about 30 ppb till 2 PM and then goes down to 5 ppb by 10 PM.

Diurnal Variation in NO_2- Summer

Diurnal Variation in O_3- Summer



Diurnal Variation in NO_2- Post Monsoon

Diurnal Variation in O_3- Post Monsoon

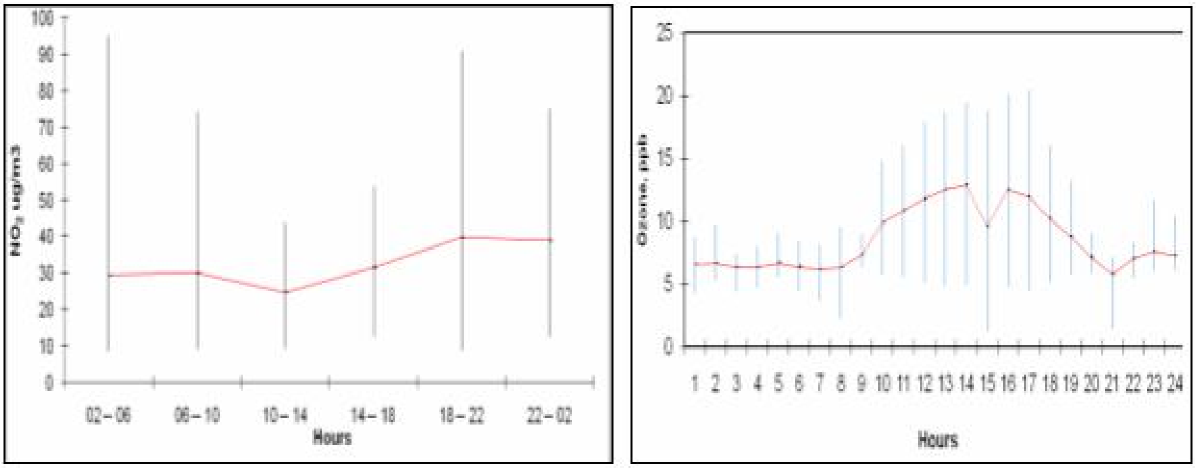
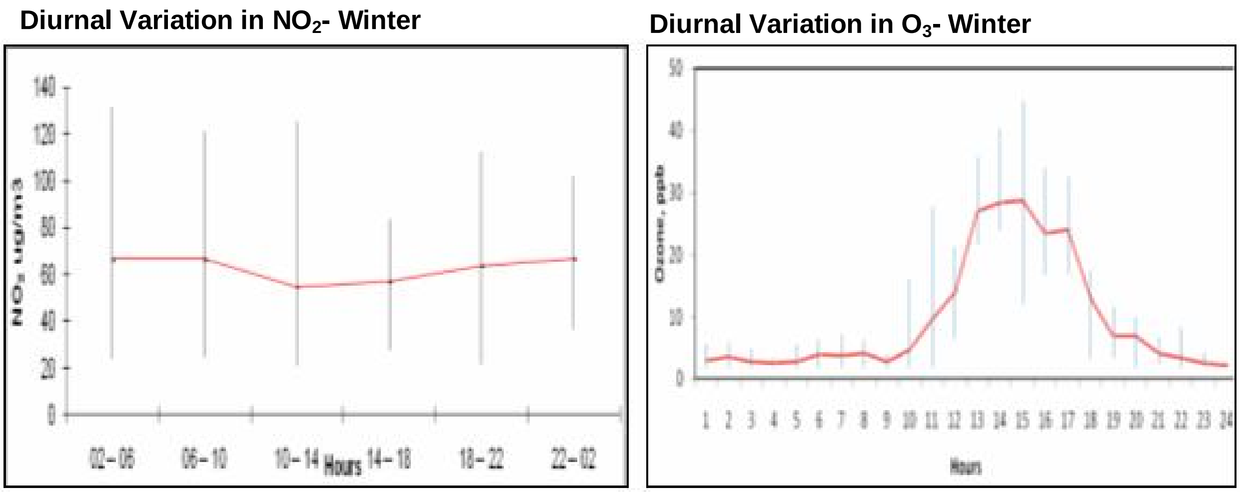


Fig 2.26 : Diurnal Variation in NO_2 and Ozone at Naraina



Diurnal Variation in NO_2- Winter

Diurnal Variation in O_3- Winter

Fig 2.26 (Contd..) : Diurnal Variation in NO_2 and Ozone at Naraina

Estimation of EC/OC Ratio

EC and OC was determined for PM samples with a view to establish the sources of carbon. 24 hourly trends of OC, EC and TC with respect to their ratios are presented in **Fig 2.27.** The concentrations of OC and EC are higher in winter and post monsoon compare to summer values, indicating built up of pollution due to adverse meteorology.

.

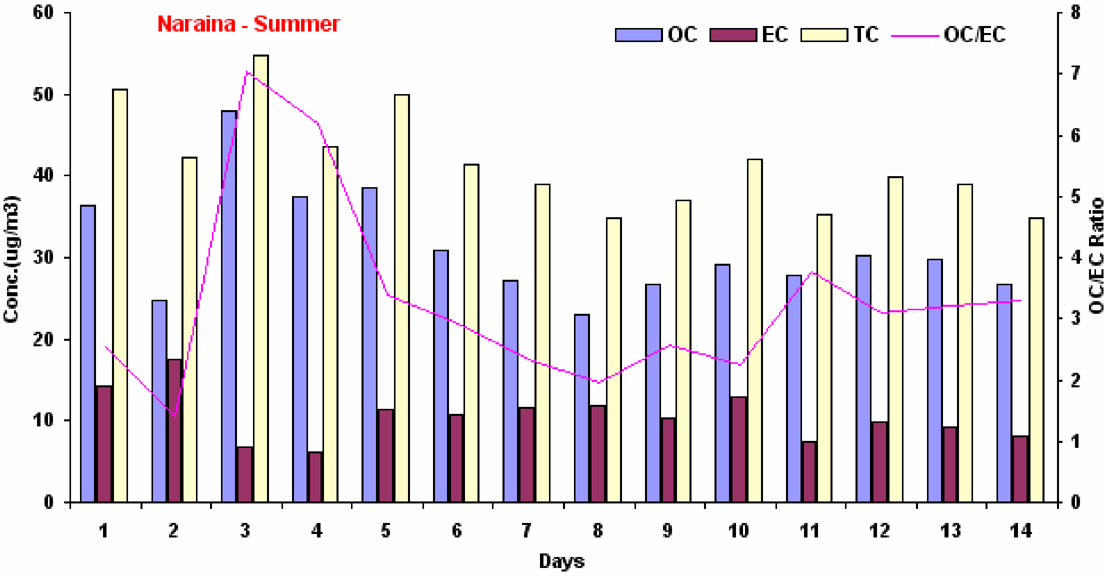


Fig 2.27 : 24 hourly trends of OC, EC and TC at Naraina

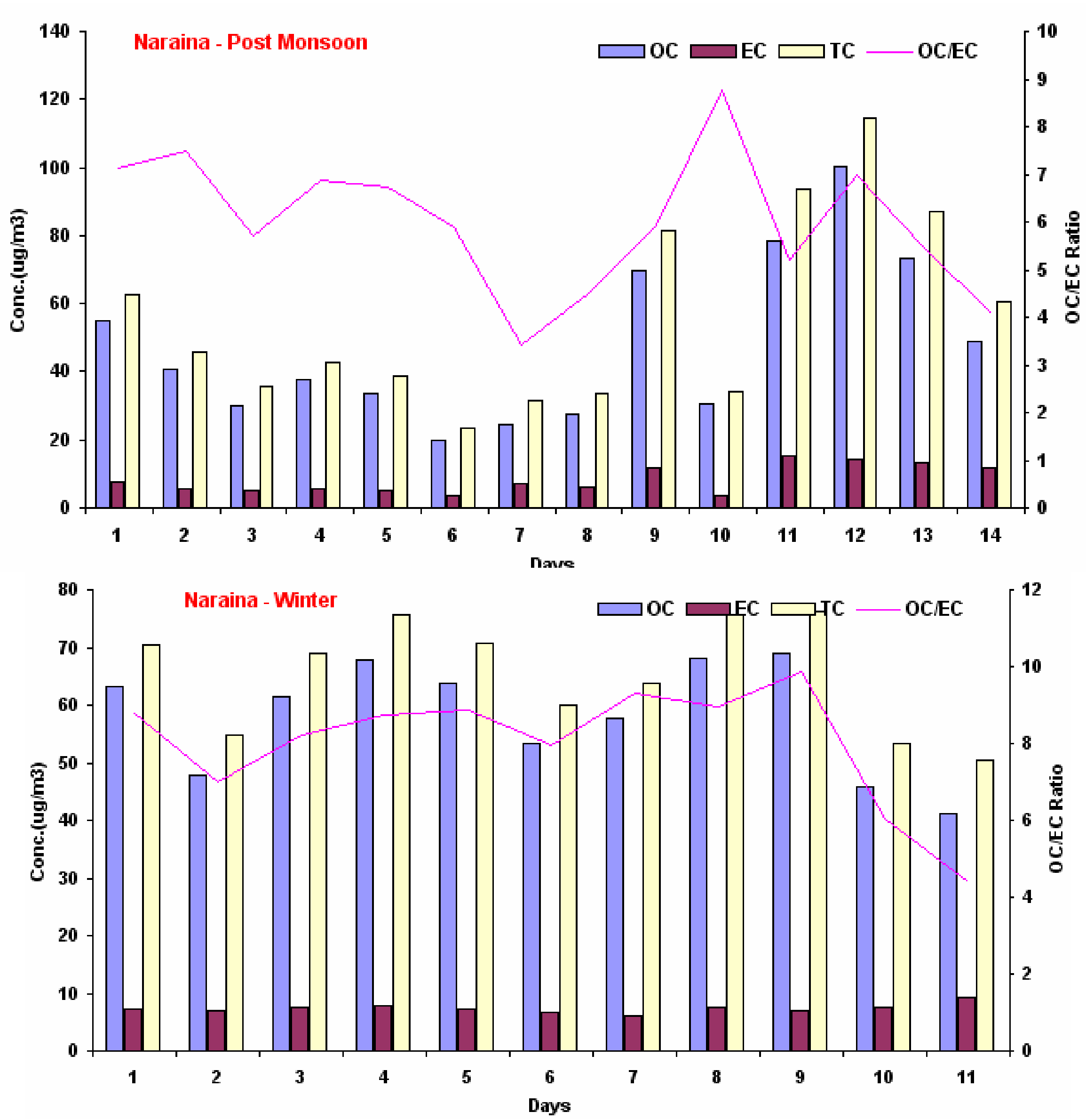


Fig 2.27 : 24 hourly trends of OC, EC and TC at Naraina Site

Mass Closure

Mass fraction of elements, ions and carbons in terms of percentage in PM_{10} is shown in **Fig 2.28.** Due to number of industries operating in the vicinity of the sampling location, refuse burning and heavy duty vehicles carbonaceous species are higher. Poor road conditions and resuspension of dust add to crustal elements in PM_{10}.

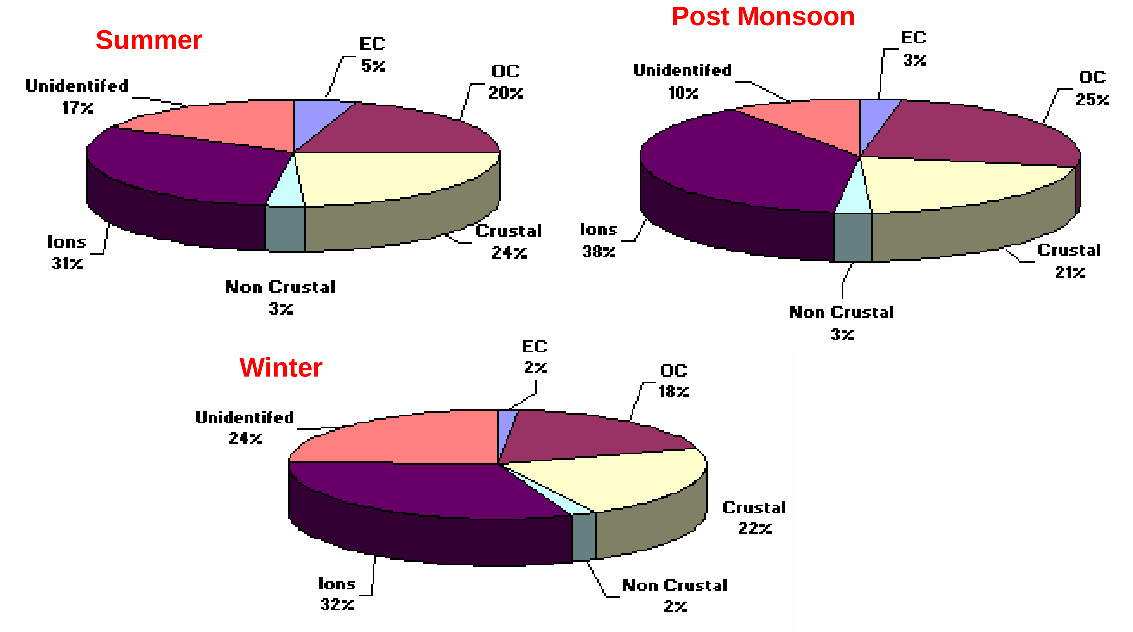


Fig 2.28 : Percent Mass Closure of PM_{10} at Naraina in three seasons

2.3.4 SSI-GTK (Industrial)

Site Description

It represents Industrial area activities and located in Jahangirpuri Industrial Area. The study zone has two main roads, GT Karnal Road (NH1) and outer ring road as shown in **Fig. 2.29**. The intersection (Makraba Chowk) of these roads is at a distance of about 800 m (aerially) from the monitoring location. NH1 leads to Haryana and North Indian States, whereas outer ring road carries traffic within Delhi between ISBT side and Madhuban Chowk-Rohini-Pitampura area. Very high traffic can be observed throughout the day. The population of the study zone is estimated to be about 50,000, residing mainly in the nearby areas like Jahangirpuri, Sanjay Nagar, Adarsh Nagar, Electricity Colony, Rajasthan Udyog Nagar, Sanjay Gandhi Transport Nagar, Rajiv Nagar etc. Of the total population, nearly 60% of the population lives in slum areas. Construction work for metro rail was under progress during the study period. Overall, the study region can be characterized as industrial-cum-residential area with limited commercial activities.

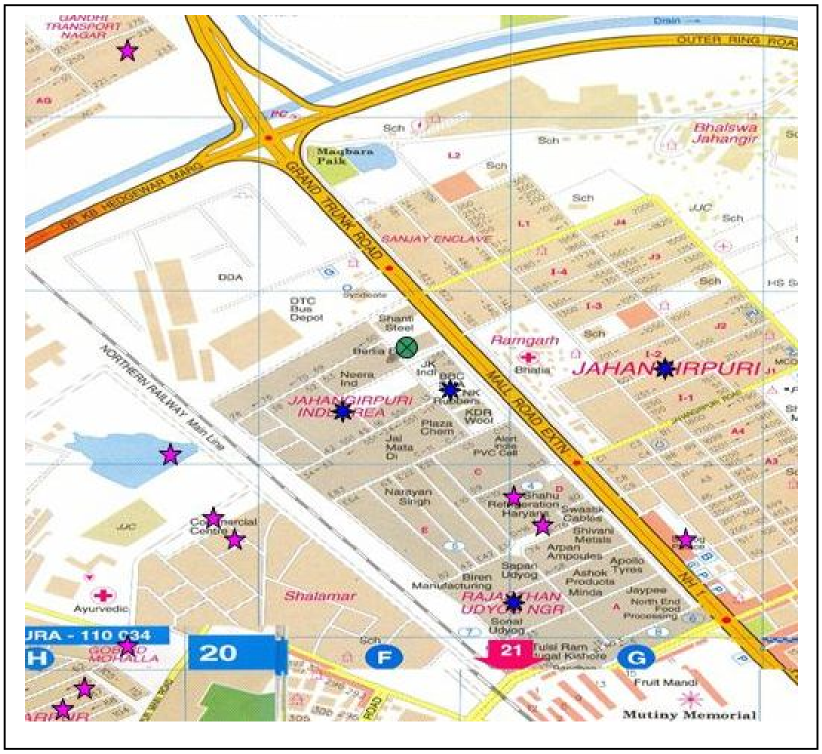


Fig. 2.29: Study Zone (2 km x 2 km): SSI-GTK

Air Quality Monitoring

Ambient air quality monitoring results at the site for all three seasons are presented in **Tables 2.10 a-b-c**. As can be seen from these tables, SPM values always exceed the CPCB standard 500 µg/m^3 on Post Monsoon and Winter seasons in all three seasons due to combination of activities like industrial area, vehicular traffic, construction activities and slum area refuse burning activities. RSPM values also exceed the CPCB standard 200 µg/m^3 on most of the days in all three seasons. The average SPM and RSPM trends indicate that the values in post monsoon and winter are higher. This is attributed to low mixing during these seasons.

Table 2.10a : Air Quality Status at SSI-GTK (Summer)

	N	Min	Max	Average	Per98	Stdev	CV
SPM	20	169.3	685	423.5	659.7	122.1	0.29
RSPM	20	83.7	297	176.4	282.7	62	0.35
PM_{10}	20	94.5	417.7	250.7	417.4	104.6	0.42
$PM_{2.5}$	3	6	46	20.5	44.6	18.4	0.90
SO_2	20	4.2	19.5	11.9	18.9	4.8	0.40
NO_2	20	34	92.8	62.5	91.8	19.2	0.31
O_3	7	7.9	21.9	15.4	21.5	4.7	0.31
CO	7	0.7	1.2	1	1.2	0.1	0.10
CH_4	NA	NA	NA	NA	NA	NA	NA
NMHC	NA	NA	NA	NA	NA	NA	NA
THC	NA	NA	NA	NA	NA	NA	NA
HCHO	1	7		7			NA

Table 2.10b : Air Quality Status at SSI-GTK (Post Monsoon)

	N	Min	Max	Average	Per98	Stdev	CV
SPM	20	762.2	1776.3	1263.3	1712.4	247.5	0.196
RSPM	20	317	895.8	571.3	844.9	155.3	0.272
PM_{10}	19	389	1425	815.1	1332.3	241.3	0.296
$PM_{2.5}$	3	146	699	382.7	683.2	285	0.745
SO_2	20	33.9	144.2	82.9	141.5	31.1	0.375
NO_2	20	81.4	216	145.8	206.1	33.2	0.228
O_3	7	18	42.2	26	40.3	7.7	0.296
CO	7	0.5	1.8	1.5	1.8	0.5	0.333
CH_4	7	2.9	3.9	3.2	3.9	0.4	0.125
NMHC	7	0.5	1.7	0.9	1.6	0.4	0.444
THC	7	3.5	5.3	4.2	5.3	0.8	0.190
HCHO	1			17			

Table 2.10c : Air Quality Status at SSI-GTK (Winter)

	N	Min	Max	Average	Per98	Stdev	CV
SPM	20	692.2	1359	928.7	1297.1	178.4	0.192
RSPM	20	330.1	542	440.6	541.6	69.6	0.158
PM_{10}	20	397	726.1	553.2	705.1	94.3	0.170
$PM_{2.5}$	3	74	320.3	211.9	317.2	125.8	0.594
SO_2	20	47.6	134	89.9	133.2	28.4	0.316
NO_2	20	98	228	162.4	227.6	36	0.222
O_3	7	18	41	25.9	39.3	7.3	0.282

CO	7	0.7	1.5	1	1.4	0.3	0.300
CH_4	7	2.4	3.5	3	3.5	0.4	0.133
NMHC	7	0.4	0.6	0.5	0.5	0	
THC	7	2.9	4	3.5	4	0.4	0.114
HCHO	0			12			

Particulate matter (SPM, RSPM, and PM_{10}) levels of SSI-GTK for all three seasons are presented in **Figures 2.30** along with regulatory standards of CPCB for SPM and RSPM. **Figures 2.31** present the variation of SO_2 and NO_2 at the site for all the three seasons. It is evident from the figures that SO_2 values are within the limits, whereas NO_2 values exceed the standards in most of the places during post monsoon and winter season due to National Highway and heavy duty vehicles plying around the area. The built of pollutants in winter and post monsoon is due to high calm condition of weather.

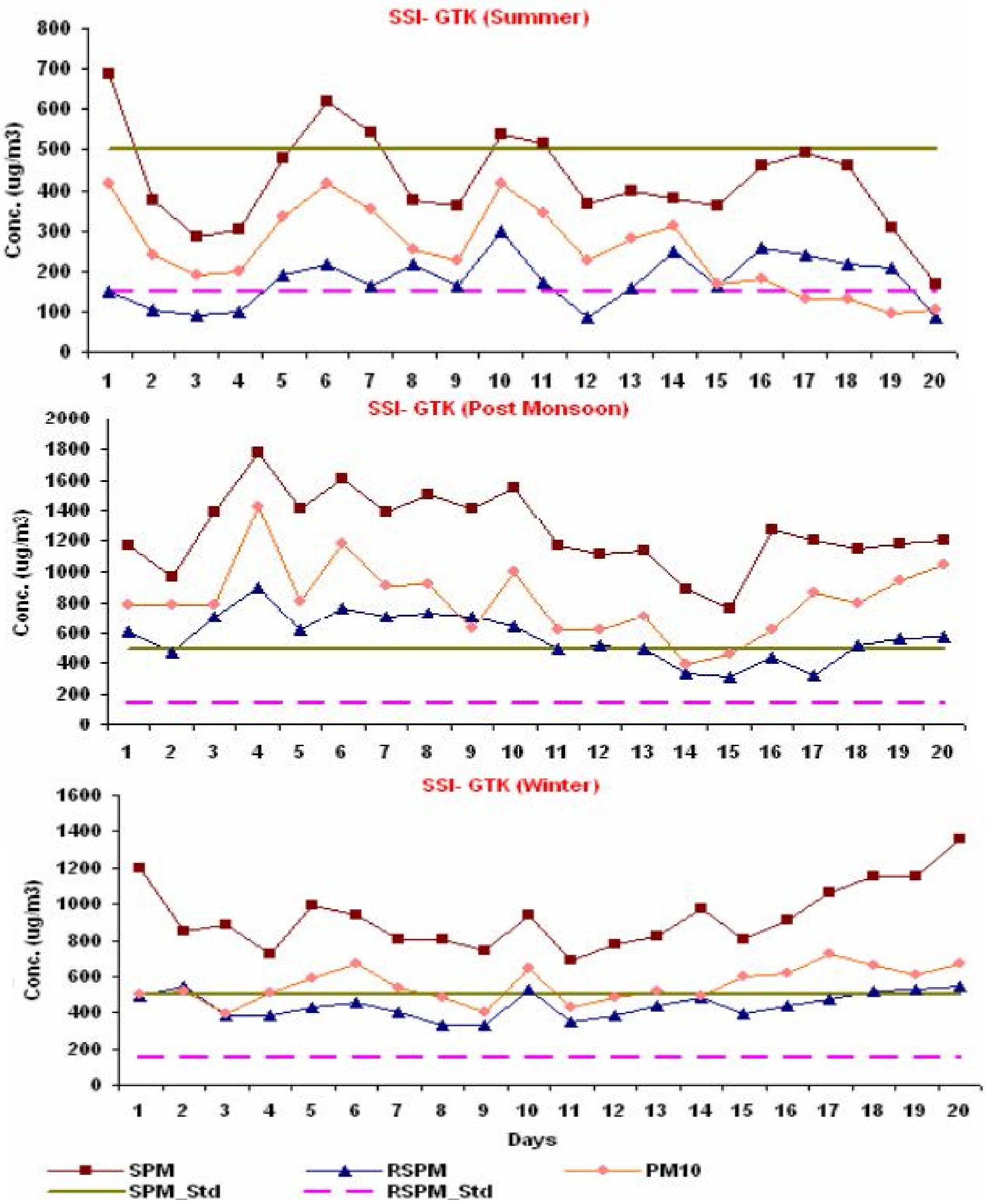


Fig 2.30 : Observed Concentration of SPM, RSPM and PM_{10} at Pitampura in all three seasons

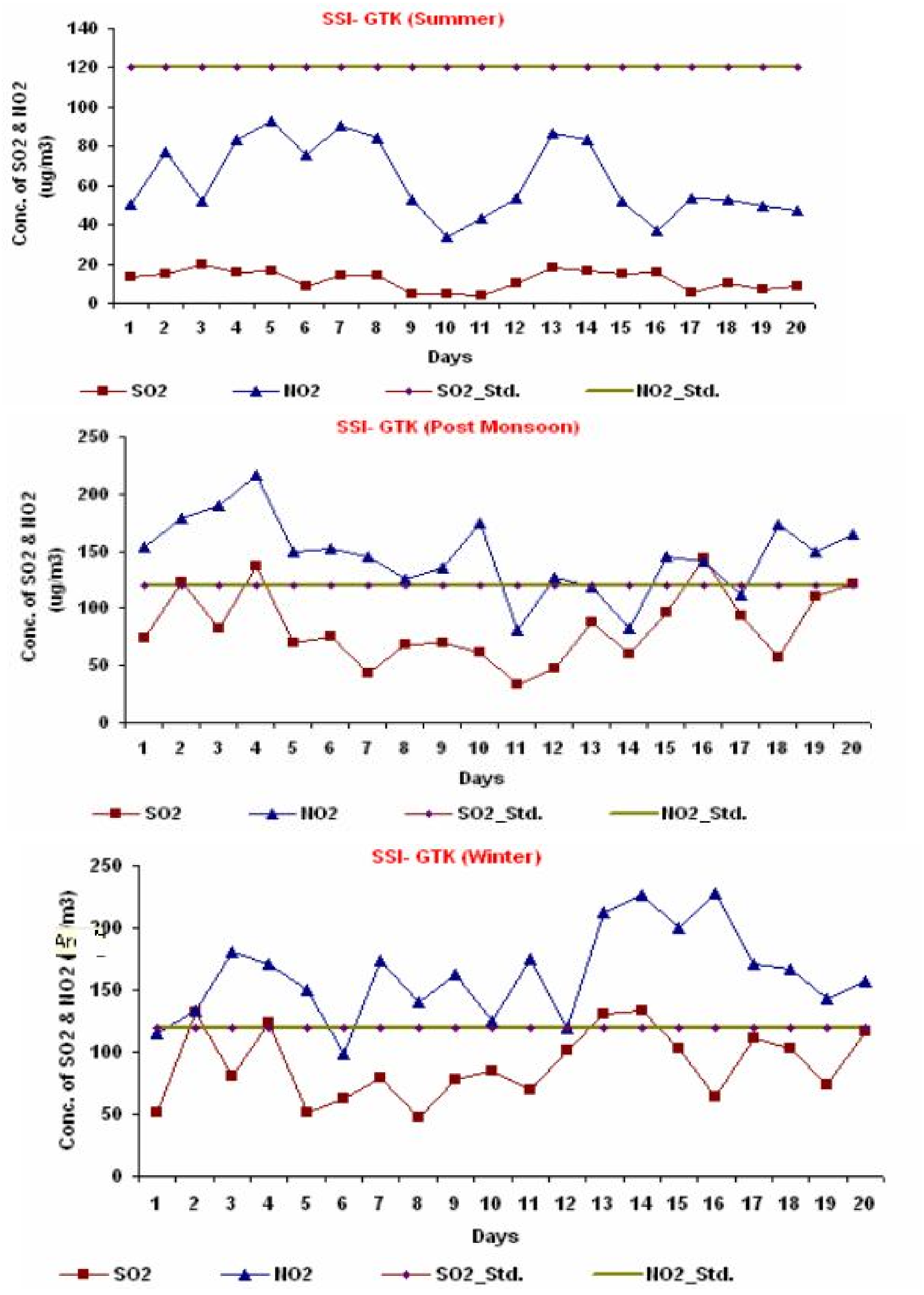


Fig 2.31 : Observed Concentration of SO_2 and NO_2 at SSI – GTK in all three seasons

The concentrations of $PM_{2.5}$ for all three seasons are presented in **Fig 2.32**. The concentration of $PM_{2.5}$ is exceeding the limit of US EPA standard of 35 µg/m^3 in post monsoon and winter.

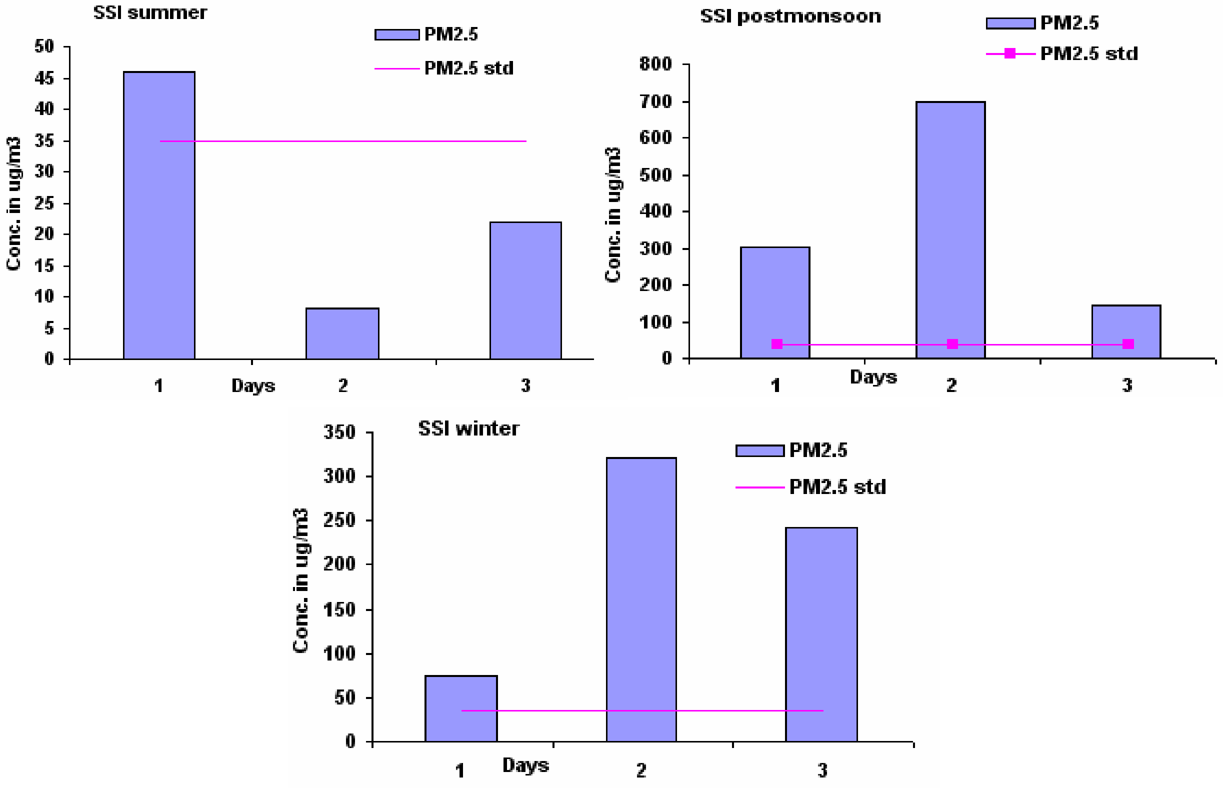


Fig 2.32 : Concentration of $PM_{2.5}$ at SSI -GTK

Figure 2.33 shows the concentration of CO for all three seasons. The concentration of CO is below the CPCB standard 2 mg/m^3 in all three seasons. **Figure 2.34** shows the concentration of Methane, Non Methane and Total Hydrocarbons. **Table 2.11** shows the 24 hourly average concentrations of VOCs for one day of all three seasons

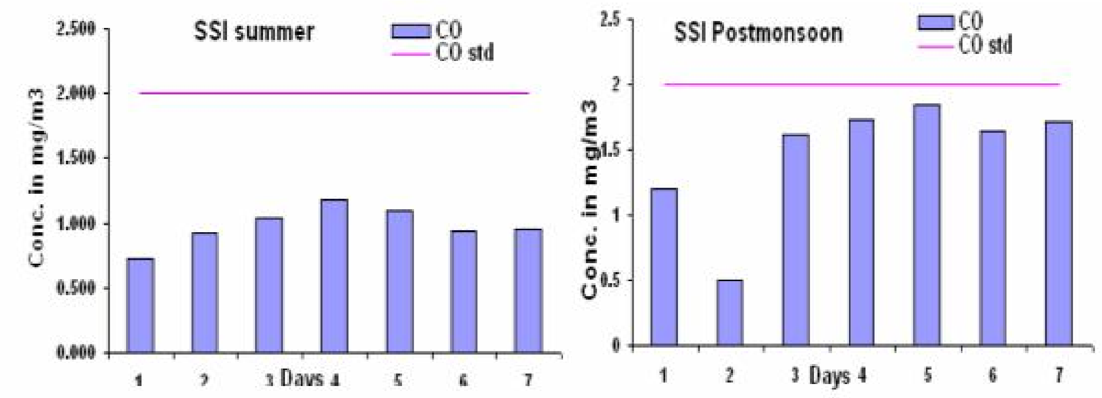


Fig 2.33 : Observed CO concentration at SSI –GTK in all three seasons

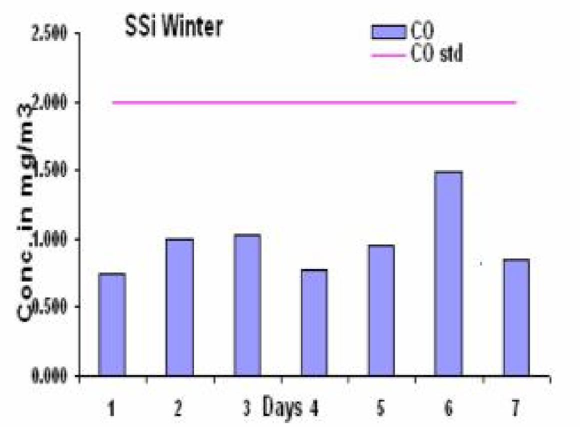


Fig 2.33 : Observed CO concentration at SSI –GTK in all three seasons

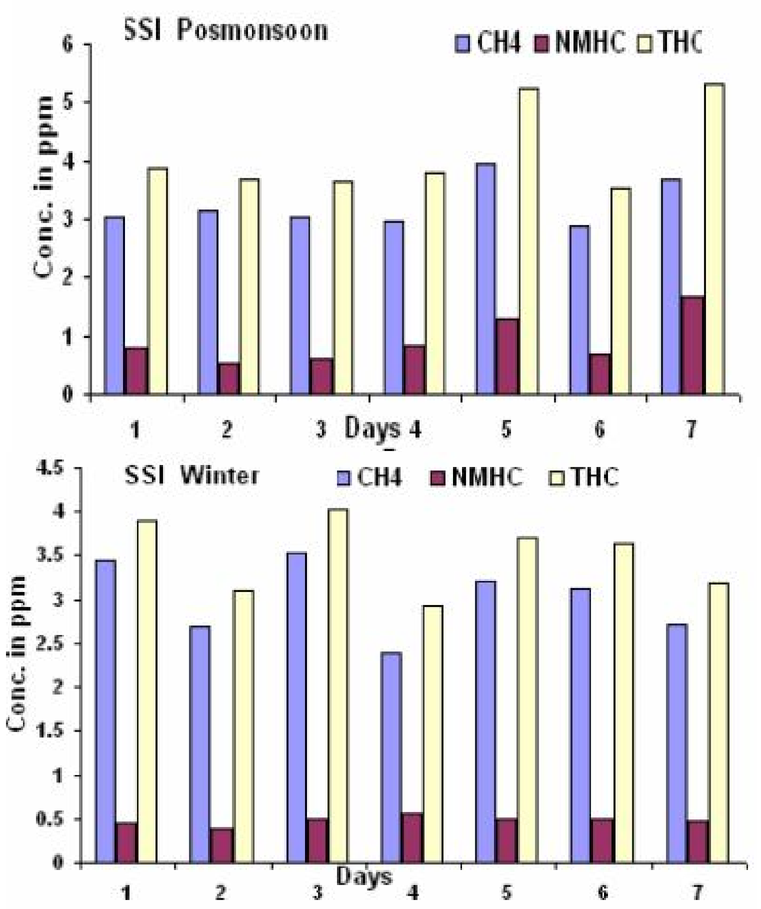
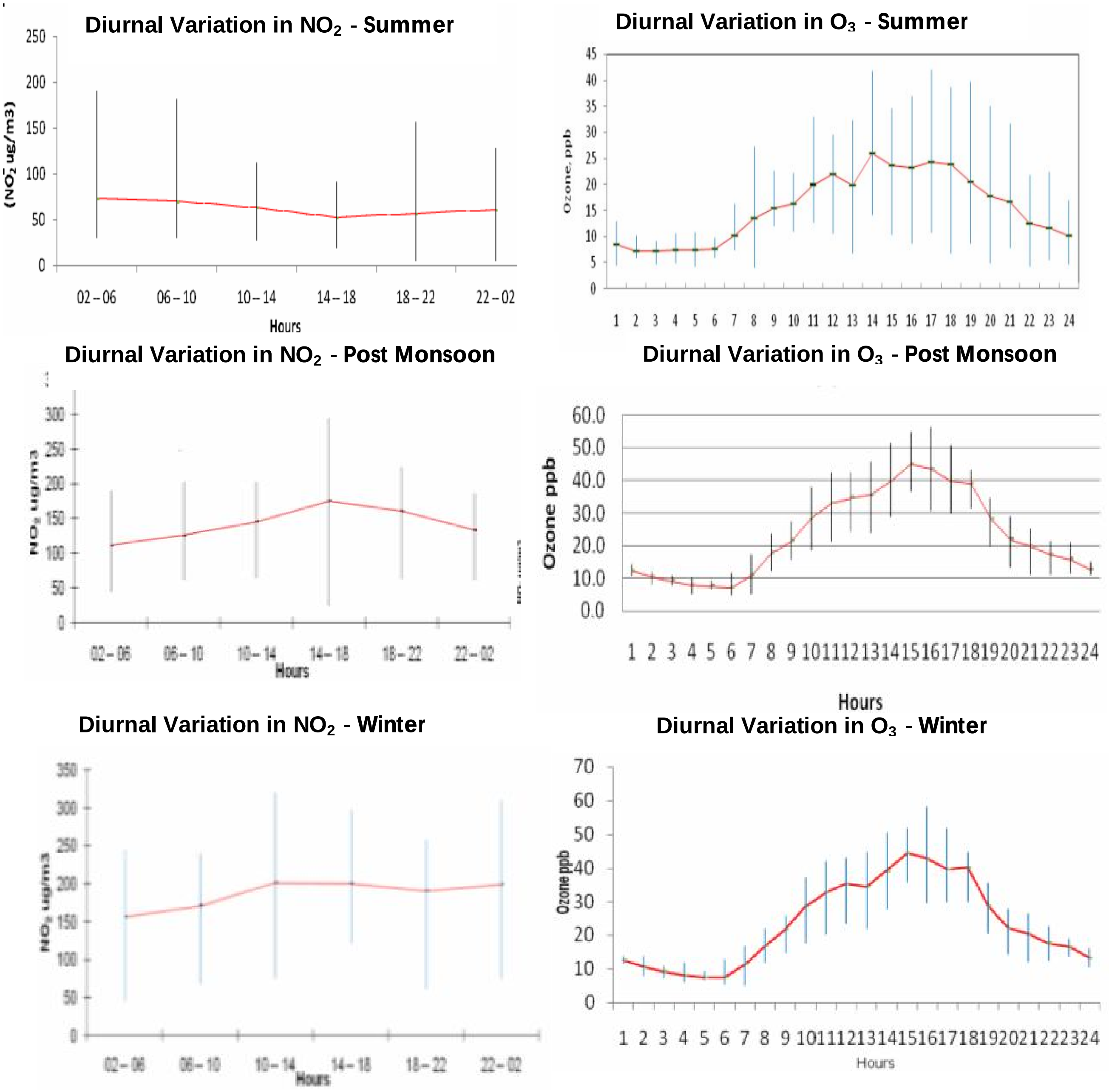


Fig 2.34 : Observed CH_4, NMHC and THC concentration at SSI- GTK in all three seasons

Table 2.11 : 24 Hourly Concentrations of VOCs

	1-3 Butadiene	Benzene
Summer	1.3	1.8
Post Monsoon	0.6	1.6
Winter	0.2	1.6

Diurnal variation in NO_2 and Ozone levels is plotted in **Figure 2.35**. It can be observed that for the Summer season the concentration of NO_2 is about 70 µg/m^3 throughout the day which is lower than post monsoon and winter. The monitored Ozone values are plotted and it can be observed that in day time the concentration of ozone increases from 6 ppb to 25 ppb by 2 PM and later falls to 15ppb by mid night. In Winter season the day time concentration of NO_2 is about 200 µg/m^3, which does not vary till mid night. Ozone concentration in winter increases to about 45 ppb by 3 PM and then goes down 10 ppb by 10 PM.



Diurnal Variation in NO_2 - Summer

Diurnal Variation in O_3 - Summer

Diurnal Variation in NO_2 - Post Monsoon

Diurnal Variation in O_3 - Post Monsoon

Diurnal Variation in NO_2 - Winter

Diurnal Variation in O_3 - Winter

Fig 2.35 : Diurnal Variation in NO_2 and Ozone at SSI-GTK

Estimation of EC/OC Ratio

EC and OC was determined for PM samples with a view to establish the sources of carbon. 24 hourly trends of OC, EC and TC with respect to their ratios are presented in **Fig 2.36.** The ratio between OC to EC indicates that in post monsoon it is in the range of 3-12 which is higher than winter and summer. Reasons for high OC to EC ratio include biomass burning, heavy duty vehicles and road dust due to continuous movement of vehicles in industrial area.

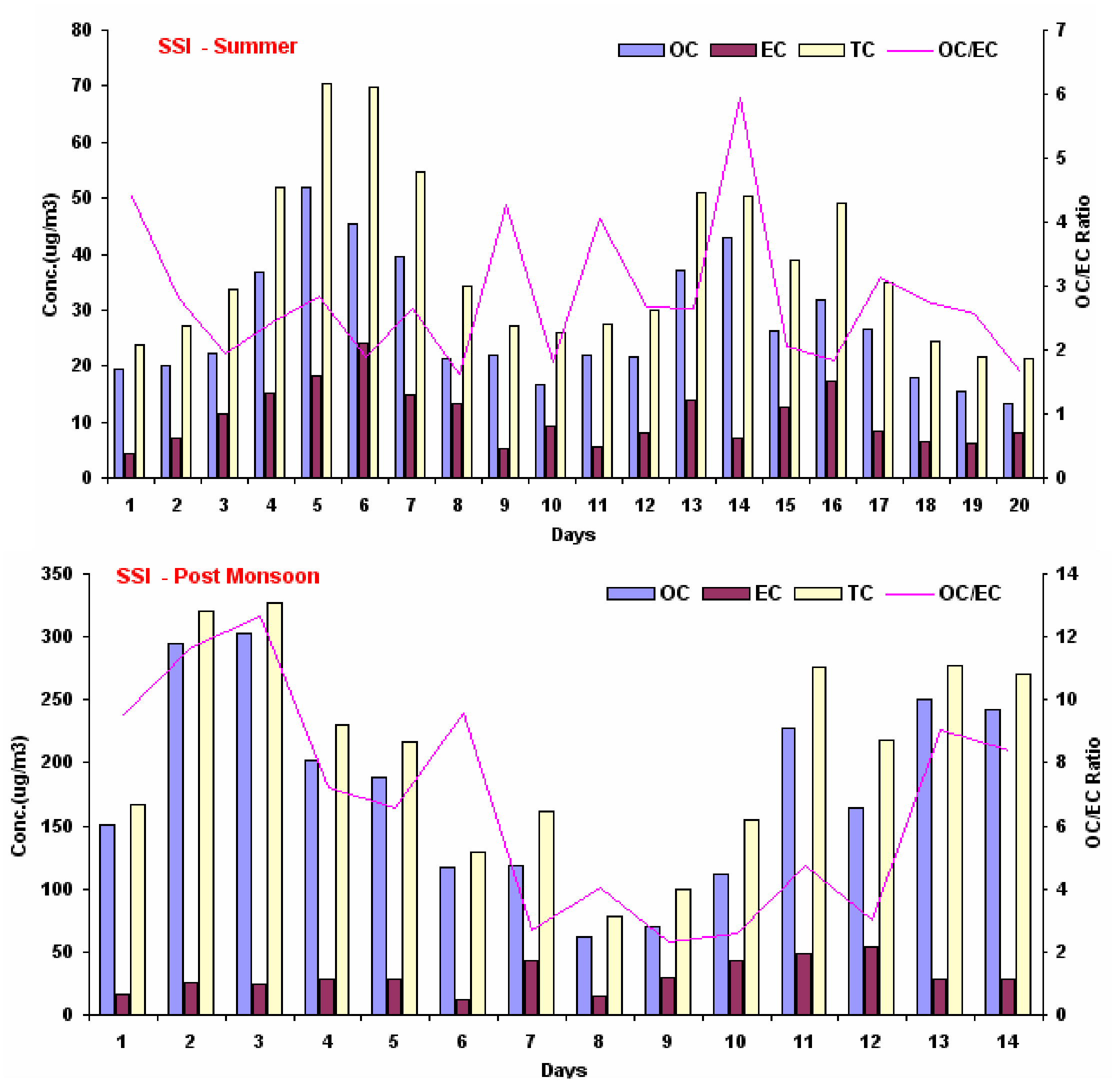


Fig 2.36 : 24 hourly trends of OC, EC and TC at SSI-GTK

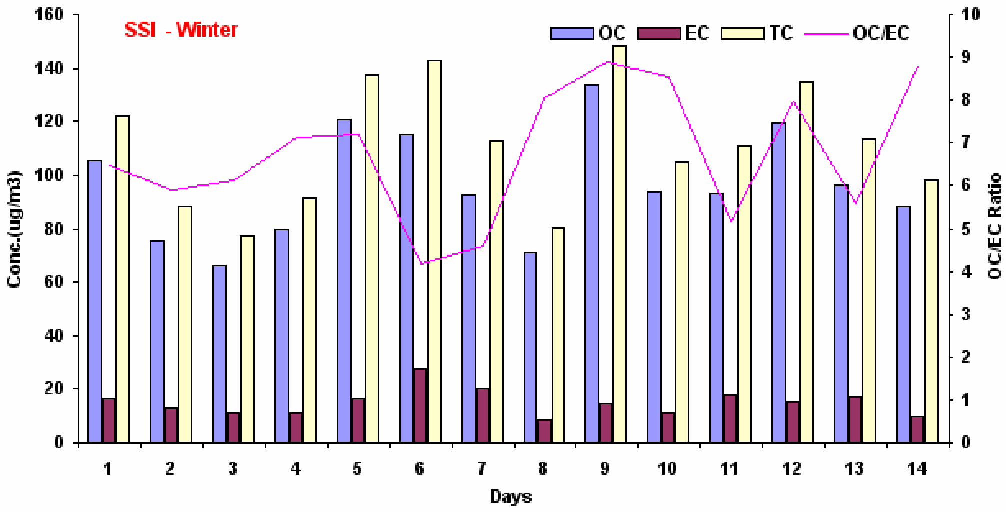


Fig 2.36 (Contd..) : 24 hourly trends of OC, EC and TC at SSI-GTK

Mass Closure

Mass fraction of elements, ions and carbons in terms of percentage in PM_{10} is shown in **Fig 2.37.** High contribution of ions like sulphate is observed in all the three seasons due to coal combustion in industrial area and wood burning in slums nearby. Road dust and construction activities during the sampling period are significant contributors to crustal elements.

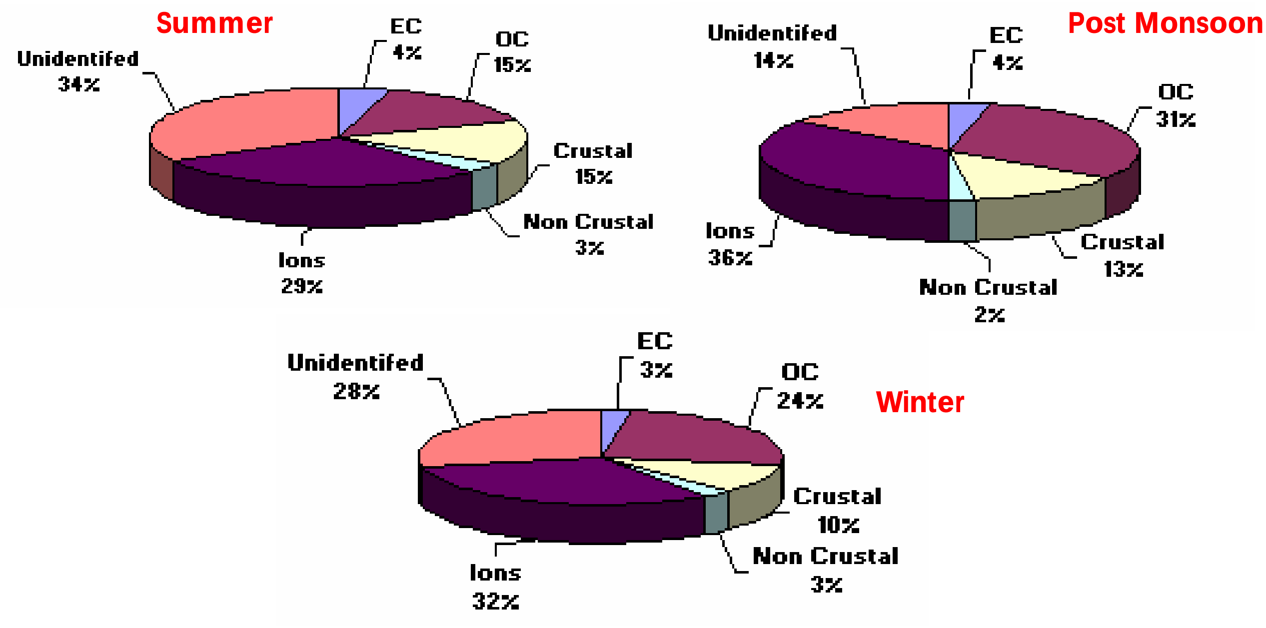


Fig 2.37 : Percent Mass Closure of PM_{10} at SSI –GTK in three seasons

2.3.5 Ashram Chowk

Site Description

It represents “kerbside” air quality scenario. The site is in proximity of one of the busiest traffic intersections (Ashram Chowk) in Delhi. It is surrounded by ring roads connecting to Sarai Kale Khan, Mathura road, Lajpat nagar and Nizamuddin area, in different directions with a flyover on outer ring road (Sarai Kale Khan – Lajpat Nagar). The junction connects two States, namely UP (through Noida Toll Bridge) and Haryana (through Mathura road leading to Faridabad and to Gurgaon via Dhaula Kuan). Traffic activity is very high through out the day. During night hours, heavy duty vehicles, particularly trucks can be seen in large number. Nizamuddin railway station and Sarai Kale Khan bus stand are about 2 km away from the Ashram Chowk. This area is primarily a residential area with limited commercial activities as shown in **Figure 2.38**. The total population of the study zone is estimated to be about 67,000 residing in the areas like New Friends Colony, Maharani Bagh, Sriniwaspuri, Nehru Nagar, Siddhartha Nagar etc. Overall, the study zone can be defined as residential-cum-commercial activity zone with very high traffic activity throughout day and night.

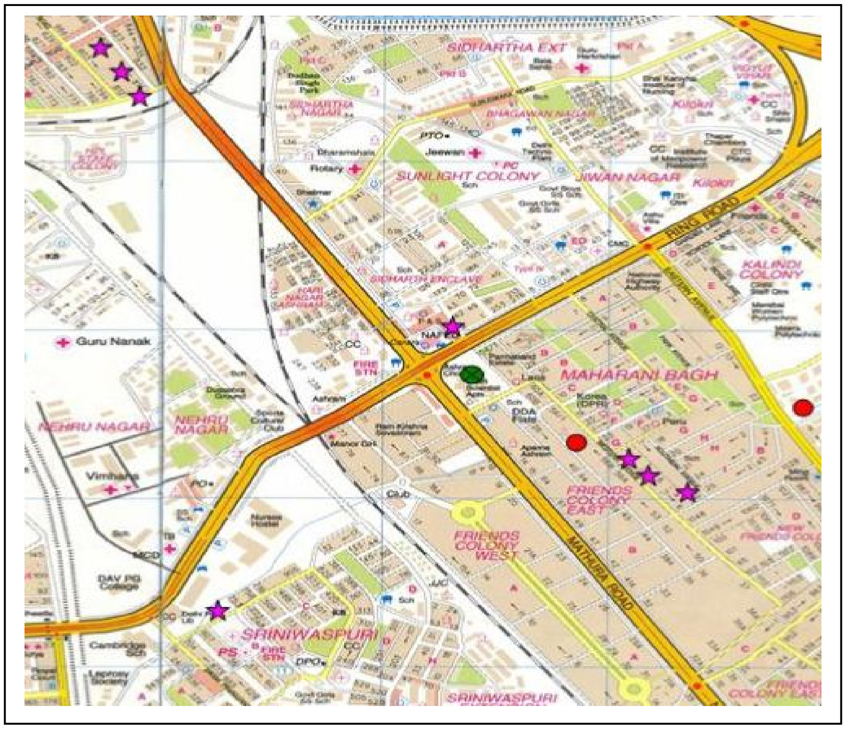


Fig. 2.38: Study Zone (2 km x 2 km): Ashram Chowk

Air Quality Monitoring

Ambient air quality monitoring results at the site for all three seasons are presented in **Tables 2.12 a-b-c** . As can be seen from these tables, SPM RSPM values always exceed the CPCB standard in all three seasons. The average SPM and RSPM trends indicate that the values in post monsoon and winter are higher. This is attributed to low mixing during these seasons and also higher traffic volume.

Table 2.12a : Air Quality Status at Ashram Chowk (Summer)

	N	Min	Max	Average	Per98	Stdev	CV
SPM	20	577	985	800.3	959.8	114.2	0.14
RSPM	20	114.3	323.7	212	316.6	56.1	0.26
PM10	19	153	383.5	297.1	381.5	69.3	0.23
PM2.5	3	56	102	80	101.2	23.1	0.29
SO2	20	3	12.8	6.1	12	2.7	0.44
NO2	20	26.6	61	48.4	60.9	9.3	0.19
O3	7	6.8	101	25.7	91.9	33.8	1.32
CO	7	1.4	1.5	1.5	1.5	0	0.00
CH4		NA	NA	NA	NA	NA	
NMHC		NA	NA	NA	NA	NA	
THC		NA	NA	NA	NA	NA	
HCHO	1			12			0.00

Table 2.12b : Air Quality Status at Ashram Chowk (Post Monsoon)

	N	Min	Max	Average	Per98	Stdev	CV
SPM	20	678.2	1097.3	889.7	1076	118.5	0.13
RSPM	20	127.1	581	409.8	579.7	126.1	0.31
PM10	20	138	798	453.3	767.5	162.1	0.36
PM2.5	3	148	226.1	181.8	223.9	40.1	0.22
SO2	20	6.9	24.8	14.4	24.1	4.8	0.33
NO2	20	67	172	114.2	171.6	37.5	0.33
O3	7	10.9	22.1	16.8	22	4.9	0.29
CO	7	1.5	1.9	1.7	1.9	0.2	0.12
CH4	7	2	2.8	2.3	2.8	0.3	0.13
NMHC	7	0.9	1.5	1.3	1.5	0.2	0.15
THC	7	3	4.1	3.6	4.1	0.4	0.11
HCHO	1			15			0.00

Table 2.12c : Air Quality Status at Ashram Chowk (Winter)

	N	Min	Max	Average	Per98	Stdev	CV
SPM	20	501.3	860.9	681.6	857.7	107.4	0.16
RSPM	20	229.5	627	374	604.2	110.8	0.30
PM10	19	261.9	585	392.8	558.5	87.6	0.22
PM2.5	3	104	203.1	165.8	202.6	54	0.33
SO2	20	9.7	20	14.9	19.2	2.4	0.16
NO2	20	52	150.2	93.8	144.8	28.1	0.30
O3	2	21.4	58.5	39.9	57.7	26.2	0.66
CO	7	1.5	1.9	1.6	1.9	0.2	0.13
CH4	7	2.8	3.5	3.1	3.5	0.2	0.06
NMHC	7	0.4	0.7	0.6	0.7	0.1	0.17
THC	7	3.4	4	3.7	3.9	0.2	0.05
HCHO	NA			11			0.00

Particulate matter (SPM, RSPM, and PM$_{10}$) levels of Ashram chowk for all three seasons are presented in **Fig 2.39** which shows that SPM and RSPM values are always above the prescribed standards. **Figures 2.40** presents the variation of SO_2 and NO_2 at the site for all the three seasons.

It is evident from the figures that SO_2 values meet the standards in all seasons. As this site represents “kerb site”, the vehicular exhaust contribute to high concentration of NO_2 which exceed the standards in post monsoon and winter.

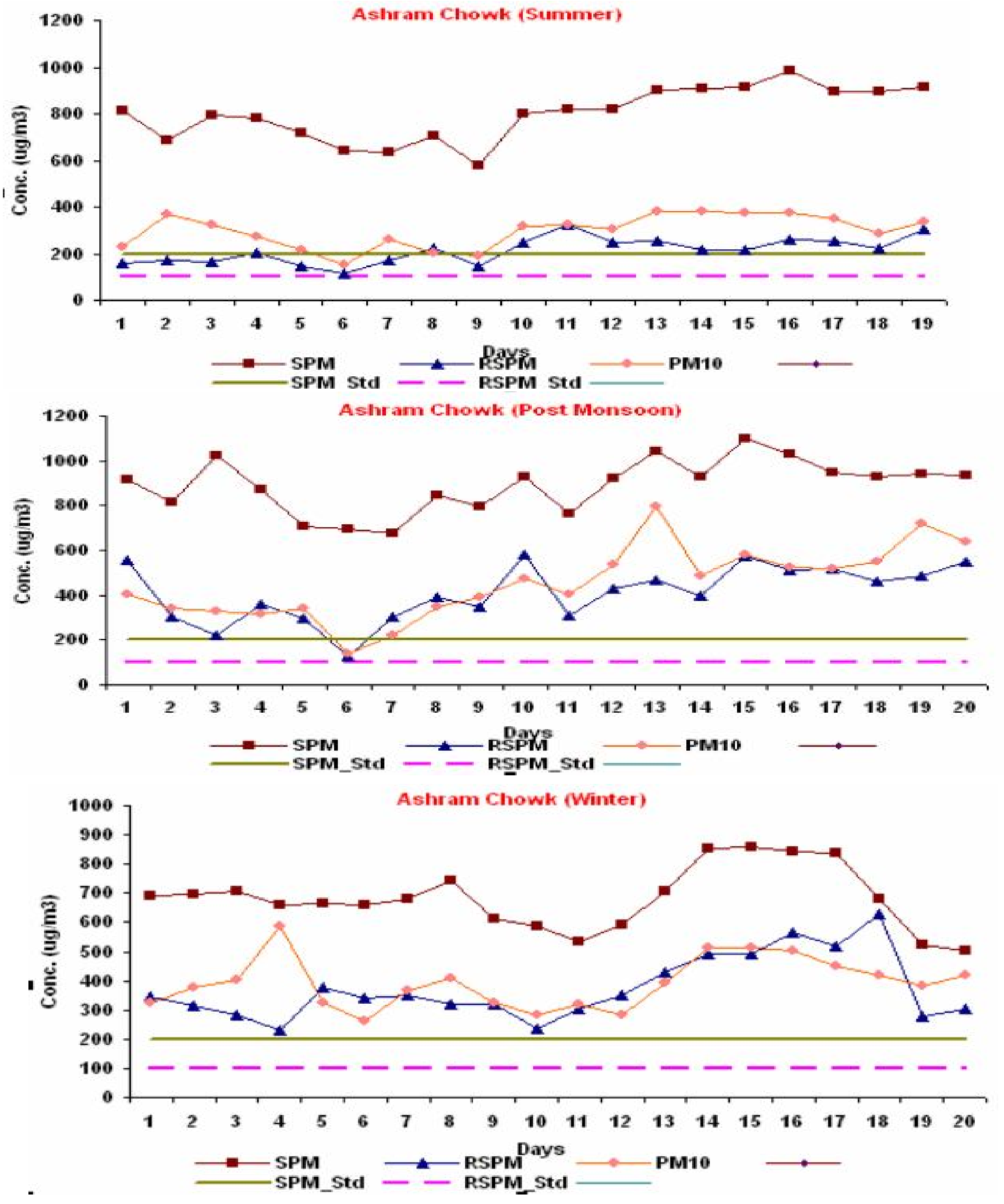


Fig 2.39 : Observed Concentration of SPM, RSPM and PM$_{10}$ at Ashram Chowk in all three seasons

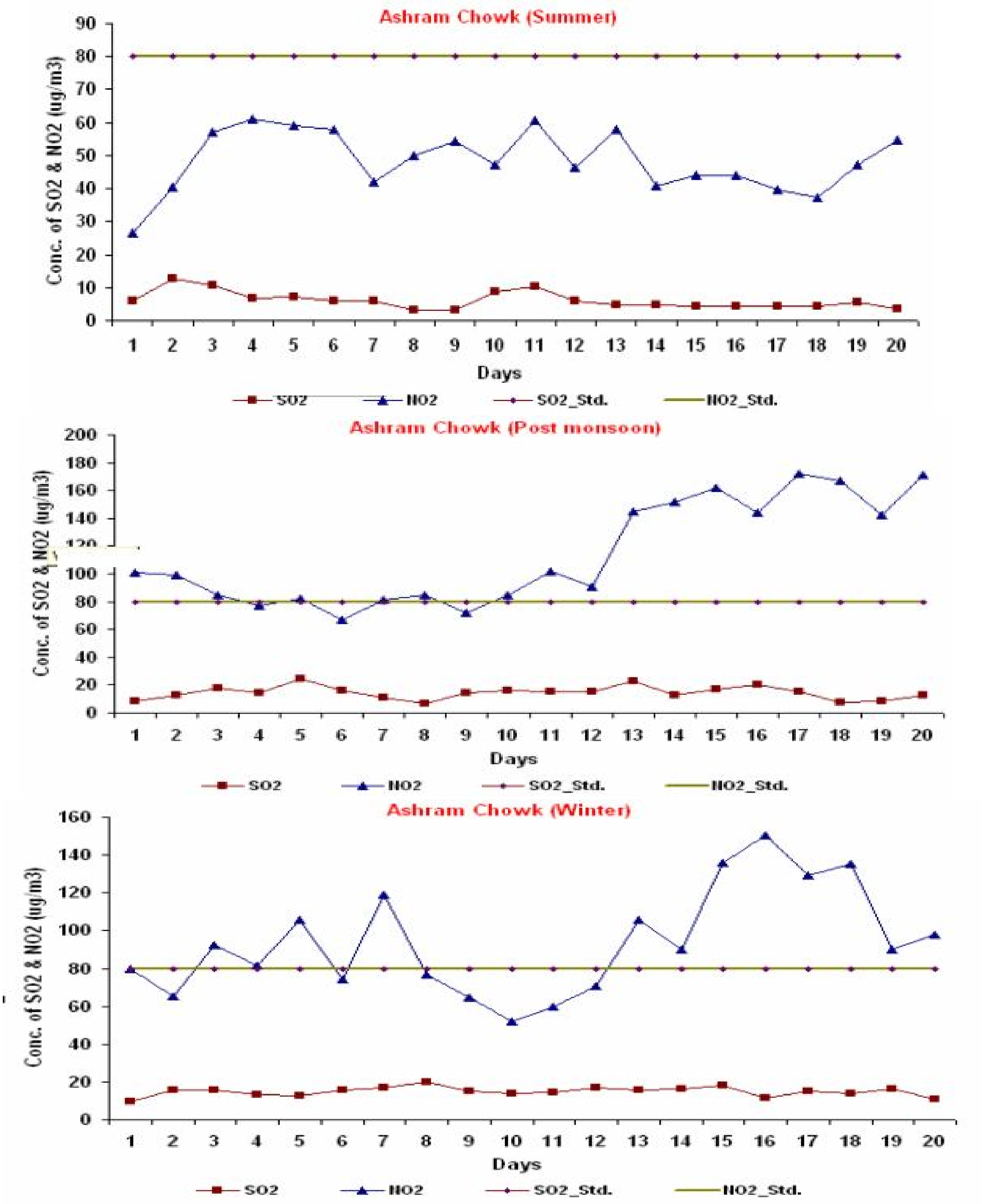


Fig 2.40 : Observed Concentration of SO_2 and NO_2 at Ashram Chowk in all three seasons

The concentrations of $PM_{2.5}$ for all three seasons are presented in **Fig 2.41**. The concentration of $PM_{2.5}$ is exceeding the limit of US EPA standard of 35 µg/m^3 in all seasons, due to fine particulate matter contributed from vehicles and to some extent from other combustion sources.

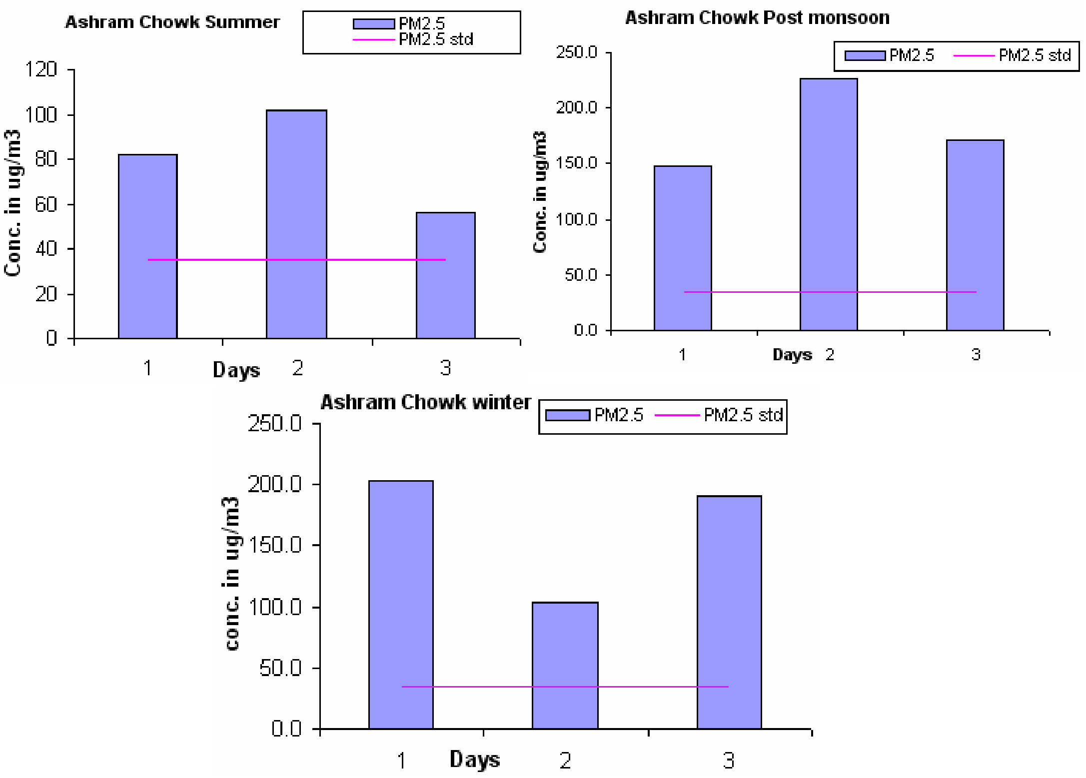
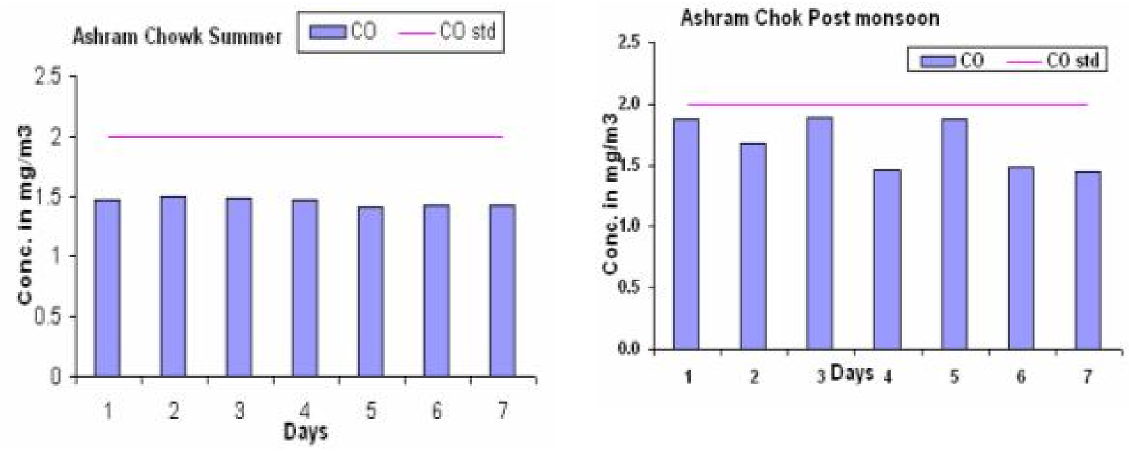


Fig 2.41 : Concentration of $PM_{2.5}$ at Ashram Chowk

Figure 2.42 shows the concentration of CO for all three seasons. The concentration of CO is below the CPCB standard 2 mg/m^3 in all three seasons. **Figure 2.43** shows the concentration of Methane, Non Methane and Total Hydrocarbons. **Table 2.13** shows the 24 hourly average Concentrations of VOCs for one day of all three seasons.



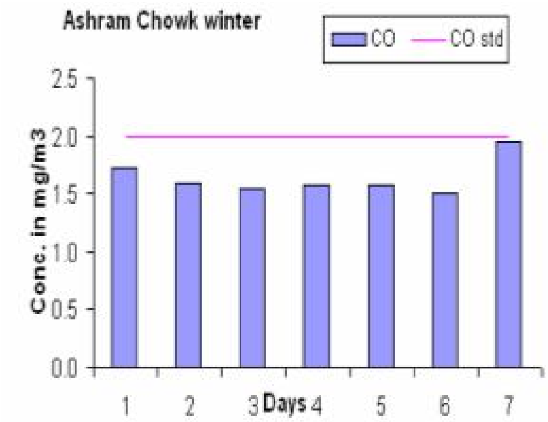


Fig 2.42 : Observed CO concentration at Ashram Chowk in all three seasons

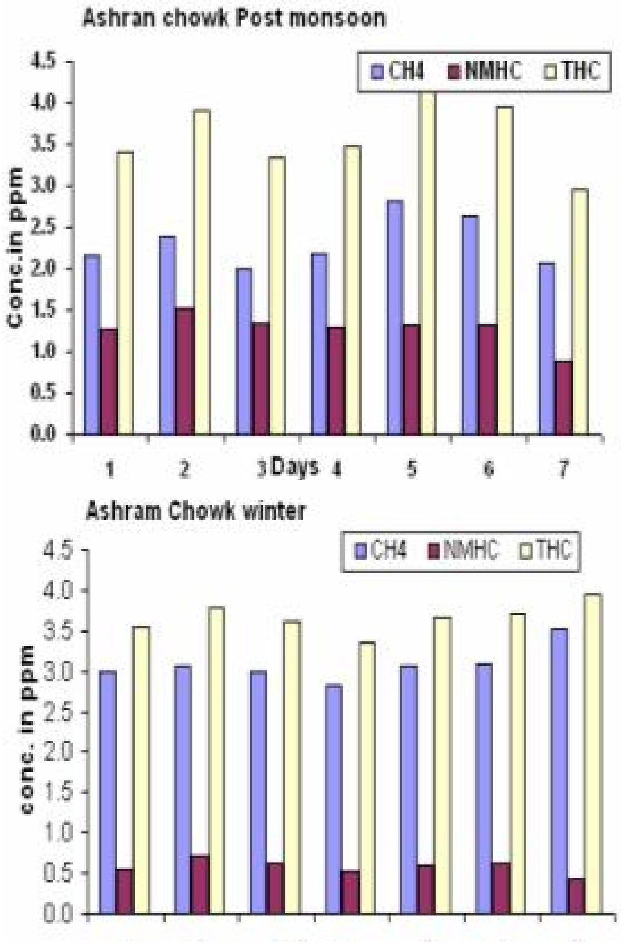
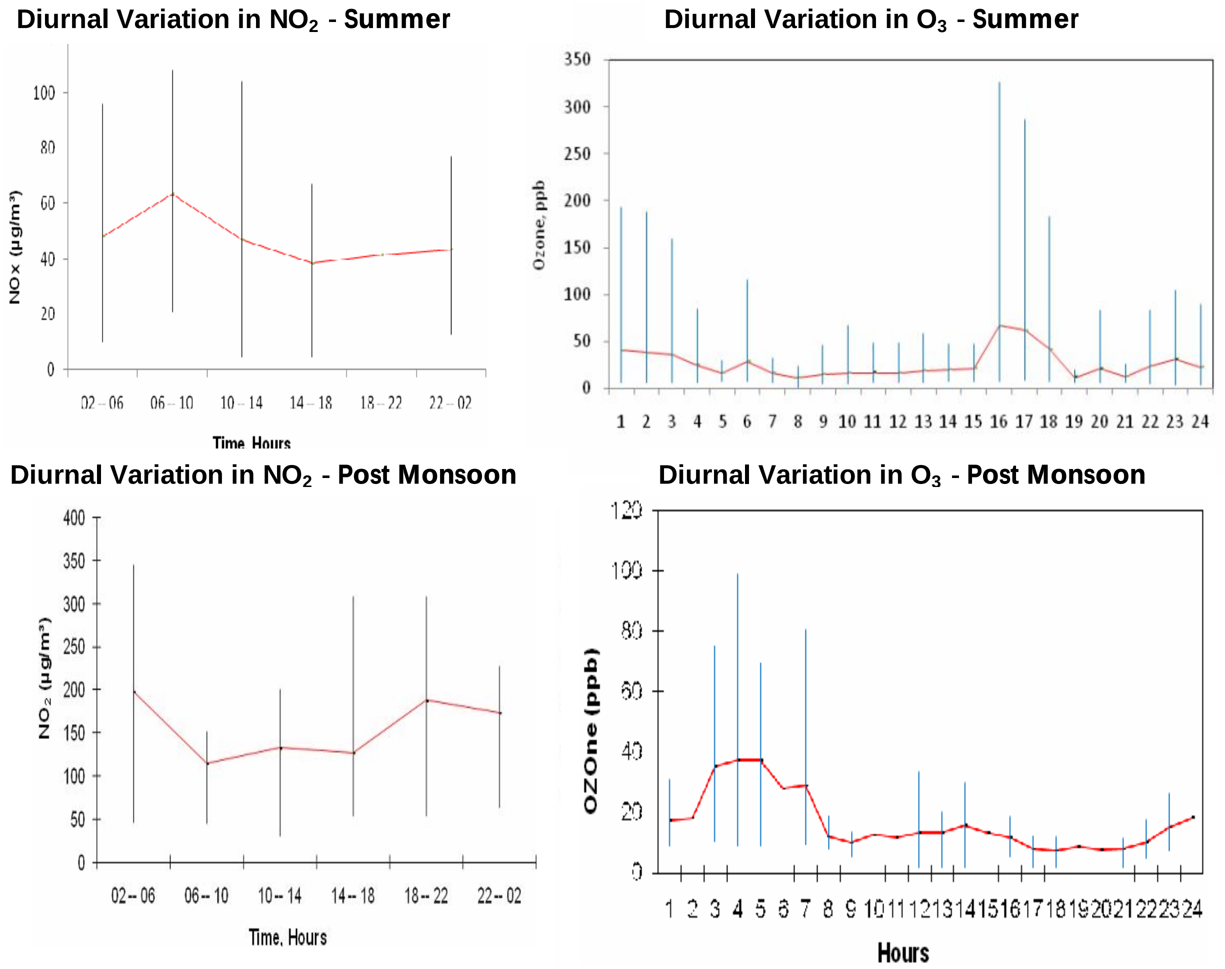


Fig 2.43 : Observed CH_4, NMHC and THC concentration at Ashram Chowk in all three seasons

Table 2.13 : 24 Hourly Average Concentrations of VOCs

	1-3 Butadiene	Benzene
Summer	0.5	1.6
Post Monsoon	1.5	3.1
Winter	0.9	1.5

Diurnal variation in NO_2 and Ozone levels is plotted in **Fig 2.44.** It can be observed that for the Summer season the day time concentration of NO_2 is about 65 µg/m^3 till 10 AM and then goes down to about 40 µg/m^3 till 6 PM then it remains constant till mid night. NO_2 values are higher in post monsoon and winter compare to summer. The ozone concentrations are unevenly distributed and do not show distinct peak in the afternoon of each day as in the case of other locations.



Diurnal Variation in NO_2 - Summer

Diurnal Variation in O_3 - Summer

Diurnal Variation in NO_2 - Post Monsoon

Diurnal Variation in O_3 - Post Monsoon

Fig 2.44 : Diurnal Variation in NO_2 and Ozone at Ashram Chowk

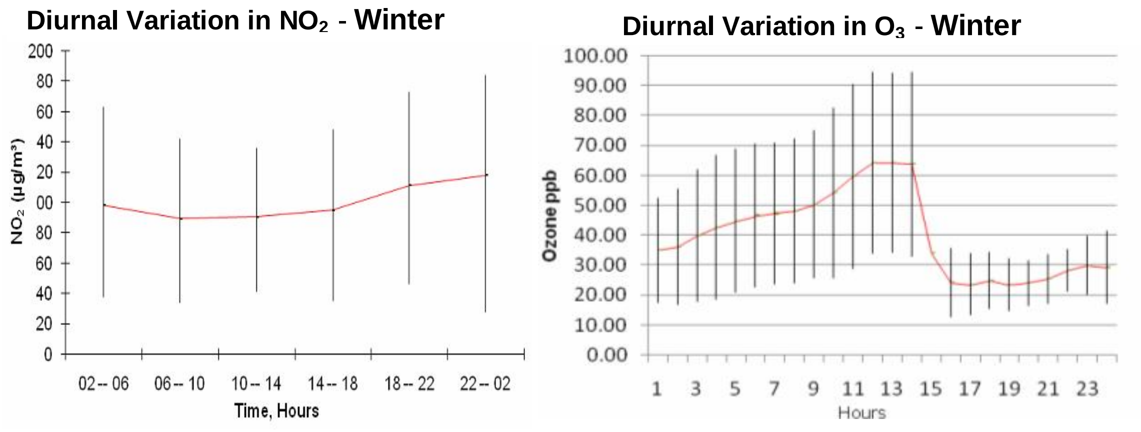


Fig 2.44 (Contd..) : Diurnal Variation in NO_2 and Ozone at Ashram Chowk

Estimation of EC/OC Ratio

EC and OC was determined for PM samples with a view to establish the sources of carbon emission. 24 hourly trends of OC, EC and TC with respect to their ratios are presented in **Fig 2.45.** Concentration of EC and OC is normally high during post monsoon, winter compared to summer.

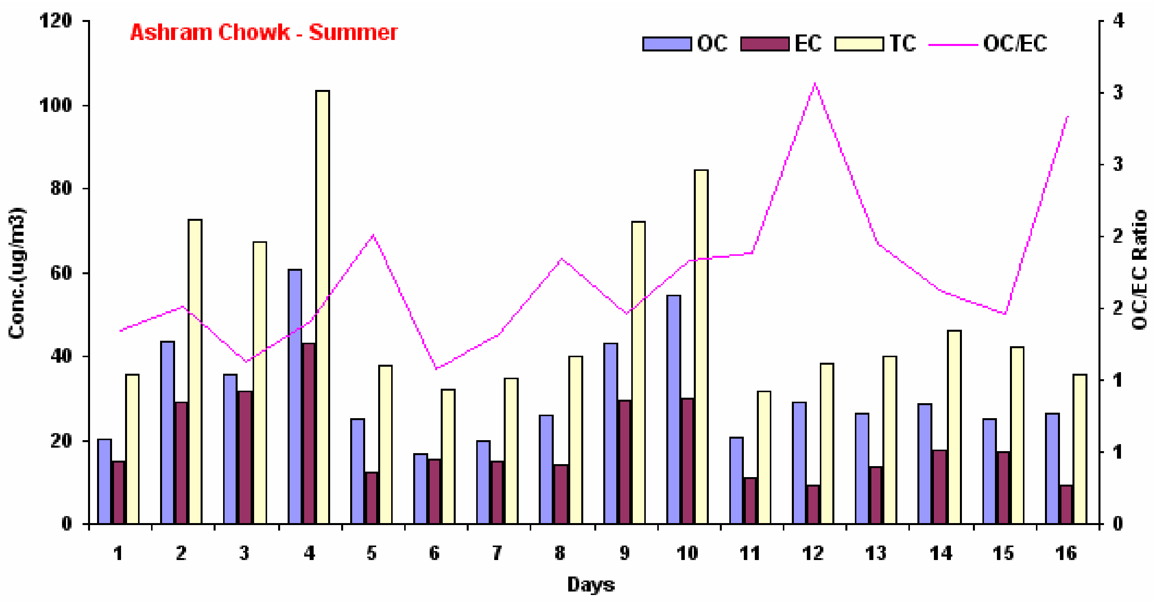


Fig 2.45 : 24 hourly trends of OC, EC and TC at Ashram Chowk

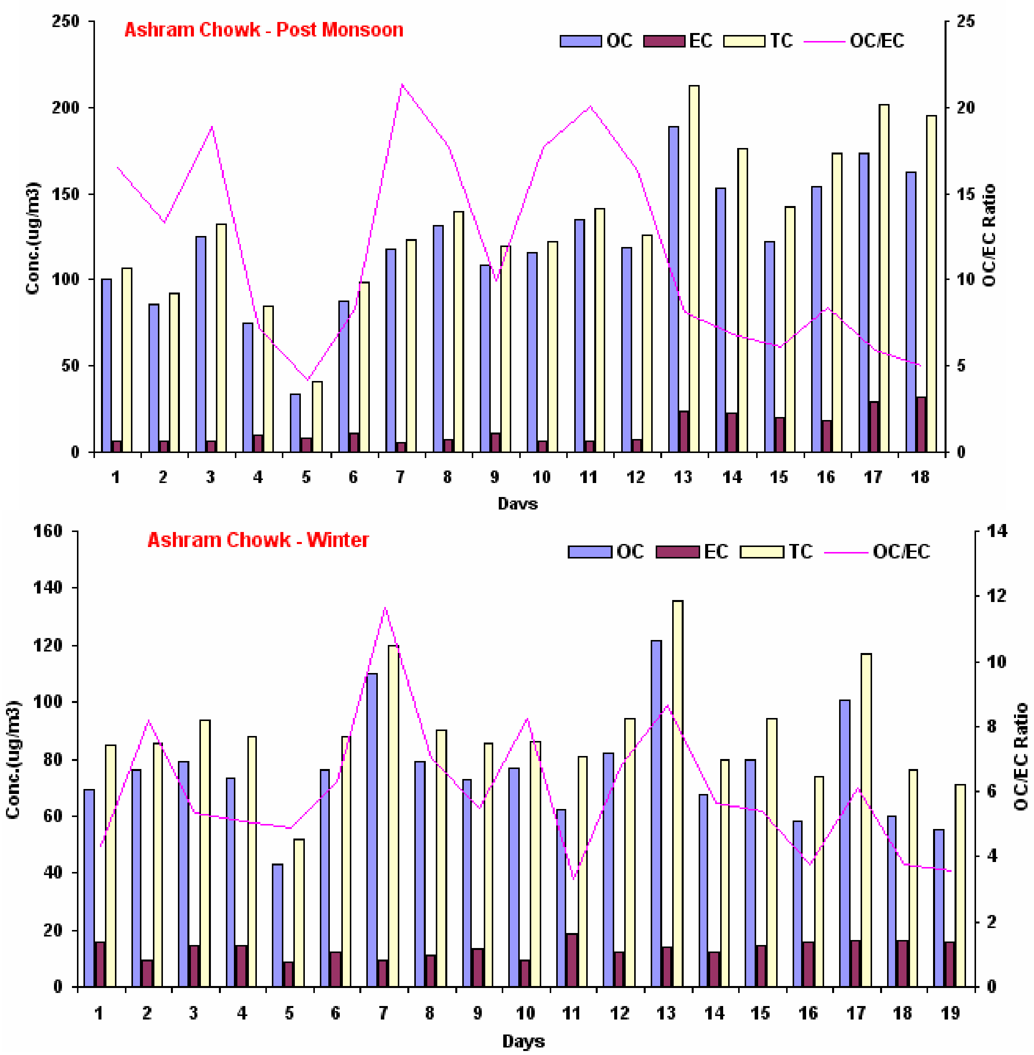
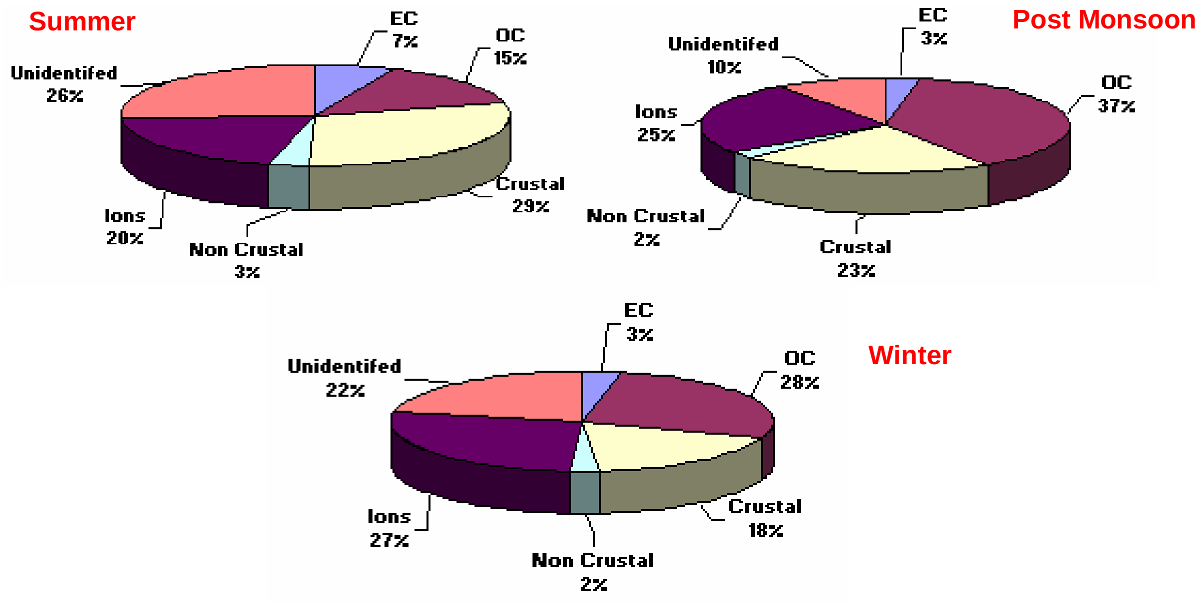


Fig 2.45 : 24 hourly trends of OC, EC and TC at Ashram Chowk

Mass Closure

Mass fraction of elements, ions and carbons in terms of percentage in PM_{10} is shown in **Fig 2.46.** High percent contribution from carbonaceous fraction is observed. Total PM mass at this site also has significant contribution from crustal elements mainly due to resuspension of road dust caused by continuous movement of vehicles in this area.



.

Fig 2.46 : Percent Mass of PM_{10} at Ashram Chowk

2.3.6 Dhulakuan

Site Description

It represents another "kerbside" location. Dhaula Kuan is a major intersection of roads in Delhi. Five major through fares in Delhi meet at Dhaula Kuan as shown in **Fig. 2.47**. Passing through the intersection are the Ring Road (Mahatma Gandhi Marg), National Highway 8, (Swaran Jayanti Marg leading to Gurgaon), which feed traffic around Delhi and from Central Delhi to Gurgaon, and points south and southwest, respectively. NH 8 is also the primary route of traffic from Delhi to Delhi Airport.

Upper Ridge Road joins these two roads here, and serves both as an artery connecting NH 8 and NH 10 (through Naraina, Rajaouri Garden to Najafgarh), and as a way to connect West Delhi and South Delhi without going through the congested Connaught Place commercial hub. A major infrastructure project during early 2000s has led to the construction of a fly over that eliminated stop lights and improved traffic flow. In addition to being a major road hub, Dhaula Kuan is also a primary stop on the Delhi Ring Railway and will be the location of a Delhi Metro stop when construction is completed on the Connaught Place - Airport line. Currently, Dhaula Kuan serves as a primary exchange point for multimodal travellers, and its importance is expected to grow as the Delhi Metro and Terminal 3 at Delhi Airport is constructed.

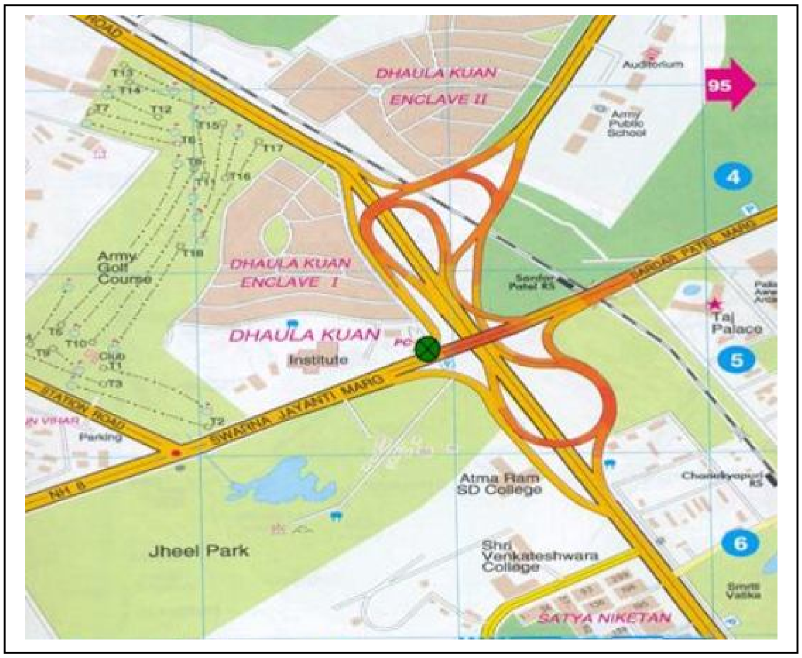


Fig. 2.47 : Study Zone (2 km x 2 km): Dhaula Kuan

Air Quality Monitoring

Ambient air quality monitoring results at the site for all three seasons are presented in **Tables 2.14 a-b-c**. As can be seen from these tables, SPM and RSPM values always exceed the CPCB standard in all three seasons. This is due to higher traffic volume near the site.

Table 2.14a : Air Quality Status at Dhaula Kuan (Summer)

	N	Min	Max	Average	Per98	Stdev	CV
SPM	20	409	764.3	528.6	738	93.5	0.18
RSPM	20	115.7	358.3	197	352.9	65.2	0.33
PM 10	-	NA	NA	NA	NA	NA	
PM 2.5	-	NA	NA	NA	NA	NA	
SO2	20	6	12.5	8.4	12.4	2.2	0.26
NO2	20	40.8	93.3	68.4	92.8	14.6	0.21
O3	7	7.5	9.6	8.6	9.5	0.7	0.08
CO	7	1.3	1.5	1.4	1.5	0.1	0.07
CH4		NA	NA	NA	NA	NA	
NMHC		NA	NA	NA	NA	NA	
THC		NA	NA	NA	NA	NA	
HCHO	1			18			0.00

Table 2.14b: Air Quality Status at Dhaula Kuan (Post Monsoon)

	N	Min	Max	Average	Per98	Stdev	CV
SPM	20	178.9	444.4	305.6	417.9	71.7	0.23
RSPM	20	104.7	255.3	149.2	250.4	42	0.28
PM10	20	96	352.8	195.3	340.4	73.9	0.38
PM2.5	3	43	55	49.3	54.8	6	0.12
SO2	20	6	9.4	7.3	9.1	1.1	0.15
NO2	20	22.4	59.5	40	58.3	10.8	0.27
O3	6	8.9	19.1	12.7	18.6	3.7	0.29
CO	7	1.1	2	1.7	2	0.4	0.24
CH4	7	2.1	2.8	2.4	2.8	0.3	0.13
NMHC	7	1.1	1.5	1.2	1.5	0.2	0.17
THC	7	3.2	4.1	3.6	4.1	3.3	0.92
HCHO	1			16			0.00

Table 2.14c : Air Quality Status at Dhaula Kuan (Winter)

	N	Min	Max	Average	Per98	Stdev	CV
SPM	20	364.4	970.8	566.1	938	169.2	0.30
RSPM	20	98.1	337.2	226.1	329.5	67.1	0.30
PM10	19	188	536	346.9	503.9	89.1	0.26
PM2.5	3	137.3	142.7	140	142.6	3.8	0.03
SO2	20	5.7	34.6	15.5	33.3	8.7	0.56
NO2	20	42	97.7	74.6	97.7	18.4	0.25
O3	3	49.8	67.6	58.7	67.2	12.6	0.21
CO	7	1	2.7	1.4	2.6	0.6	0.43
CH4	7	2.7	3.4	2.9	3.4	0.3	0.10
NMHC	7	0.6	1	0.7	0.9	0.1	0.14
THC	7	3.3	4.4	3.6	4.3		0.00
HCHO	NA			8			0.00

NA – Sampling could not be carried out

Particulate matter (SPM, RSPM, and PM$_{10}$) levels of Dhaula Kuan for all three seasons are presented in **Figures 2.48** along with regulatory standards of CPCB for SPM and RSPM. **Figures 2.49** presents the variation of SO$_2$ and NO$_2$ at the site for all the three seasons. It is evident from the figures that SO$_2$ values meet the standards in all seasons, whereas NO$_2$ values exceed the standards in winter on many days and few days in summer.

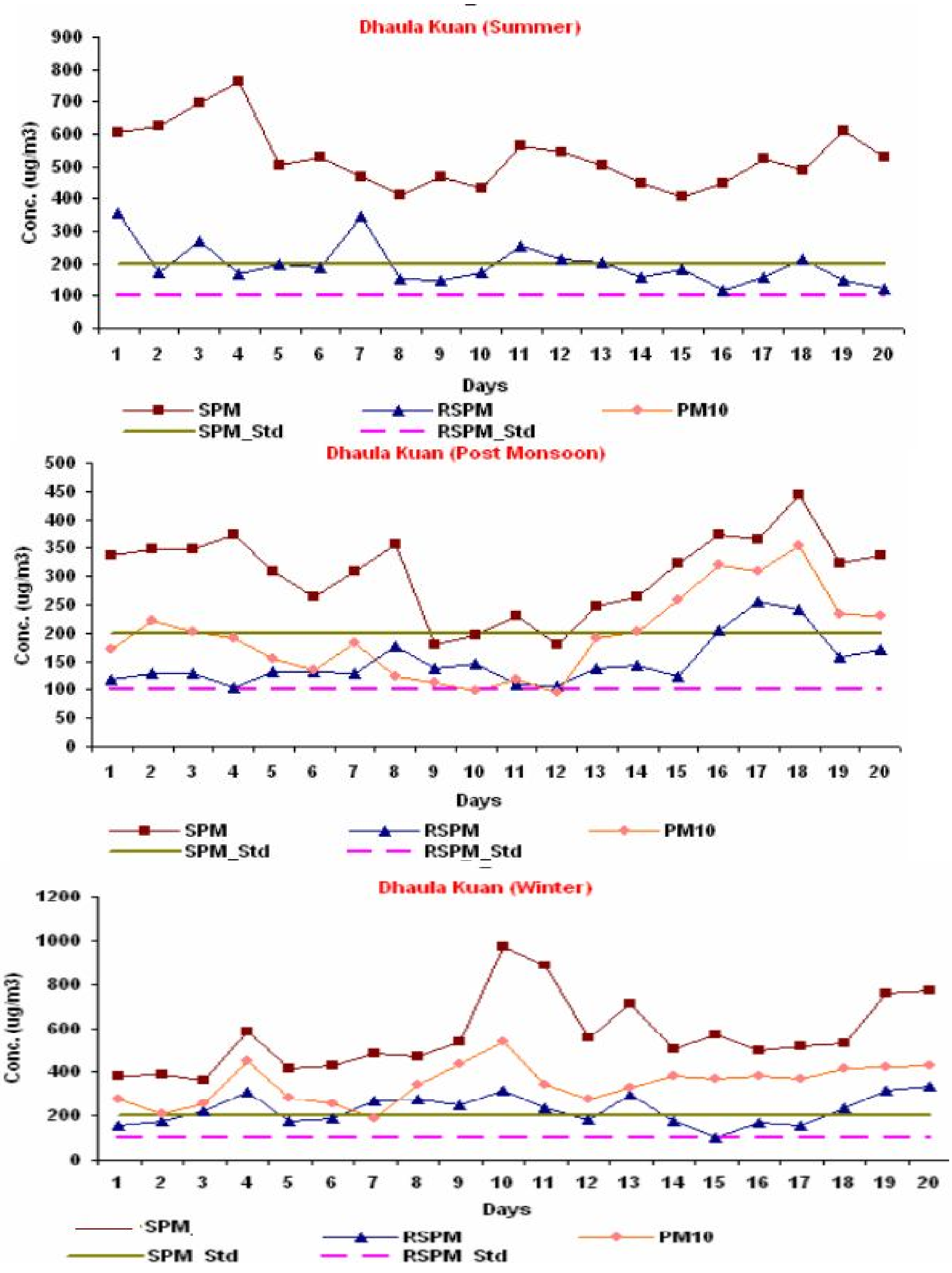


Fig 2.48 : Observed Concentration of SPM, RSPM and PM$_{10}$ at Dhaula Kuan

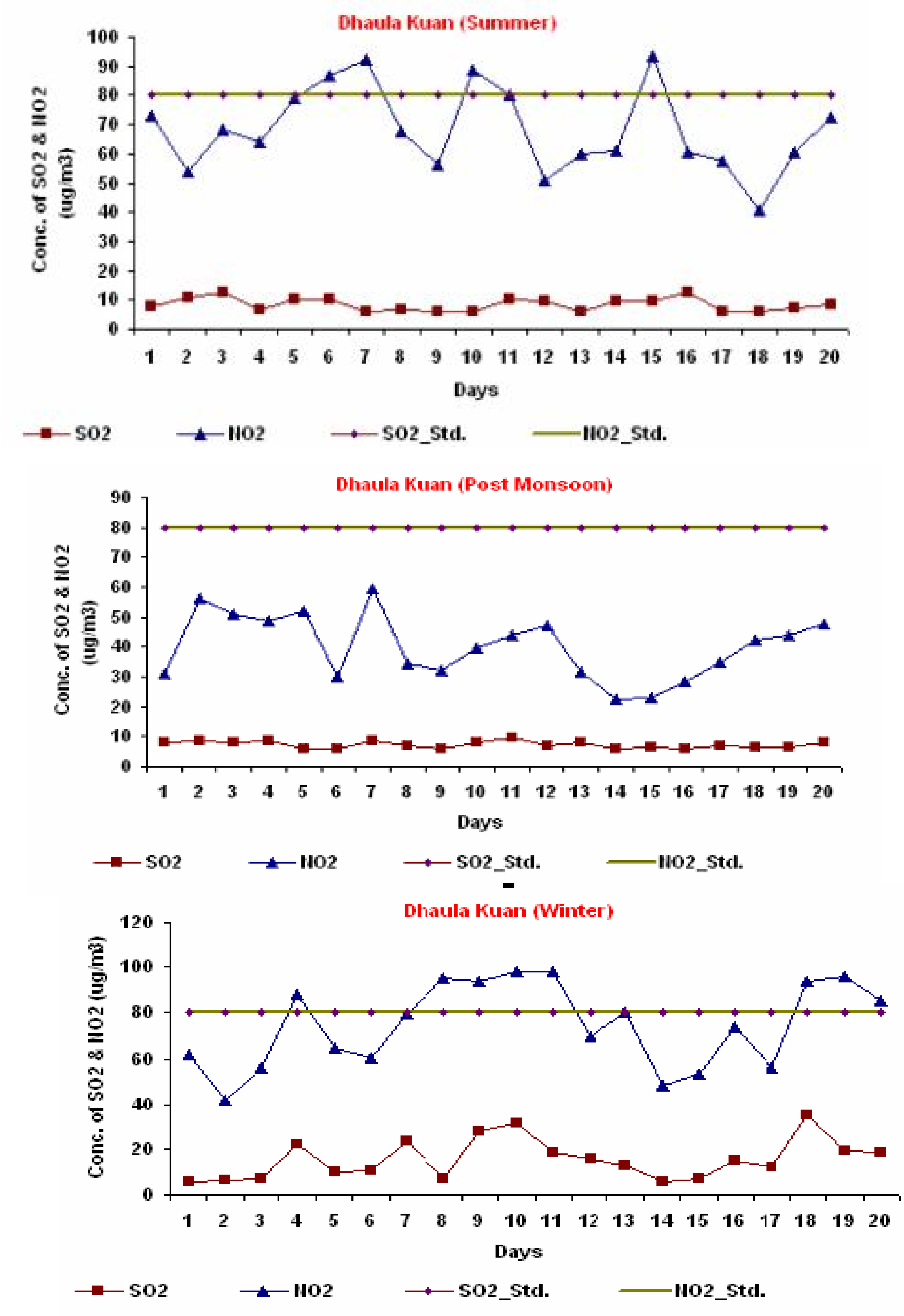


Fig 2.49 : Observed Concentration of SO_2 and NO_2 at Dhaula Kuan in all three seasons

The concentrations of $PM_{2.5}$ for all three seasons are presented in **Fig 2.50**. The concentration of $PM_{2.5}$ is exceeding the US EPA standard of 35 µg/m^3 in post monsoon and winter.

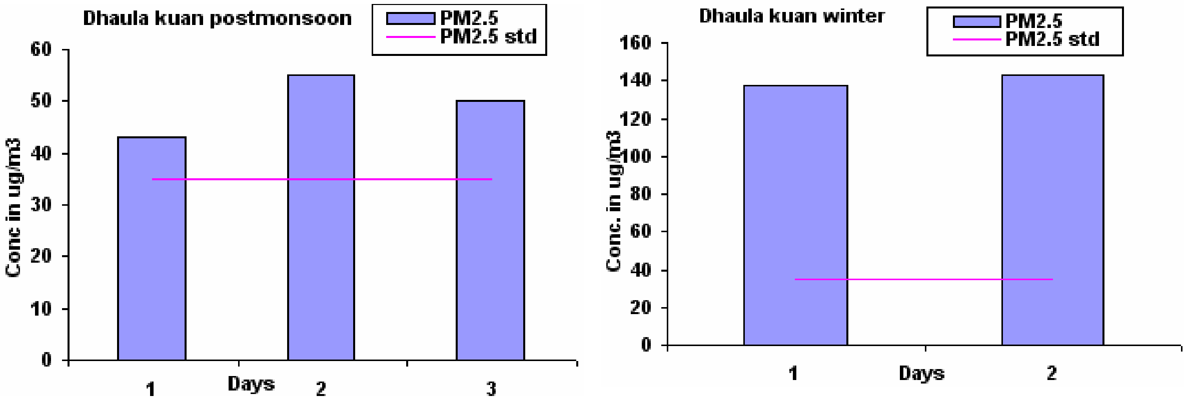


Fig 2.50 : Concentration of PM2.5 at Dhaula Kuan

Fig 2.51 shows the concentration of CO for all three seasons. The concentration of CO is below the CPCB standard 2 mg/m^3 in summer and it touches the CPCB standard few days of post monsoon and exceed in winter once. **Figure 2.52** shows the concentration of Methane, Non Methane and Total Hydrocarbons. **Table 2.15** shows the 24 hourly average Concentrations of VOCs for one day of all three seasons

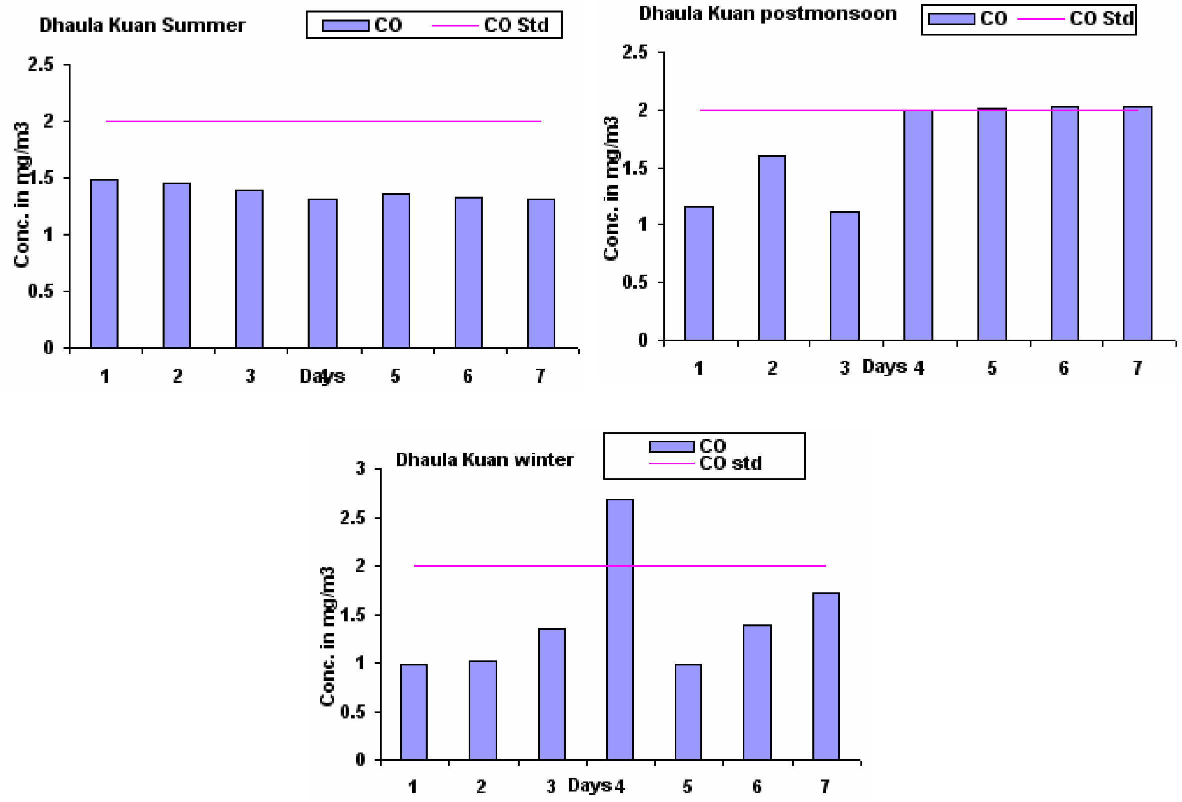


Fig 2.51 : Observed CO concentration at Dhaula Kuan in all three seasons

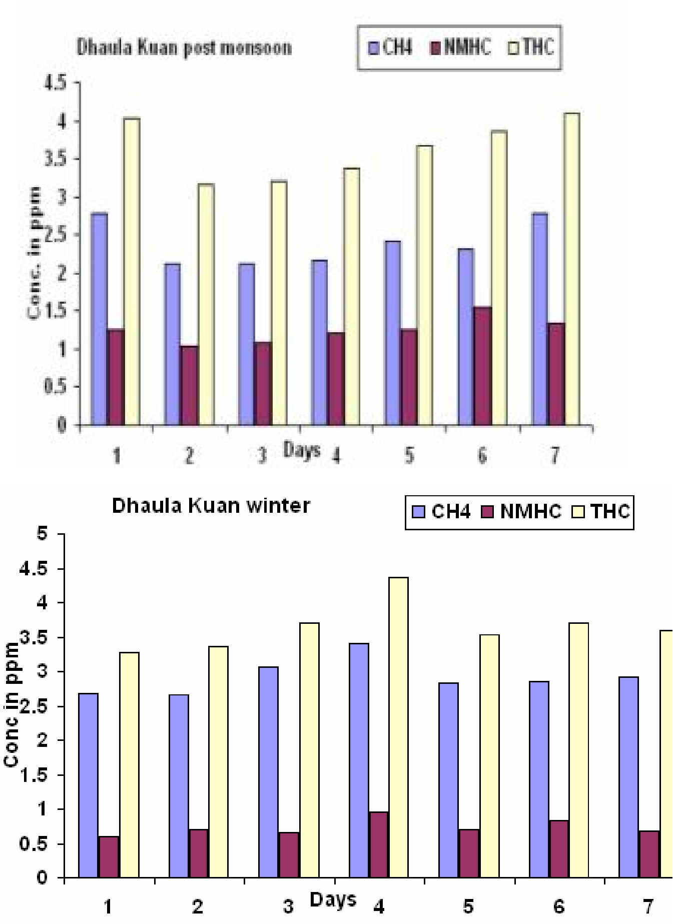
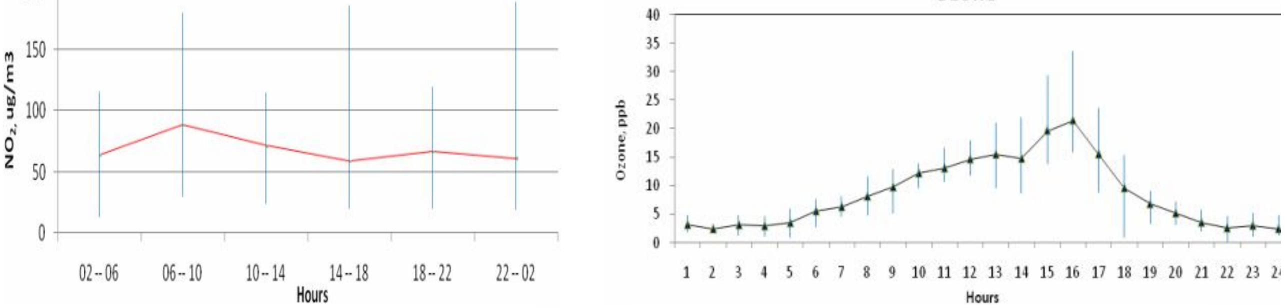


Fig 2.52 : Observed CH_4, NMHC and THC concentration at Dhaula Kuan in all three seasons

Table 2.15 : 24 Hourly Concentrations of VOCs

	1-3 Butadiene	**Benzene**
Summer	0.4	1.7
Post Monsoon	0.7	1.0
Winter	0.6	2.3

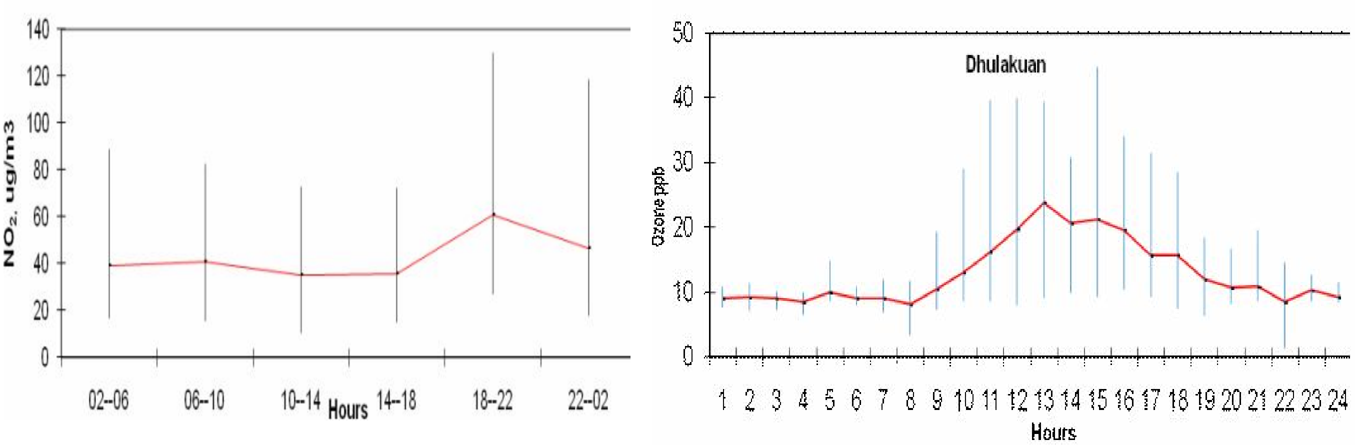
Diurnal variation in NO_2 and Ozone levels are plotted in **Figure 2.53.** It can be observed that for the Summer season the day time concentration of NO_2 is about 80 µg/m^3 till 10 AM before going to about 60 µg/m^3 till 6PM and before rising to about 70 µg/m^3 by 10 PM. The Ozone concentration increases to about 20 ppb till 4 PM and then gradually falls to 5 ppb by 10 PM. In Winter season the day time concentration of NO_2 goes down from 90 µg /m^3 to 50 µg /m^3 and after sunset it goes upto to 100 µg /m^3 till mid night. Ozone concentration remains at about 65 ppb till 10 AM then it gradually decreases about 20 ppb by mid night.


Diurnal Variation in NO_2 - Summer

Diurnal Variation in O_3 - Summer

Diurnal Variation in NO_2 - Post Monsoon

Diurnal Variation in O_3 - Post Monsoon



Diurnal Variation in NO_2 - Winter

Diurnal Variation in O_3 - Winter

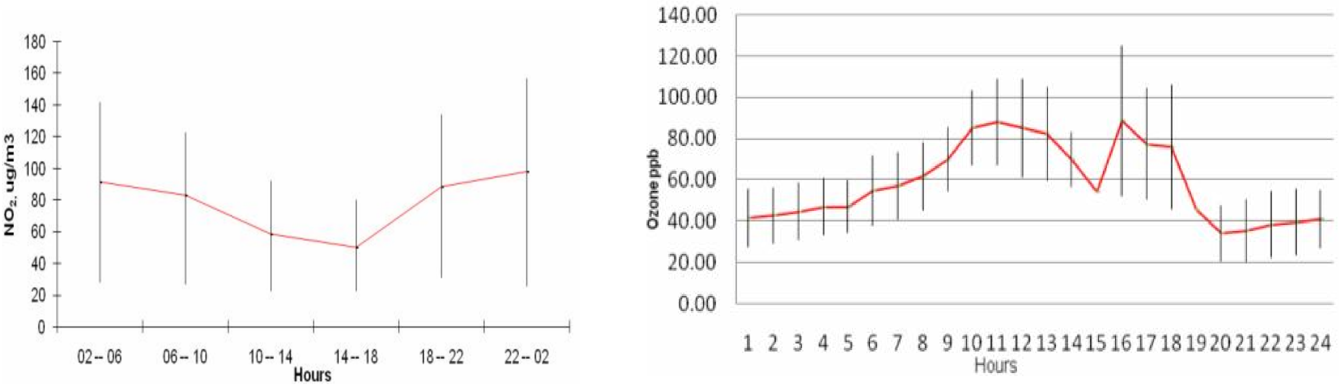


Fig 2.53 : Diurnal Variation in NO_2 and Ozone at Dhaula Kuan

Estimation of EC/OC Ratio

EC and OC was determined for PM samples with a view to establish the sources of carbon. 24 hourly trends of OC, EC and TC with respect to their ratios are presented in **Fig 2.54.** Winter values of OC are higher than in post monsoon.

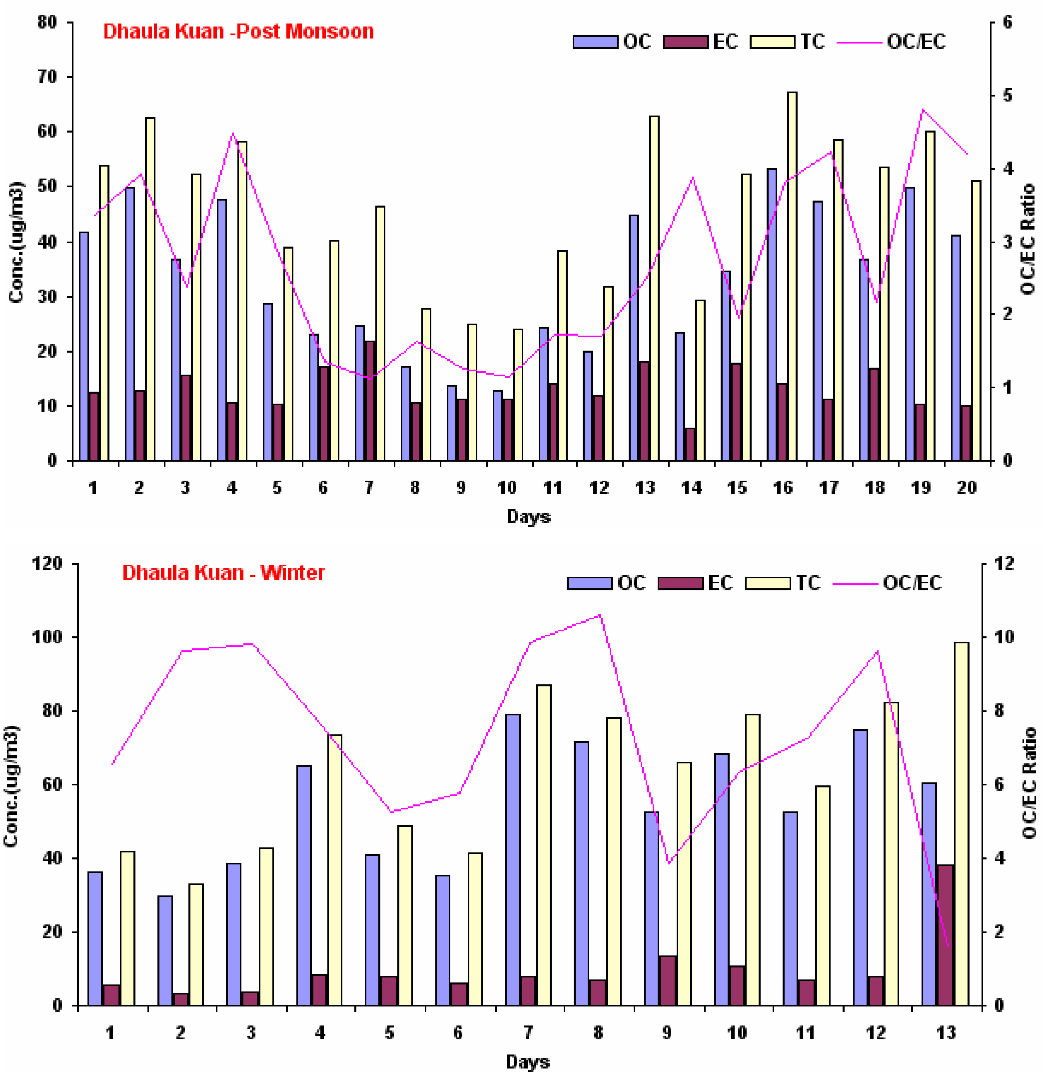


Fig 2.54 : 24 hourly trends of OC, EC and TC at Dhaula Kuan

Mass Closure

Mass fraction of elements, ions and carbons in terms of percentage in PM_{10} is shown in **Fig 2.55.** Vehicular traffic mostly contributes to EC, whereas resuspension of dust due to vehicular movement at national highways gets reflected in crustal percent of PM mass. Biomass burning related OC values are reflected to be similar in winter and post monsoon.

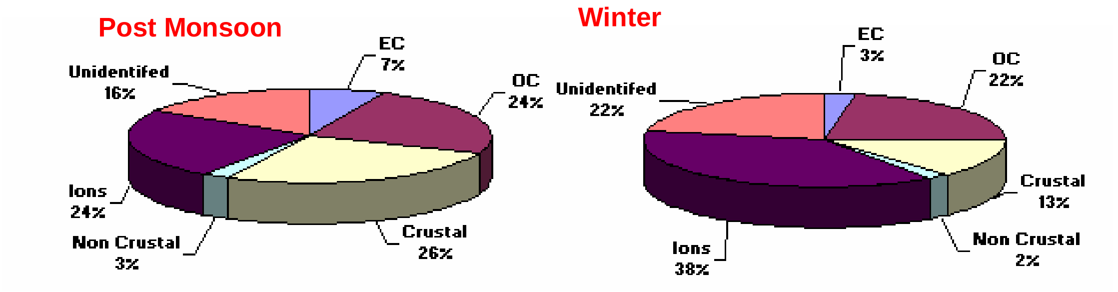


Fig 2.55 : Percent Mass of PM_{10} at Dhaula Kuan

2.3.7 Mayapuri (Lajwanti Garden Chowk)

Site Description

It represents “kerbside” activities. The site is in close proximity of traffic intersection, known as Lajwanti Garden Chowk. The site represents residential-cum-industrial area with some commercial activities. Number of industries are also located and can be seen in N-E sector and S-W Sector of the 2km x 2km study zone map as shown in **Fig. 2.56**, known as Mayapuri Industrial Area Phase I and Phase II. Shahid Bhagat Sing Marg/Jail Road (through Tilak nagar, Hari nagar, Maya Enclave area) to Station road (Kariappa Marg) is the major road and other main road connects Mayapuri-Sagarpur area. On the ring road, near traffic intersection, a flyover is constructed. In W-NW sector of the study zone, Tihar Jail campus in a large area is located. Besides, the region has residential colonies with reasonable green cover and a garden (Lajwanti garden). The total population of the study zone is about 60,000, residing in the areas like Hari Nagar, Khajan Basti, Nangal Raya, Sagarpur, Janakpuri and Shivnagar area. Overall, the study zone can be defined as moderate activity zone.

Fig. 2.56 : 2 km x 2 km Study Zone: Mayapuri

Air Quality Monitoring

Ambient air quality monitoring results at the site for all three seasons are presented in **Tables 2.16 a-b-c**. As can be seen from these tables, SPM values always exceed the CPCB standard in all three seasons and RSPM values exceed the standards in Summer and Winter. This is due to higher traffic volume near the site.

Table 2.16a : Air Quality Status at Mayapuri (Summer)

	N	Min	Max	Average	Per98	Stdev	CV
SPM	20	338	922.3	603.9	893.8	163	0.27
RSPM	20	94.7	229.7	152.4	218.1	38.4	0.25
PM10	14	137.2	518.2	344.3	515.8	111.8	0.32
PM2.5	3	54	55	54.5	55	0.7	0.01
SO2	20	3.8	10	6.7	9.6	1.4	0.21
NO2	20	31.2	75.5	47.2	74.4	12.7	0.27
O3	7	19.2	31.5	27.5	31.5	4.6	0.17
CO	7	0.9	1.2	1	1.1	0.1	0.10
CH4		NA	NA	NA	NA	NA	NA
NMHC		NA	NA	NA	NA	NA	NA
THC		NA	NA	NA	NA	NA	NA
HCHO	1			15			NA

Table 2.16b : Air Quality Status at Mayapuri (Post Monsoon)

	N	Min	Max	Average	Per98	Stdev	CV
SPM	20	258.5	697	422.1	688.3	128	0.30
RSPM	20	42.2	177	98.4	169.8	36.4	0.37
PM10	20	84	499	251.4	483.2	111.9	0.45
PM2.5	3	112	176	141.3	174.4	32.3	0.23
SO2	20	4	6.7	5.3	6.6	0.8	0.15
NO2	20	25.6	45.6	32.5	43.8	5.4	0.17
O3	7	17.3	24.1	21.6	24	2.6	0.12
CO	7	1.4	3.3	2.6	3.3	0.7	0.27
CH4	7	1.8	2.7	2.3	2.7	0.3	0.13
NMHC	7	1.1	1.7	1.3	1.6	0.2	0.15
THC	7	3	4.1	3.7	4.1	0.4	0.11
HCHO	1			14			0.00

Table 2.16c : Air Quality Status at Mayapuri (Winter)

	N	Min	Max	Average	Per98	Stdev	CV
SPM	20	656	1463.7	1110.6	1429	247.2	0.22
RSPM	19	179.8	535.5	350.3	528.6	94.5	0.27
PM10	19	233	688	453	681.9	132.5	0.29
PM2.5	3	128.9	326.8	209.4	320.6	104	0.50
SO2	19	5	16.2	10.4	15.2	2.8	0.27
NO2	19	38	90.4	65.4	89.2	15	0.23
O3	1			20.9			0.00
CO	7	0.7	2	1.4	2	0.5	0.36
CH4	7	2.7	3.5	3	3.4	0.3	0.10
NMHC	7	0.5	0.9	0.7	0.9	0.1	0.14
THC	7	3.3	4.2	3.8	4.2	0.3	0.08
HCHO	NA			6			0.00

Particulate matter (SPM, RSPM, and PM_{10}) levels of Mayapuri for all three seasons are presented in **Figures 2.57** along with regulatory standards of CPCB for SPM and RSPM. **Figures 2.58** presents the variation of SO_2 and NO_2 at the site for all the three seasons.

It is evident from the figures that SO_2 values meet the standards in all seasons, whereas NO_2 values exceed the standards in post monsoon and winter on few occasions as evident from the seasonal plots.

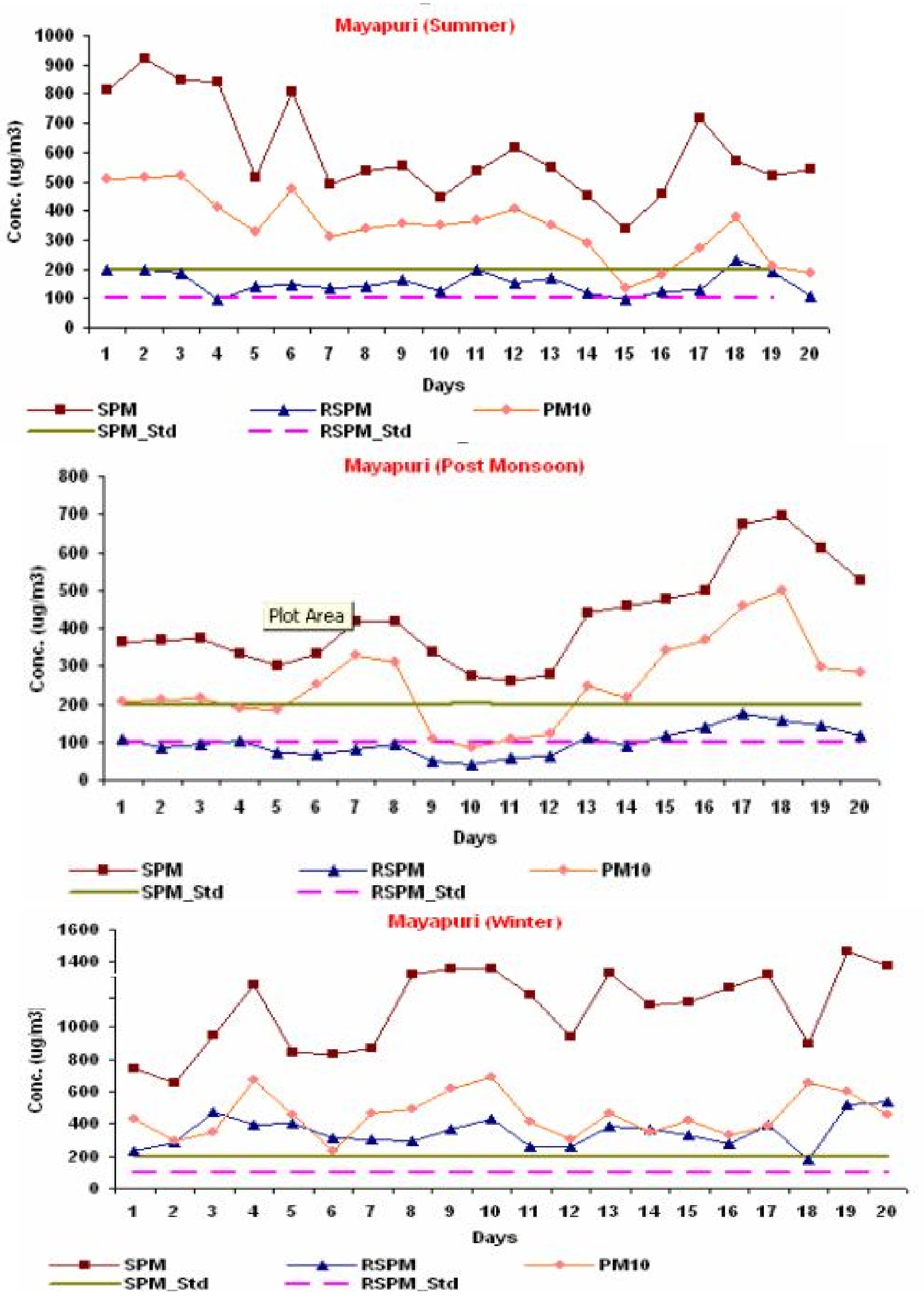


Fig 2.57 : Observed Concentration of SPM, RSPM and PM_{10} at Mayapuri in all three seasons

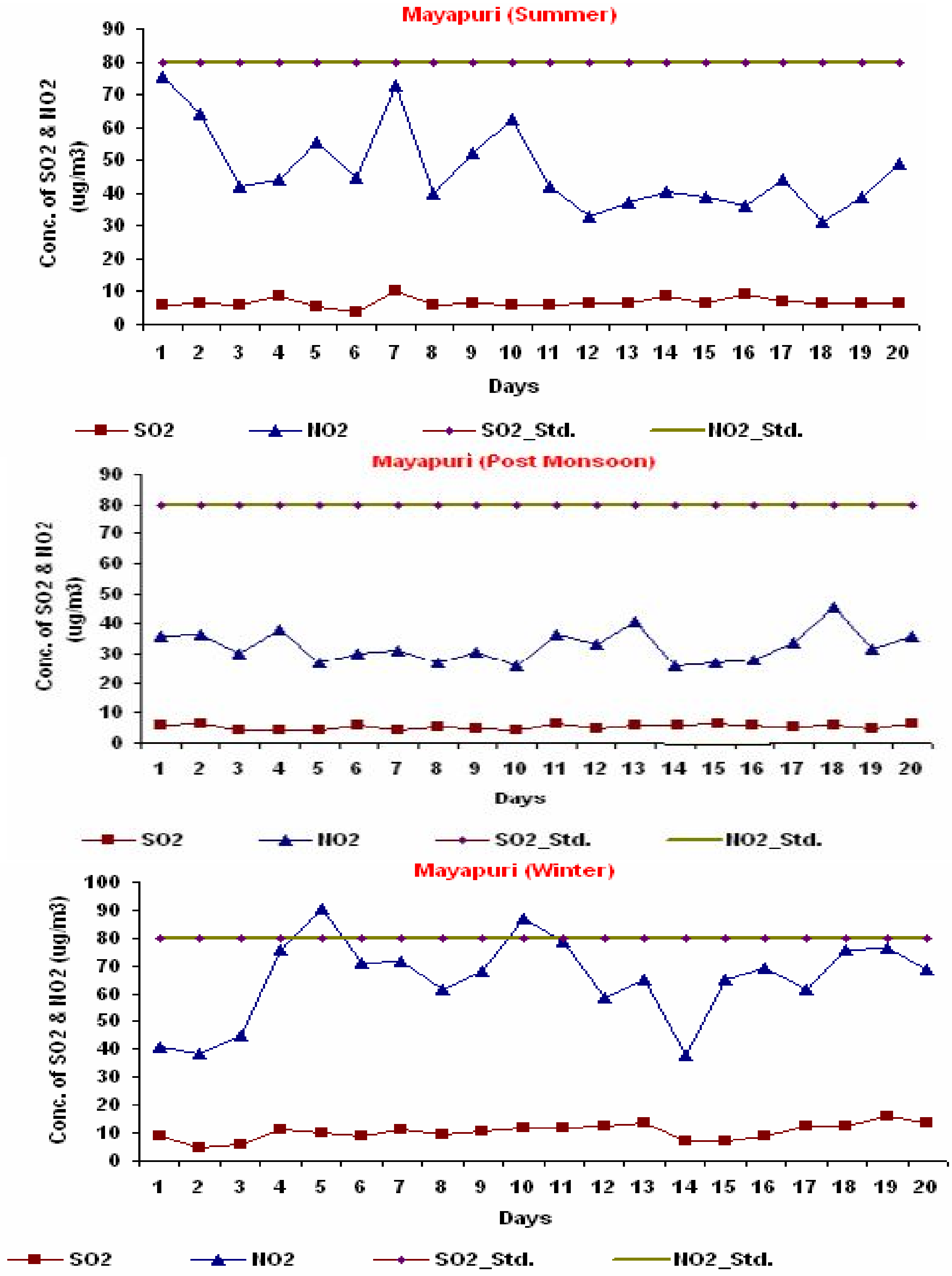


Fig 2.58 : Observed Concentration of SO_2 and NO_2 at Mayapuri in all three seasons

The concentrations of $PM_{2.5}$ for all three seasons are presented in **Fig 2.59**. The concentration of $PM_{2.5}$ is exceeding the limit of US EPA standard of 35 µg/m^3 in all seasons as other PM (SPM, RSPM) background values are also higher. Winter values are highest indicating accumulation.

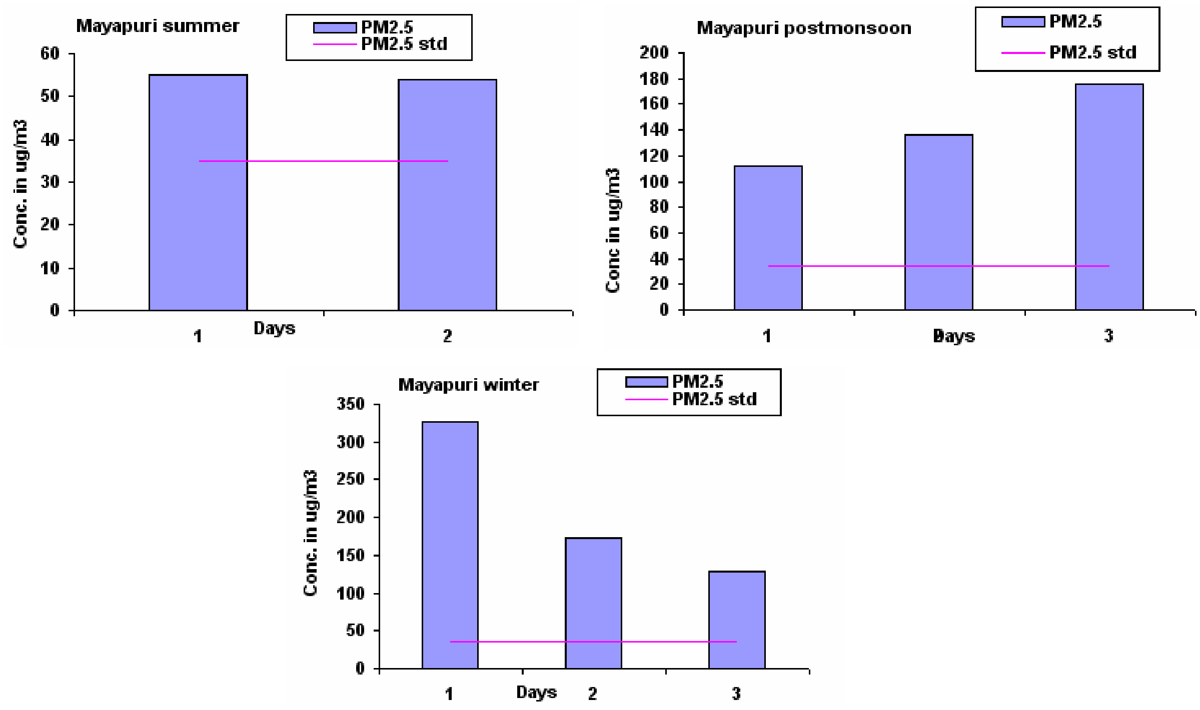
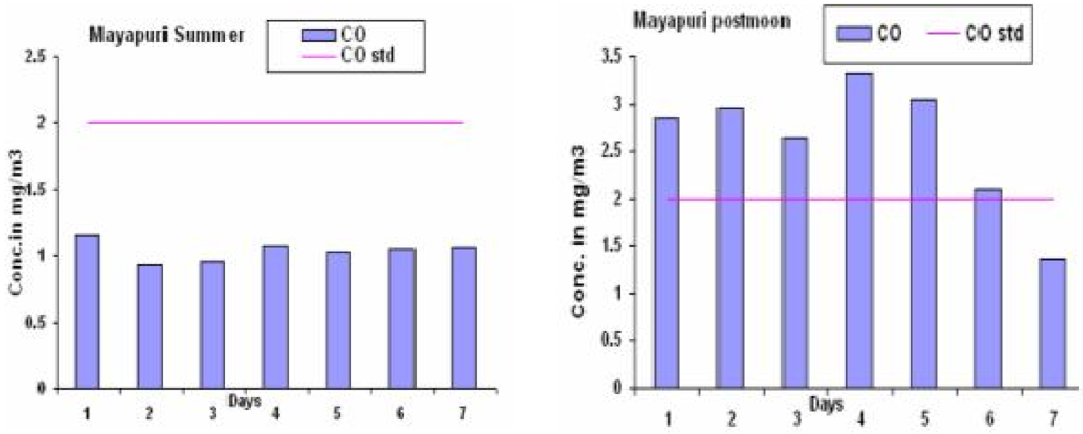


Fig 2.59 : Concentration of $PM_{2.5}$ at Mayapuri Site

Figure 2.60 shows the concentration of CO for all three seasons. The concentrations of CO exceed the CPCB standard 2 mg/m^3 in post monsoon on most of the days. **Figure 2.61** shows the concentration of Methane, Non Methane and Total Hydrocarbons. **Table 2.17** shows the 24 hourly average Concentrations of VOCs for one day of all three seasons.



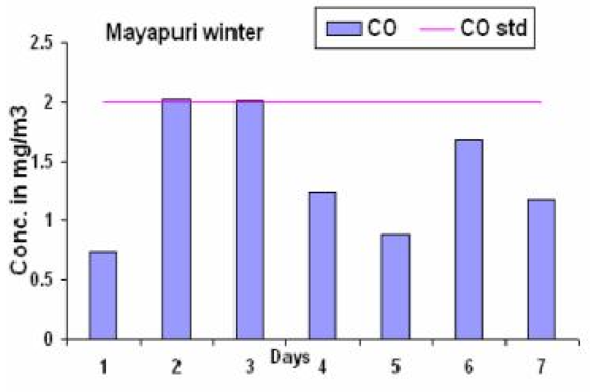


Fig 2.60 : Observed CO concentration at Maypauri in all three seasons

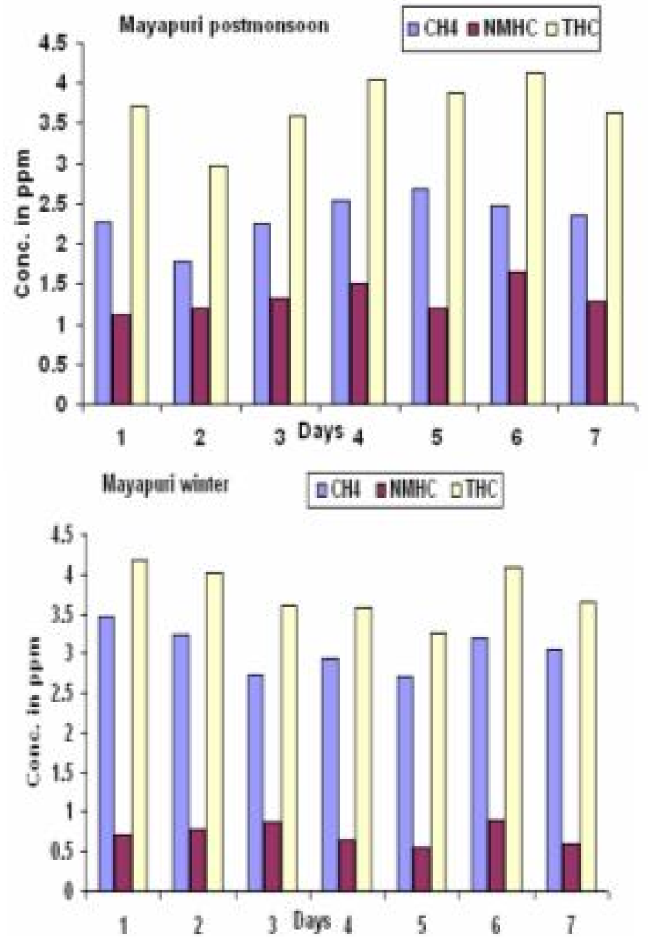


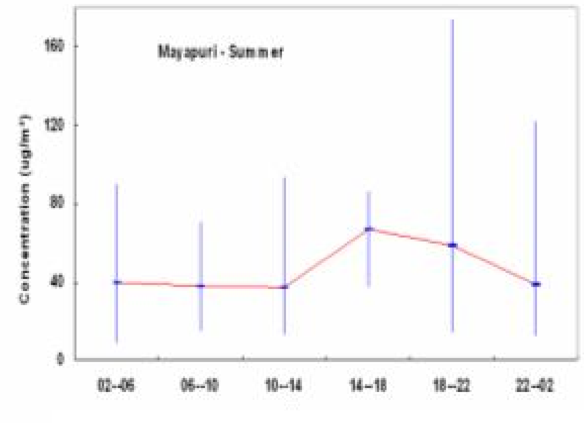
Fig 2.61 : Observed CH_4, NMHC and THC concentration at Maypuri in all three seasons

Table 2.17 : 24 Hourly Concentrations of VOCs

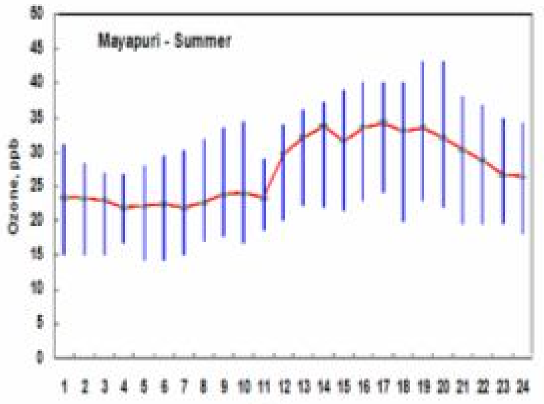
	1-3 Butadiene	Benzene
Summer	0.3	1.0
Post Monsoon	0.8	1.3
Winter	0.7	2.7

Diurnal variations in NO_2 and Ozone levels are plotted in **Figure 2.62**. It can be observed that for the Summer season the day time concentration of NO_2 is about 40 µg /m^3 till 2 PM which increases to about 70 µg/m^3 by 6 PM and later gradually declines to about 30 µg/m^3 by midnight. In Winter season the day time concentration of NO_2 is about 60 µg/m^3 which is higher than summer and post monsoon. It increases gradually after sunset to about 80 ppb by midnight. Highly variable ozone values are observed which could be attributed to many local factors and emission loads.

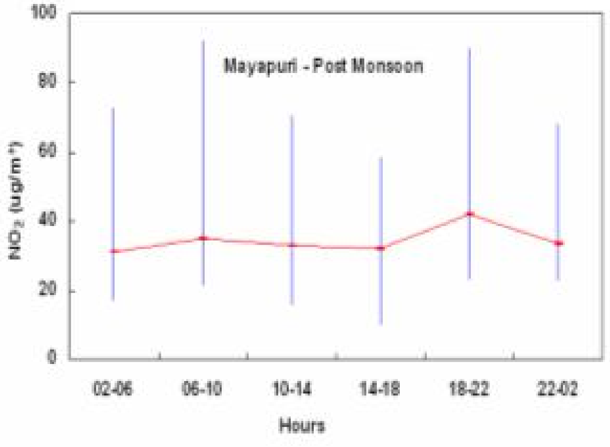
Diurnal Variation in NO_2 - Summer



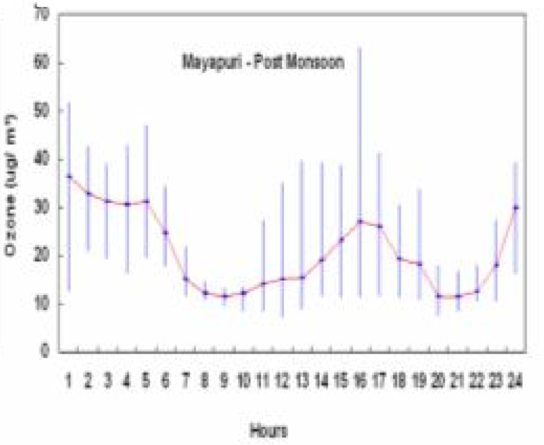
Diurnal Variation in O3 - Summer

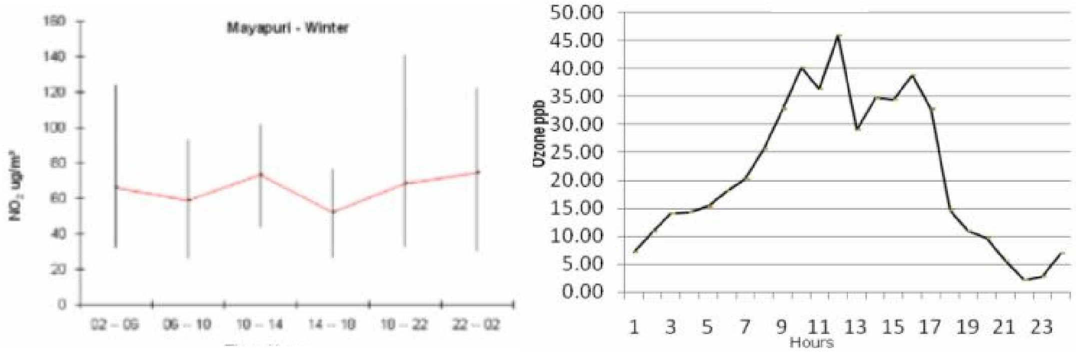


Diurnal Variation in NO_2 -Post Monsoon



Diurnal Variation in NO_2 - Post Monsoon





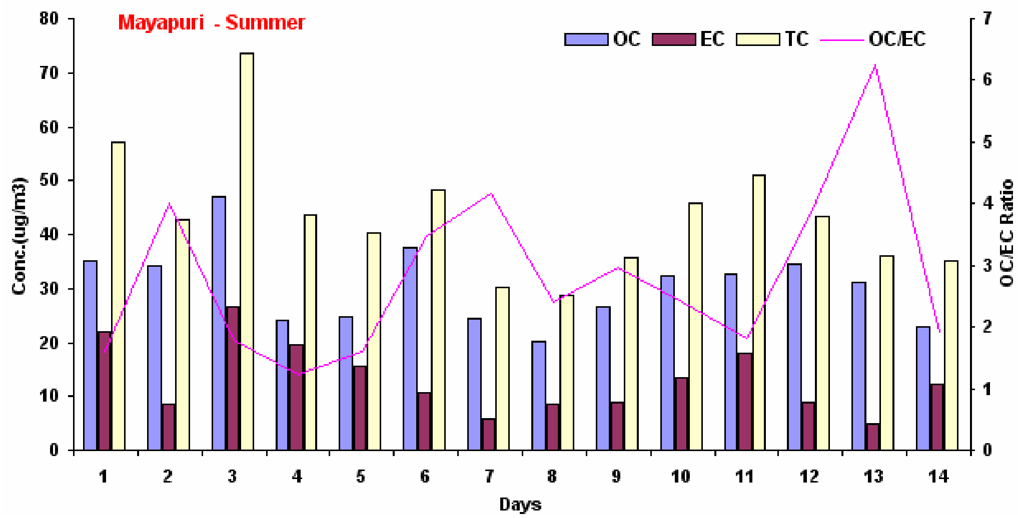
Diurnal Variation in NO_2 -Winter

Diurnal Variation in O3 - Winter

Fig 2.62 : Diurnal Variation in NO_2 and Ozone at Mayapuri

Estimation of EC/OC Ratio

EC and OC was determined for PM samples with a view to establish the sources of carbon emission. 24 hourly trends of OC, EC and TC and also their ratios are presented in **Fig 2.63.** The ratio between OC to EC indicates that higher ranges of 4-10 are witnessed in winter which is higher than summer and post monsoon. Winter meteorology plays an important role.



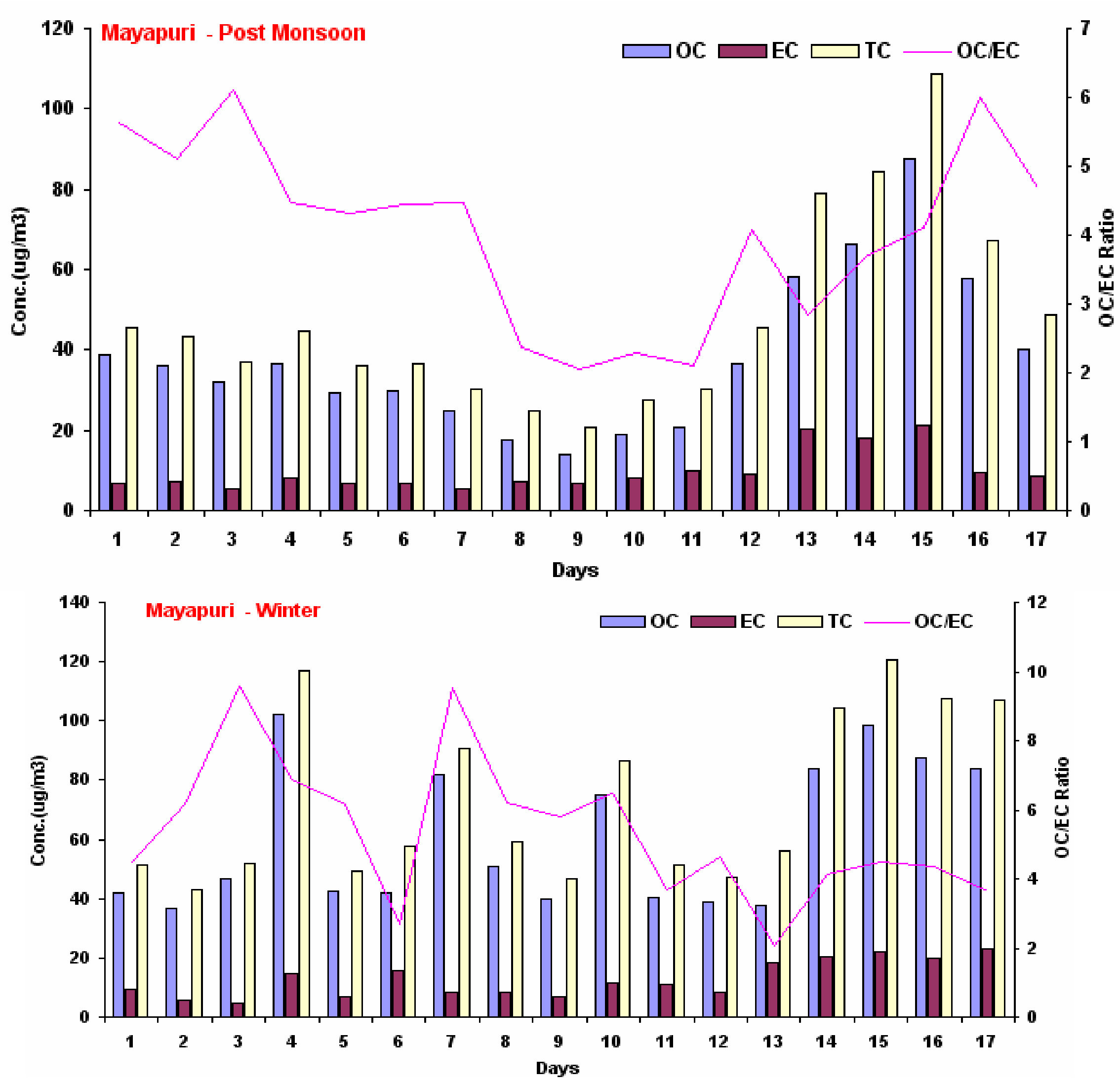


Fig 2.63 : 24 hourly trends of OC, EC and TC at Mayapuri

Mass Closure

Mass fraction of elements, ions and carbons in terms of percentage in PM_{10} is shown in **Fig 2.64.** Vehicular emissions and biomass burning are major sources for organic carbon**.** At this site Cl^{-}, SO_4^{--}, Mg^{+} and Ca^{++} ions concentrations are very high. High percentage of ions and unidentified fractions indicate domination of sources besides vehicles. Percentage of low crustal mass indicates lower contribution from resuspended dust.

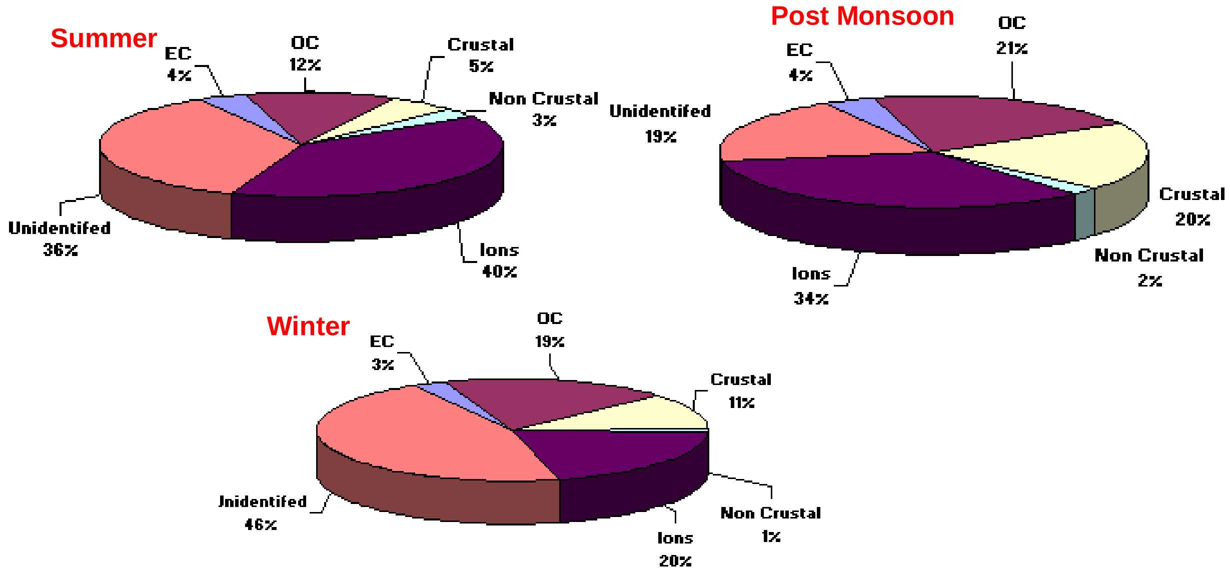


Fig 2.64 : Percent Mass of PM_{10} at Mayapuri

2.3.8 Anand Vihar

Site Description

It represents another kerbside activities. The monitoring site is near the Inter-State Bus Terminus (ISBT), which caters to the States of Uttar Pradesh, Uttaranchal and Himachal Pradesh as shown in **Fig. 2.65** Anand Vihar is a posh residential area and a fast developing commercial center in East Delhi District. The study zone is thinly populated with estimated total population of about 15,000 only. The main areas are Anand Vihar, Savita Vihar, Kaushambi. Sahibabad industrial area and Patparganj industrial area are in close proximity. Towards east direction, UP border is just 100 m away from the monitoring site. The main road, Ghazipur road connects to NH24. Anand Vihar is on the proposed Delhi Metro Rail route. Wave's Cineplex, EDM Mall, Pacific Mall and Sahibabad Industrial Area are the major landmarks of Anand Vihar. Overall, the study zone can be defined as industrial-cum-commercial zone with less residential activities. However, due to proximity to ISBT, movement of traffic is relatively high.

Fig 2.65 : 2 km x 2 km Study Zone: Anand Vihar

Air Quality Monitoring

Ambient air quality monitoring results at the site for all three seasons are presented in **Tables 2.18 a-b-c**. As can be seen from these tables, SPM RSPM values always exceed the CPCB standard in all three seasons. The average SPM and RSPM trends indicate that the values in Summer and Post Monsoon are higher. Higher SPM values can be attributed to resuspension as well as construction and industrial activities.

Table 2.18a : Air Quality Status at Anand Vihar (Summer)

	N	Min	Max	Average	Per98	Stdev	CV
SPM	20	716.7	1944.3	1272.1	1936	361.4	0.28
RSPM	20	207.7	673	353.2	638.3	119.7	0.34
PM10	19	163	486	307.4	482.1	98.3	0.32
PM2.5	3	56	102	80	101.2	23.1	0.29
SO2	20	5.8	33.8	14.2	33.1	8.6	0.61
NO2	20	18	67.1	36.8	67.1	14.3	0.39
O3	7	7.7	33	21.5	32.4	8.7	0.40
CO	7	1.4	1.6	1.5	1.6	0.1	0.07
CH4		NA	NA	NA	NA	NA	NA
NMHC		NA	NA	NA	NA	NA	NA
THC		NA	NA	NA	NA	NA	NA
HCHO	1			5			0.00

Table 2.18b: Air Quality Status at Anand Vihar (Post Monsoon)

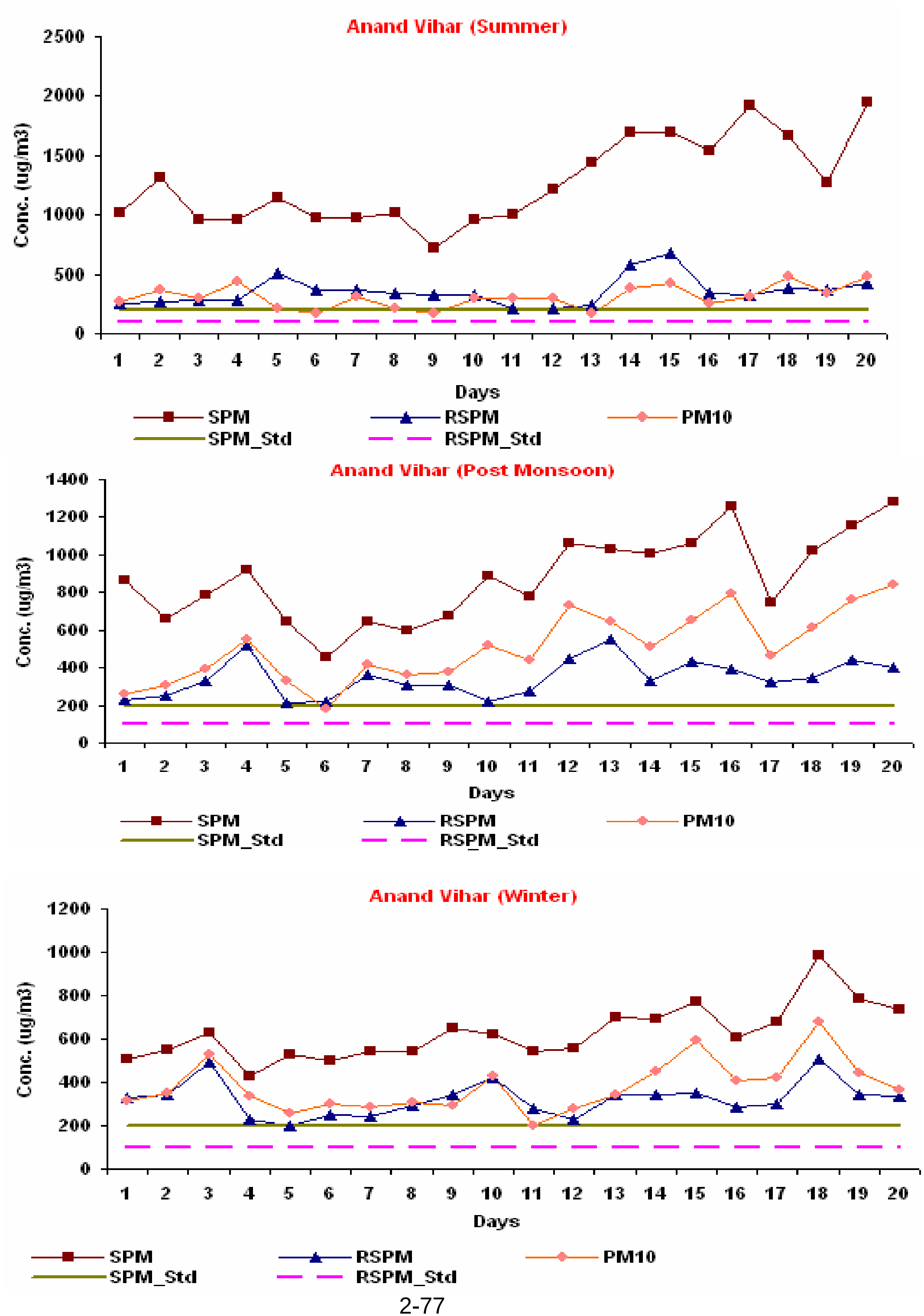
	N	Min	Max	Average	Per98	Stdev	CV
SPM	20	459.4	1285	878.2	1275.9	230	0.26
RSPM	20	215.7	547	344.9	535.3	98.2	0.28
PM10	20	177	842.3	507.7	824.4	188.4	0.37
PM2.5	3	146	268	207.7	265.6	61	0.29
SO2	20	6.7	49	23.2	46.9	12.1	0.52
NO2	20	41.4	125	85.4	122.7	25.4	0.30
O3	7	22.5	44.9	35.7	44.7	8.6	0.24
CO	7	1.3	2.3	1.7	2.3	0.4	0.24
CH4	7	1.8	3.4	2.5	3.4	0.6	0.24
NMHC	7	0.9	1.4	1.2	1.4	0.2	0.17
THC	7	2.7	4.6	3.7	4.6	0.7	0.19
HCHO	1			16			0.00

Table 2.18c : Air Quality Status at Anand Vihar (Winter)

	N	Min	Max	Average	Per98	Stdev	CV
SPM	20	429.1	987.8	627.8	911.8	128.8	0.21
RSPM	20	197.7	503.7	322	498.8	80.4	0.25
PM10	20	198	678	379.9	646.7	118	0.31
PM2.5	3	175.7	224.4	198	223.2	24.6	0.12
SO2	20	8.2	33	16	30.7	6.2	0.39
NO2	20	43.5	102	71.7	101.2	17.6	0.25
CO	7	1.2	2.1	1.7	2.1	0.4	0.24
O3	NA	NA	NA	NA	NA	NA	NA
CH4	7	2.4	3.4	2.9	3.4	0.4	0.14
NMHC	7	0.2	1	0.5	1	0.3	0.60
THC	7	2.7	4.3	3.4	4.3	0.6	0.18
HCHO	NA			11			0.00

Particulate matter (SPM, RSPM, and PM_{10}) levels of Anand Vihar for all three seasons are presented in **Fig 2.66** which shows exceeding values when compared with the prevailing standards. **Fig 2.67** presents the variation of SO_2 and NO_2 at the site for all the three seasons.

It is evident from the figures that SO_2 values meet the standards in all seasons, whereas NO_2 values exceed the standards on some of the days in post monsoon and winter.



Anand Vihar (Summer)

Anand Vihar (Post Monsoon)

Anand Vihar (Winter)

Fig 2.66 : Observed Concentration of SPM, RSPM and PM_{10} at Anand Vihar in all three seasons

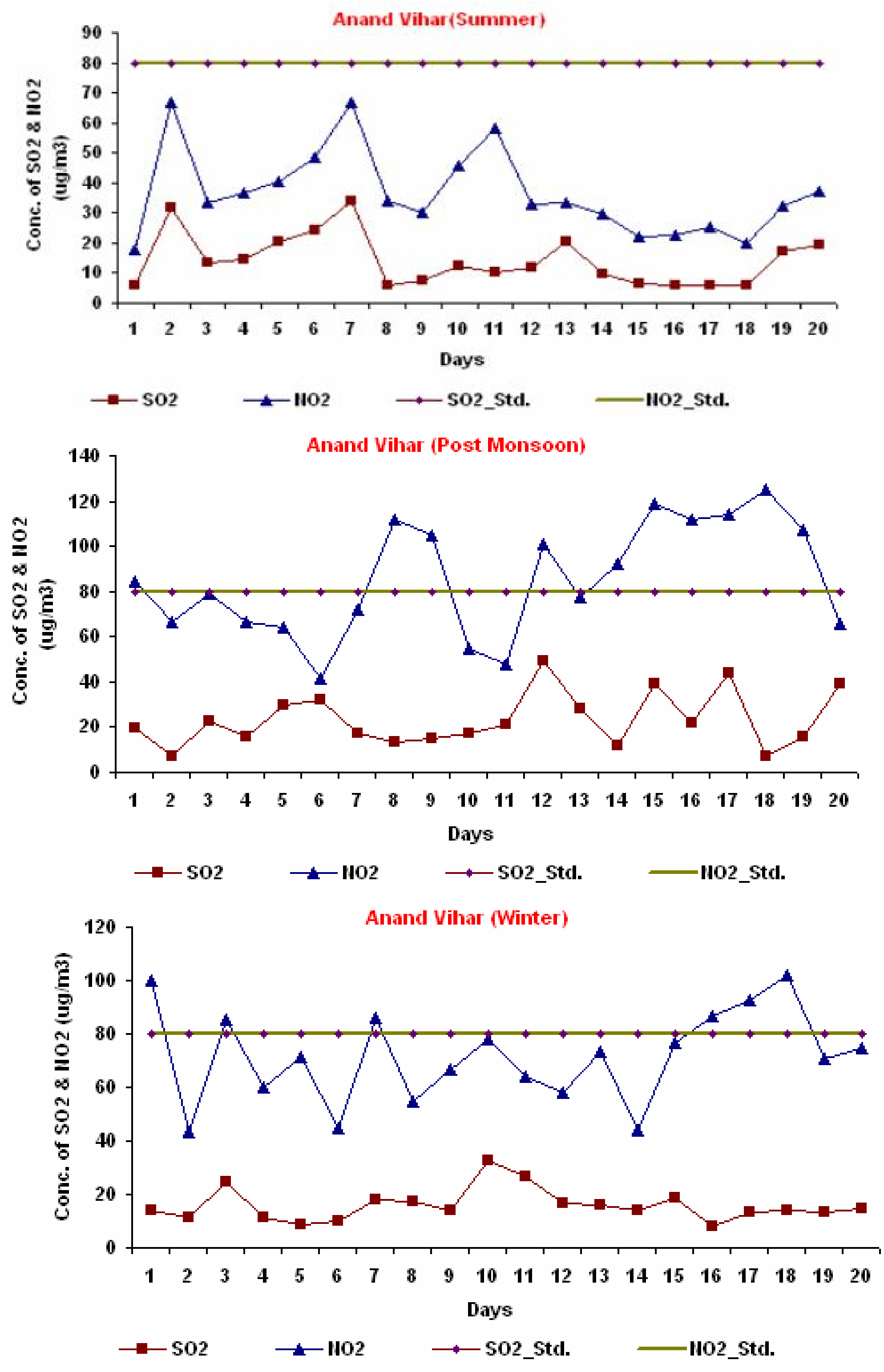


Fig 2.67 : Observed Concentration of SO_2 and NO_2 at Anand Viha in all three seasons

The concentrations of $PM_{2.5}$ for all three seasons are presented in **Fig 2.68**. The concentration of $PM_{2.5}$ is exceeding the US EPA standard of 35 µg/m^3 in all seasons. Winter and post monsoon values are higher than summer owing to large calm percentage.

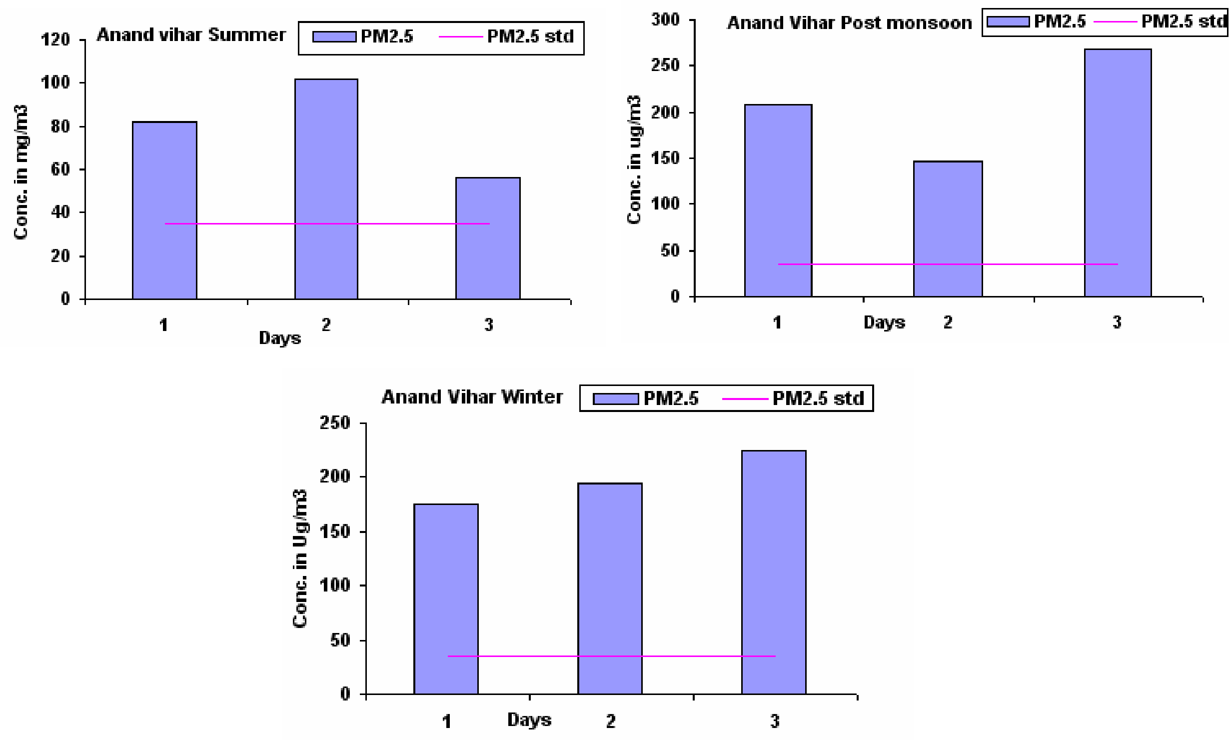
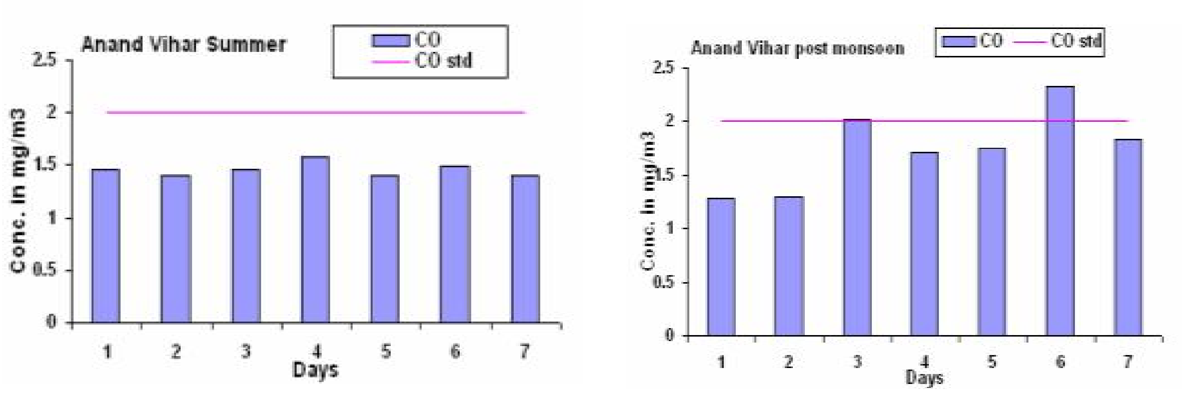


Fig 2.68 : Concentration of $PM_{2.5}$ at Anand Vihar

Fig 2.69 shows the concentration of CO for all three seasons. It exceeded the CPCB standards on some of the days of Post Monsoon and Winter. **Figure 2.70** shows the concentration of Methane, Non Methane and Total Hydrocarbons for post monsoon and winter. **Table 2.19** shows the 24 hourly average Concentrations of VOCs for one day of all three seasons.



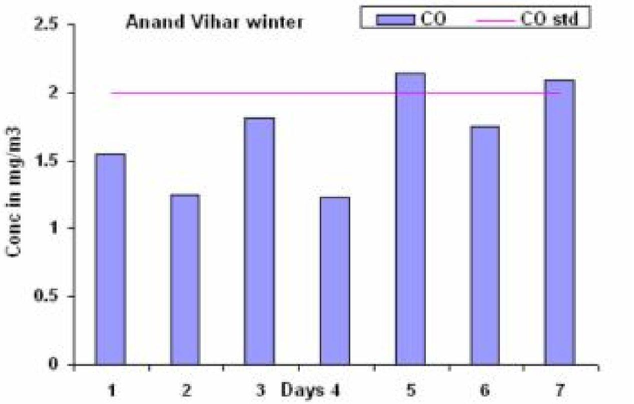


Fig 2.69 : Observed CO concentration at Anand Vihar in all three seasons

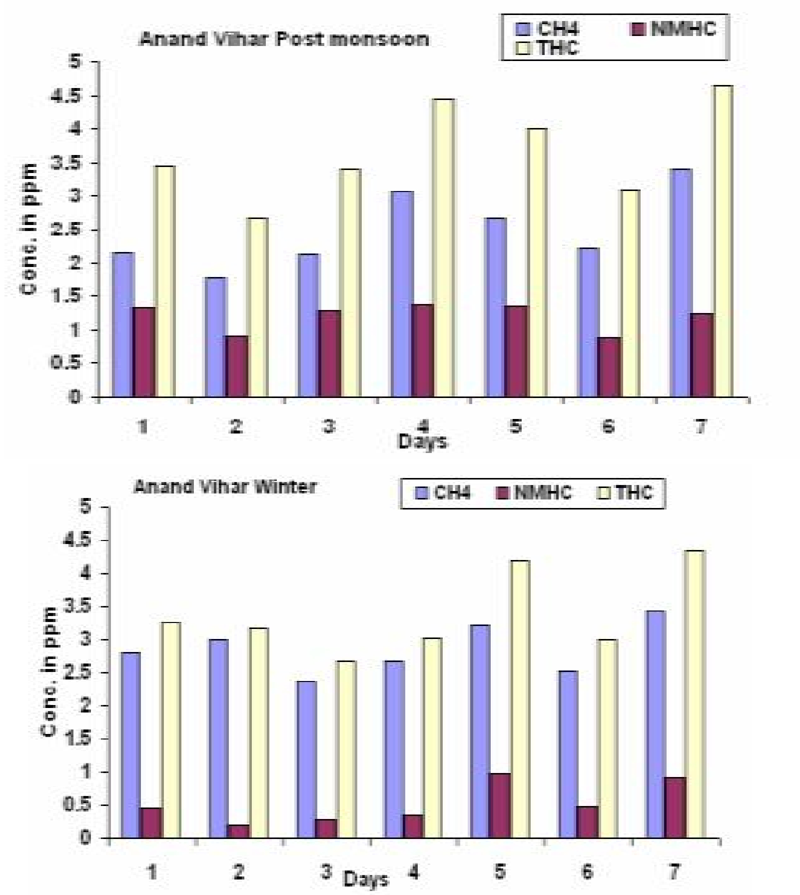
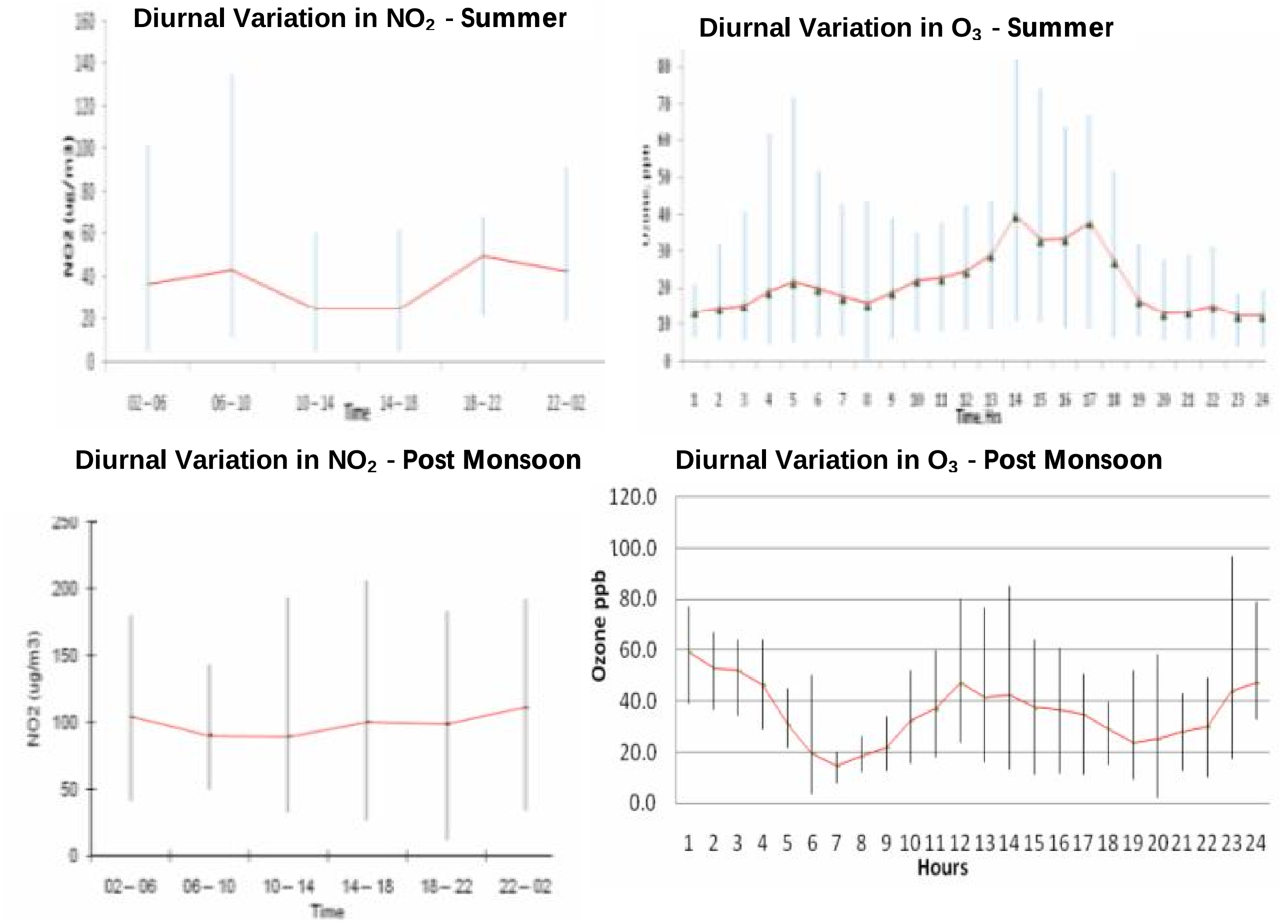


Fig 2.70 : Observed CH_4, NMHC and THC concentration at Anand Vihar in all three seasons

Table 2.19 : 24 Hourly Concentrations of VOCs

	1-3 Butadiene	Benzene
Summer	1.1	1.1
Post Monsoon	0.9	1.9
Winter	0.5	1.2

Diurnal variations in NO_2 and Ozone levels are plotted in **Figure 2.71**. It can be observed that NO_2 values are higher in winter and post monsoon compared to Summer. The monitored Ozone values are plotted and it can be observed that both NO_2 and Ozone follow a diurnal cyclic pattern. In Winter season the day time concentration of NO_2 is about 80-100 µg/m^3. Ozone concentration remains at about 6 ppb till 9AM and later it increases to about 30 ppb by 2 PM and then goes down to 5 ppb by 10 PM.



Diurnal Variation in NO_2 - Summer

Diurnal Variation in O_3 - Summer

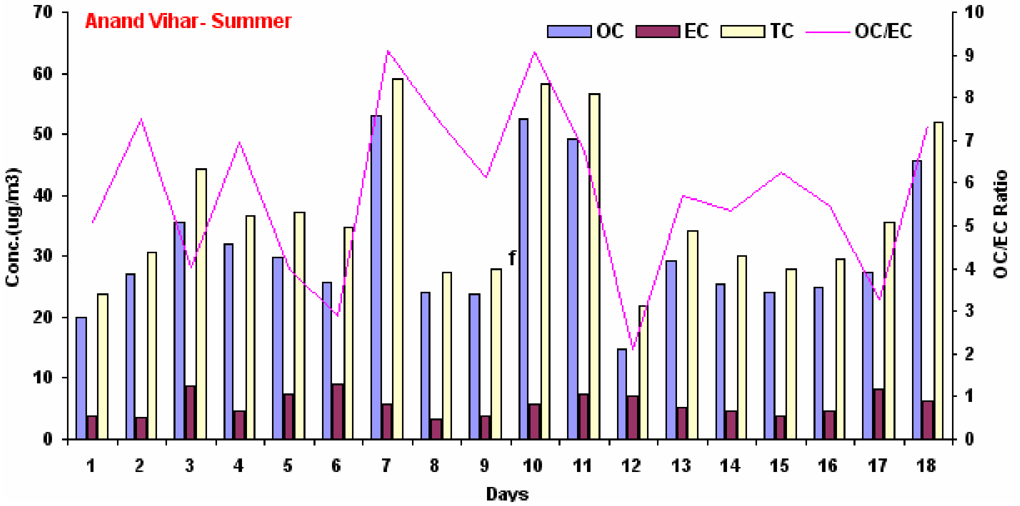
Diurnal Variation in NO_2 - Post Monsoon

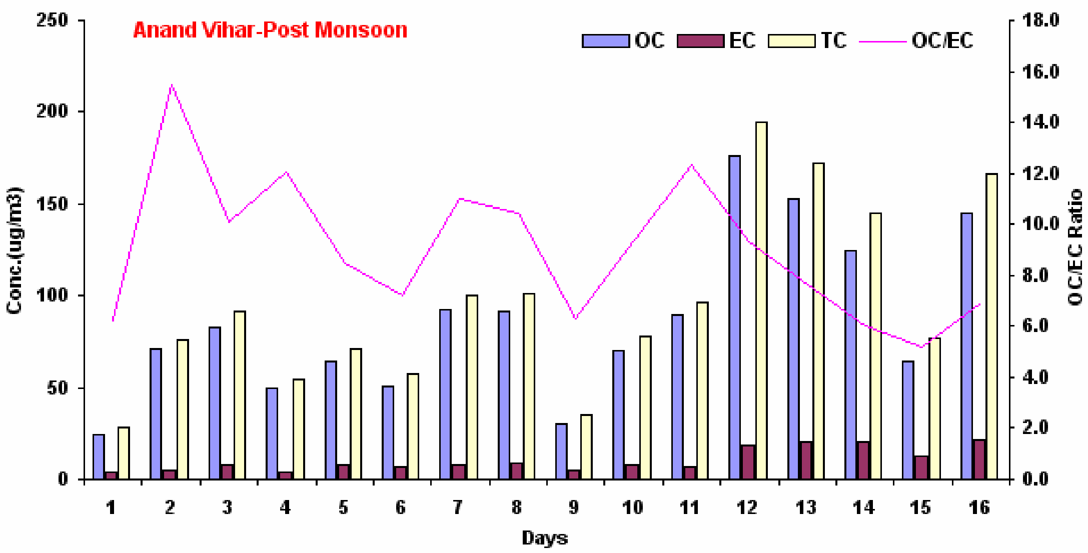
Diurnal Variation in O_3 - Post Monsoon

Fig 2.71 : Diurnal Variation in NO_2 and Ozone at Anand Vihar

Estimation of EC/OC Ratio

EC and OC was determined for PM samples with a view to establish the sources of carbon emitting sources. 24 hourly trends of OC, EC and TC with respect to their ratios are presented in **Fig 2.72.** Highest concentrations of OC and EC were observed in post monsoon followed by winter season with OC /EC ratio ranging from 6-14.





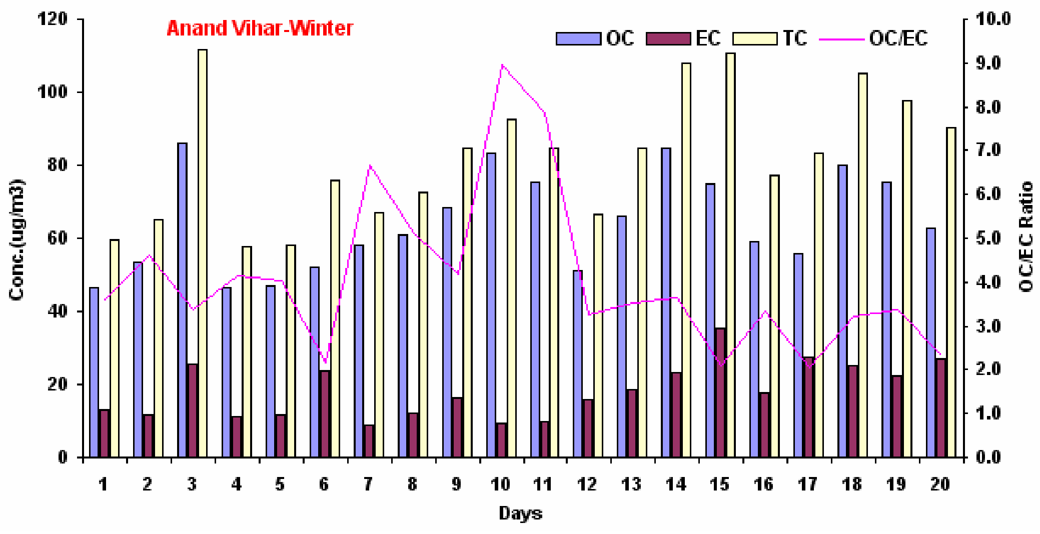


Fig 2.72 : 24 hourly trends of OC, EC and TC at Anand Vihar

Mass Closure

Mass fraction of elements, ions and carbons in terms of percentage in PM_{10} is shown in **Fig 2.73.** Private vehicles, DG sets, other combustion sources in this area contribute to high OC and EC. Soil contributes to high percentage of crustal elements. Unidentified mass of PM is very high.

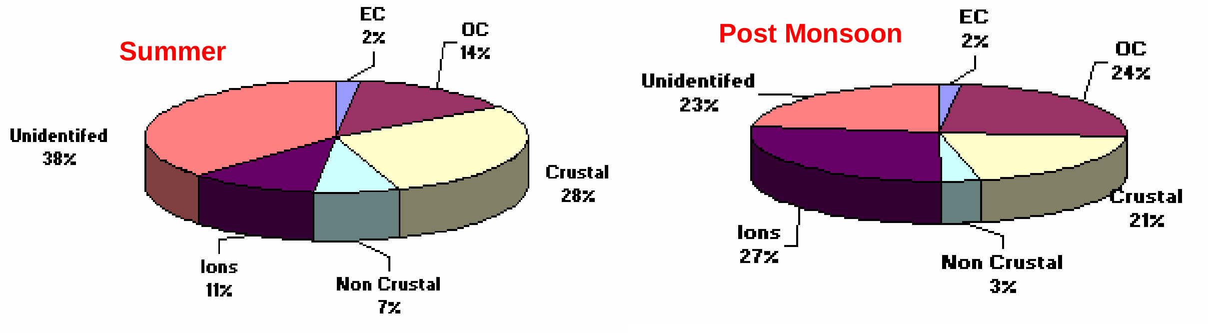


Fig 2.73: Percent Mass of PM_{10} at Anand Vihar

2.3.9 ISBT

Site Description

ISBT stands for Inter-State Bus Terminus, which connects mainly North Indian States like Haryana, Punjab, Himachal Pradesh, Jammu & Kashmir and Uttar Pradesh. Traffic activity in the study zone is very high. To ease the traffic congestion, flyovers are constructed on different roads. On eastern side, it connects to trans-Yamuna area. River Yamana lies within the study zone and occupies almost half of the study zone area as shown in **Figure 2.74.** In the western part of the map, ISBT, metro-rail station, bus stand for local transport exist. Traffic from Haryana and UP side and also from Trans Yamuna area is very high. The study zone has very less resident population, but the floating population is very high and thus the commensurate commercial activities like eateries, hotels & restaurants etc. are also significant. Overall, the region can be defined as a very high traffic activity zone with moderate commercial activities.

Fig 2.74 : Study Zone (2 km x 2 km): ISBT

Air Quality Monitoring

Ambient air quality monitoring results at the site for all three seasons are presented in **Tables 2.20 a-b-c**. As can be seen from these tables, SPM and RSPM values always exceed the CPCB standard in all three seasons. The average SPM and RSPM trends indicate that the values in post monsoon and winter are very high. This is attributed to low mixing during these seasons and also high traffic density near the site.

Table 2.20a : Air Quality Status at ISBT (Summer)

	N	Min	Max	Average	Per98	Stdev	CV
SPM	20	311.3	649.7	460.1	647.4	117.8	0.26
RSPM	20	83.7	310.3	166	282.6	50.6	0.30
PM_{10}	20	92	218.5	148.8	NA	NA	NA
$PM_{2.5}$	3	102	114	107	113.6	6.2	0.06
SO_2	20	3	13.5	6.7	12	2.3	0.34
NO_2	20	34.7	60.8	47.8	59.7	7.8	0.16
O_3	7	18.7	22.1	20.6	22.1	1.2	0.06
CO		1.4	2.5	1.9	2.4	0.4	0.21
CH_4		NA	NA	NA	NA	NA	NA
NMHC		NA	NA	NA	NA	NA	NA
THC		NA	NA	NA	NA	NA	NA
HCHO	1			7			0.00

Table 2.20b : Air Quality Status at ISBT (Post Monsoon)

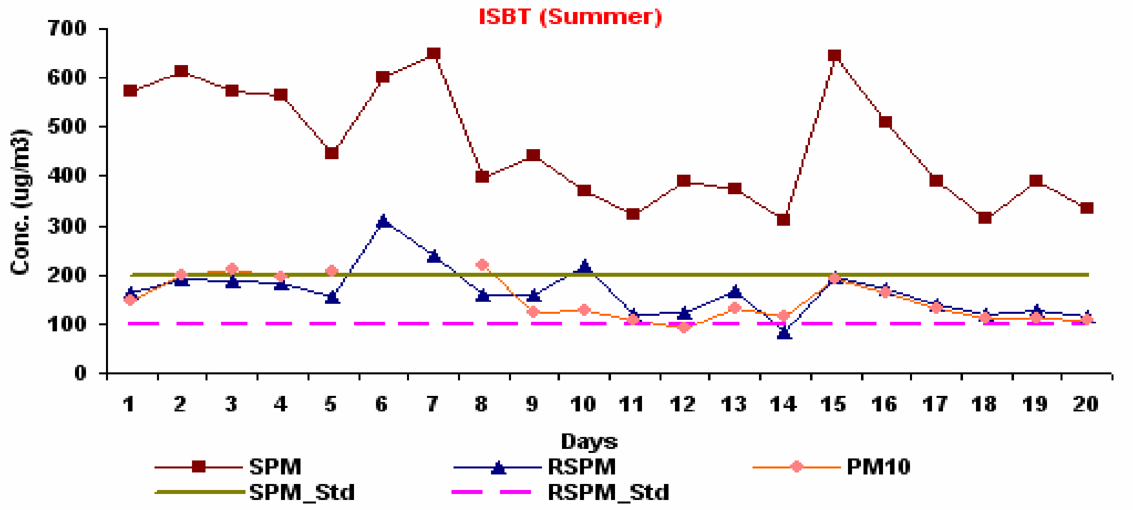
	N	Min	Max	Average	Per98	Stdev	CV
SPM	20	670.1	1569	1263.9	1566.5	216.7	0.17
RSPM	20	223.3	688	545.4	684.8	118.4	0.22
PM_{10}	17	240	1053	675	1043.5	246.7	0.37
$PM_{2.5}$	3	103	199	149.3	683.2	285	1.91
SO_2	20	7	32.2	19	31.7	7.4	0.39
NO_2	20	69.3	182.8	123.9	176.1	29.2	0.24
O_3	5	11.3	43.3	24.3	42.8	15	0.62
CO		1.2	2.3	1.8	2.2	0.4	0.22
CH_4	7	2.7	3.3	2.9	3.3	0.3	0.10
NMHC	7	0.4	0.7	0.5	0.7	0.1	0.20
THC	7	3.1	4	3.5	3.9	0.3	0.09
HCHO	1			18			0.00

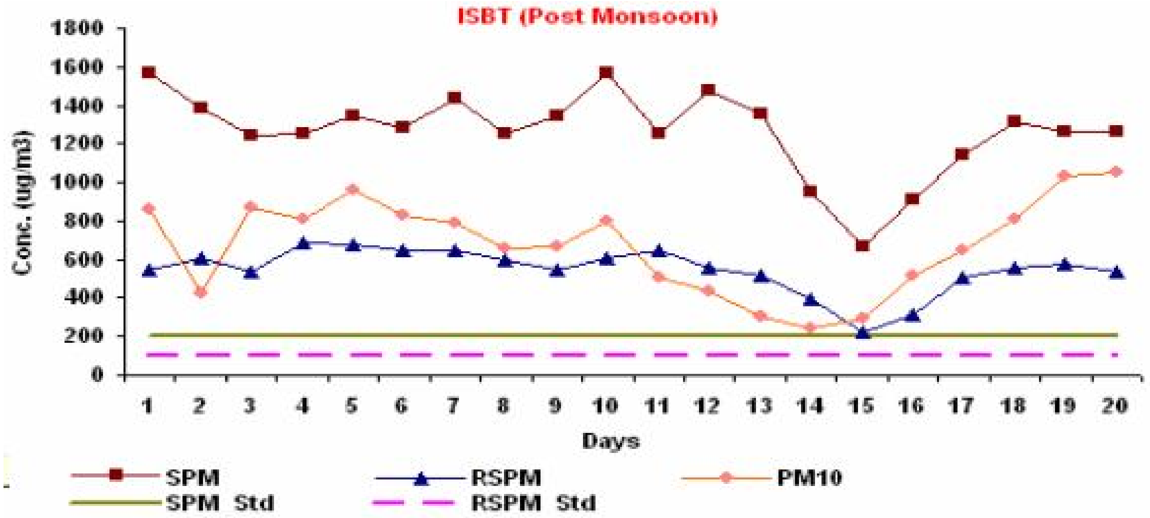
***Table* 2.20c : Air Quality Status at ISBT (Winter)**

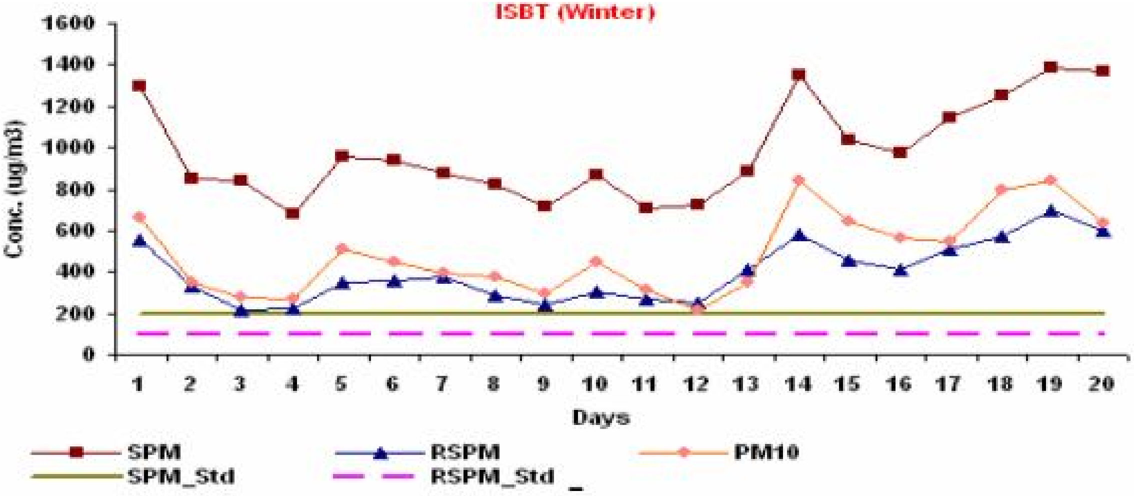
	N	Min	Max	Average	Per98	Stdev	CV
SPM	20	680.9	1382.2	983.6	1377.1	233.8	0.24
RSPM	20	214.6	695.5	400.3	658.9	142.8	0.36
PM_{10}	20	212	838	487.2	837.2	195.2	0.40
$PM_{2.5}$	3	122.4	160	136.9	158.7	20.2	0.15
SO_2	20	6	28.1	18	28.1	6.4	0.36
NO_2	20	60.4	149	112	148.7	27.4	0.24
O_3	7	10.9	15.8	12.8	15.7	1.9	0.15
CO	7	0.6	1.9	1	1.9	0.4	0.40
CH_4	7	2.7	3.5	3	3.4	0.3	0.10
NMHC	7	0.4	0.8	0.6	0.8	0.2	0.33
THC	7	3.2	4.1	3.5	4.1	0.3	0.09

HCHO				9			0.00

Particulate matter (SPM, RSPM, and PM_{10}) levels of ISBT for all three seasons are presented in **Fig 2.75** which exceeds all the time the prescribed limits. **Fig 2.76** presents the variation of SO_2 and NO_2 at the site for all the three seasons. It is evident from the figures that SO_2 values meet the standards in all seasons, whereas NO_2 values exceed the standards substantially in post monsoon and winter.







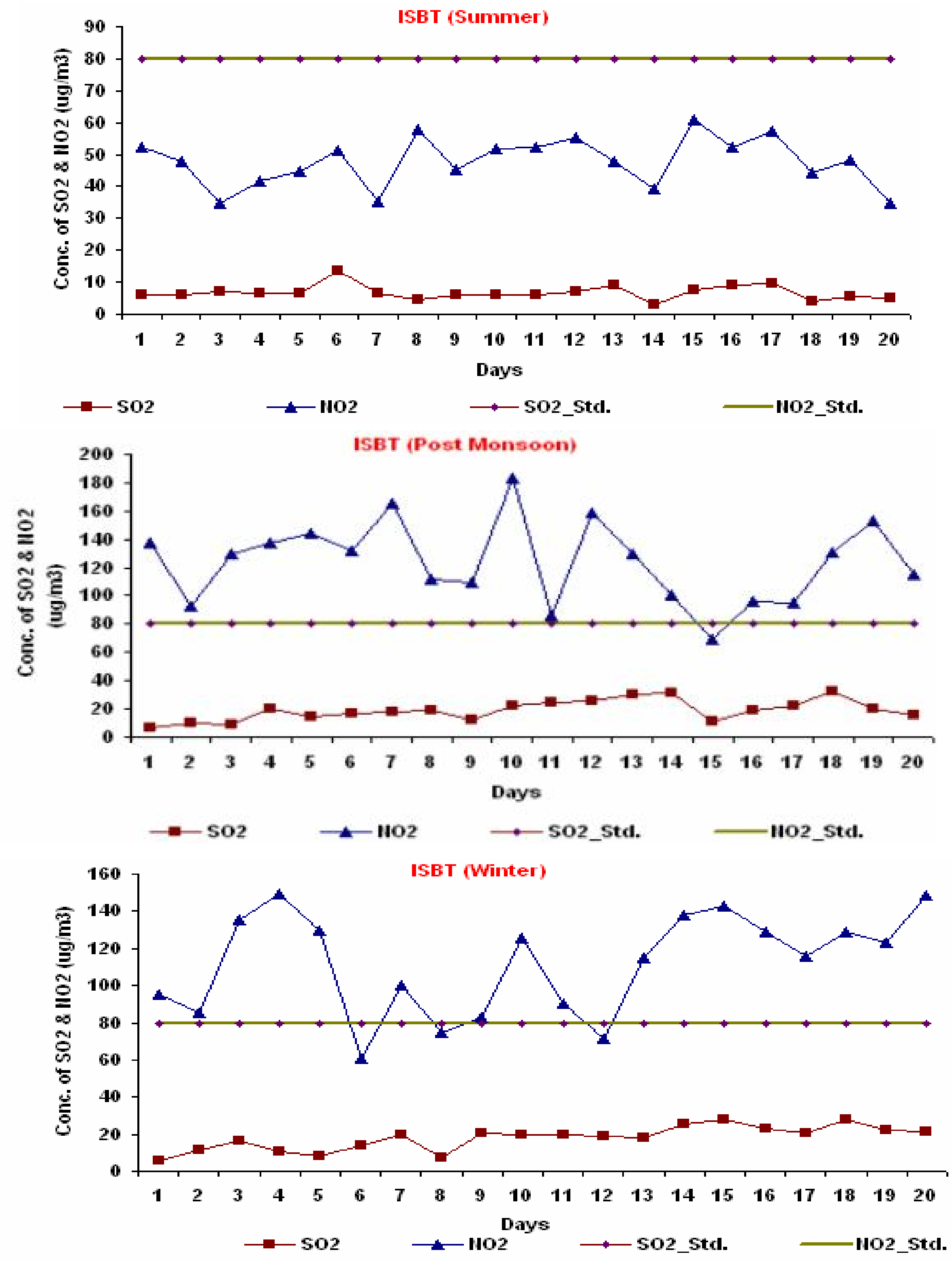


Fig 2.76 : Observed Concentration of SO_2 and NO_2 at ISBT in all three seasons

The concentrations of $PM_{2.5}$ for all three seasons are presented in **Fig 2.77**. The concentration of $PM_{2.5}$ is exceeding the US EPA standard of 35 µg/m^3 in all seasons.

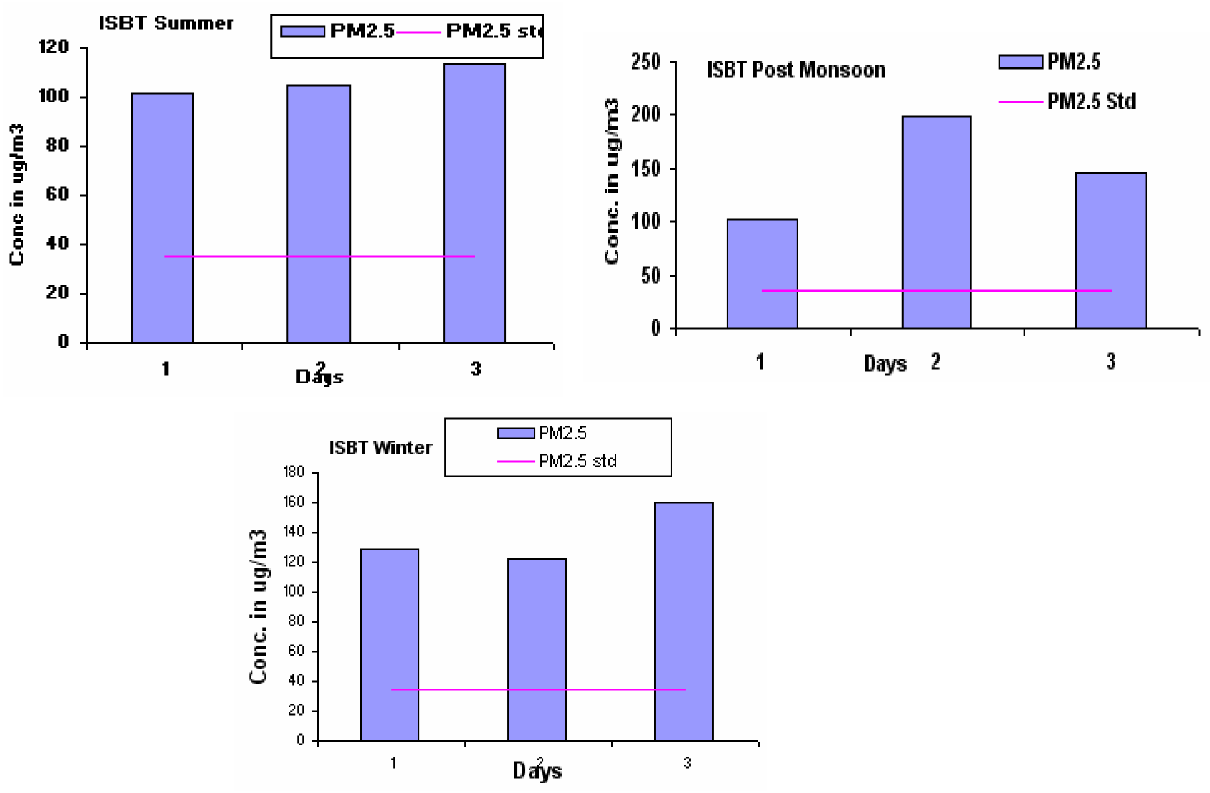
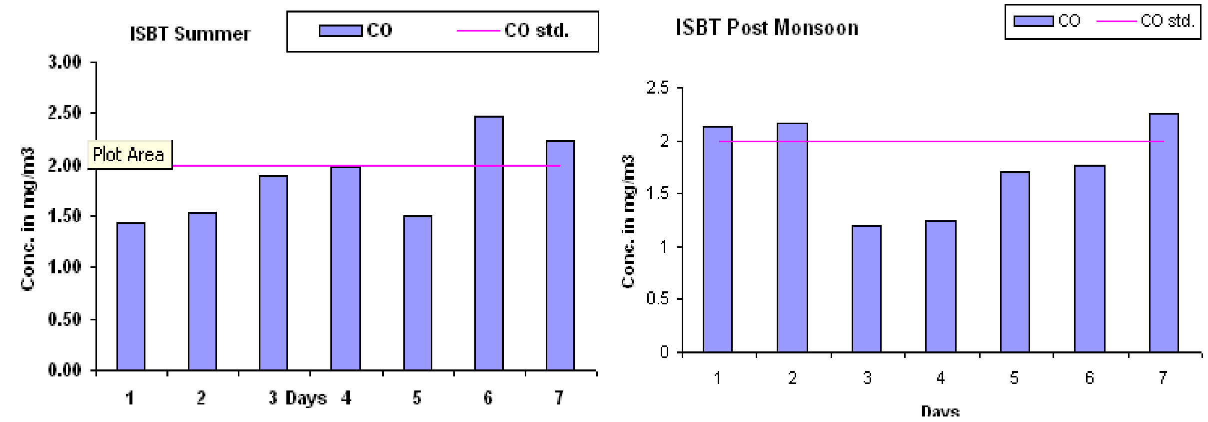


Fig 2.77 : Concentration of $PM_{2.5}$ at ISBT Site

Figure 2.78 shows the concentration of CO for all three seasons. It exceeds the CPCB standards on some of the days of summer and Post Monsoon. **Figure 2.79** shows the concentration of Methane, Non Methane and Total Hydrocarbons. **Table 2.21** shows the 24 hourly average Concentrations of VOCs for one day of all three seasons.



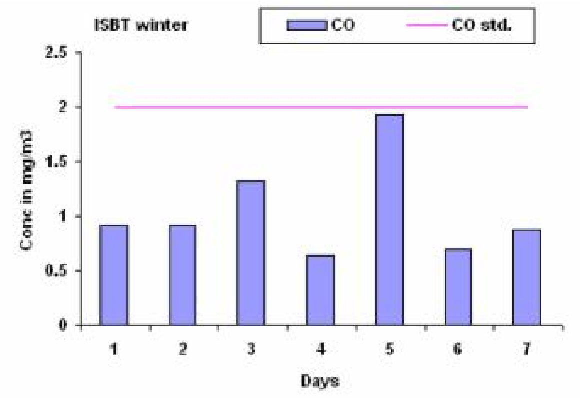


Fig 2.78 : Observed CO concentration at ISBT in all three seasons

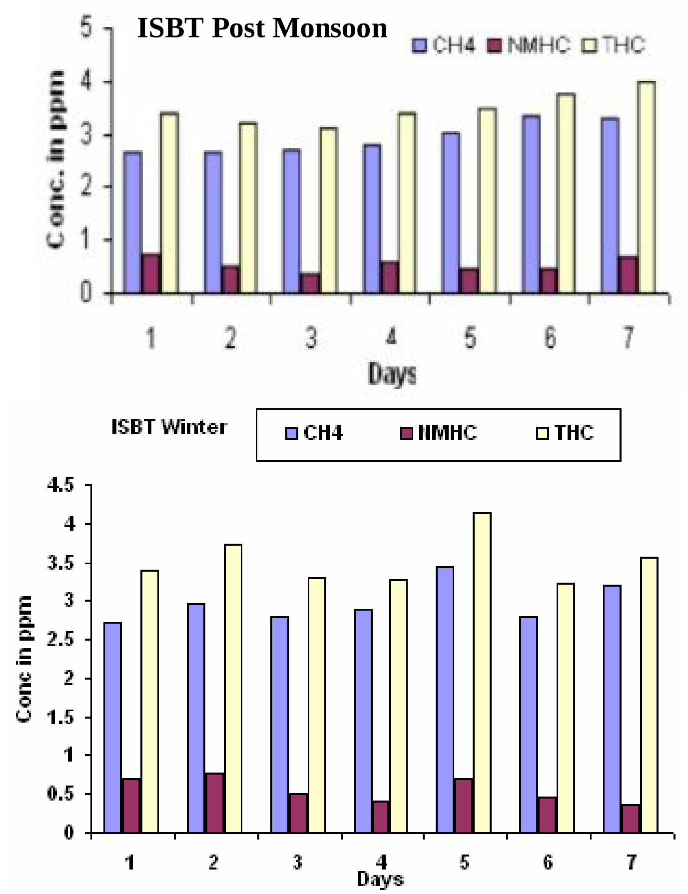


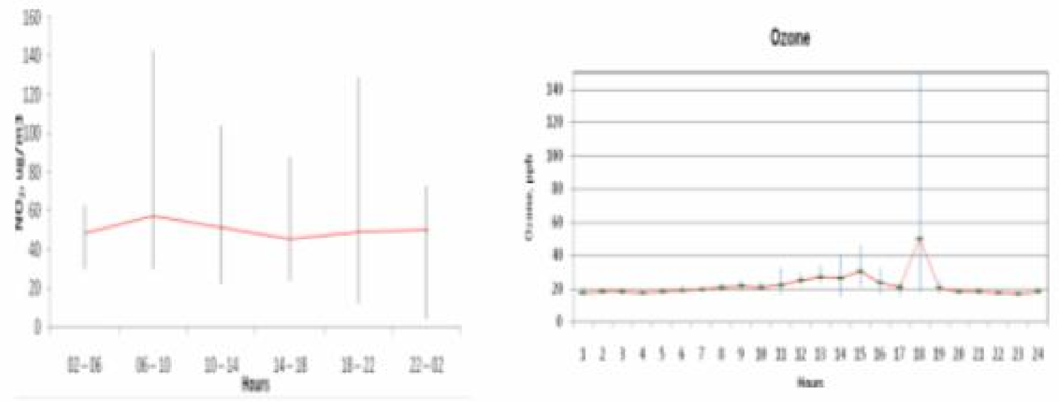
Fig 2.79 : Observed CH_4, NMHC and THC concentration at ISBT in all three seasons

Table 2.21 : 24 Hourly Concentrations of VOCs

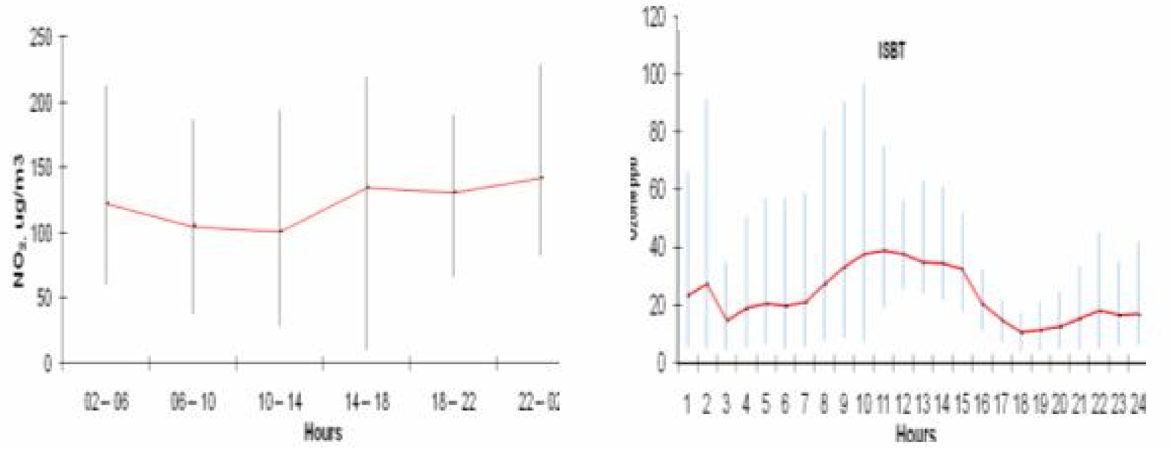
	1-3 Butadiene	Benzene
Summer	1.3	0.8
Post Monsoon	0.8	1.5
Winter	1.1	2.6

Diurnal variations in NO_2 and Ozone levels are plotted in **Fig 2.80.** It can be observed that for the Summer season the day time concentration of NO_2 is always lower than winter and post monsoon. Winter NOx values are highest in night which has been seen at few kerb site locations as well. The ozone concentration varies widely which could be due to highly variable NOx concentrations.

Diurnal Variation in NO_2 - Summer **Diurnal Variation in O_3 - Summer**



Diurnal Variation in NO_2 - Post Monsoon **Diurnal Variation in O_3 - Post Monsoon**



Diurnal Variation in NO_2 - Winter **Diurnal Variation in O_3 - Winter**

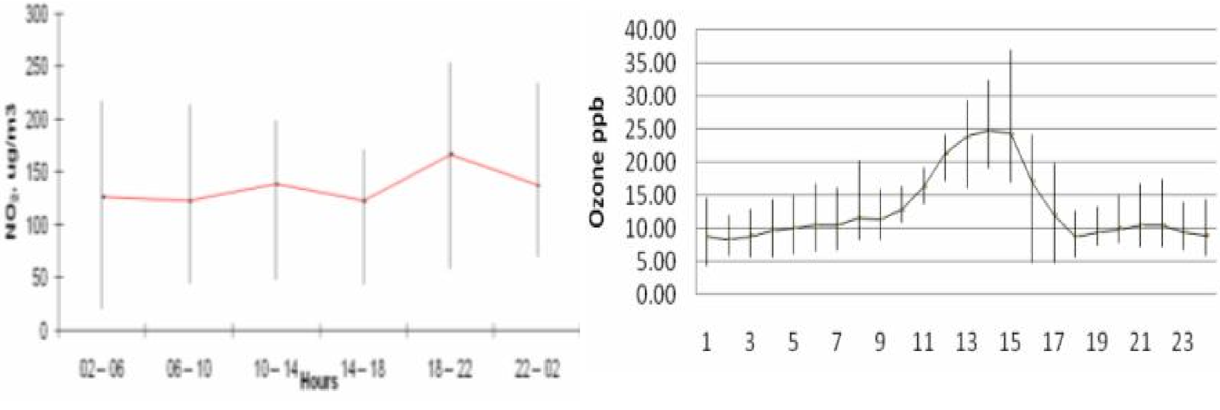
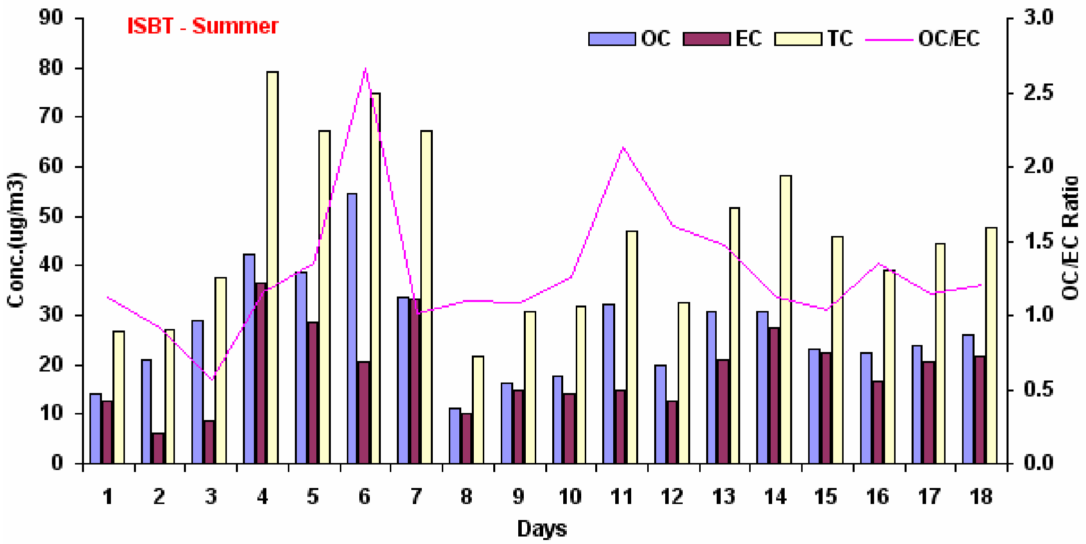
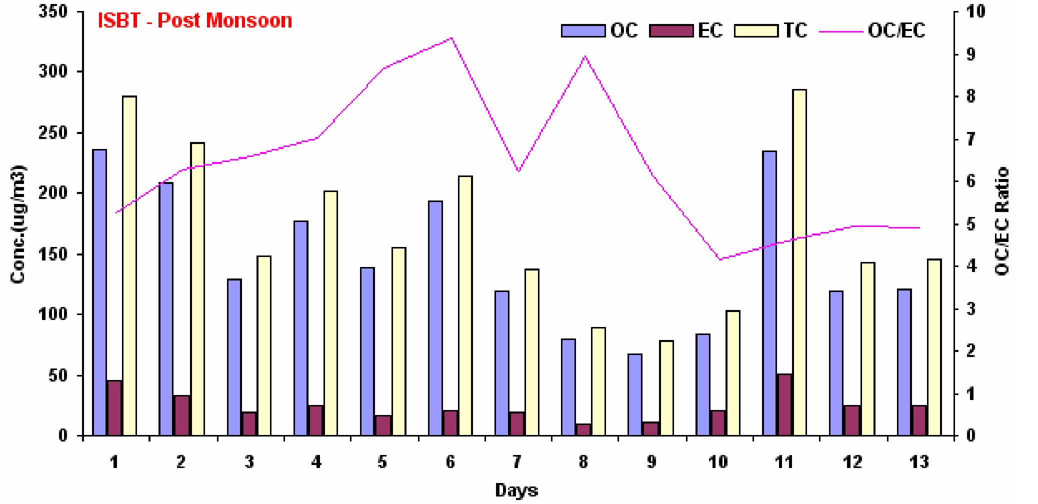


Fig 2.80: Diurnal Variation in NO_2 and Ozone at ISBT

Estimation of EC/OC Ratio

EC and OC was determined for PM samples with a view to establish the sources of carbon emissions. 24 hourly trends of OC, EC and TC with respect to their ratios are presented in **Fig 2.81.** The OC, EC ratio observed at ISBT show low values compared to Ashram and Dhaula Kuan. OC values go upto 230 µg/m^3.





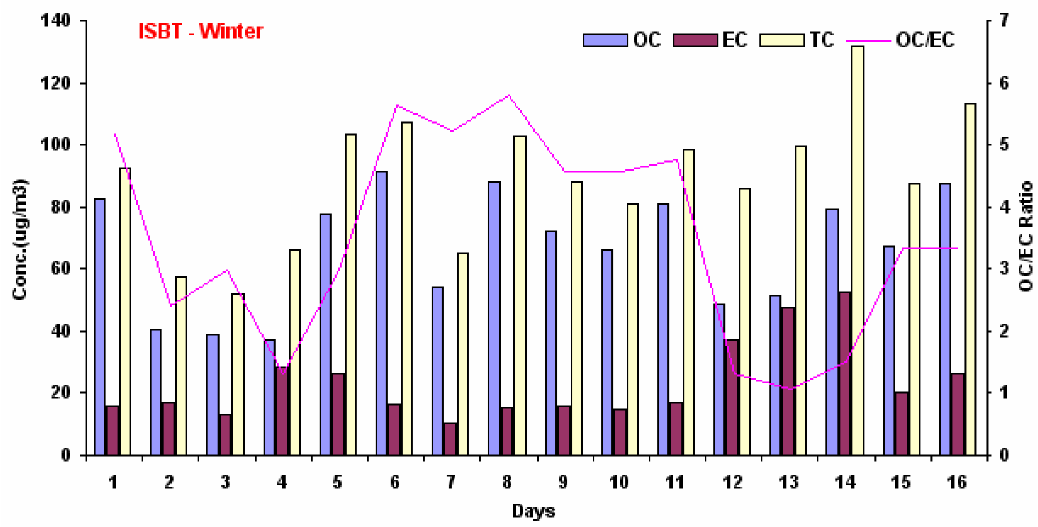


Fig 2.81 : 24 hourly trends of OC, EC and TC at ISBT

Mass Closure

Mass fraction of elements, ions and carbons in terms of percentage in PM_{10} is shown in **Fig 2.82.** ISBT has bus terminal with continuous movement of public transport buses which contributes to high percent contribution of OC and EC. EC accounts for 14% of total PM load (higher than Asharm, Dhaula Kuan) in summer, which is possibly due to large number of diesel vehicles plying in that area. This continuous movement of vehicles results in resuspension of road dust which gets reflected in higher percent of crustal elements in summer. In other season crustal contribution is lower.

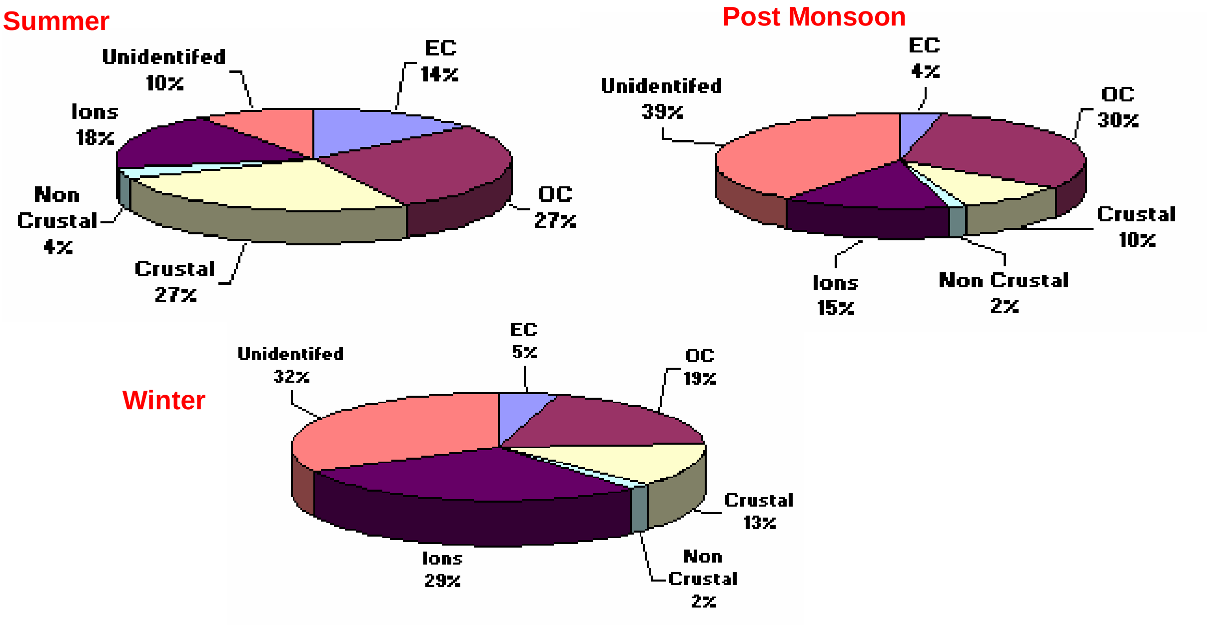


Fig 2.82 : Percent Mass of PM_{10} at ISBT

2.3.10 Loni Road (Kerb Site)

Site Description

This station represents kerbside activities and located near Golchakkar (Loni Mod) on Loni road leading to Saharanpur in UP. A major road, Wazirabad Road- Managl Pandey Marg connecting to NH 24 at Mohan Nagar, passes through the study region as shown in **Figure 2.83**. Though traffic movement is not very high on this road, the road conditions is extremely bad. The study zone has mainly residential areas with a few of DDA parks. UP Border at Loni in north direction is less than 2 kms away from the site. The area is highly populated with an estimated population of about 1.15 lakhs, settled in all the directions, in the areas like Gokulpur, Ganga Vihar, Meet Nagar, Amar Colony, Chitrakoot, Kardampuri, Yamuna Vihar, Gokulpuri etc. The study zone is dominated by middle and low income group people. The region has commercial activities all along the main roads. The road that leads to Loni is poorly maintained and due to movement of traffic, road dust re-suspension can be observed almost through out the year. Overall, the study zone can be considered as residential-cum-commercial activity zone.

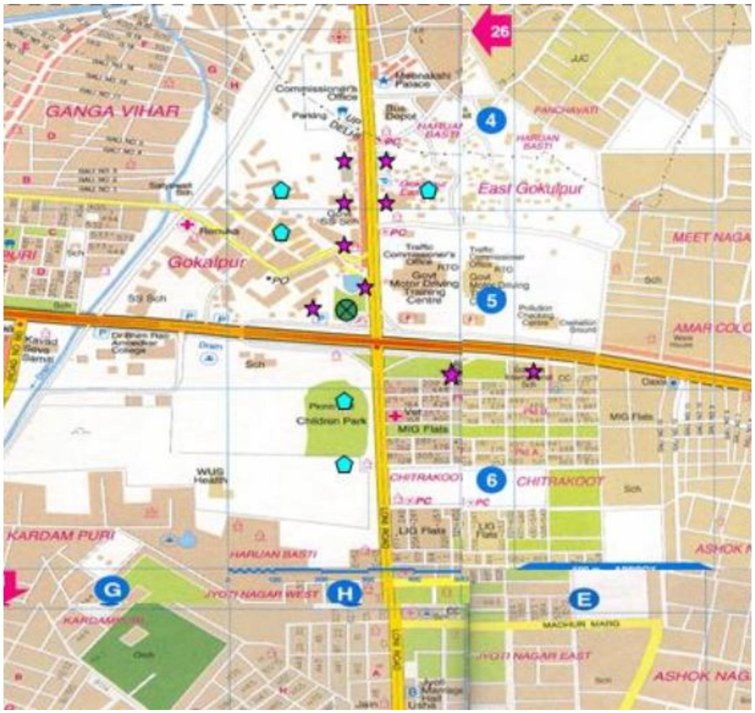


Fig. 2.83: Study Zone (2 km x 2 km): Loni Road

Air Quality Monitoring

Ambient air quality monitoring results at the site for all three seasons are presented in **Tables 2.22 a-b-c**. As can be seen from these tables, SPM and RSPM values always exceed the CPCB standard in all three seasons. This is attributed to construction and poor road repair activities in this area.

Table 2.22a : Air Quality Status at :Loni Road (Summer)

	N	Min	Max	Average	Per98	Stdev	CV
SPM	20	541.3	2568	1338.8	2516.2	569.1	0.43
RSPM	20	171.7	453	304.9	449.5	85.2	0.28
PM_{10}	18	130.7	868.5	375.2	811.5	186.9	0.50
$PM_{2.5}$	3	46	47	46.3	47	0.6	0.01
SO_2	20	4	22	9.7	21.6	5.9	0.61
NO_2	20	9.4	57.1	32.9	57.1	13.6	0.41
O_3	7	9.4	42.9	25.2	41.9	12.4	0.49
CO	7	2.2	2.9	2.6	2.9	0.3	0.12
CH_4		NA	NA	NA	NA	NA	NA
NMHC		NA	NA	NA	NA	NA	NA
THC		NA	NA	NA	NA	NA	NA
HCHO	1			11			0.00

Table 2.22b : Air Quality Status at Loni Road (Post Monsoon)

	N	Min	Max	Average	Per98	Stdev	CV
SPM	20	1058	3877	2765.1	3825.3	881.9	0.32
RSPM	20	311	1385	757.3	1377.4	297.1	0.39
PM_{10}	20	341	2023	1051.5	1912	479.3	0.46
$PM_{2.5}$	3	347	375	361	374.4	19.8	0.05
SO_2	20	6	9	6.9	8.6	0.8	0.12
NO_2	20	36	67	43.9	63.6	8.6	0.20
O_3	7	33.7	45.4	41.2	45.2	3.8	0.09
CO	7	1.4	2.2	1.8	2.2	0.3	0.17
CH_4	7	2.2	3.1	2.5	3.1	0.3	0.12
NMHC	7	0.8	1.5	1.2	1.4	0.2	0.17
THC	7	3.2	4.4	3.7	4.3	0.4	0.11
HCHO	1			19			0.00

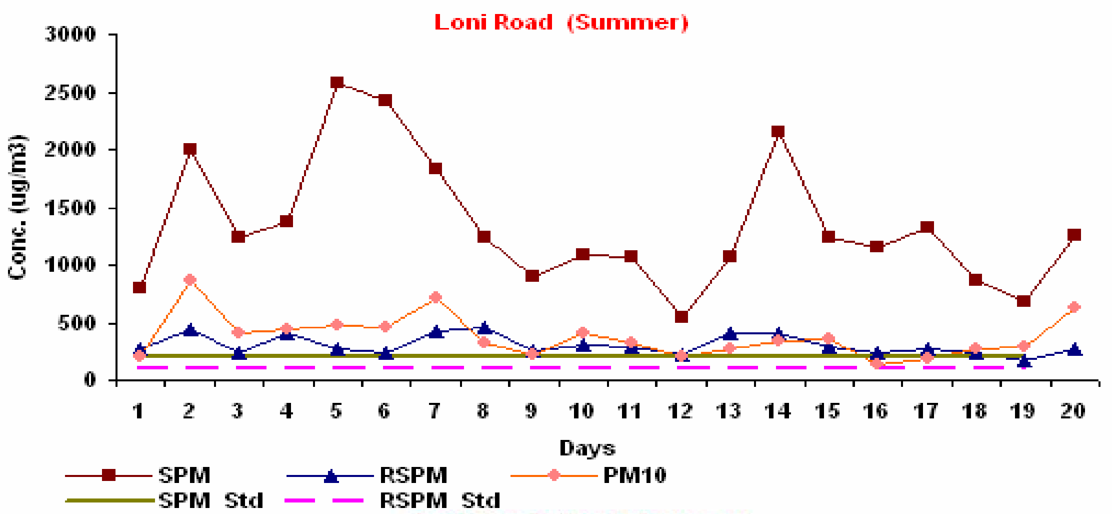
Table 2.22c : Air Quality Status at Loni Road (Winter)

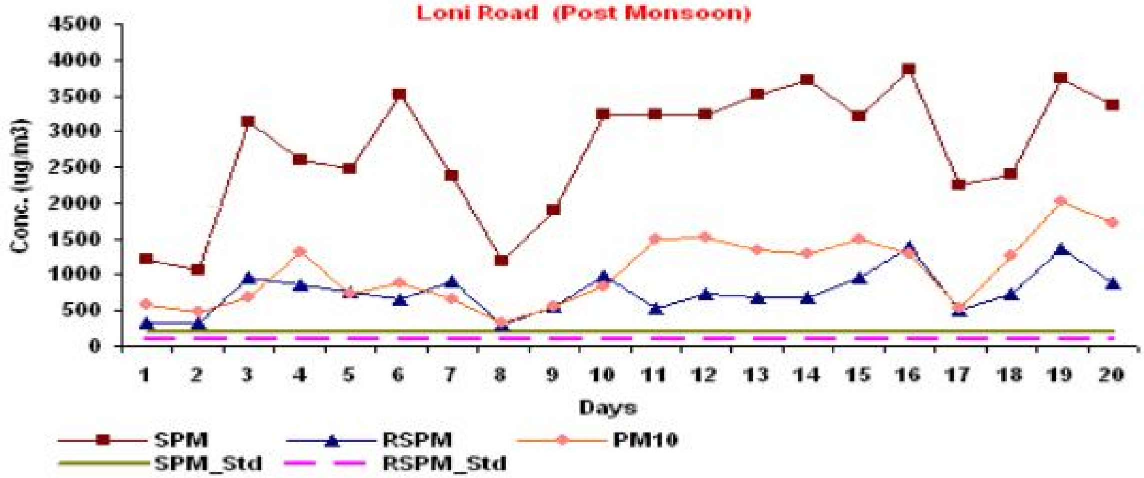
	N	Min	Max	Average	Per98	Stdev	CV
SPM	20	654.3	1903	1122.8	1865.1	368.1	0.33
RSPM	20	175	639.1	380.6	625.8	144.6	0.38
PM_{10}	19	243	895	456.2	807.8	170.2	0.37
$PM_{2.5}$	3	276	350.2	307.4	348.1	38.4	0.12
SO_2	20	11	33	21.4	33	6.7	0.31
NO_2	20	47.3	93	74	92.1	11	0.15
O_3	1						
CO	7	1.3	2.2	1.7	2.2	0.3	0.18
CH_4	7	3.1	4	3.6	4	0.3	0.08
NMHC	7	0.5	0.8	0.7	0.8	0.1	0.14

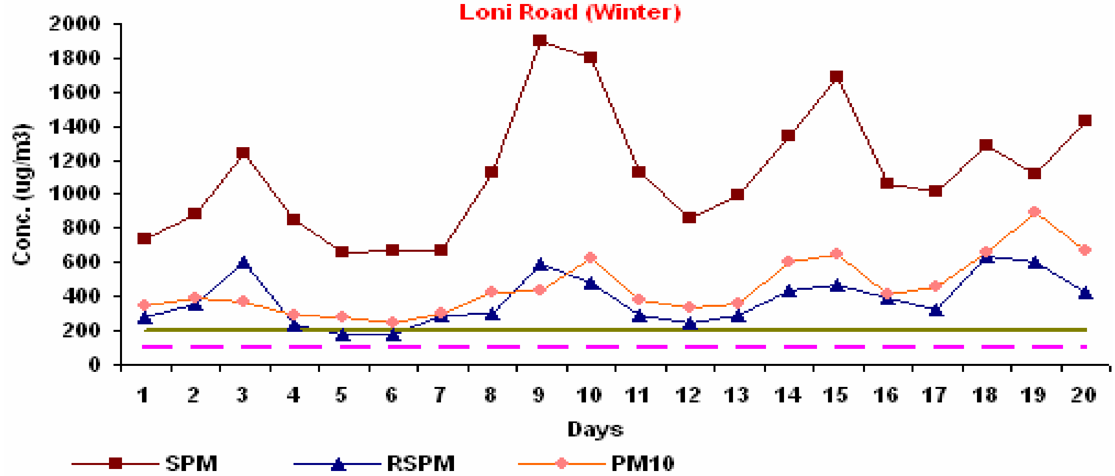
THC	7	3.6	4.7	4.3	4.7	0.4	0.09
HCHO				8			0.00

Particulate matter (SPM, RSPM, and PM_{10}) levels of Loni Road for all three seasons are presented in **Fig 2.84** along with regulatory standards of CPCB for SPM and RSPM. The sites consistently give higher RSPM due to local conditions of road and open space.

Figures 2.85 presents the variation of SO_2 and NO_2 at the site for all the three seasons. It is evident from the figures that SO_2 values meet the standards in all seasons, whereas NO_2 values exceed the standards on some days in winter.







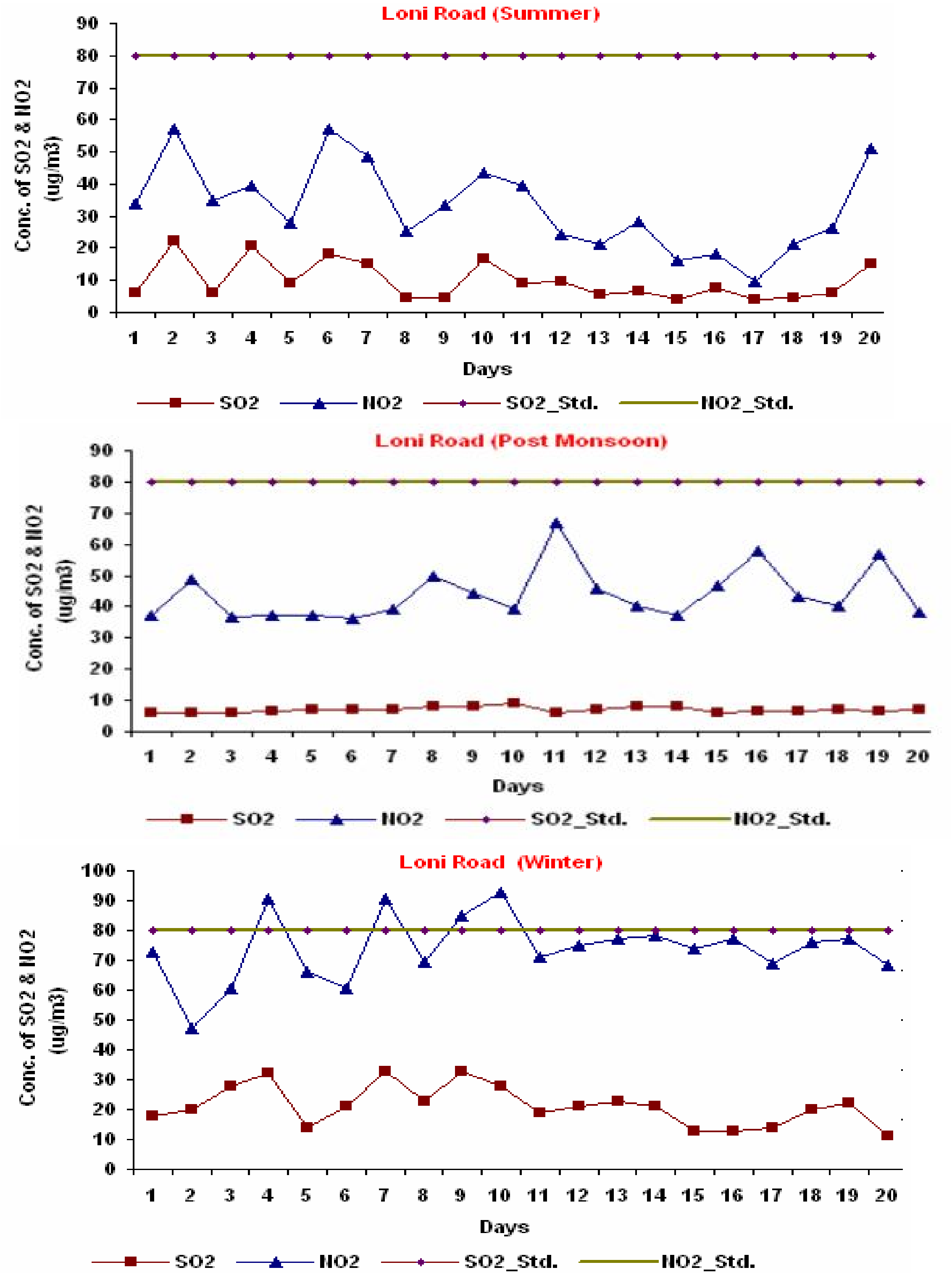


Fig 2.85 : Observed Concentration of SO_2 and NO_2 at Loni Road in all three seasons

The concentrations of $PM_{2.5}$ for all three seasons are presented in **Fig 2.86.** The concentration of $PM_{2.5}$ is exceeding the limit of US EPA standard of 35 µg/m^3 in all seasons.

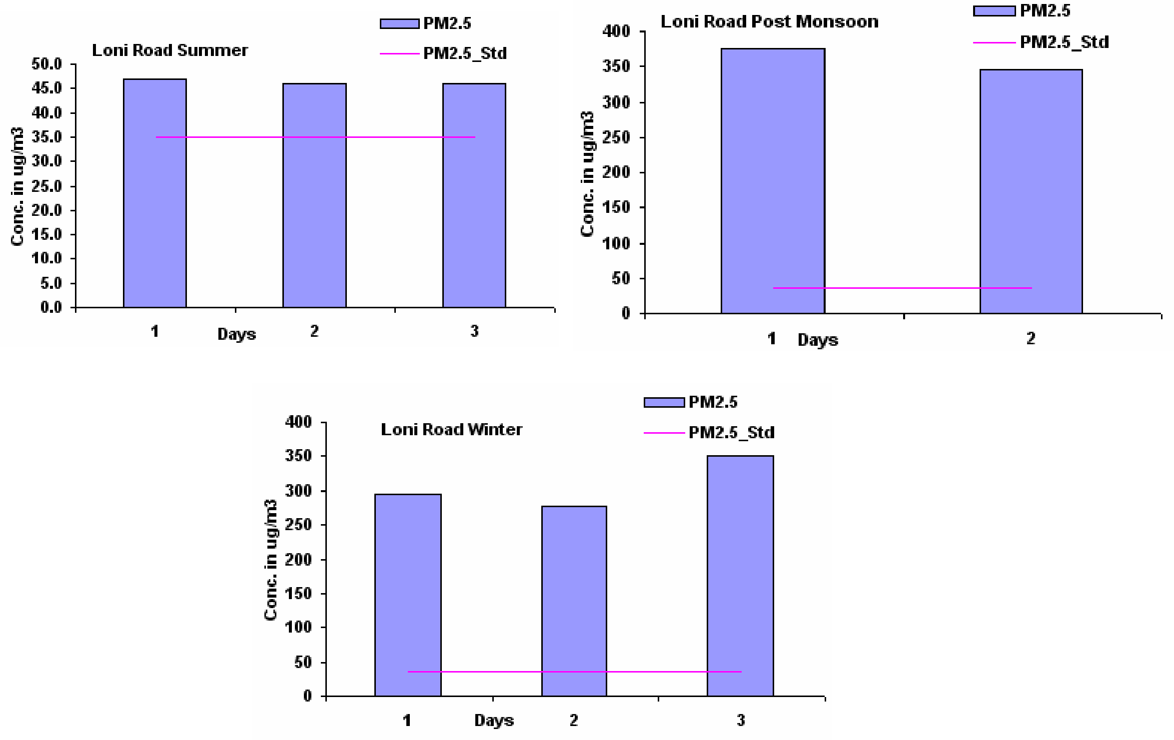


Fig 2.86 : Concentration of $PM_{2.5}$ at Loni Road

Figure 2.87 shows the concentration of CO for all three seasons. The concentration of CO exceed the CPCB standard 2 mg/m^3 on all days of summer season and some days of post monsoon. **Figure 2.88** shows the concentration of Methane, Non Methane and Total Hydrocarbons. **Table 2.23** shows the 24 hourly average Concentrations of VOCs for one day of all three seasons.

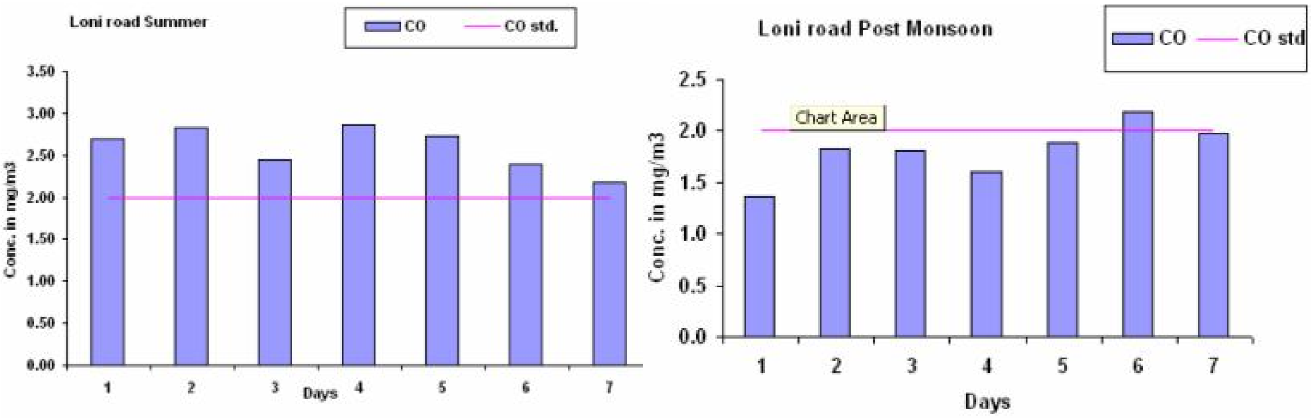


Fig 2.87 : Observed CO concentration at Loni Road in all three seasons

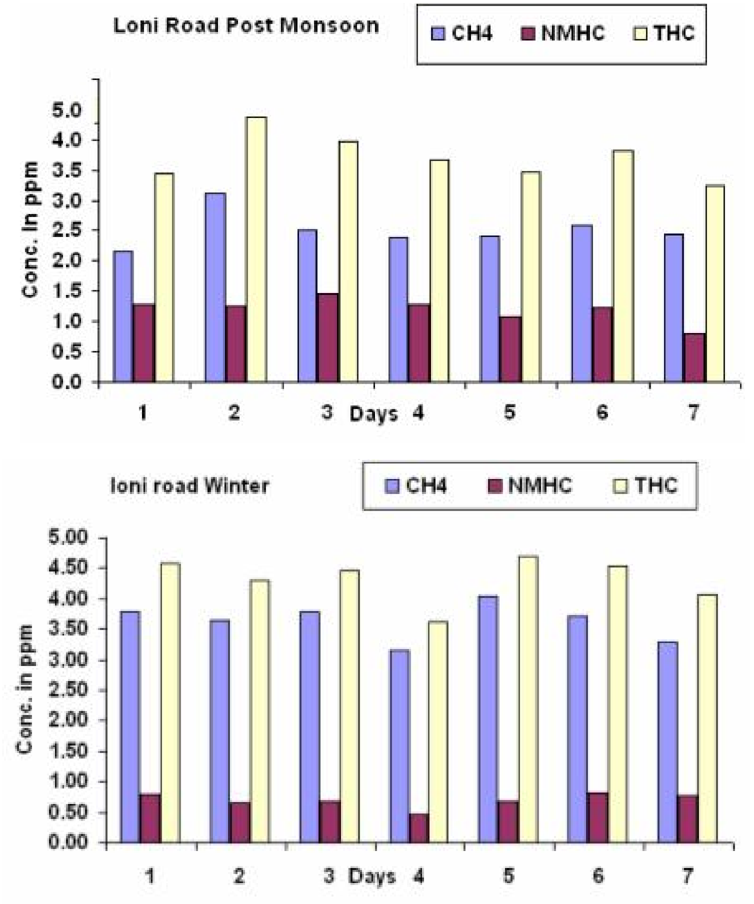
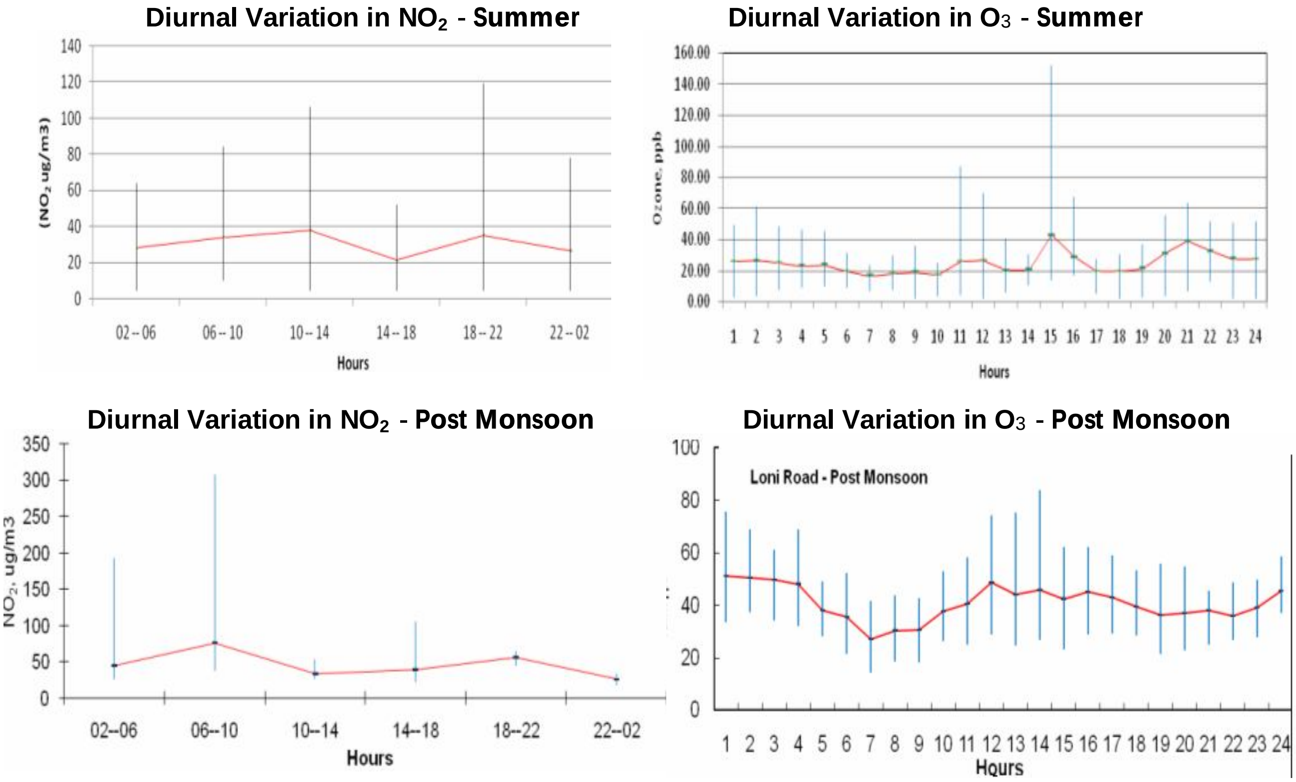


Fig 2.88 : Observed CH_4, NMHC and THC concentration at Loni Road in all three seasons

Table 2.23 : 24 Hourly Concentrations of VOCs

	1-3 Butadiene	Benzene
Summer	0.6	1.2
Post Monsoon	0.8	0.9
Winter	0.6	1.0

NOx and Ozone diurnal variations are presented in **Fig 2.89**. Ozone concentrations are highly variable at kerb site locations.


Diurnal Variation in NO_2 - Summer

Diurnal Variation in O_3 - Summer

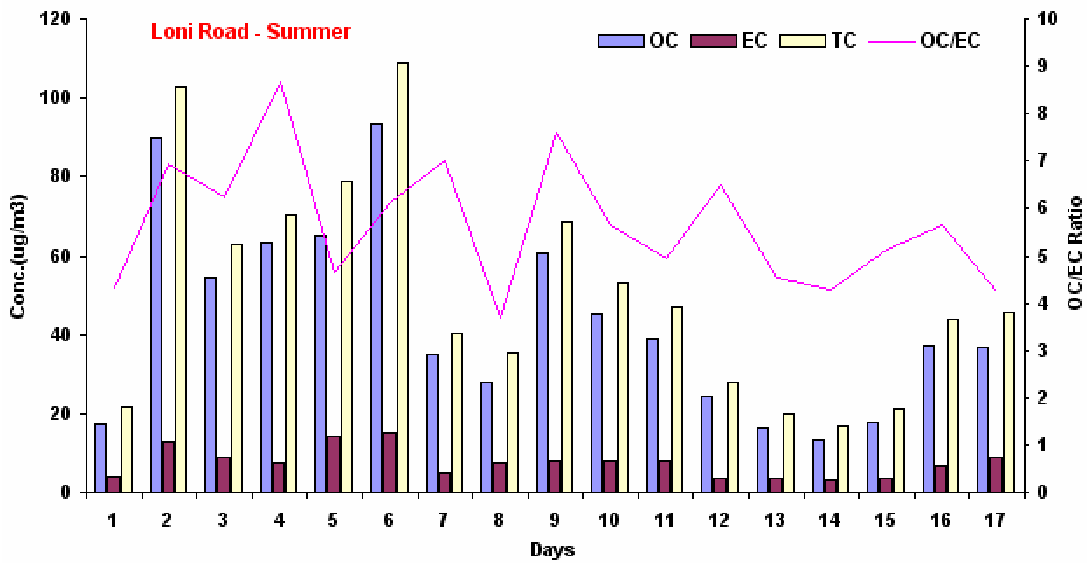
Diurnal Variation in NO_2 - Post Monsoon

Diurnal Variation in O_3 - Post Monsoon

Fig 2.89 : Diurnal Variation in NO_2 and Ozone at Loni Road

Estimation of EC/OC Ratio

EC and OC was determined for PM samples with a view to establish the sources of carbon emissions. 24 hourly trends of OC, EC and TC with respect to their ratios are presented in **Fig 2.90.** Highest OC/ EC ratios were witnessed for post monsoon season.



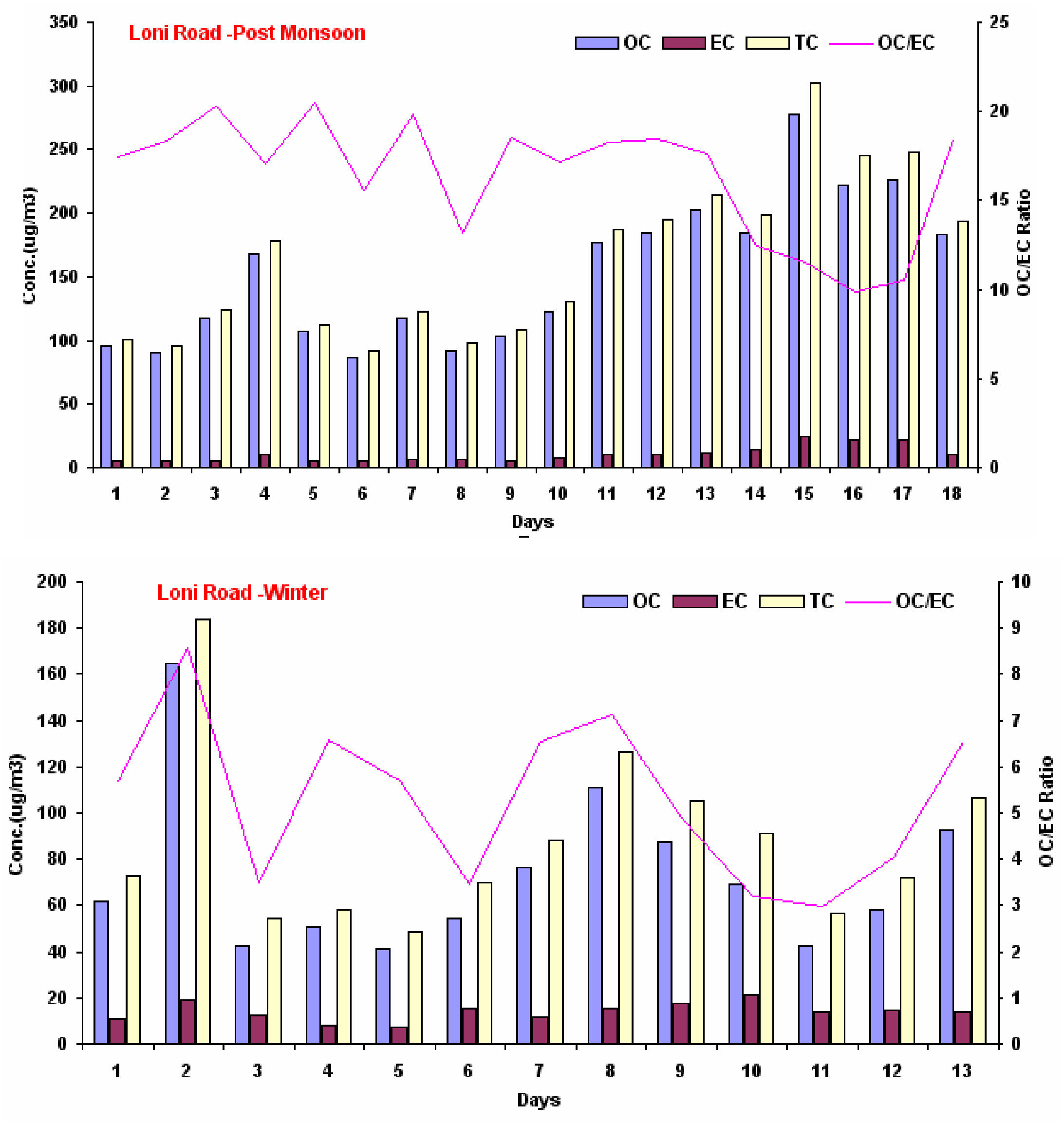


Fig 2.90 : 24 hourly trends of OC, EC and TC at Loni Road

Mass Closure

Mass fraction of elements, ions and carbons in terms of percentage in PM_{10} is shown in **Fig 2.91.** Ions like SO_4^{--}, Cl^- etc are due to heavy vehicular traffic in this area which also contributes significantly to coarse particulate matter in all the three seasons. Crustal elements have maximum contribution in total particulate matter load in winter. Loni road kerb site location experiences high impacts of road construction/ repair, household biomass burning. These factors are also responsible for highly varying PM values and corresponding other parameters.

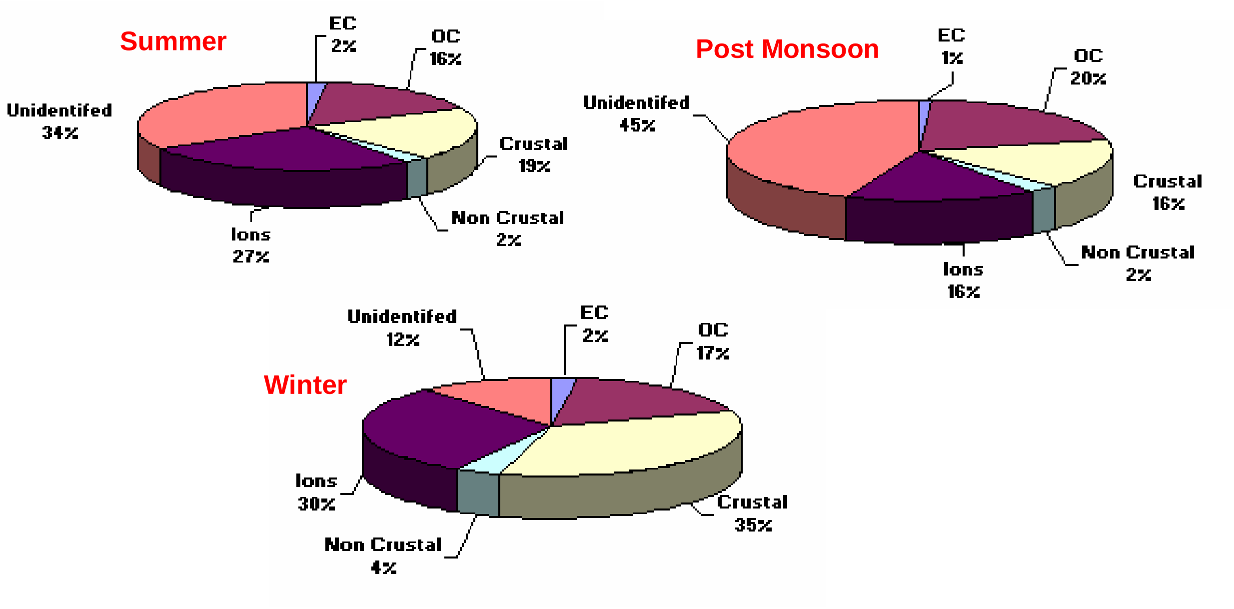


Fig 2.91: Percent mass of PM_{10} at Loni Road

2.3.11 Correlation Matrix of Sources

With view to understand correlation of different pollutant, correlation matrix was drawn for different season at ten sites. The major attributes for correlation considered were PM_{10}, OC, EC, TC, SO_2, NO_2, NO_3, SO_4 and NH_4. A separate correlation was also attempted for PM2.5 and EC-OC as it is know that most of the engine combustion PM is in fine range. $PM_{2.5}$ correlation data with OC, EC and TC is given in **Annexure**.

The correlation at this reference site is presented below :

a. Prahladpur

Summer

	PM10	OC	EC	TC	SO2	NO2	NO3	SO4	NH4
PM10	1.00	0.71	0.35	0.79	-0.30	0.16	0.93	0.56	-0.90
OC		1.00	-0.02	0.94	-0.22	-0.36	0.86	0.50	-0.46
EC			1.00	0.33	0.01	-0.26	0.06	-0.54	-0.70
TC				1.00	-0.20	-0.42	0.83	0.28	-0.68
SO2					1.00	0.16	-0.43	-0.42	0.26
NO2						1.00	0.04	0.48	-0.09
NO3							1.00	0.73	-0.72
SO4								1.00	-0.21
NH4									1.00

Post Monsoon

	PM10	OC	EC	TC	SO2	NO2	NO3	SO4	NH4
PM10	1.00	0.83	0.69	0.86	0.72	0.57	0.82	0.25	0.63
OC		1.00	0.65	0.99	0.44	0.42	0.84	0.29	0.48
EC			1.00	0.75	0.70	0.81	0.94	0.25	0.96
TC				1.00	0.51	0.52	0.91	0.31	0.60
SO2					1.00	0.63	0.64	0.54	0.74
NO2						1.00	0.74	0.44	0.83
NO3							1.00	0.32	0.87
SO4								1.00	0.29
NH4									1.00

Winter

	PM10	OC	EC	TC	SO2	NO2	NO3	SO4	NH4
PM10	1.00	0.73	0.23	0.80	-0.37	-0.11	0.24	-0.36	0.24
OC		1.00	-0.24	0.97	-0.18	0.15	0.35	-0.20	-0.05
EC			1.00	-0.01	-0.20	-0.17	0.27	0.06	0.40
TC				1.00	-0.24	0.11	0.43	-0.19	0.04
SO2					1.00	0.25	-0.09	0.04	-0.68
NO2						1.00	-0.05	0.19	-0.22
NO3							1.00	0.59	0.51
SO4								1.00	0.53
NH4									1.00

At this site PM_{10} correlate well with TC, NO_3 and SO_4 in summer, where as in post monsoon it correlated well with TC, SO_2, NO_2, NO_3 and NH_4. In winter, however, PM_{10} did not correlate with other attributes except TC. The correlation with NO_3 and SO_4 indicates the formation of secondary aerosol. PM_{10} is well correlated with SO_2 showing the presence of coal combustion. In winter season correlation coefficients between NH_4 & SO_4 is fairly high indicating the formation of $(NH_4)_2SO_4$ through secondary processes.

B. Pitampura

The correlation matrix of Pitampura, a designated residential area is given below :

Summer

	PM10	OC	EC	TC	SO2	NO2	NO3	SO4	NH4
PM10	1.00	-0.18	-0.28	-0.23	0.67	0.08	0.79	0.92	0.85
OC		1.00	0.75	0.96	0.04	0.48	0.16	-0.03	-0.02
EC			1.00	0.91	0.20	0.18	-0.14	-0.14	-0.16
TC				1.00	0.11	0.38	0.04	-0.08	-0.08
SO2					1.00	-0.14	0.49	0.71	0.48
NO2						1.00	-0.07	0.16	0.41
NO3							1.00	0.75	0.62
SO4								1.00	0.86
NH4									1.00

Post Monsoon

	PM10	OC	EC	TC	SO2	NO2	NO3	SO4	NH4
PM10	1.00	-0.78	0.56	-0.75	-0.53	-0.03	0.38	0.35	0.46
OC		1.00	-0.19	1.00	-0.06	-0.20	-0.17	-0.11	-0.04
EC			1.00	-0.11	-0.83	-0.58	0.16	0.22	0.30
TC				1.00	-0.12	-0.25	-0.16	-0.09	-0.02
SO2					1.00	0.33	-0.13	-0.18	-0.43
NO2						1.00	-0.62	-0.69	-0.57
NO3							1.00	1.00	0.93
SO4								1.00	0.94
NH4									1.00

Winter

	PM10	OC	EC	TC	SO2	NO2	NO3	SO4	NH4
PM10	1.00	0.90	0.70	0.41	0.25	-0.48	0.33	0.16	0.39
OC		1.00	0.87	0.33	0.06	-0.39	0.48	0.45	0.51
EC			1.00	-0.13	0.30	-0.38	0.57	0.57	0.54
TC				1.00	-0.59	-0.11	-0.24	-0.23	0.04
SO2					1.00	-0.20	0.10	-0.22	0.09
NO2						1.00	0.02	0.09	0.03
NO3							1.00	0.87	-0.01
SO4								1.00	0.10
NH4									1.00

The results indicate that PM_{10} did not correlated with OC and TC in summer and post monsoon, whereas in winter OC, EC and TC correlate well. NO_3 and SO_4 correlate well indicating similar sources and high possibility of secondary reaction. PM_{10} strongly correlate with OC in only winter, which indicates that PM_{10} is influenced by winter bio mass burning. High correlation between OC-EC in summer & winter indicate combustion of biomass specially during the winter. Similarly PM_{10} & EC correlate well during the Post monsoon & winter seasons indicating Vehicular emission. In summer, PM_{10} is well correlated with SO_2 & SO_4 showing the presence of coal combustion. In summer and post monsoon seasons we observe that correlation coefficients between NH4 & SO4 are 0.86 and 0.94 indicating the formation of $(NH_4)_2SO_4$.

C. Naraina

Naraina is mixed used category region with industries, commercial and residential zones.

Summer

	PM10	OC	EC	TC	SO2	NO2	NO3	SO4	NH4
PM10	1.00	0.06	0.42	0.28	0.51	-0.02	1.00	0.06	0.42
OC		1.00	-0.39	0.89	0.10	-0.36		1.00	-0.39
EC			1.00	0.07	0.33	0.60			1.00
TC				1.00	0.28	-0.09			
SO2					1.00	0.07			
NO2						1.00			
NO3							1.00	0.06	0.42
SO4								1.00	-0.39
NH4									1.00

Post Monsoon

	PM10	OC	EC	TC	SO2	NO2	NO3	SO4	NH4
PM10	1.00	0.90	0.83	0.90	-0.22	-0.19	-0.05	-0.33	-0.09
OC		1.00	0.90	1.00	-0.37	0.03	-0.03	-0.28	-0.01
EC			1.00	0.92	-0.48	0.07	-0.05	-0.35	0.12
TC				1.00	-0.39	0.04	-0.03	-0.29	0.01
SO2					1.00	-0.32	-0.18	0.37	-0.38
NO2						1.00	0.01	-0.02	0.01
NO3							1.00	0.57	0.75
SO4								1.00	0.43
NH4									1.00

Winter

	PM10	OC	EC	TC	SO2	NO2	NO3	SO4	NH4
PM10	1.00	0.02	-0.21	0.01	0.66	0.32	0.58	0.79	0.05
OC		1.00	0.33	1.00	0.53	0.90	-0.17	0.10	-0.10
EC			1.00	0.36	-0.20	0.26	-0.20	-0.33	-0.40
TC				1.00	0.52	0.90	-0.18	0.09	-0.12
SO2					1.00	0.71	-0.01	0.42	-0.07
NO2						1.00	-0.12	0.20	-0.19
NO3							1.00	0.83	0.41
SO4								1.00	0.11
NH4									1.00

The correlation between of PM_{10} with OC, EC and TC is not good in summer and winter, however it is excellent in post monsoon. It correlates well with SO_2, NO_2, NO_3, SO_4 in winter indicating contribution from primary sources of SO_2 (coal combustion) and NO_2 (vehicles). It also suggests formation of secondary aerosols in winter unlike is other seasons. In summer, PM_{10} is well correlated with SO_2 showing the presence of coal combustion. NH_4 and NO_3 correlate well in winter indicating the formation of NH_4NO_3.

D. SSI –GTK

SSI –GTK site is mainly an industrial site with large and medium scale industries.

Summer

	PM10	OC	EC	TC	SO2	NO2	NO3	SO4	NH4
PM10	1.00	0.01	-0.30	-0.07	0.03	-0.16	-0.18	-0.07	-0.56
OC		1.00	0.18	0.96	0.52	0.69	-0.08	-0.24	0.14
EC			1.00	0.45	0.25	-0.06	0.63	0.37	0.74
TC				1.00	0.55	0.61	0.11	-0.12	0.33
SO2					1.00	0.75	0.45	0.33	0.35
NO2						1.00	-0.06	-0.17	0.01
NO3							1.00	0.72	0.82
SO4								1.00	0.50
NH4									1.00

Post Monsoon

	PM10	OC	EC	TC	SO2	NO2	NO3	SO4	NH4
PM10	1.00	0.80	0.31	0.84	0.37	0.73	0.93	0.68	0.50
OC		1.00	-0.02	0.99	0.50	0.91	0.88	0.12	-0.11
EC			1.00	0.15	-0.05	0.33	-0.05	0.42	0.43
TC				1.00	0.49	0.95	0.86	0.19	-0.04
SO2					1.00	0.49	0.34	-0.09	-0.11
NO2						1.00	0.68	0.05	-0.15
NO3							1.00	0.52	0.31
SO4								1.00	0.97
NH4									1.00

Winter

	PM10	OC	EC	TC	SO2	NO2	NO3	SO4	NH4
PM10	1.00	0.80	0.35	0.79	-0.22	-0.80	-0.08	0.34	0.70
OC		1.00	0.46	0.99	0.09	-0.71	0.25	0.46	0.77
EC			1.00	0.59	-0.05	-0.65	-0.33	-0.17	0.20
TC				1.00	0.07	-0.75	0.17	0.39	0.73
SO2					1.00	-0.06	0.43	0.06	0.43
NO2						1.00	-0.05	-0.29	-0.78
NO3							1.00	0.78	0.48
SO4								1.00	0.60
NH4									1.00

The PM_{10} does not correlate with any attributes in summer, however, it shows good correlation with OC, TC, NO_2, NO_3, SO_4 and NH_4 in post monsoon. In winter it continues a good correlation with OC indicating biomass burning, however, it does not correlate well with gaseous and secondary particles. In SSI in all three seasons we observe that the correlation coefficient between NH_4 & SO_4 are high (0.5, 0.97 and 0.60) indicating the formation of $(NH_4)_2SO_4$. OC & NO_2 are highly correlated (0.69 and 0.91) at SSI which also indicate vehicular and other combustion sources.

E. Ahsram Chowk

Summer

	PM10	OC	EC	TC	SO2	NO2	NO3	SO4	NH4
PM10	1.00	0.74	0.06	0.43	0.05	-0.25	0.28	0.65	1.00
OC		1.00	0.50	0.84	0.42	0.14	0.15	0.72	
EC			1.00	0.89	0.78	0.12	0.34	0.36	
TC				1.00	0.71	0.15	0.29	0.61	
SO2					1.00	0.20	0.12	0.38	
NO2						1.00	-0.23	0.32	
NO3							1.00	*0.57*	
SO4								1.00	
NH4									1.00

Post Monsoon

	PM10	OC	EC	TC	SO2	NO2	NO3	SO4	NH4
PM10	1.00	0.79	0.53	0.78	-0.02	0.73	0.57	0.50	-0.19
OC		1.00	0.68	0.99	-0.21	0.70	0.54	0.27	-0.22
EC			1.00	0.78	-0.20	0.73	0.59	-0.10	-0.05
TC				1.00	-0.22	0.74	0.58	0.21	-0.20
SO2					1.00	-0.17	0.09	0.58	0.44
NO2						1.00	0.50	0.27	-0.25
NO3							1.00	0.26	-0.06
SO4								1.00	-0.15
NH4									1.00

Winter

	PM10	OC	EC	TC	SO2	NO2	NO3	SO4	NH4
PM10	1.00	0.32	-0.03	0.33	0.16	0.71	0.57	0.68	0.69
OC		1.00	-0.44	0.99	0.39	-0.14	-0.22	-0.30	-0.25
EC			1.00	-0.30	-0.38	0.24	0.02	0.27	0.12
TC				1.00	0.35	-0.11	-0.23	-0.28	-0.24
SO2					1.00	-0.07	-0.20	-0.25	0.19
NO2						1.00	0.37	0.67	0.71
NO3							1.00	0.74	0.54
SO4								1.00	0.69
NH4									1.00

Ashram Chowk location is in the vicinity of traffic intersection with a flyover and mixed traffic. The correlation of different attributes at all sites and all seasons are variable. PM_{10} does not correlate with SO_2 whereas it correlate with NO_2 in post monsoon and winter indicating vehicular activities. PM_{10} correlation with SO_4 remains significant in all three seasons. The correlation between OC and PM_{10} are high in summer and post monsoon season indicating many types of combustion sources. In summer season, we observe that correlation coefficients between NH_4 and SO_4 is fairly high indicating the formation of $(NH4)_2SO_4$ as secondary aerosol.

F. Dhaula Kuan

Dhaula Kuan site is dominated by large number of roads with very high vehicular activities. Correlation matrix for major attributed is presented below :

Post Monsoon

	PM10	**OC**	**EC**	**TC**	**SO2**	**NO2**	**NO3**	**SO4**	**NH4**
PM10	1.00	0.64	0.04	0.62	-0.22	0.18	0.85	0.72	0.67
OC		1.00	0.03	0.95	0.19	0.27	0.52	0.56	0.88
EC			1.00	0.33	0.41	0.51	-0.27	-0.07	-0.09
TC				1.00	0.31	0.41	0.41	0.50	0.80
SO2					1.00	0.59	-0.45	-0.06	0.18
NO2						1.00	-0.13	0.26	0.40
NO3							1.00	0.55	0.53
SO4								1.00	0.79
NH4									1.00

Winter

	PM10	**OC**	**EC**	**TC**	**SO2**	**NO2**	**NO3**	**SO4**	**NH4**
PM10	1.00	0.89	0.82	0.90	0.69	0.67	0.33	0.66	0.40
OC		1.00	0.74	1.00	0.29	0.28	-0.05	0.72	0.00
EC			1.00	0.78	0.56	0.63	0.54	0.92	0.27
TC				1.00	0.32	0.32	0.01	0.76	0.03
SO2					1.00	0.96	0.74	0.24	0.76
NO2						1.00	0.87	0.38	0.86
NO3							1.00	0.39	0.79
SO4								1.00	0.11
NH4									1.00

PM_{10} correlate well with OC, TC and NO_3, SO_4 and NH_4 in post monsoon, whereas in winter it correlates additionally with EC, SO_2 and NO_2. It indicates that at Dhaula Kuan vehicle activities are dominant. High correlation between OC-EC in winter indicates biomass combustion. Similarly PM_{10} & EC correlate well during the winter indicating Vehicular emission. In post monsoon we observe that correlation coefficient between NH_4 & SO_4 are 0.79 indicating the formation of $(NH4)_2SO_4$.

G. Mayapuri

Mayapuri is low activity kerb side location with large open area. Correlation data presented below shows that PM_{10} does not correlate with almost all parameters in summer (except NO_2, 0.44 and NH_4, 0.59) indicating that road dust /crustal dust dominates the PM_{10}. However, in post monsoon season it correlates well with OC, EC, TC, SO_4 and NH_4. It indicates that combustion sources are dominant and vehicles are not contributing significantly. PM_{10} correlation with gaseous parameters improves in winter due to inversion conditions.

Summer

	PM10	OC	EC	TC	SO2	NO2	NO3	SO4	NH4
PM10	1.00	-0.20	0.02	-0.12	-0.43	0.44	-0.30	-0.41	0.59
OC		1.00	0.93	0.99	0.71	0.66	0.75	0.81	0.44
EC			1.00	0.97	0.54	0.67	0.79	0.74	0.60
TC				1.00	0.65	0.67	0.78	0.79	0.51
SO2					1.00	0.33	0.39	0.61	-0.05
NO2						1.00	0.44	0.31	0.73
NO3							1.00	0.78	0.30
SO4								1.00	0.18
NH4									1.00

Post Monsoon

	PM10	OC	EC	TC	SO2	NO2	NO3	SO4	NH4
PM10	1.00	0.99	0.80	0.98	0.10	0.19	0.04	0.66	0.64
OC		1.00	0.84	1.00	0.13	0.26	0.05	0.61	0.61
EC			1.00	0.89	0.10	0.18	0.15	0.34	0.56
TC				1.00	0.13	0.25	0.07	0.57	0.61
SO2					1.00	0.44	-0.45	-0.11	-0.38
NO2						1.00	-0.60	0.29	-0.08
NO3							1.00	-0.05	0.12
SO4								1.00	0.33
NH4									1.00

Winter

	PM10	OC	EC	TC	SO2	NO2
PM10	1.00	0.81	0.55	0.81	0.54	0.50
OC		1.00	0.64	0.99	0.65	0.50
EC			1.00	0.76	0.66	0.50
TC				1.00	0.69	0.53
SO2					1.00	0.68
NO2						1.00

H. Anand Vihar

Anand Vihar is also a kerb site location near to ISBT. It has very low population, correlation matrix given below indicates that PM_{10} does not correlate with most parameters in summer. However, in post monsoon and winter it shows good correlation with OC, EC, TC, NO_2 and NH_4 (both in post monsoon). The results suggest that PM_{10} is dominated by combustion sources in post monsoon and winter; however, in summer crustal dust sources dominate PM_{10}. High correlation between OC-EC in summer and post monsoon indicate combustion of biomass especially during the winter. Similarly PM_{10} & EC correlate well during the Post monsoon indicating vehicular and other emission. In summer and post monsoon seasons it is observed that correlation coefficients between NH_4 & SO_4 are 0.85 and 0.5 indicating the formation of $(NH_4)_2SO_4$.

Summer

	PM10	OC	EC	TC	SO2	NO2	NO3	SO4	NH4
PM10	1.00	0.31	0.04	0.29	0.09	-0.05	0.70	0.15	-0.01
OC		1.00	0.53	0.99	0.73	0.90	0.62	0.82	0.48
EC			1.00	0.62	0.39	0.48	0.13	0.63	0.55
TC				1.00	0.73	0.90	0.59	0.84	0.51
SO2					1.00	0.78	0.12	0.36	-0.11
NO2						1.00	0.31	0.77	0.46
NO3							1.00	0.58	0.44
SO4								1.00	0.85
NH4									1.00

Post Monsoon

	PM10	OC	EC	TC	SO2	NO2	NO3	SO4	NH4
PM10	1.00	0.73	0.83	0.75	-0.04	0.58	0.11	0.09	0.55
OC		1.00	0.90	1.00	0.35	0.45	0.18	0.20	0.72
EC			1.00	0.92	0.28	0.62	0.20	0.18	0.68
TC				1.00	0.35	0.47	0.18	0.20	0.72
SO2					1.00	-0.15	0.20	0.36	0.21
NO2						1.00	0.33	0.24	0.50
NO3							1.00	0.84	0.68
SO4								1.00	0.50
NH4									1.00

Winter

	PM10	OC	EC	TC	SO2	NO2
PM10	1.00	0.60	0.69	0.75	0.09	0.42
OC		1.00	0.36	0.92	0.61	0.11
EC			1.00	0.71	-0.15	0.18
TC				1.00	0.40	0.16
SO2					1.00	0.14
NO2						1.00

I. ISBT

ISBT is state bus terminus with high vehicle movement; however the region has very low population. Correlation data given below indicates that at this site PM_{10} correlate well with OC, EC, TC, NO_2, SO_4 and NH_4. The data indicates that PM_{10} is due to combustion and vehicular sources. In post monsoon and winter PM_{10} correlates with NO_3 and NH_4. In winter PM_{10} correlate very strongly with EC indicating vehicle domination and some other high temperature combustion. In ISBT summer season we observe that the correlation coefficient between NH_4 and SO_4 is 0.96 indicating the formation of $(NH_4)_2SO_4$. Correlation coefficient between EC & OC are high in both summer and post Monsoon seasons (0.6, 0.5) indicating vehicular and other combustion sources. Similarly OC & NO_2 are highly correlated (0.96) in ISBT which also indicate the presence of vehicular and other combustion sources.

Summer

	PM10	OC	EC	TC	SO2	NO2	NO3	SO4	NH4
PM10	1.00	0.62	0.46	0.62	0.37	0.46	0.24	0.70	0.81
OC		1.00	0.60	0.94	0.51	0.33	0.44	0.37	0.44
EC			1.00	0.84	0.52	0.66	0.52	0.59	0.62
TC				1.00	0.57	0.50	0.52	0.50	0.57
SO2					1.00	0.67	-0.15	0.20	0.22
NO2						1.00	-0.07	0.50	0.62
NO3							1.00	0.64	0.52
SO4								1.00	0.96
NH4									1.00

Post Monsoon

	PM10	OC	EC	TC	SO2	NO2	NO3	SO4	NH4
PM10	1.00	0.49	1.00	0.80	-0.28	0.21	0.64	0.12	0.51
OC		1.00	0.51	0.91	0.69	0.96	0.98	0.92	-0.49
EC			1.00	0.81	-0.27	0.23	0.65	0.13	0.50
TC				1.00	0.34	0.75	0.97	0.69	-0.10
SO2					1.00	0.88	0.56	0.92	-0.97
NO2						1.00	0.89	1.00	-0.73
NO3							1.00	0.84	-0.33
SO4								1.00	-0.79
NH4									0.51

Winter

	PM10	OC	EC	TC	SO2	NO2	NO3	SO4	NH4
PM10	1.00	-0.12	0.91	0.27	0.32	0.43	0.43	0.68	0.37
OC		1.00	-0.34	0.91	0.06	-0.61	0.14	0.03	0.63
EC			1.00	0.09	0.18	0.44	0.45	0.76	0.09
TC				1.00	0.14	-0.45	0.34	0.37	0.70
SO2					1.00	-0.02	0.57	0.33	0.38
NO2						1.00	0.06	0.17	0.11
NO3							1.00	0.88	0.36
SO4								1.00	0.29
NH4									1.00

J. Loni Road

Loni road is a kerb side location, however, the area is dominated by low income residential and commercial activities. The road is dilapidated conditions with poor repair and maintenance. PM_{10} correlated well with OC, EC, TC SO_2 and NO_2 in summer indicating presence of combustion sources as also vehicles. PM_{10} correlation with NO_2 in winter is also indicates influence of vehicles. Crustal components also dominate this site. In summer, PM_{10} is well correlated with SO_2 showing the presence of coal combustion. In winter and post monsoon season it is observed that correlation coefficients between NH_4 and SO_4 is fairly high indicating the formation of $(NH4)_2SO_4$. Similarly during these seasons NH4 and NO_3 correlate well indicating the formation of NH_4NO_3.

Summer

	PM10	OC	EC	TC	SO2	NO2	NO3	SO4	NH4
PM10	1.00	**0.80**	**0.81**	0.81	**0.90**	0.67	0.50	-0.39	0.05
OC		1.00	**0.91**	1.00	0.68	0.57	0.71	-0.35	0.19
EC			1.00	0.93	0.77	0.78	0.61	-0.35	0.29
TC				1.00	0.70	0.60	0.71	-0.36	0.21
SO2					1.00	0.82	0.40	-0.23	0.10
NO2						1.00	0.55	-0.02	0.33
NO3							1.00	0.03	0.19
SO4								1.00	-0.40
NH4									1.00

Post Monsoon

	PM10	OC	EC	TC	SO2	NO2	NO3	SO4	NH4
PM10	1.00	**0.88**	**0.75**	0.87	-0.10	0.42	0.29	0.17	0.43
OC		1.00	**0.93**	1.00	-0.18	0.57	0.52	0.19	0.70
EC			1.00	0.95	-0.21	0.63	0.60	0.23	0.81
TC				1.00	-0.19	0.58	0.54	0.19	0.72
SO2					1.00	-0.13	-0.34	-0.15	-0.16
NO2						1.00	0.40	0.44	0.72
NO3							1.00	0.61	**0.84**
SO4								1.00	**0.50**
NH4									1.00

Winter

	PM10	OC	EC	TC	SO2	NO2	NO3	SO4	NH4
PM10	1.00	**0.58**	0.01	0.58	0.28	0.69	0.15	0.01	-0.03
OC		1.00	0.00	0.99	0.71	0.53	0.27	0.39	0.54
EC			1.00	0.15	-0.10	0.19	-0.63	0.20	-0.14
TC				1.00	0.69	0.55	0.17	0.41	0.52
SO2					1.00	0.73	0.72	0.85	0.85
NO2						1.00	0.52	0.60	0.51
NO3							1.00	0.47	**0.72**
SO4								1.00	**0.62**
NH4									1.00

2.3.12 Comparison of Ten Sites

The particulate and gaseous pollutants were compared for all ten sites. The average concentration of ten sites is presented in **Figure 2.92.**

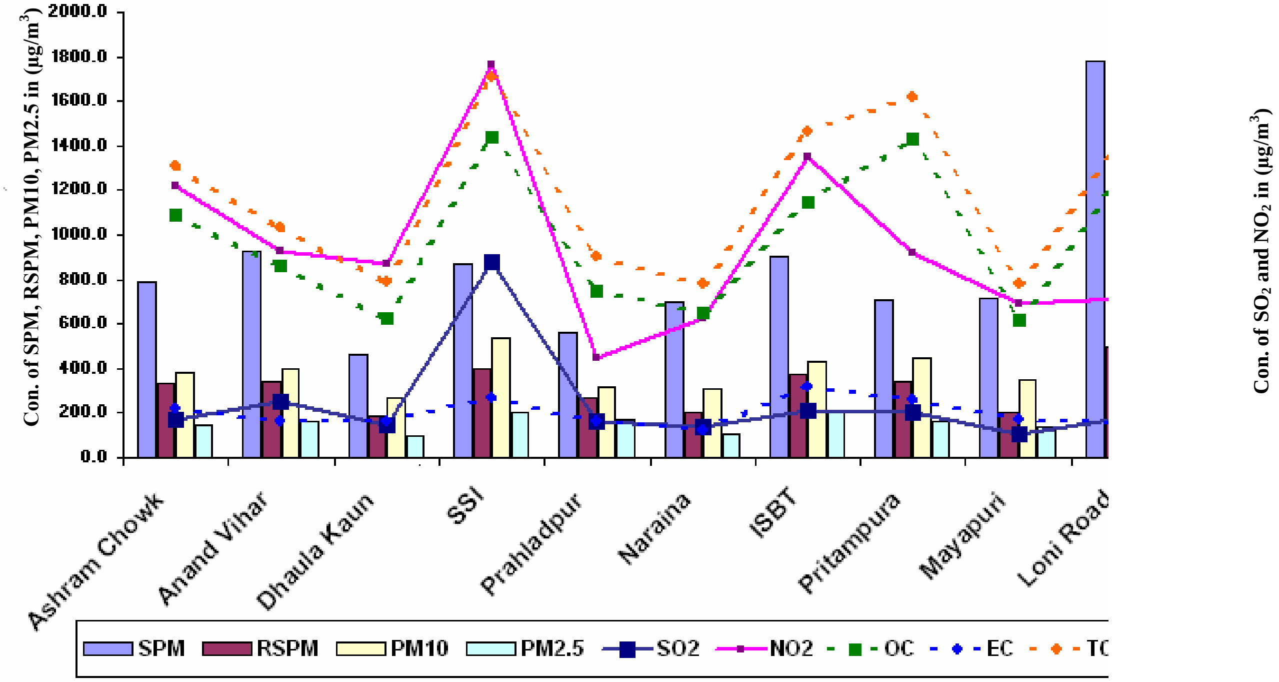


Figure 2.92 : Average Concentration of Particulate and Gaseous Pollutants at Ten Sites

The background site Prahladpur that shows the levels of coarse & fine particulate matter exceeds the standard. Similarly in all remaining sites as well, same trend for particulate pollution has been noticed. SPM concentration were highest in Loni, followed by Anand Vihar, ISBT, SSI, whereas RSPM concentration were higher at Loni, SSI and ISBT at other sites similar trends were observed. Being a Kerb site (Loni Road) and industrial and SSI shows high concentration of PM_{10}, and at ISBT, Pitampura it is ranging from 200-400 µg/m^3. Dhaula Kuan shows lowest PM_{10} concentrations. At all sites $PM_{2.5}$ concentrations are exceeding the USEPA standard 35 µg/m^3. Whereas the criteria pollutant NO_2 exceeded than the CPCB standard value at Karb site ISBT, Ashram Chowk it's a clear indication that vehicular movement is more at this site. Being an industrial site (SSI) NOx concentration is high. Whereas, in remaining in all seven locations the levels of NO_2 & SO_2 are within the limit as per the CPCB norms.

Figure 2.93 presents the carbonaceous concentrations at ten sites.

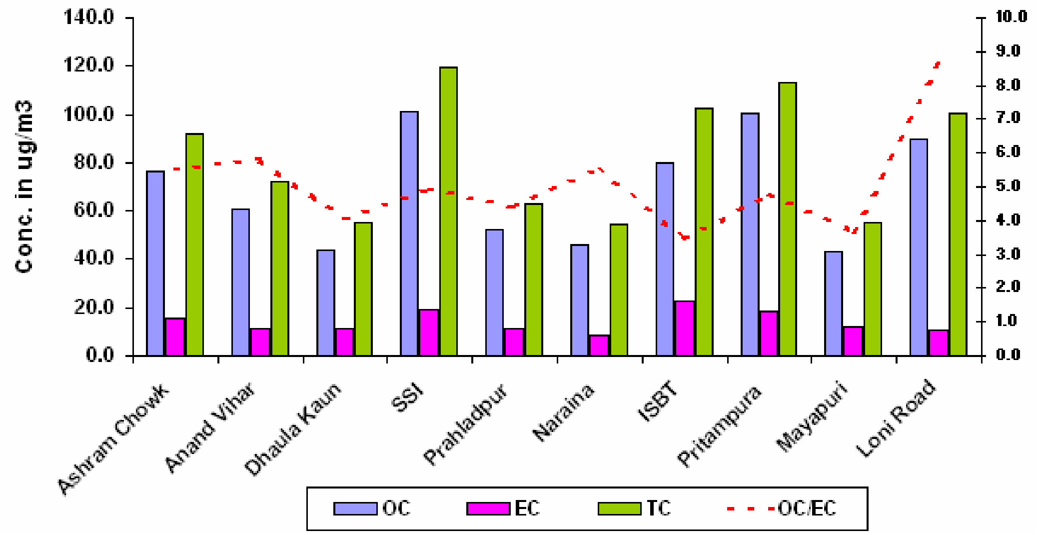


Figure 2.93 : Average Concentration of Carbonaceous Species in PM_{10}

Higher OC concentrations observed at SSI followed by Pitrampura, ISBT, Loni Road and Ashram Chowk, whereas lower at Dhaula Kuan, Naraina and Mayapuri. Higher EC concentration were observed at ISBT, SSI and lowest at Naraina. The OC/EC ratio maximum at Loni followed by Naraina and Anand Vihar, lowest at ISBT and Mayapuri. The major sources of carbonaceous species are basically from refuse burning activities, vehicular movement resupension of dust, high temperature fuel oil combustion. The concentrations of carbonaceous species are higher in fine fractions.

2.3.13 Mass Closure at Ten Sites

Mass closure analysis has been performed for all sites with a view to understand the percent contributions from multiple sources. Mass fraction of elements, ions and carbons with unidentified fraction in PM_{10} is presented in **Table 2.24**.

Table 2.24: Percent Mass Contribution at Ten Different Sites

	Prahladpur			Pitampura			Naraina			SSI- GTK		
	S	PM	W	S	PM	W	S	PM	W	S	PM	W
EC	3.2	4.2	3.3	7.0	3.3	4.9	4.9	3.1	1.6	4.3	3.7	2.7
OC	14.1	33.7	19.5	20.2	41.5	23.5	20.2	25.0	18.2	15.4	30.7	24.4
Crustal	13.7	23.2	11.2	13.3	14.5	18.5	24.0	21.0	22.4	14.5	13.2	10.4
Non Crustal	7.0	6.0	2.8	5.4	2.2	2.3	3.2	3.0	1.9	3.3	2.3	2.8
Ions	35.8	27.5	44.6	42.4	32.8	35.0	30.7	38.2	31.7	29.3	35.6	31.5
Unidentified	26.3	5.4	18.6	11.7	5.7	15.8	17.0	9.7	24.0	33.2	14.5	28.2

	Ashram Chowk			Dhaula Kuan			Mayapuri			Anand Vihar		
	S	PM	W	S	PM	W	S	PM	W	S	PM	W
EC	6.5	2.9	3.4		6.7	2.8	3.8	3.9	2.8	1.9	2.0	
OC	14.7	37.6	27.1		24.1	21.9	12.4	21.1	18.7	14.3	23.7	
Crustal	29.3	22.7	18.1		26.7	13.3	5.2	19.7	11.3	28.5	20.7	
Non Crustal	3.3	2.2	2.4		2.6	2.1	3.1	2.1	1.4	7.5	3.3	
Ions	20.3	25.0	26.7		23.7	38.1	39.5	34.1	20.2	10.6	27.1	
Unidentified	25.8	9.6	22.4		16.2	21.8	36.0	19.1	45.6	37.3	23.2	

***** S & W – Data not available

	ISBT			Loni Road		
	S	PM	W	S	PM	W
EC	14.1	3.6	4.8	2.0	1.0	2.4
OC	28.1	30.4	19.1	16.2	20.4	17.2
Crustal	26.7	10.2	13.3	19.3	16.2	34.9
Non Crustal	3.7	1.6	1.6	2.5	2.4	3.8
Ions	17.6	14.7	28.8	26.8	16.1	30.1
Unidentified	9.8	39.4	32.4	33.3	43.9	11.7

- **Prahladpur**, representing background site has maximum contribution from carbonaceous fraction (OC and EC) during post monsoon season due to various activities like biomass burning. Non-crustal fraction contributes marginally in winter season; however, contribution from ionic fraction is maximum in winter.
- **Pitampura**, representing residential site, contribution of OC is more in Post monsoon and winter season as compared to summer season. Ions contribute maximum to particulate matter load in summer. Maximum portion of PM_{10} remains unidentified in winter.
- **Naraina**, a mixed-use site, OC fraction has maximum contribution in Post monsoon due to biomass burning, fuel oil combustion activity etc. Crustal elements have more contribution in summer season due to favorable meteorological conditions. Due to high humidity in Post monsoon, ions contribution is maximum in this season. Maximum portion of PM_{10} remains unidentified in winter.

- **SSI**, an industrial area has maximum contribution of OC in winter season due to various activities like coal combustion, heavy vehicular traffic etc. Crustal elements have highest concentration in summer due to high wind speed. Due to high humidity, ionic species make up maximum portion of coarse particulate matter in Post monsoon season.
- **Ashram Chowk**, a kerbsite, OC contributes maximum in Post monsoon and winter season due to meteorological conditions like low wind speed and lower mixing height. Due to high wind speed, crustal fraction comprising of road dust contributes maximum in summer. Different ions contribute to a greater extent to total PM load in winter.
- **Dhaula kuan** has comparatively more contribution from OC and Crustal elements due to high vehicular exhaust and resuspended road dust respectively. Ions and unidentified portion's contribution is comparatively more in winter season.
- **Mayapuri**, a kerbsite, has maximum contribution from carbonaceous fraction (OC and EC) in Post monsoon. Ions and non-crustal elements contribute maximum to total PM load in summer. Due to aerosol bound water, unidentified portion is maximum in winter.
- In case of **Anand Vihar**, greater OC contribution is in Post monsoon season. Road dust contribution is more in summer due to meteorological conditions. Due to humid atmosphere, contribution of ions is more in Post monsoon as compared to summer season.
- **ISBT**, being a kerbsite, maximum contribution is from organic carbon in all the three seasons. Crustal elements have more contribution in summer season due to high wind speed that makes the soil dust airborne. Ions form a predominant portion of coarse particulate matter at this site in winter season. Unidentified portion is highest in Post monsoon probably due to high humidity resulting in more quantity of aerosol bound water.
- **Loni road** has major OC contribution in post monsoon season. In case of maximum contribution of crustal fraction is observed in winter season. Ions amount for a major portion of particulate matter in winter season. Due to aerosol bound water and analytical errors unidentified portion is higher in post monsoon.

Air quality of ten sites varies due to site characteristics, population density, topography and meteorology of different seasons.

2. 3.14 Molecular Marker Analysis

The PM samples of all sites were analysed for molecular markers. These markers are signature molecules which indicate the sources bases on their presence as also on their abundances. Their presence and absence indicates the impacts of sources close to the site or away. Representative samples from all 10 sites were analysed at Desert Research Institute, Nevada. Table 4.3 presents the summary of the major markers found at various sites in Delhi. The variation of markers with respect to the reference site Prahladpur, ratios of all markers have been presented in **Table 2.25.** To understand the levels at which their abundances are at all the locations, ratio of different molecular marker levels with respect to reference site, Prahaladpur was computed as shown in **Table 2.26.**

Table 2.25 : Average Concentration of Molecular Marker (in ng/m^3) for all three seasons

	Anand vihar	Ashram Chowk	Dhaulakuan	ISBT	Loni Road	Mayapuri	Naraina	Pitampura	Prahladpur	SSIGTK
PAHs	9.2	7.5	4.0	5.8	9.7	2.2	8.0	7.7	14.9	12.3
n-alkane	37.0	27.7	20.9	23.3	33.8	9.1	34.4	33.8	44.8	65.9
Hopane	2.9	2.4	1.9	1.8	2.6	1.6	1.7	2.2	1.4	3.7
Sterane	2.3	1.3	1.1	1.0	1.8	0.7	1.1	1.3	1.0	2.7
Methyl-alkane	0.4	0.4	0.3	0.4	0.4	0.2	0.3	0.4	0.2	0.7
Branched-alkane	1.7	1.4	1.2	1.1	1.1	0.7	0.9	0.9	1.2	3.1
Cycloalkane	0.9	0.8	0.5	0.8	1.3	0.3	0.8	0.8	1.9	2.4
Alkene	5.9	6.8	3.1	7.5	17.3	1.7	10.5	9.6	6.2	23.4
Levoglucosan	2798.0	3250.4	1690.2	2296.4	3812.5	1130.4	4578.0	4877.3	4310.4	3810.4

Table 2.26: Ratio of Markers and their Variation with reference Station Prahaladpur

	Anand vihar	Ashram Chowk	Dhaulakuan	ISBT	Loni Road	Mayapuri	Naraina	Pitampura	SSIGTK
PAHs	0.6	0.5	0.3	0.4	0.6	0.1	0.5	0.5	0.8
n-alkane	0.8	0.6	0.5	0.5	0.8	0.2	0.8	0.8	1.5
Hopane	2.1	1.8	1.4	1.3	1.9	1.2	1.3	1.6	2.7
Sterane	2.2	1.3	1.1	0.9	1.7	0.7	1.1	1.2	2.6
Methyl-alkane	1.9	1.8	1.3	1.8	1.9	0.9	1.4	1.7	3.7
Branched-alkane	1.5	1.2	1.0	1.0	1.0	0.6	0.8	0.8	2.6
Cycloalkane	0.5	0.4	0.3	0.4	0.7	0.1	0.4	0.4	1.3
Alkene	1.0	1.1	0.5	1.2	2.8	0.3	1.7	1.6	3.8
Levoglucosan	0.6	0.8	0.4	0.5	0.9	0.3	1.1	1.1	0.9

As can be seen from the tables above, the variation is random in most of the places. However, the presence of hopanes and steranes at all the sites in much higher quantities compared to Prahaladpur indicates that vehicles effect is prevalent at all sites of Delhi. Even residential location such as Pitampura shows much higher values of these vehicular markers compared to Naraina and ISBT. The marker for biomass burning “Levoglucosan” is found to be highest at residential site of Pitampura followed by Naraina, Prahaldpur and SSI-GTK. It clearly indicates that large amount of biomass burning is prevalent all across Delhi and adjoining areas. **Figure 2.94** depicts the variation in levels for all sites. It shows lowest biomass burning at Mayapuri. N-Alkane and Alkene values were highest at SSI-GTK which could be attributed to industrial processes present in the industrial area.

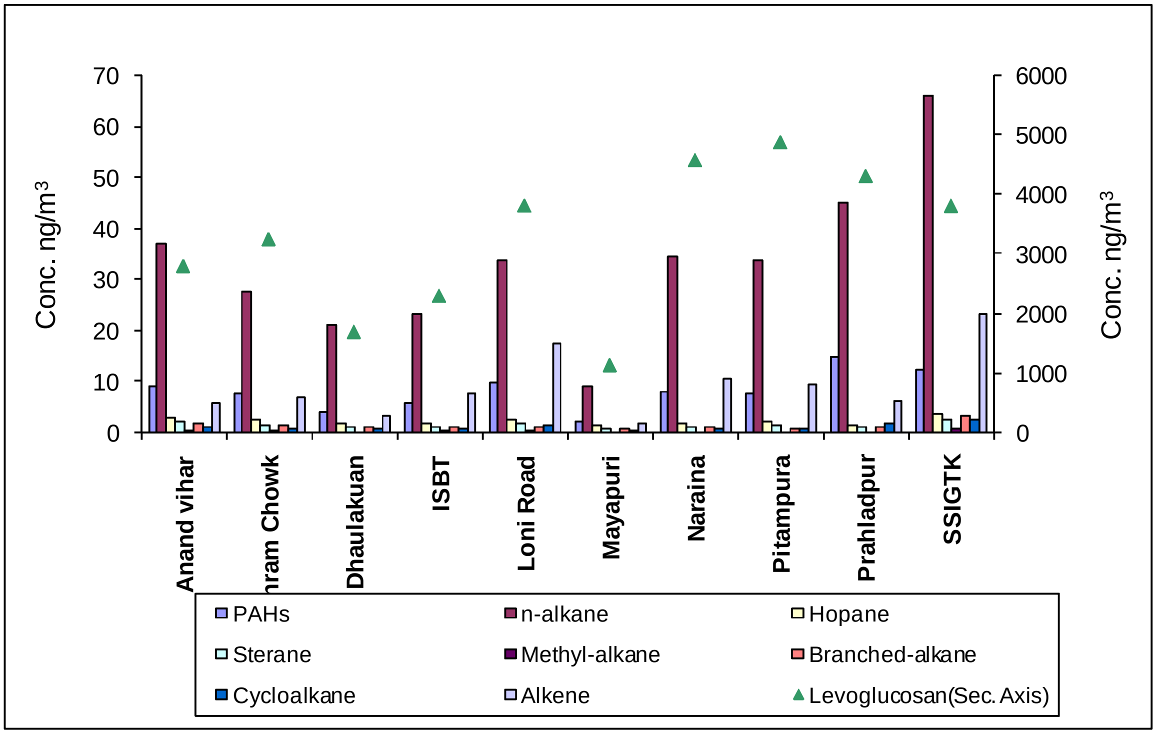


Figure 2.94: Molecular Markers Concentrations at all Sites in Delhi

2.4 Summary

The data analysis based on monitoring carried out at 10 locations show large variability. Respirable Particulate Matter levels are in the range of 200-500 µg/m^3, and do not meet the standards at most of the places. Whereas gaseous pollutants such as SO_2 meet standards at all locations. NO_3 in PM10 should normally be less at the reference station as compared to kerbside , but in case of Delhi, NO_3 is high at reference location, due to nearby agricultural and fertiliser application activities. However, NO_2 levels have exceeded at all the kerbside locations, where the vehicular activities are intense but the same is well within the CPCB standards at reference.

Monitoring data was also analyzed for carbonaceous fractions along with crustal, non-crustal and ionic components. All these provide ample information about local sources as also possible transported sources at the site. The monitored values amply indicate that all kerb sites do not necessarily show signs of kerb sites as many of them are with moderate activities and in residential and open spaces. Correlations of PM with gaseous pollutants are limited in many locations as the latter is not always correlated with similar sources contributions of PM. Secondary PM formations are noticed at few locations and in certain seasons.

Seasonal variation indicates that values are normally higher in winter and post monsoon (as this sampling is close to winter months) compared to summer. This fact is also corroborated with meteorology data collected during the study as also from IMD.

Molecular marker analyses of samples from all locations provide glimpses of marker elements of sources present in the city. Biomass burning and vehicles related markers prominently indicate the places of high occurrences.

Chapter 3 describe the emission loads for all sources based on primary and secondary data collected for 10 sites as also for the whole city.

Chapter 3

Emission Inventory

3.0 Introduction

Air quality of a region is influenced by various sources present and their emission rates. Identification and quantification of various sources are necessary to link them with the existing air quality levels measured at certain locations as well as predict air quality at various locations. It helps in assessing the impact of additional nearly sources in and around the region and also to evaluate the control strategies for certain emission sources. Air pollution sources are broadly categorized as area (domestic and fugitive combustion type emission sources), industrial (point) sources and vehicular (line) sources. In the present study, various emission sources divided under these three broad categories are given below in **Table 3.1**.

Table 3.1: Source Categories and Types of Sources of Air Pollution

Source Category	Types of Sources
Area Sources	• Domestic cooking & heating • Burning of waste derived fuels • Bakeries • Crematoria • Hotels & Restaurants • Open eat outs • Open burning (refuse/biomass/ tyre etc. burning) • Paved & unpaved roads, Construction/Demolition/ Alteration activities for buildings, roads, flyovers • Waste Incinerators • DG Sets
Point Sources	• Large scale industries • Medium scale industries • Small scale industries
Vehicular Sources	• 2 Wheelers (Scooters, Motor Cycles, Mopeds) • 3 Wheelers (CNG) • 4 Wheelers (Gasoline, Diesel, CNG) • LCVs (Light Commercial Vehicles) • Trucks (Trucks, min-trucks, multi-axle trucks) • Buses (Diesel, CNG)

Emission inventory of different sources of air pollution has been prepared for the ten Study Zones of 2 km x 2 km size around the air quality monitoring sites. This emission inventory has been used to estimate through extrapolation method for total emissions for the whole of the city. The main purpose of 2 km x 2 km study zones is to accurately identify and quantify emissions from different sources to be used to predict air quality in the study zones and compare the predicted air quality levels with the measured air quality levels. Emission inventory has been prepared in terms of five major pollutants, viz. PM_{10}, SO_2, NOx, CO and HC.

In this chapter, emission inventory of ten study zones with respect to three broad source categories viz. area, industrial and vehicular sources is presented. Emission inventory of different sources for the city level has been presented in the later part of the chapter.

3.1 Emission Inventory of 2 km x 2 km Study Zones

The ten identified Study Zones of 2 km x 2 km around the air quality monitoring stations are Ashram Chowk, Dhaula Kuan, Mayapuri (Lajwanti Garden), ISBT (Ring Road), Loni Road, Anand Vihar, Naraina, SSI-GTK, Pitampura and Prahladpur. The characteristics of these study zones are described earlier in **Chapter 2**.

3.1.1 Emission Inventory: Area Sources

In addition to industries and automobiles, burning of different types of fuels (solid, liquid & gaseous) and waste materials in domestic as well as commercial sectors air pollution in urban regions. Most of the domestic coal burning in urban region is observed in slum areas. However, changing pattern is now being observed as there is rapid increase in the use of LPG as cooking fuel. Due to phenomenal increase in population, there is a requirement for adequate civic services, infrastructure and urban development in Delhi. Delhi is emerging as a major player in international centers of education, health care, tourism, sports and business, which require complimentary facilities such as hotels, restaurants and bakeries catering to various economic groups. All these activities contribute to air pollution from area sources in Delhi.

3.1.1.1 Approach and Methodology

In the area source inventory of domestic sector, the emissions from residential fuel combustion are considered and in commercial sector, emissions from different sources such as hotels, restaurants, bakeries, crematoria have been considered. Besides emissions from solid waste, combustion, open burning, medical waste burning, generator sets, construction activities etc. are also accounted for. Data on area source activities were collected from various Government and Non-Government departments/agencies. The required information was collected through interviews with the concerned authorities/ persons in respective activities. In addition, fuel consumption data and related information were obtained through primary surveys of residences, hotels, restaurants, crematoria etc in the study zones (2 km x 2 km area) around each of the ten AQM stations. Data collected on various source categories were analyzed. The emissions from various activities were estimated by applying CPCB recommended compilation of data from various sources emission factors.

3.1.1.2 Collection of Secondary Data

Secondary data relating to various area sources was collected from different agencies. The type of information and their sources are listed in **Table 3.2**.

Table 3.2: Type and Sources of Information for Area Source Emission Inventory

Information collected	Source of information
District/ward wise map and population distribution & registered deaths	Office of Registrar General
Total number of households and their fuel consumption viz. LPG, kerosene, wood etc. for cooking and lighting purposes	Office of Registrar General
Location and number of slum households	Slum and JJ Wing of MCD
Details of crematoria (location, number of dead bodies burnt etc.	Health department of MCD, NDMC, DCB, Department of Economics and Statistics
Solid waste and Hospital waste incinerators (number, capacity, type and consumption of fuel etc), open burning of waste	MCD, DPCC
Hotels, restaurants, eating houses, dhabas (number, capacity and type)	MCD, NDMC, Office of Commissioner of Excise, Entertainment & Luxury Taxes, Association of Hotels/Restaurants, Department of Economics and statistics
Bakeries (names and locations)	MCD, Directorate of small scale Industries, Bakery association
Commercial generators set (capacity, number and fuel consumption)	Generator set manufacturers/suppliers
Number and location of co-operative societies	Registrar of co-operative societies
Road and building construction activities	PWD, MCD
Diesel locomotives (Number, trips, consumption of diesel)	Northern Railways
Fuel supply data (LPG, NG, Kerosene etc.)	PPAC, IOCL, Food and Consumers Department, IGL

In addition, data on annual fuel consumption with respect to various fuels were collected from Petroleum Planning and Analysis Cell (PPAC, New Delhi) for the period 2001-02 to 2006-07. Information on PNG consumption was collected from Indraprastha Gas Limited (IGL)

3.1.1.3 Collection of Primary Data

Primary data on demographic profile and fuel consumption in various activities/ sources such as household cooking, hotels, restaurants, bakeries, crematoria, medical waste incinerators, generator sets and related information on solid waste disposal, construction activities were obtained in the prescribed format through primary survey in the study zones around each of the AQM stations. Household surveys have been conducted using questionnaires given in **Annexure III** (**Form A3.1)**, which include information on total number of persons in family, type and usage of different fuels, power failure and use of generator sets and socio-economic details. Surveys in commercial sectors were conducted using questionnaires given in **Annexure III** (**Form A3.2),** which included number of sources and related information, and fuel consumption data for various other area source activities.

3.1.1.4 Data Analysis and Emission Load Estimation

Data collected on various source categories in each of the study zones was analyzed with respect to type of fuels, operating hours, fuel use pattern, diurnal and seasonal variation for the following:

- Estimation of population in each 2 km x 2 km study zone
- Estimation of slum population in each 2 km x 2 km study zone
- Estimation of fuel consumption in different types of source categories in each 2 km x 2 km study zone
- Comparison of fuel consumption in summer and winter seasons
- Identification of land use based on Eicher Map of Delhi City, available in 500 m x 500 m grid size
- Estimation of emission load in terms of five major pollutants, viz. PM10, $SO_{2,}$ NOx, CO, and HC in each of the 2 km x 2 km study zones using collected data on each category of source and applicable emission factors.
- Estimation of emission load from open burning (based on quantity estimation/ visual observations)
- Estimation of PM10 load due to construction activities in each study zone
- Estimation of percent emission contribution (in terms of PM10, $SO_{2,}$ NOx, CO, and HC) for each source category in each of the study zones.
- Preparation of overall average fuel consumption and emission scenario based on the data collected for the ten 2 km x 2 km study zones

3.1.1.5 Emission Factors

A wide variety of emission factors (EFs) are available depending upon the type of fuel, combustion process, control system installed etc. CPCB recommended /available emission factors from various studies/reports for various types of fuels and combustion processes were used for estimation of emission load. Since, emission factors were not provided for LPG in domestic sector, the emission factors reported in EPA study (2000) conducted for measurement of emissions from fuel combustion in household cooking stoves in India were used for estimating emissions. In case of any particular pollutant for which emission factor is not available, emission factor from AP-42 (2000) has been used for calculations. The emission factors used in the emission load calculations are summarized in **Annexure III.**

3.1.1.6 Data Analysis

Results of analyzed data presented in **Table 3.3** indicate that the areas surrounding Loni Road and Pitampura AQM sites are having population of about one lakh. Slum population was observed near Naraina, SSI and Ashram Chowk sites. More than 30000 slum residents were found to inhabit near Naraina and SSI-GTK sites. Photograph of slums present near Naraina site is shown in **Plate 3.1**.

Table 3.3: Various Types of Area Sources around AQM Locations

AQM Location	Population	Slum population	Sources							
			Hotels & Restaurants	Dhabas & Sweet Shops	Bakeries	Crematoria	Open Burning	Gen sets	Medical Waste Incinerator	Locomotive
Ashram Chowk	62508	4495	14	-	-	-	300 kg	1236	-	3
ISBT	27481	-	7	-	-	-	-	927	-	-
Dhaula Kuan	20623	-	10	-	-	-	-	985	-	-
Mayapuri	60373	-	12	9	1	-	-	427	-	-
Anand vihar	25416	-	14	-	-	-	250 kg	129	-	-
Loni Road	117317	-	9	-	-	-	-	276	-	-
Pitampura	95472	-	19	-	2	-	-	860	-	-
SSI-GTK	20781	33020	-	-	-	-	-	513	-	14
Naraina	43464	30817	14	4	1	-	-	875	-	38
Prahladpur	28817	-	-	6	-	-	-	407	-	-

- Hotels/ restaurants and Dhabas are situated in the study zones of almost all the sites. Photograph of street vendors observed at Loni Road site is shown in **Plate 3.2.**
- No crematorium was observed near any one of the AQM locations. No medical waste incinerator and solid waste disposal facility was found near any one of the sites.
- During the period of power cuts, generator sets are operated in residential co-operative societies as well as commercial shops. Various capacities of generators sets are used depending on the requirement of power.

- Open burning was observed during survey at Ashram Chowk and Anand Vihar. A photograph of open burning at Ashram Chowk is shown in **Plate 3.3**.
- Diesel locomotives are plying for carrying goods near Ashram Chowk, Naraina and Anand Vihar locations.

Plate 3.1: Slums near Naraina Site

Plate 3.2: Street Vendors Stalls at Loni Road

Plate 3.3: Open Burning around Ashram Chowk Site

3.1.1.7 Emission Load Estimation

Based on the fuel consumption and applicable emission factors, emission load from different types of area sources in each of the study zones has been estimated as discussed in the following sub-sections.

I. Domestic Sector

Based on the information collected from households survey in different areas in the study zones around the AQM sites, it was observed that LPG is the major fuel used in domestic sector. Besides, PNG, Kerosene, Coal, Wood and Dung Cakes etc. are also used as fuels in households as a source of heat energy. Slums were observed near Naraina, Anand Vihar, SSI-

GTK, Loni Road and Ashram Chowk sites. More than 5000 slum households are located near Naraina and SSI-GTK sites. Coal and kerosene are the major fuels used by slum population. Use of dung cake by the population residing near Loni road site was observed. The average consumption of various fuels (LPG, PNG, Kerosene, Coal, Wood and Dung Cakes) per family was estimated based on the information collected from households survey at each site. Per capita consumption of LPG ranged from 0.066-0.32 kg/day, with maximum at Anand Vihar site. Kerosene consumption ranged from 0.002-0.026 litre per capita per day, with the highest at Prahladpur. Per capita consumption of coal ranged from 0.004-0.13 kg/day. Wood consumption ranged from 0.005-0.029 kg per capita per day, with the highest at Loni road. Use of dung cake by the population, residing near Loni road site at the rate of 0.052 kg per capita per day was observed. PNG at the rate of 1.80 scm per capita per day was mostly used by the residents near Ashram Chowk. Estimated emissions from fuel combustion in residential areas and slums in the study zones around the AQM sites are presented in **Table 3.4 and Table 3.5.**

Table 3.4: Emissions from Residential Fuel Combustion

AQM Location	Pollutant Emission (kg/day)				
	PM10	SO_2	NOx	CO	HC
Ashram Chowk	24.2	12.9	18.1	153.3	104.7
ISBT	1.9	0.0	11.3	54.1	67.9
Dhaula Kuan	1.3	0.0	7.6	36.6	45.9
Mayapuri	12.5	0.5	22.7	176.7	147.3
Anand vihar	4.2	0.0	25.3	121.4	152.1
Loni Road	68.1	4.9	57.4	786.9	529.2
Pitampura	6.7	0.0	40.7	195.2	244.7
SSI-GTK	1.3	0.3	7.5	40.0	45.6
Naraina	5.9	1.1	17.4	118.5	109.4
Prahladpur	10.3	4.5	11.4	132.4	76.8

Table 3.5: Emissions from Fuel Combustion in Slums

AQM Location	Pollutant Emission (kg/day)				
	PM10	SO_2	NOx	CO	HC
Ashram Chowk	21.94	3.46	3.60	168.45	45.72
ISBT	-	-	-	-	-
Dhaula Kuan	-	-	-	-	-
Mayapuri	-	-	-	-	-
Anand vihar	-	-	-	-	-
Loni Road	-	-	-	-	-
Pitampura	-	-	-	-	-
SSI-GTK	202.55	29.38	30.95	1515.49	406.60
Naraina	125.59	19.30	20.33	958.90	262.80
Prahladpur	-	-	-	-	-

ii. Hotels / Restaurants / Dhabas

Hotels/restaurants and Dhabas are located more in the area such as Pitampura, Anand Vihar, Naraina and Ashram Chowk sites as compared to other sites. In hotels & restaurants, commercial grade LPG cylinder of 17.9 Kg capacity is mostly used. In dhabas, mostly coal is used in tandoor. Consumption of coal in Dhabas is around 20-30 Kg/day. Estimated emissions from hotels, restaurants, sweet shops, dhabas etc. are summarized in **Table 3.6.**

Table 3.6: Emissions from Hotel & Restaurants

AQM Location	Pollutant Emission(kg/day)				
	PM10	SO_2	NOx	CO	HC
Ashram Chowk	0.04	0.01	0.07	0.35	0.29
ISBT	0.01	0.00	0.07	0.29	0.36
Dhaula Kuan	0.02	0.00	0.11	0.49	0.62
Mayapuri	5.47	3.64	1.15	7.07	3.19
Anand vihar	3.33	2.20	1.00	4.40	1.73
Loni Road	0.72	0.14	0.21	0.99	1.02
Pitampura	15.22	10.43	3.11	19.30	8.41
SSI-GTK	-	-	-	-	-
Naraina	0.05	0.01	0.27	1.19	1.49
Prahladpur	0.46	0.01	0.05	3.48	0.82

iii. Bakeries

Bakeries are found near Pitmapura, Naraina and Mayapuri locations. Based on the information collected during survey and discussions held with the authorities of Bakery Association, it was noticed that most of the bakeries use wood as a fuel and average wood consumption in each bakery is approximately 50 kg/day. Based on the above information, emissions from bakeries were estimated and presented in **Table 3.7.**

Table 3.7: Emissions from Bakeries

AQM Location	Pollutant Emission (kg/day)				
	PM10	SO_2	NOx	CO	HC
Ashram Chowk	-	-	-	-	-
ISBT	-	-	-	-	-
Dhaula Kuan	-	-	-	-	-
Mayapuri	0.86	0.01	0.07	6.31	5.73
Anand vihar	--	--	--	--	--
Loni Road	--	-	---	--	--
Pitampura	1.73	0.02	0.13	12.63	11.45
SSI-GTK					
Naraina	0.86	0.01	0.07	6.31	5.73
Prahladpur	-	-	-	-	-

iv. Crematoria

Air pollutants are emitted as a result of wood burning in crematoria. No crematorium was found to be located in the study zone of 2 km x 2 km around any one of the AQM locations. Hence, no emissions were estimated. However, it was observed that crematorium at Nigambodh Ghat is located at about half km away from study zone of the ISBT AQM site.

V. Waste Incinerators

Air pollutants are also emitted from incineration of waste in incinerators. Discussions with DPCC officials revealed that there are three private agencies duly approved by DPCC Delhi, namely Synergy Waste Management Company, Biocare Technology Services Limited and M/s Symbarkey Pvt Ltd which have provided facility for treatment of biomedical waste. These units collect waste from the hospitals/dispensaries in the city. First two units operate at Nangloi and Samaipur while the third one operates outside Delhi. Since no medical waste incinerator was located in the study zone around any one of the AQM stations, no emissions were estimated.

VI. Generator Sets

Due to power shortage in Delhi and hence, power cuts have become a routine affair in the city. During the power cut periods, generator sets are operated in residential co-operative societies as well as commercial establishments. Some co-operative societies situated in Sahibabad (Uttar Pradesh) area partly fall in study zone at Anand Vihar location. While on an average, 2-3 hrs of power failure is commonly reported in most of the parts of Delhi, it was about 6-8 hrs in Sahibabad area. Various capacities of generators sets are used depending on the requirement of power. As information on exact number of generator sets around AQM sites was not available, total number of generator sets used in residence is assumed to have been uniformly distributed, based on the survey data, in proportion to population distribution. Based on the data on number of flats in co-operative societies and information on generator sets during the survey, and the data on registered co-operative societies in Delhi, number of generator sets in co-operative societies was estimated. For estimation of number of generator sets in commercial establishments, ratio of gensets and population was applied, assuming that all the commercial shops have generator sets. Total number of commercial establishments in Delhi was taken from Delhi Statistical Handbook, 2006. Based on the number of generator sets and power failure hours, emissions from generator sets were estimated. Estimated emissions from residential as well as commercial generator sets are presented in **Table 3.8.**

Table 3.8: Emissions from Generator Sets

AQM Location	Pollutant Emission (kg/day)				
	PM10	SO_2	NOx	CO	HC
Ashram Chowk	7.7	7.2	109.2	23.6	8.7
ISBT	7.4	6.9	105.0	8.4	22.7
Dhaula Kuan	3.6	3.4	51.0	11.0	4.1
Mayapuri	1.6	2.5	20.0	20.8	10.1
Anand vihar	20.8	20.1	300.3	66.4	9.7
Loni Road	0.2	1.3	0.8	2.0	5.3
Pitampura	5.2	4.8	73.4	5.9	15.9
SSI-GTK	4.4	4.1	61.9	13.4	4.9
Naraina	5.6	16.4	59.6	212.2	65.7
Prahladpur	1.7	1.6	24.5	5.3	2.0

vii. Solid Waste Disposal/Open burning

Information on solid waste disposal in Delhi was obtained from MCD. Delhi has three landfill sites at Gazipur, Okhla and Bhalsawa where municipal solid waste is disposed off. None of the landfill sites are situated near any one of the AQM stations. Moreover, open burning of waste is carried out at the landfill sites, as well as near some of the AQM locations, viz. Ashram Chowk and Anand Vihar. Based on information collected, approximate quantity of waste burned in open space at Ashram Chowk and Anand Vihar is considered for emissions calculations. Emissions from open burning are estimated and given in **Table 3.9**.

Table 3.9: Emissions from Open Burning

AQM Location	Pollutant Emission (kg/day)				
	PM10	SO_2	NOx	CO	HC
Ashram Chowk	2.4	0.15	0.90	12.60	6.45
Anand Vihar	2.00	0.13	0.75	10.50	5.38

viii. Construction Activities

Air pollutants emitted from the construction activities mainly comprise of PM_{10}. Building and road construction are two examples of construction activities. During the survey, flyover construction activity was observed at SSI-GTK and Naraina AQM locations. PM10 emissions have been calculated by using PM10 emission factors as per AP-42, 2000. The emission factor used is 1.2 tons of PM10 per acre month of activity.

Data on construction activities were obtained from Public Works Department and Delhi Development Authority. From this data, area and duration of construction were obtained. The area of land disturbed per kilometer was calculated. Finally, acre-months were calculated on the basis of area and duration of construction. Following the above approach, PM10 emission load from road construction activities were estimated. Estimated PM10 emissions from construction activities are presented in **Table 3.10.**

Table 3.10: PM10 Emissions from Construction Activities

AQM Location	PM10 Emission (kg/day)
SSI-GTK	963.76
Naraina	140.38

ix. Diesel Locomotives

Air pollutants are also emitted from diesel locomotives. Diesel locomotives are plying for carrying goods near Ashram Chowk, Naraina and SSI-GTK locations. Information on number of locomotives, diesel consumption and distance traveled in Delhi was obtained from Northern Railways. Length of rail line in respective grids has been calculated from the Eicher map and emission load from diesel locomotives has been estimated using data on number of locos and diesel consumption applying USEPA -1992 emission factors. Estimated emissions from diesel locomotives are given in **Table 3.11**.

Table 3.11: Emission Load from Locomotives

AQM Location	Pollutant Emission (kg/day)			
	PM10	SO_2	NOx	CO
Ashram Chowk	0.085	0.260	3.571	4.532
SSI- GTK	0.215	0.659	9.062	11.501
Naraina	1.144	3.514	48.298	61.291

x. Total Emissions

Total emissions from area source activities in study zones around each AQM site are summarized in **Table 3.12.** Among all the study zones, highest area source emissions in terms of all the five pollutants are estimated at Naraina and SSI-GTK while minimum area source emissions are estimated at Dhaula Kuan.

Table 3.12: Emission Load from Area Source Activities in the study zones

AQM Location	Pollutant Emission Rate (kg/day)				
	PM10	SO_2	NOx	CO	HC
Ashram Chowk	54.2	22.2	134.5	355.2	162.9
ISBT	19.4	6.9	116.3	62.8	90.9
Dhaula Kuan	4.9	3.4	58.7	48.1	50.6
Mayapuri	20.4	6.6	44.0	210.9	166.3
Anand vihar	30.2	22.5	327.4	202.7	169.0
Loni Road	69.0	6.3	58.4	789.9	535.5
Pitampura	139.6	15.3	117.4	233.0	280.4
SSI-GTK	1171.2	34.4	109.4	1580.3	457.1
Naraina	278.4	36.8	97.7	1297.2	445.2
Prahladpur	12.5	6.1	36.0	141.2	79.6

Among the ten study zones, estimated emission load for PM ranges between 4.9 kg/d (at Dhaula Kuan) and 1171.2 kg/d (at SSI-GTK), SO_2 ranges between 3.4 kg/d (at Dhaula Kuan) and 36.8 kg/d (at Naraina), NOx ranges between 36 kg/d (at Prahladpur) and 327.4 kg/d (at Anand Vihar), CO ranges between 48.1kg/d (at Dhaula Kuan) and 1580.3 kg/d (at SSI-GTK), and HC ranges between 50.6 kg/d (at Dhaula Kuan) and 535.5 kg/d (at Loni road).

Combustion in slums shows dominance in contributing to emissions at Naraina, SSI-GTK and Ashram Chowk sites. However, generators are the most dominating sources at most of the sites except at Loni road and SSI-GTK sites. Hotels and restaurants are also contributing to the emissions at Mayapuri and Pitampura sites while diesel locomotives show contribution at Naraina.

Contribution of emissions from different types of fuels used under area source categories (except construction activity) in all the study zones is presented in **Figs. 3.1** through **3.10.** Fuel type based emissions are presented in **Annexure III.** From these figures, it can be seen that LPG is the dominant fuel contributing to pollutant emissions in ISBT, Dhaula Kuan, Mayapuri, Anand Vihar, Loni Road, Pitampura and Prahladpur. Wood and kerosene contribute to pollutant emissions in Naraina, SSI-GTK, Mayapuri and. Ashram chowk. Coal is also contributing to emissions in Ashram chowk, Pitampura, Naraina, Anand Vihar, Mayapuri and SSI-GTK.

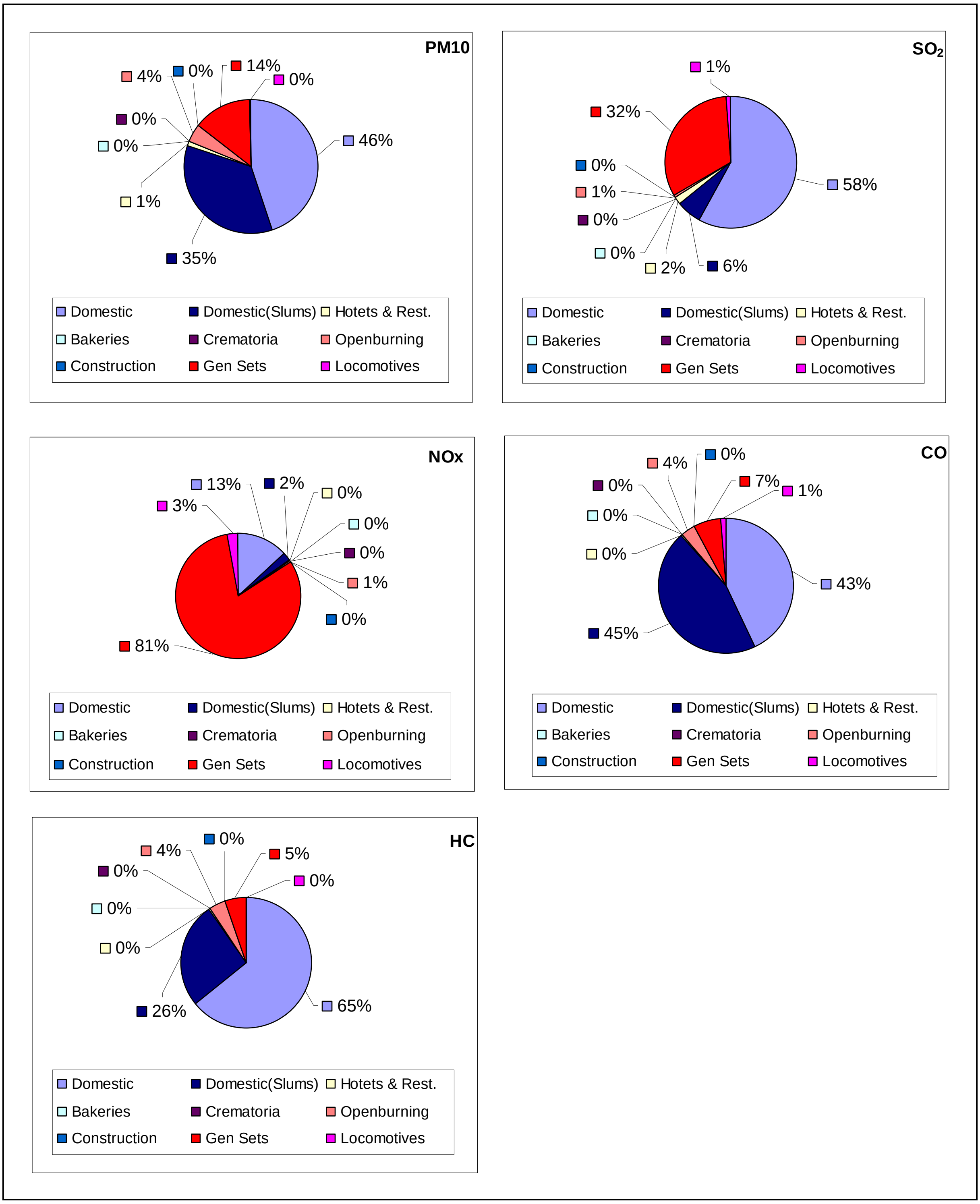


Fig. 3.1: Contribution of Emissions from various Area Source Activities: Ashram Chowk

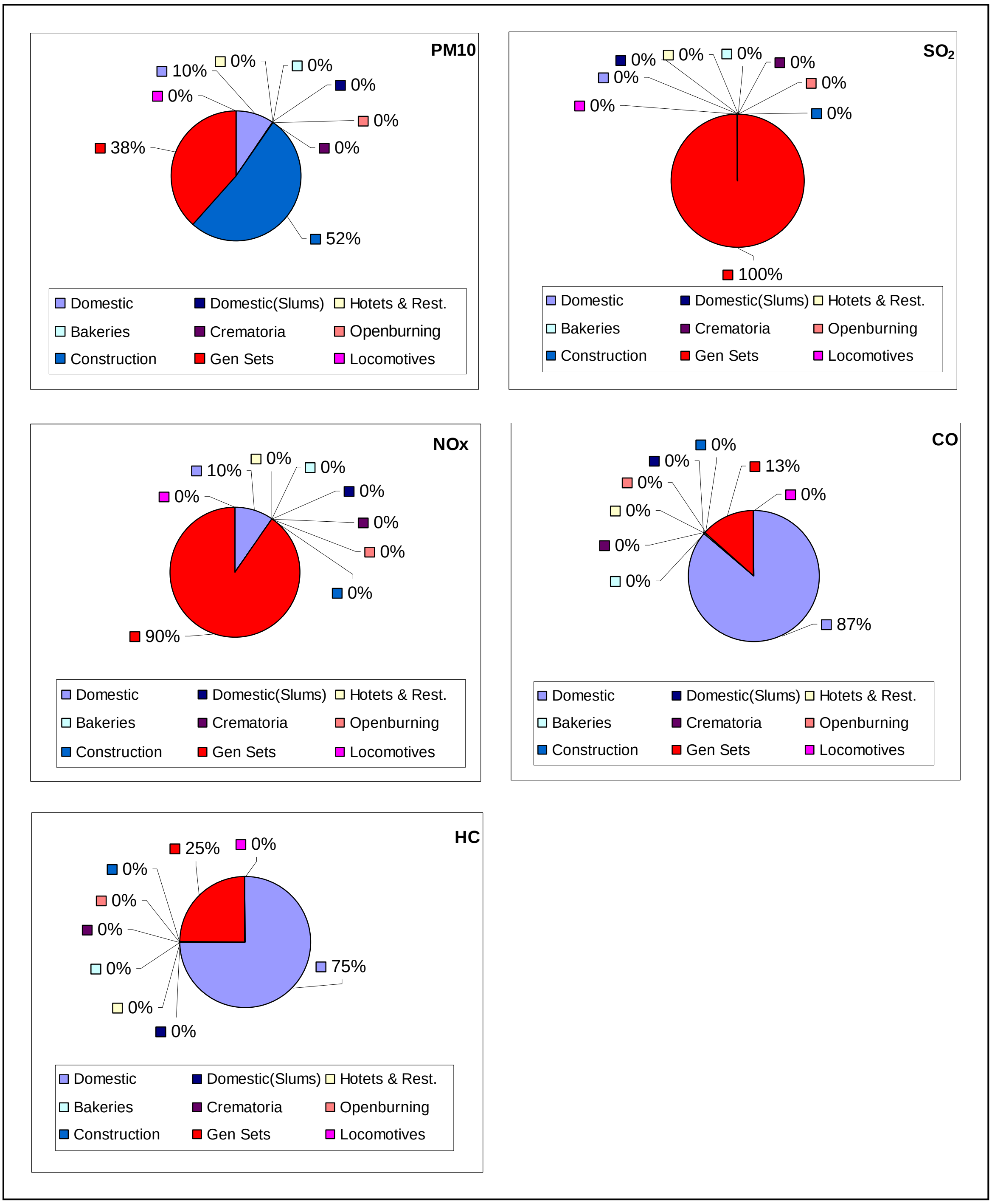


Fig. 3.2: Contribution of Emissions from various Area Source Activities: ISBT

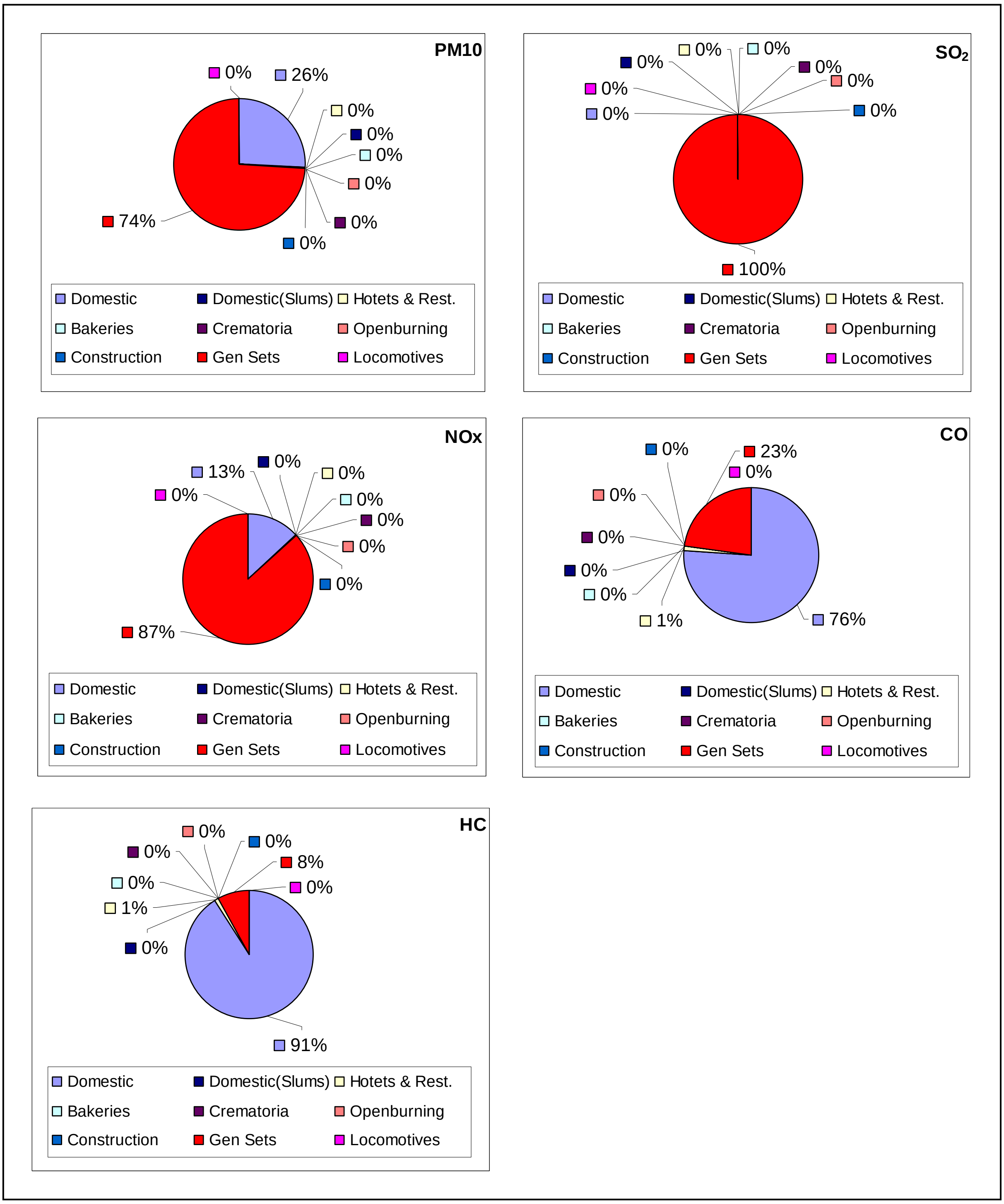


Fig. 3.3: Contribution of Emissions from various Area Source Activities: Dhaula Kuan

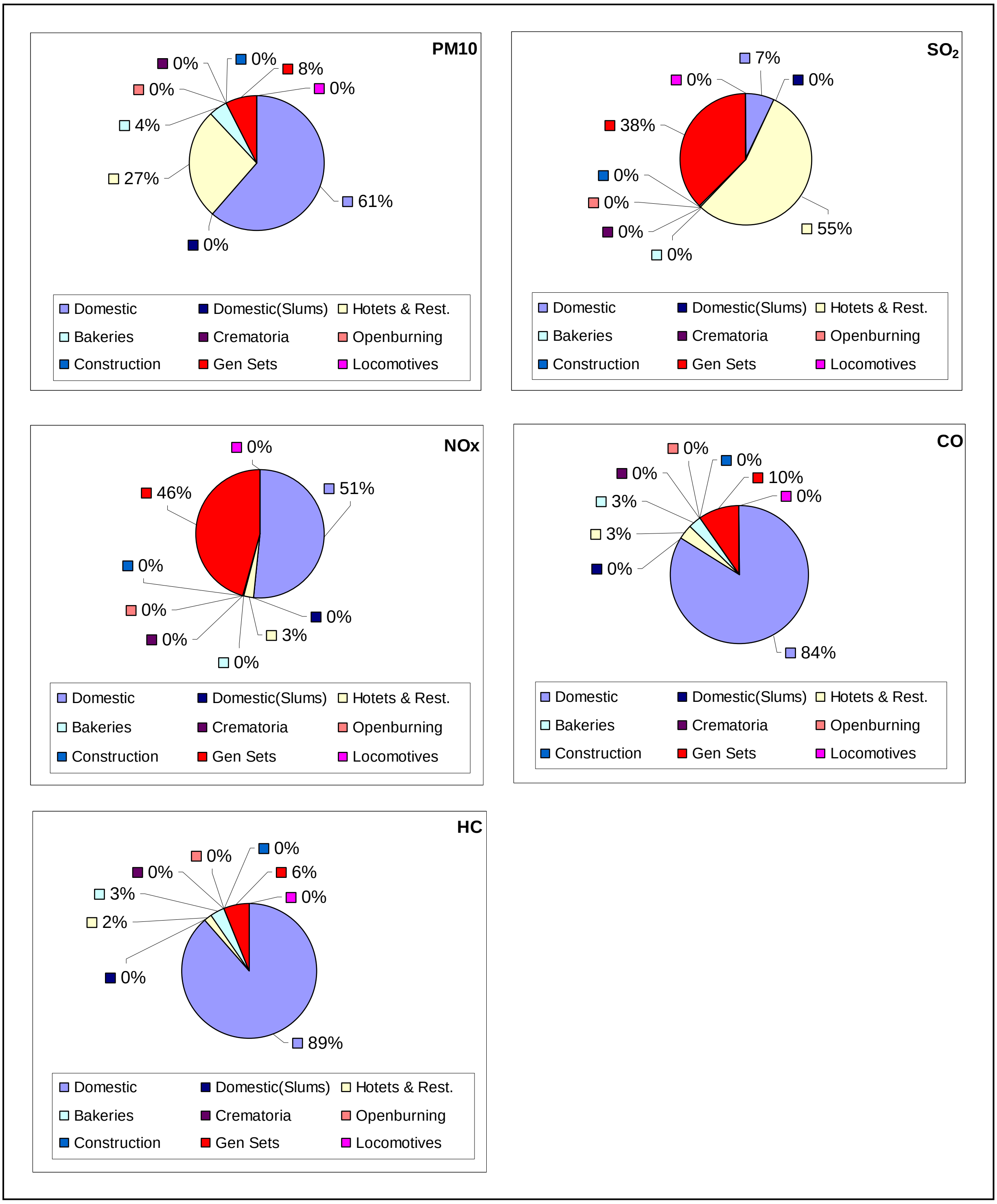


Fig. 3.4: Contribution of Emissions from various Area Source Activities: Mayapuri

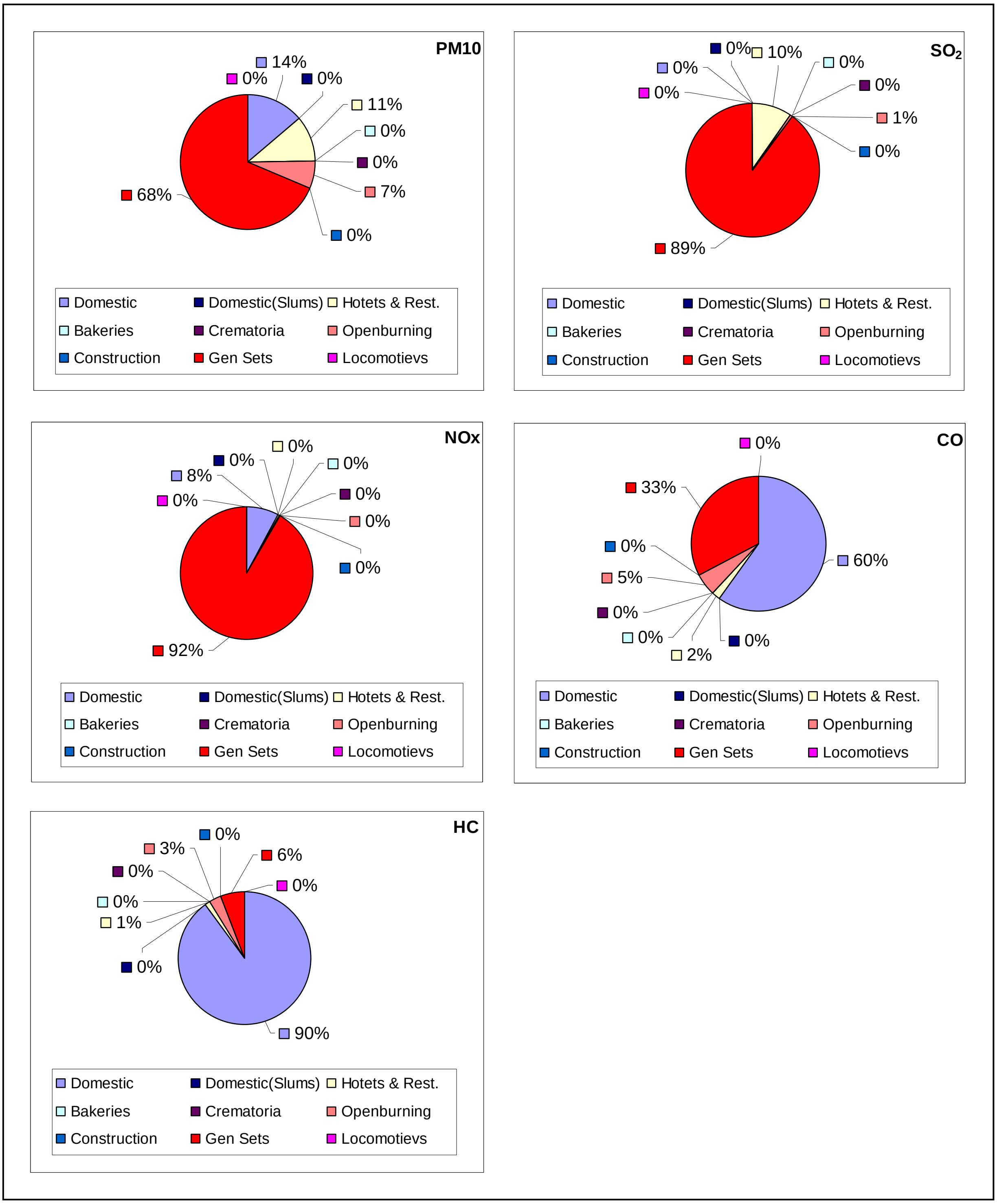


Fig. 3.5: Contribution of Emissions from various Area Source Activities: Anand Vihar

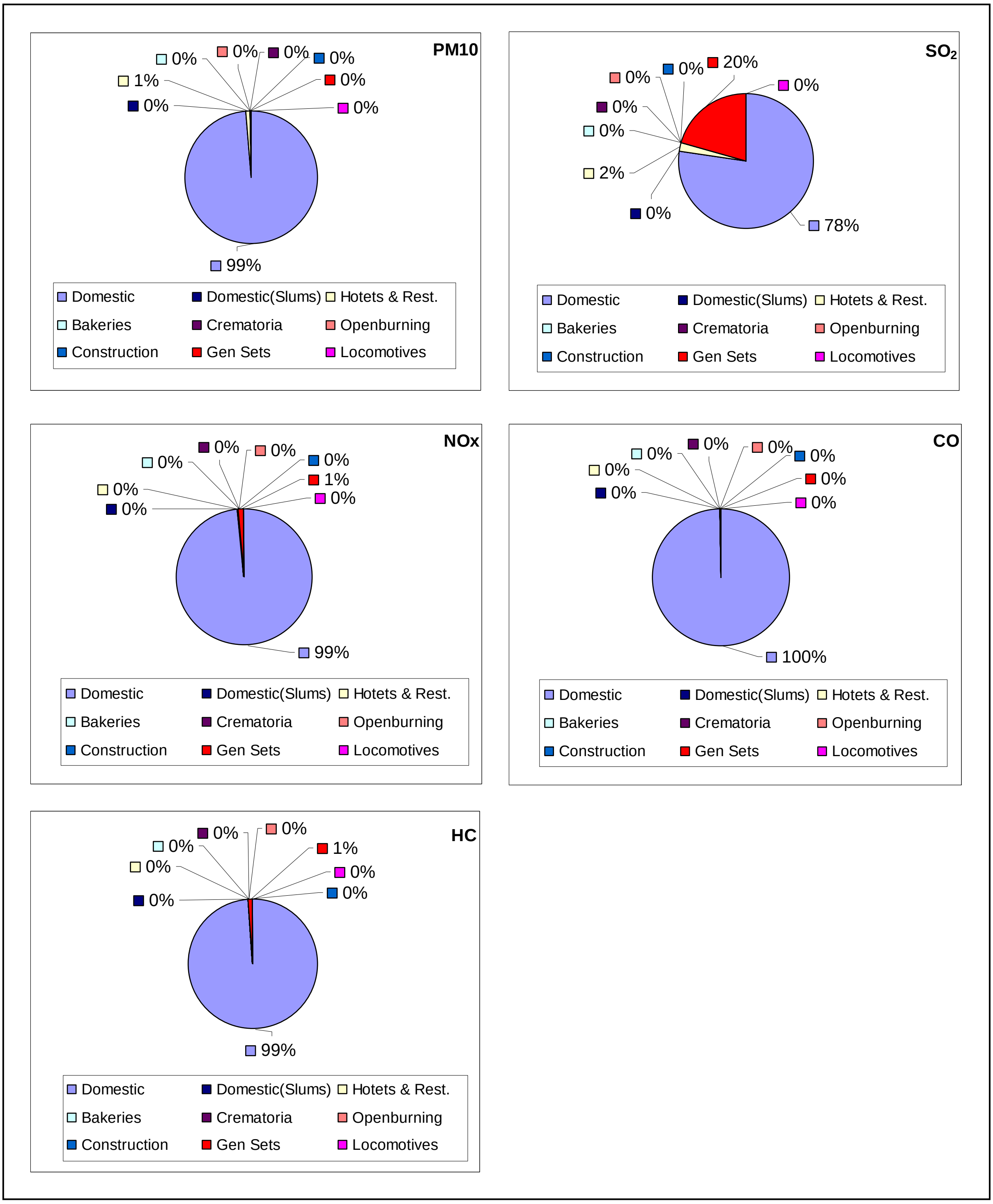


Fig. 3.6: Contribution of Emissions from various Area Source Activities: Loni Road

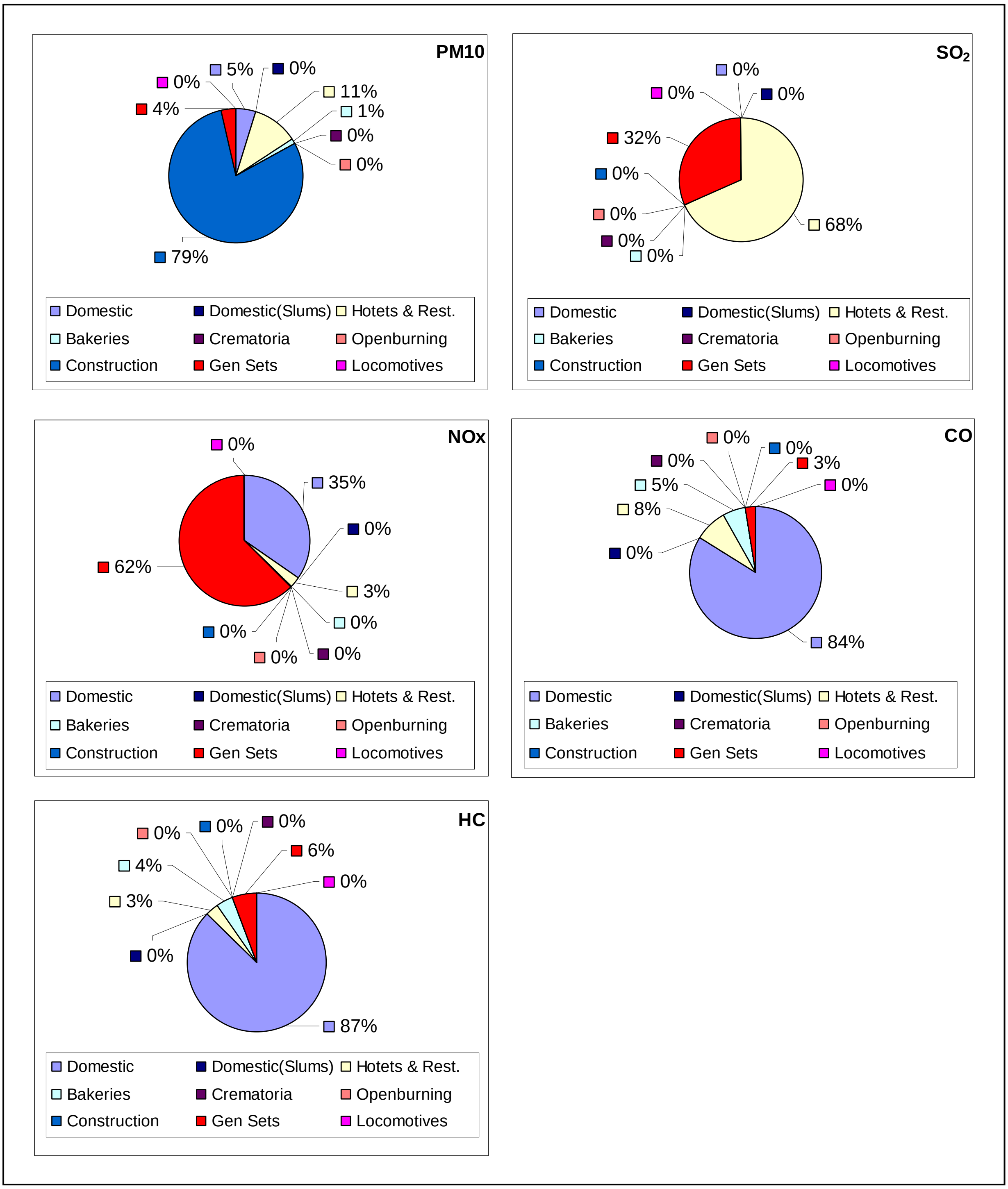


Fig. 3.7: Contribution of Emissions from various Area Source Activities: Pitampura

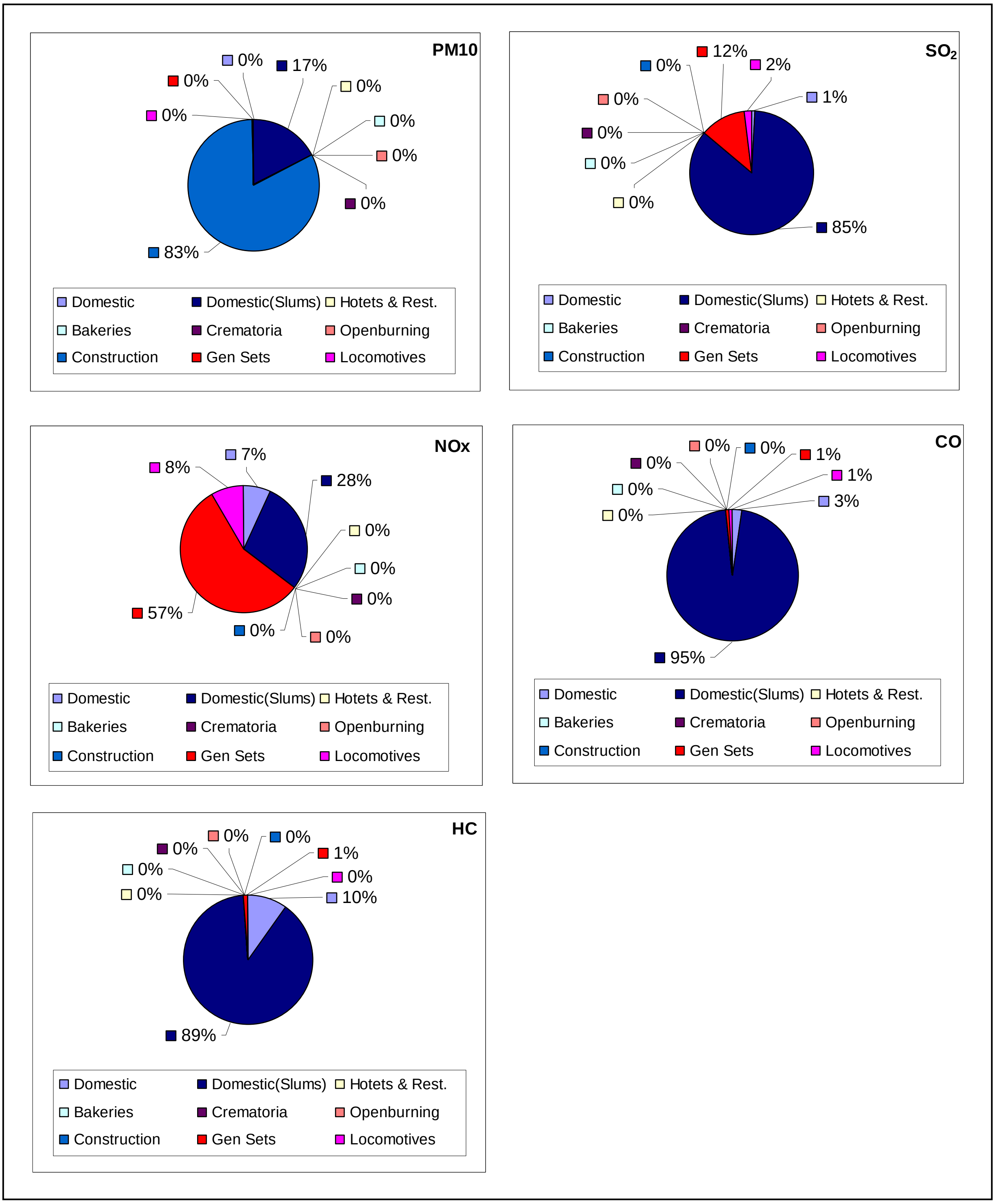


Fig. 3.8: Contribution of Emissions from various Area Source Activities: SSI-GTK

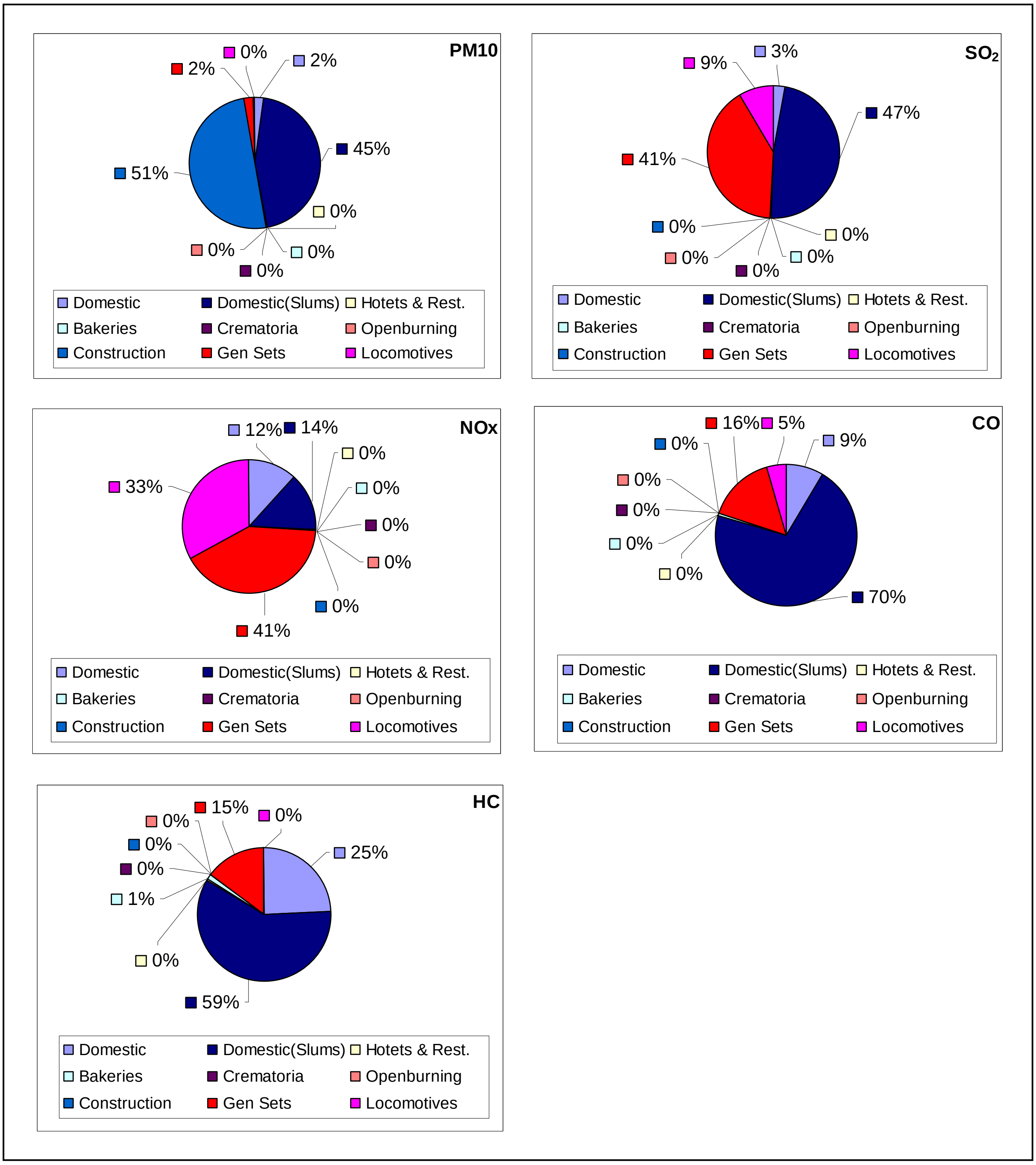


Fig. 3.9: Contribution of Emissions from various Area Source Activities: Naraina

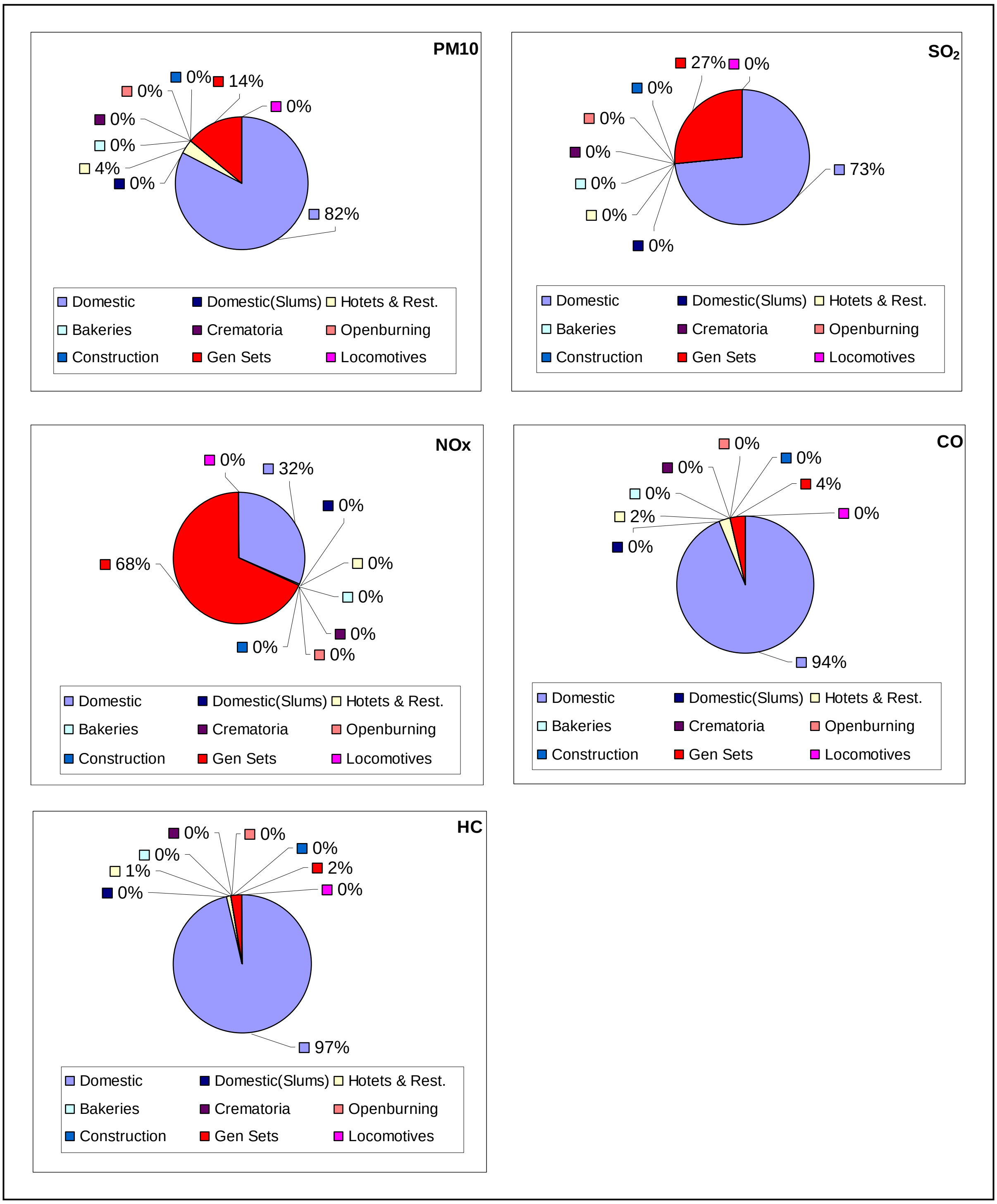


Fig. 3.10: Contribution of Emissions from various Area Source Activities: Prahladpur

3.1.2 Emission Inventory: Industrial Sources

Industrial/point source emissions comprise of all emissions released through high chimneys/ stacks as a result of process of industrial activities occurring in large, medium and small-scale industries. Emissions from the use of different types of fossil fuels used by the industries for boilers, furnaces as well as emissions from various manufacturing units are the potential sources from this sector. Emission load estimation is mostly based on primary surveys as also secondary data collected from major industries. As per the Economic Survey of Delhi 2001-2002, there were about 1,29,000 industrial units in Delhi in 1998 against 85,050 units in 1991. The industrial units are scattered in 36 industrial estates (conforming areas) of the region. Total number of registered industries during 1981-91 and 1998 are given below as:

Year	Total No. of Industries
1981	42,000
1991	85,050
1998	1,29,000

Rapid industrial and urban development has led to formation of isolated industrial pockets in Delhi. According to National Capital Territory (NCT) fact sheet of Delhi, only about 2000 (2%) of the total industrial units are in approved industrial areas, while the remaining units are spread over the city in residential and commercial areas. Most of these are located in the west, southwest and southern parts of the city. Northwesterly winds often drag pollution from western industrial areas across the city. Among these, about 1000 industries are air polluting in nature including three coal based thermal power plants located Badarpur, Rajghat and Indraprastha.

For preparation of emission inventory from industrial sources, various government organizations viz. CPCB, DPCC, concerned Government Institutions, Office of Commissioner of Industries, Govt. of NCT, Delhi, District Industrial Centre (DIC) and other organizations in Delhi were approached. Specific information on production capacities, raw materials used, manufacturing processes, fuel consumption etc. were collected from the available records. Information on fuel shift in industries as well as shifting of polluting industries outside Delhi was also collected from DPCC and CPCB.

The total emission loads in all the study zones from different industries were computed to assess spatial distribution of industrial emissions. Emphasis was given to data collection from all the major industrial sources. Emission factors recommended by CPCB were used for various point sources. The emission factors published by USEPA were also used wherever the corresponding emissions factors were not available.

3.1.2.1 Approach/Methodology

NEERI team visited all the industrial estates for surveying visible stacks and emissions and collection of primary data from representative industries through questionnaires. It was observed that small scale/cottage industries, in general, display their identity and such units have limited access in congested places. Such units appear like small scale engineering units or units with small pit furnace/boilers. A few stacks are seen with very low emissions while others appear to be abandoned. Information on fuel consumption in these industries viz. Furnace Oil (FO), Light Diesel Oil (LDO), Low Sulphur Heavy Stock (LSHS), Compressed Natural Gas (CNG) etc. in the DMC area has been obtained from DPCC, while information on coal use was obtained from Annual Survey of Industries, Coal India report, Central Electricity Authority Report (2002-03).

The total gross emissions have been estimated for all types of industries viz. power plants, metallurgical, engineering, food, textile, chemical and other industries using appropriate CPCB/AP-42 emission factors.

3.1.2.2 Collection of Primary and Secondary Data and Data Analysis

Secondary data has been collected from many organizations, industries, reports and also open source information. Type and source of information is given in **Table 3.13.** Questionnaire form for collection of data from the industries is given in **Annexure III**.

Table 3.13 : Type and Source of Information: Industrial Sources

Sr.	Information Obtained	Source of Data/Information (Agency/Office/Industry)
1.	Major air polluting industries i.e. power plants and medium scale industries and small scale industries	DPCC (Delhi Pollution Control Committee)
2.	Information as per Questionnaire on capacity, fuel use (type and quality), type of control and details of stack emissions, performance of control systems (as per questionnaire)	Rajghat Thermal Power Plant Pragati Power Co. Ltd. Indraprastha Power House Gas Turbine Power Station Badarpur Power Plant
3.	Information about medium scale air polluting Industries CPCB (Polluting Industries Report)	CPCB
4.	Information about Closed Industries as per Hon'ble High Court orders. Closed Industries Report	White paper
5.	Information about fuel supplied annually to power plants.	Central Electricity Authority (CEA), www.cea.com
6.	Information on total fuel supply to Delhi (Year wise). Internet site.	Delhi stat.com; www.delhistat.com
7.	Information on total fuel supply to Delhi (Year wise) from 2000 to 2003 Information on total fuel supply to Delhi (Year wise). Annual fuel sale record	Indian Oil Corporation Limited (IOCL), Delhi
8.	Information on total number of registered Industries. From internet site, Industrial Directory	Department of industries, Delhi, www.comind.nic.in
9.	Collected information as per Questionnaire from individual industry	Small Scale Industries

According to the CPCB and DPCC, the polluting industries are classified into three categories as red (highly polluting), orange category (moderately polluting) and green category (non- polluting) industries. The industries under red category are banned in Delhi region, whereas orange category industries are allowed to operate.

According to National Council of Applied Economic Research (NCAER) Industrial Census Report, 2002, there are 17,112 polluting industries in Delhi. Out of which, 2266 units are of air polluting nature (DPCC data). A report (Delhi White Paper, 2003) states that many industries like brick kilns, stone crushers, hazardous industries and hot mix plants in the region have been closed. Status of polluting industries in Delhi is given in **Table 3.14a** and **Table 3.14b**.

Table 3.14a: Status of Total Polluting Industries in Delhi

Status	Number of Industries
Operational	17,112
Closed	2,390
Vacant plots	2,125
Total	**21627**

Table 3.14b: Status of Air Polluting Industries in Delhi

Industrial Category	Air Polluting Industries
Large Scale – Power Plants	5
Medium Scale	9
Small scale (located in 36 Industrial Estates)	2252
Total	**2266**

Source: NCAER, Industrial Census Report of New Delhi 2003, DPCC, CPCB, and Delhi

Large-scale industries are power plants based on coal and gas. Out of five plants three are located near IP Estate and other two are near Pragati Maidan and Badarpur area. Three power plants are coal based (Indraprastha Power Plant, Rajghat, Badarpur) and two are gas based (Pragati Power Plant and Gas Turbine. The medium scale industries are concentrated in Lawrence road Industrial area whereas the small scale industries are scattered in all the 36 industrial areas of the region. The information on these industries relating to their location, type and quantity of fuel used etc. was obtained from DPCC, individual power plants and reports of Central Electric Authority (CEA, 2000, 2001 and 2002). Category-wise breakup of these industries is given in **Table 3.15** and details of medium scale industries are given in **Table 3.16.**

Table 3.15 : Category wise Breakup of Air Polluting Industries in Delhi

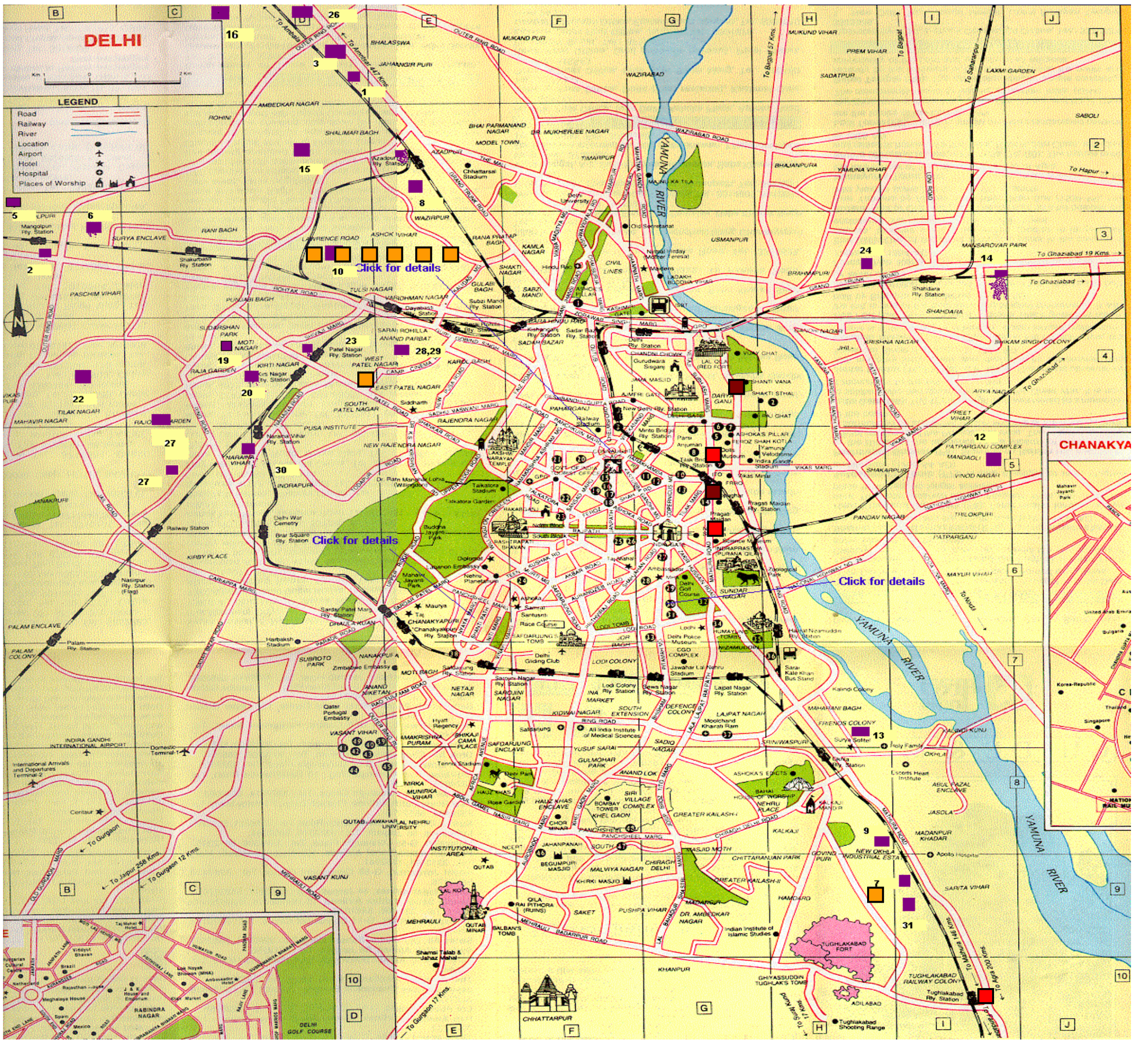
Type of Industries	No. of Industries	Type of Industries	No. of Industries
Power	5	Textile	162
Engineering	590	Plastic	222
Chemical	110	Pharmaceuticals	42
Metallurgical	183	Food	89
Rubber	152	Others	711
Total Number of Industries			**2266**

Source: NCAER, New Delhi Industrial Census Report 2003, DPCC and TPS

Table 3.16 : Medium Scale Air Polluting Industries in Delhi

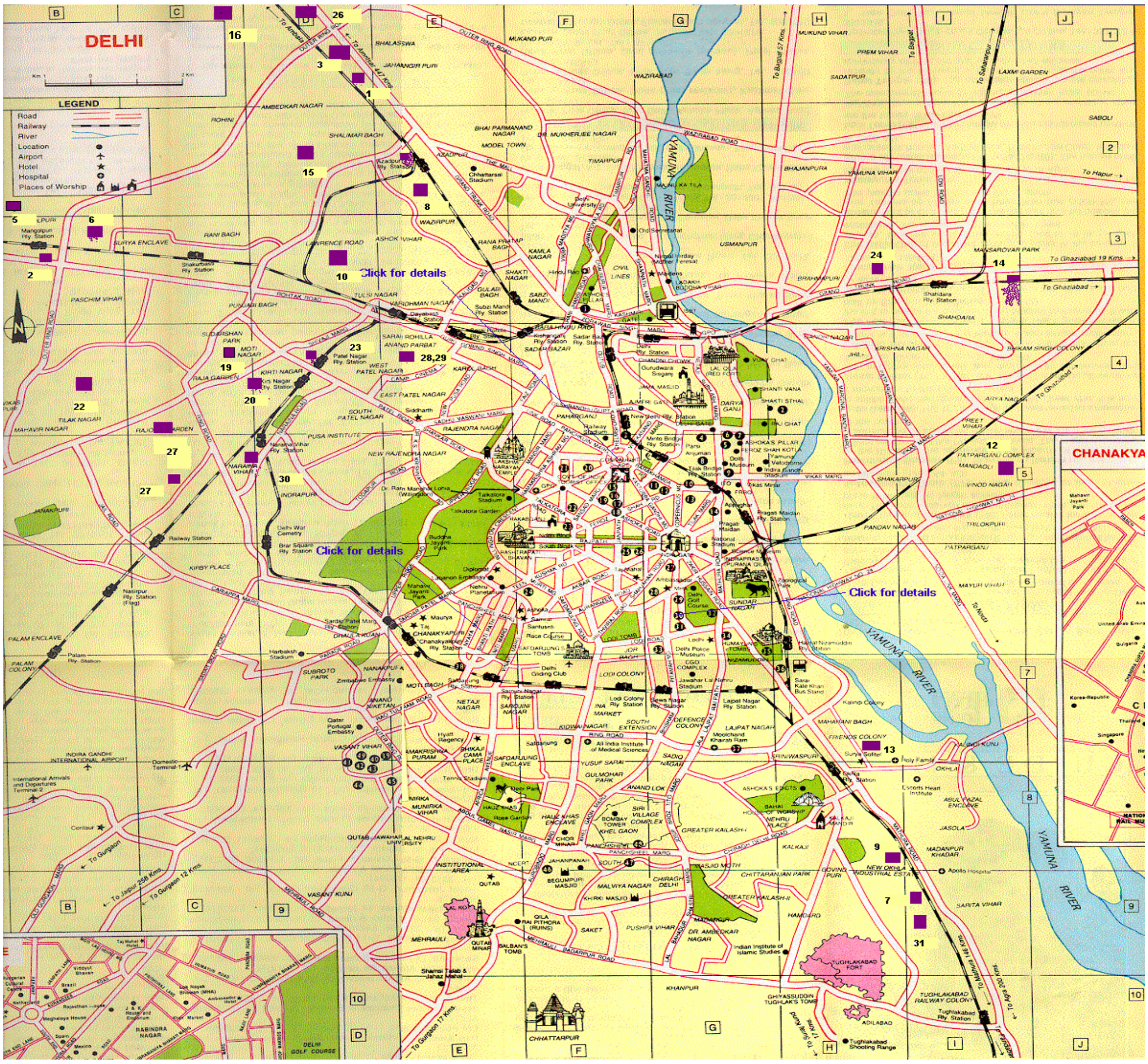
S.No	Medium Scale Industries	Location	Category
1.	Nafed Cold storage	Lawrence road	Storage
2.	Shakti Hosiery	Lawrence road	Textile
3.	Pearl drinks ltd	Lawrence road	Food
4.	Modern Food ltd	Lawrence road	Food
5.	Kaytis Food processes	Lawrence road	Food
6.	Britannia Industries ltd	Lawrence road	Food
7.	Mothers Dairy	Patparganj	Food
8.	Snow White Dry cleaning	Okhla phase III	Washing
9.	Delhi milk scheme	West Patel Nagar	Food

Location of Large and Medium Scale Industries is shown in **Fig. 3.11**, whereas Small Scale Industries are shown in **Fig. 3.12.**



Gas Based Power Plant 🟫 Thermal Power Plant 🟥 Medium Scale Industries (9) 🟧

Fig. 3.11: Map Showing Location of Power Plants and Medium Scale Industries in Delhi



1	Rajasthan Ind. Estate	2	Udyog Nagar Ind. Estate	3	SMA Industrial Estate
4.	SSI Industrial Area	5	DSIDC Nangoli Ind. Estate	6	Mangolpuri Ind. Estate Ph I
7	Okhla Ind. Estate Ph II	8	G.T. Karnal Ind. Estate	9	Okhla Ind. Estate Ph III
10	Lawrence Ind. Estate	11	Mohan Ind. Estate	12	Patparganj Ind. Estate
13	Friends Colony Ind. Estate	14	Jhilmil Ind. Estate	15	Wazirpur Ind. Estate
16	Badli Ind. Estate	17	Mohan Coop. Ind. Estate	19	Motinagar Ind. Estate
20	Kirtinagar Ind. Estate	22	Tilak Nagar Ind. Estate	23	Najafgarh Road Ind. Estate
24	Shadara Ind. Estate	26	Smaipur Ind. Estate	27	Mayapuri Ind. Estate Ph I
28	Anand Prabhat Ind. Estate	29	Naraina industrial estate Ph I	30	Okhala findustrial estate Ph I
31	Mangolpuri Ind. Estate Ph II	32	Naraina industrial estate Ph II	33	Mayapuri Ind. Estate Ph II
34	Dilshad	35	Shazadbag	36	Narela

Figure 3.12: Map Showing Industrial Estates (SSI) in Delhi

3.1.2.3 Emissions Estimations

Of the total 2252 small scale industries, 723 units lie in the ten 2 km x 2 km study zones. The information available on the small-scale industries were categorized with respect to nature of product, byproduct, viz. power, metallurgical, engineering, chemicals, textiles and food/beverages etc. and presented in **Tables 3.17.**

Table 3.17: Study Zone-wise Details of Small Scale industries

Type of Industries	Nar1	AV1	GTK1	GTK2	AV2	N2	GTK3	GTK4	MP Phase I	
	Mayapuri Phase I	**Patparganj**	**Rajasthan Udyog**	**GT Karnal**	**Shahibabad**	**Naraina Phase I**	**SSI**	**SMA**	**Lajwanti garden**	**Total**
Engineering	41	15	26	23	2	14	15	10	26	**172**
Chemical	5	3	8	2	1	13	1	2	14	**49**
Metallurgical	0	6	5	10	-	5	-	8	56	**90**
Rubber	13	-	8	2	-	1	-	2	26	**52**
Textile	6	3	5	12	1	4	1	1	10	**43**
Plastic	-	12	4	1	-	18	9	4	25	**73**
Pharmaceutical	1	4	1	1	1	8	-	-	-	**16**
Food	1	3	2	2	1	2	3	3	1	**18**
Others	23	44	20	14	9	19	3	1	77	**210**
Total	**90**	**90**	**79**	**67**	**15**	**84**	**32**	**31**	**235**	**723**

Nariana – (Narina I + Mayapuri -I), Lajwanit Garden – Mayapuri I, Anand Vihar – PatParganj +Sahibad, SSI-GTK -(GTK + SSI +SMA+ Rajasthan Udyog)

It can be observed that five large-scale power plants located near IP Estate (3), Pragati Maidan (1) and Badarpur area (1) constitute major industries. Out of SSIs, group industries under the category “others” form the largest group which are mixed group of industries. Fuels used in these industries include LSHS, LDO, HSD, LPG/FG, NG and coal. According to DPCC, FO and coal are banned in Industries in New Delhi and coal supply is mostly limited to power plants, in which only beneficiated coal with less than 35% ash is used. Also the Sulphur content of these fuels is less than 0.5 %. Some industries are using NG/CNG as fuel. The information on fuel used in power plants was obtained from CEA Report as well as respective power plants. The beneficiated coal is supplied to power plants. It is mandatory now in Delhi that FO and coal should not be used as fuels in other industries. The difference between consumption and supply figures imply that there may be some other sources of fuel supply and consumption in the region. Hence both top-down and bottom-up approaches have been used for data analysis and a blend of these two is used to get optimal outcome. Emission loads were estimated by using CPCB recommended emission factors wherever they are available and in other cases AP-42 emission factors were used. The emission factors used for industrial sources are given in **Annexure III.** The total emissions (in terms of PM10, SO_2, NOx, HC and CO) from different types of Small Scale industries in Anand Vihar, SSI-GTK, Mayapuri and Naraina Study zones are summarized in **Tables 3.18 (a, b, c, d & e)** and their contribution is presented through **Figs. 3.13 to 3.16**

Table 3.18a: Emissions from Different Small Scale Industries at Anand Vihar

Type of Industries	Pollutant Emissions (kg/day)				
	PM10	SO_2	NOx	HC	CO
Engineering	7.2	30.0	309.5	7.9	21.8
Chemical	8.9	1.7	678.9	1.7	4.6
Metallurgy	1.8	1.6	466.7	2.0	5.4
Textile	114.3	7.5	44.7	3.2	8.8
Plastic	6.7	42.9	90.2	7.2	20.1
Pharma	0.9	1.4	12.4	1.0	2.7
Food	1.6	1.5	351.3	1.8	4.9
Others	22.0	71.5	435.2	22.2	60.8

Table 3.18b: Emissions from Different Small Scale Industries at SSI-GTK

Type of Industries	Pollutant Emissions (kg/day)				
	PM10	SO_2	NOx	HC	CO
Engineering	55.9	75.7	787.4	62.8	170.4
Chemical	9.6	8.9	135.4	10.8	29.2
Metallurgy	62.2	62.6	879.3	70.2	189.9
Rubber	9.5	8.9	134.2	10.7	29.0
Textile	17.6	16.4	249.0	19.9	53.8
Plastic	16.2	15.9	228.3	18.2	49.3
Pharma	10.9	10.2	154.0	12.3	33.3
Food	1.0	9.5	12.8	1.0	2.9
Others	31.3	198.9	422.3	33.9	94.3

Table 3.18c: Emissions from Different Industries Small Scale at Lajwanti Garden (Mayapuri)

Type of Industries	Pollutant Emissions (kg/day)				
	PM10	SO_2	NOx	HC	CO
Engineering	8.9	10.7	126.2	10.1	27.3
Chemical	3.3	3.1	46.5	3.7	10.0
Metallurgy	13.3	30.3	185.6	14.8	40.4
Rubber	15.5	34.1	216.8	17.3	47.2
Textile	17.9	17.4	253.4	20.2	54.7
Plastic	12.4	11.6	175.6	14.0	37.9
Food	0.0	1.6	0.1	0.0	0.1
Others	30.2	46.6	424.3	33.9	92.0

Table 3.18d: Emissions from Different Small Scale Industries at Naraina

Type of Industries	Pollutant Emissions (kg/day)				
	PM10	SO_2	NOx	HC	CO
Engineering	34.1	80.9	476.3	38.1	103.7
Chemical	6.4	6.0	91.0	7.3	19.6
Metallurgy	11.4	54.7	157.9	12.6	34.6
Rubber	5.2	4.9	74.1	5.9	16.0
Textile	23.0	21.5	325.6	26.0	70.3
Plastic	19.5	18.1	275.0	21.9	59.4
Pharma	2.2	3.0	30.4	2.4	6.6
Food	1.4	1.3	19.5	1.6	4.2
Others	38.5	37.4	544.7	43.5	117.7

Table 3.18e: Emission Load of SSI Units in 2 km x 2 km Study Zones: Delhi, 2006-07

Sr. No	**Study Zone (Industrial Areas)**	**Industrial Estates**	**Emission Load (Kg/day)**				
			PM10	**SO_2**	**NOx**	**HC**	**CO**
1.	Mayapuri (Lajwanti Garden) (Mayapuri Industrial Area Phase II)	Lajwanti Garden	**101.54**	**155.40**	**1428.4**	**114.05**	**309.55**
2.	Anand Vihar (Shahibabad & Patparganj)	Shahibabad	121.70	79.43	9.56	0.50	2.50
		Patparganj	41.56	78.72	2379.2	46.55	126.61
3.	SSI-GTK (G T Karnal, Rajastan Udyog Nagar, SMA & SSI)	G.T. Karnal Rd	44.68	222.67	610.44	48.94	135.12
		Rajstan Udyog Nagar	87.66	108.11	1236.7	98.70	267.45
		SMA	40.87	38.10	577.73	46.09	124.7
		SSI	32.70	30.49	462.27	36.88	99.83
4.	Naraina (Naraina Industrial Estate Phase I)	Naraina Phase I	57.88	69.48	817.13	65.20	176.64
	(Mayapuri Industrial Area Phase I)	Mayapuri Phase I	83.80	158.32	1177.3	94.019	255.39
		Total	**612.31**	**940.72**	**8698.74**	**550.81**	**1497.79**

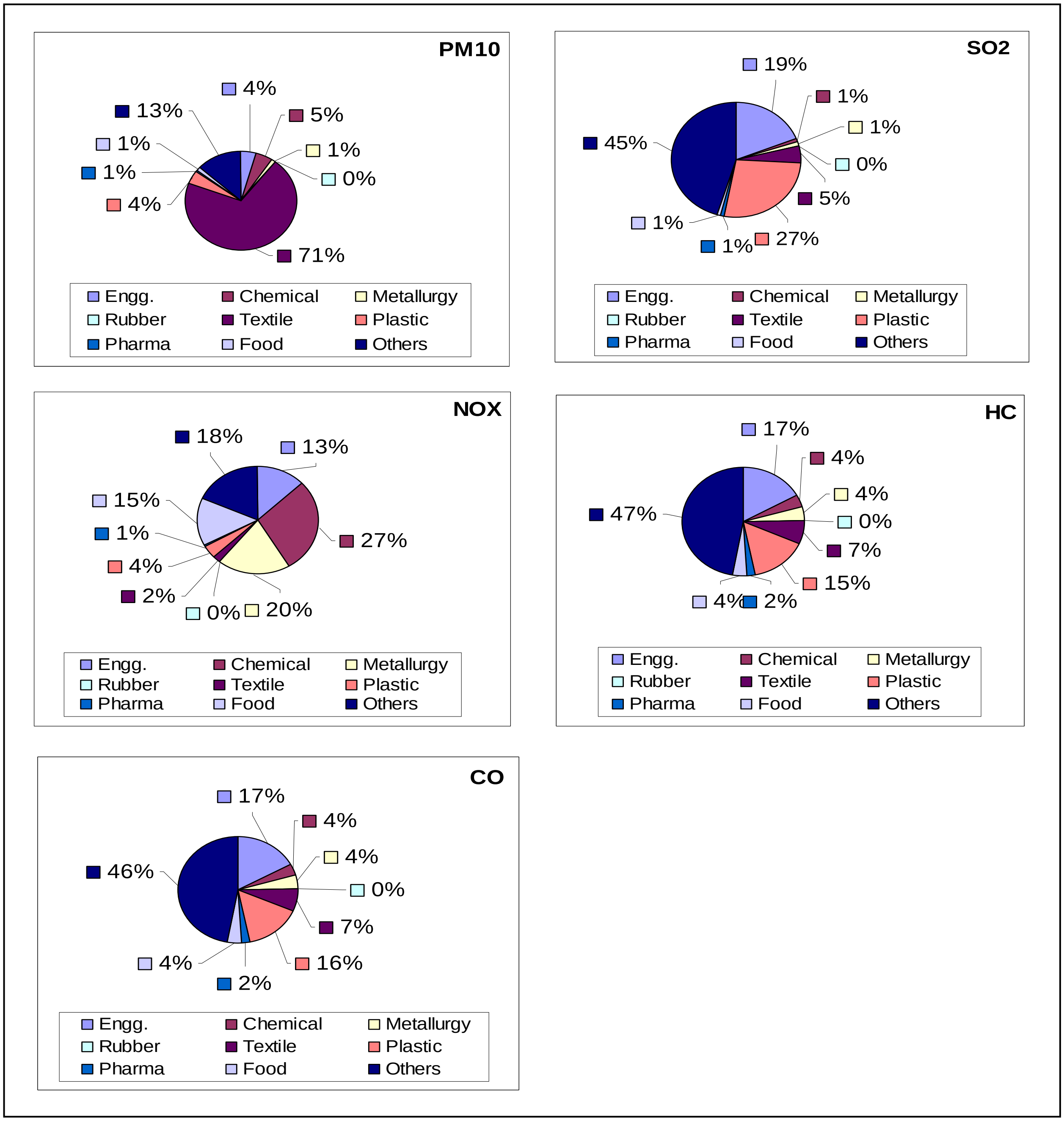


Fig. 3.13: Percentage Emission Contribution from Industries: Anand Vihar

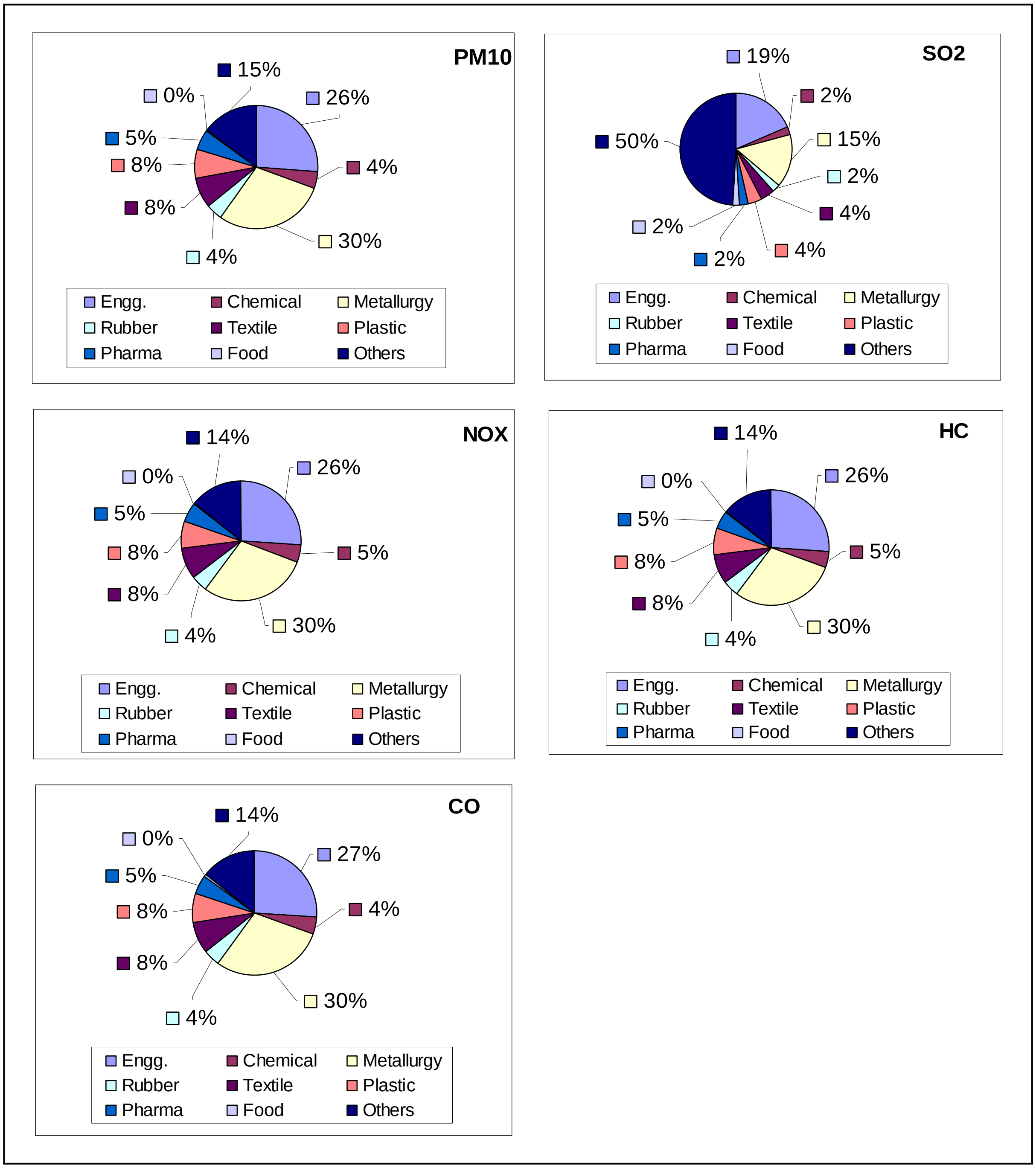


Fig. 3.14: Percentage Emission Contribution from Industries: SSI - GTK

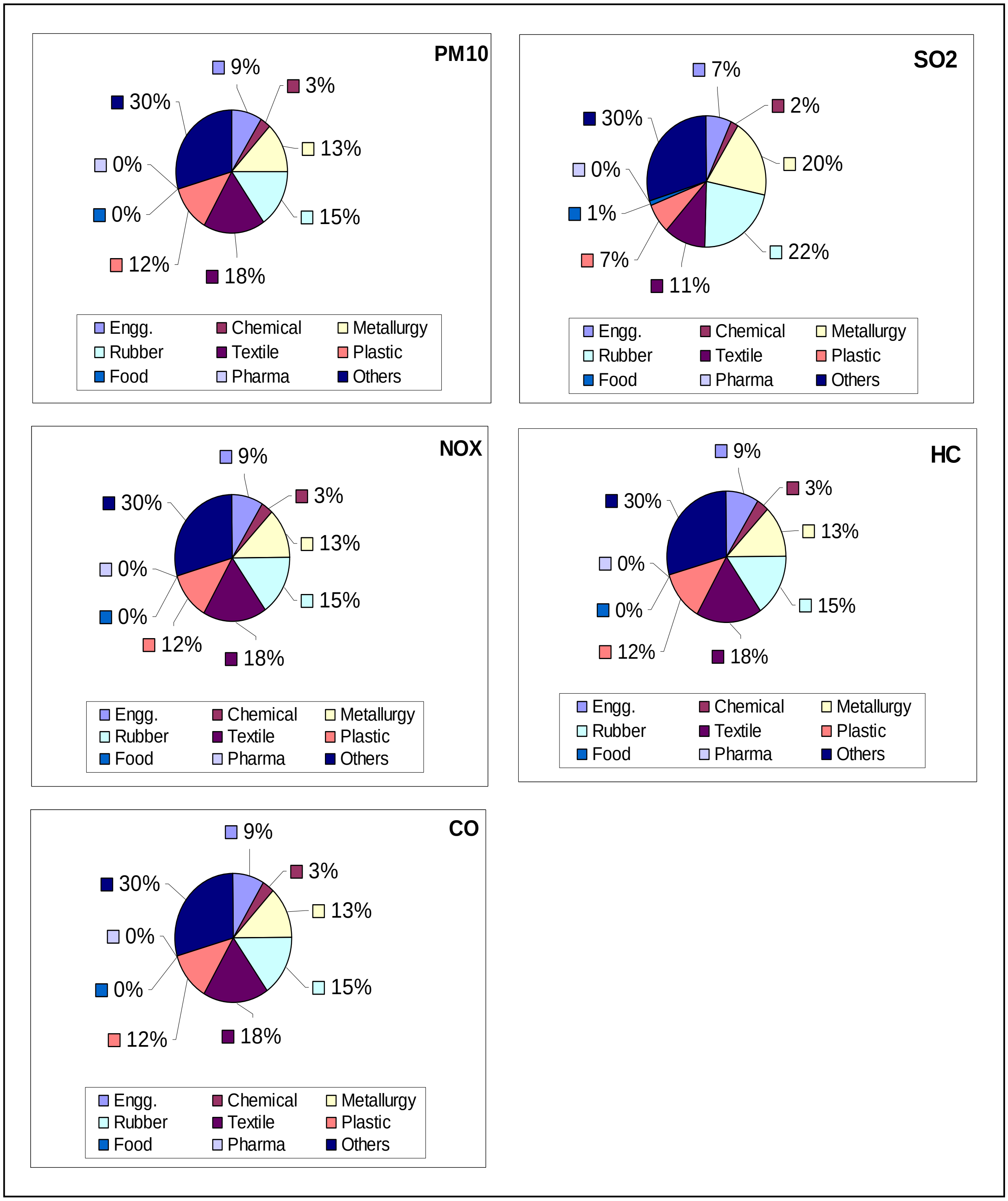


Fig.3.15: Percentage Emission Contribution from Industries: Mayapuri (Lajwanti Garden)

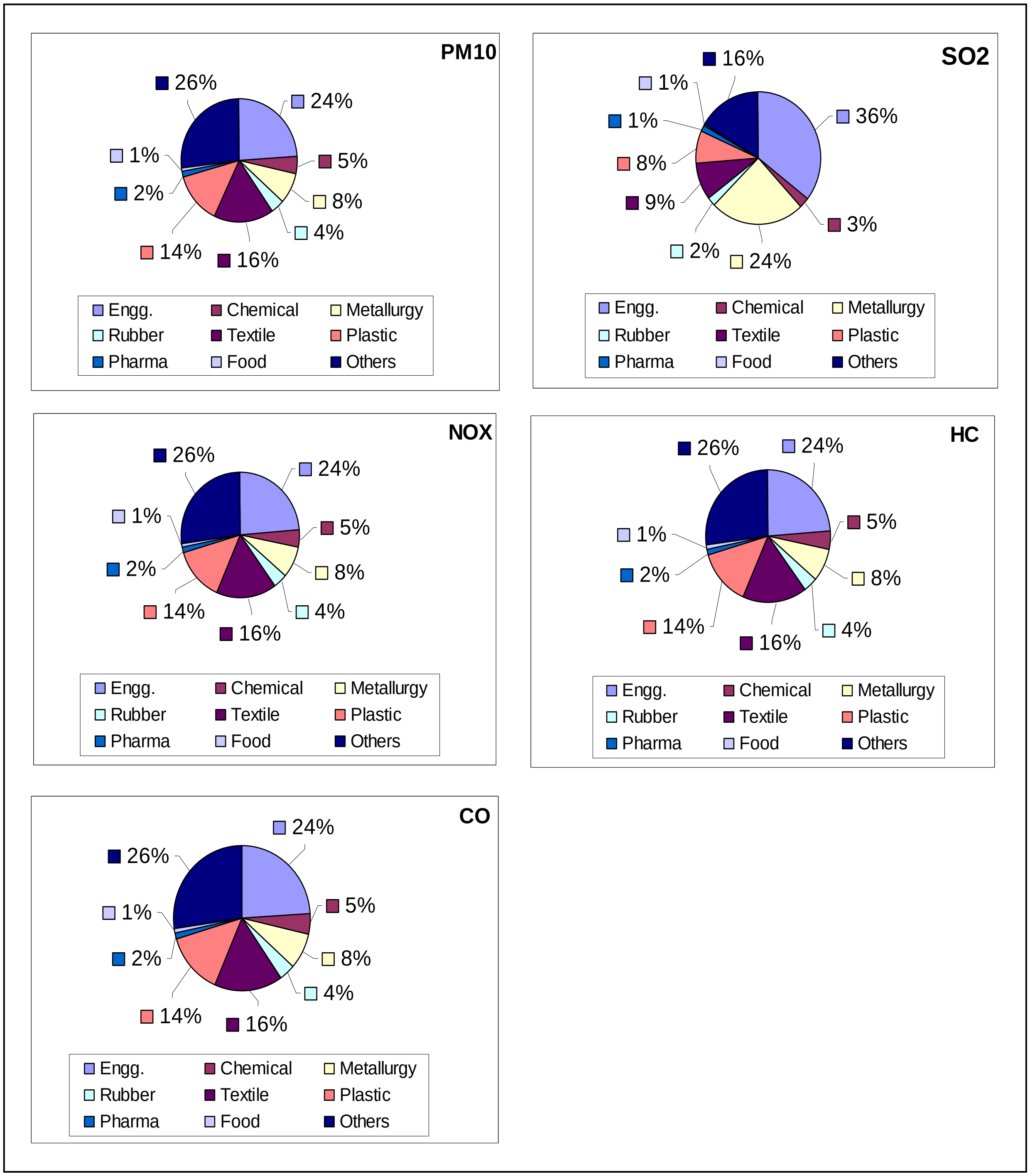


Fig. 3.16: Percentage Emission Contribution from Industries: Naraina

3.1.3 Emission Inventory: Vehicular Sources

Preamble

Vehicular emissions are considered to be one of the major source categories of air pollution in Delhi. Tremendous increase in the number of vehicles has contributed significantly to the increase in combustion of petroleum products. The vehicular pollution in Delhi has grown from 64% to 72% in the last decade (1990-2000) whereas petroleum and diesel consumption have grown by 400% and 300% respectively in the last two decades.

The quantity of air pollutants emitted by different categories of vehicles is directly proportional to the average distance traveled by each type of vehicle, number of vehicles plying on the road, quality of fuels being used, age and technology of vehicles in use etc. However, several other factors, such as geographical locations, unplanned development of business areas, inadequate and poorly maintained roads as well as adopted practices of inspection and maintenance of vehicles; unplanned traffic flow, meteorological conditions and non-availability of effective emission control technology etc. also contribute to the air pollution from vehicular sources.

In 2002, Central Road Research Institute (CRRI), New Delhi conducted traffic survey study at different locations in Delhi and estimated pollution load contribution of different categories of vehicles. Emissions from the tail pipes of the automobiles were estimated on the basis of vehicle-kilometers traveled (VKT) by different types of vehicles and the fuel used. The total vehicle kilometers traveled and the estimated total emission load (in 2002) from different categories of vehicles is presented in **Table 3.19**.

As per the study, the total distance traveled by all categories of vehicles in Delhi was estimated to be about 792 lakhs km. Of this, 2-Wheelers and 4-Wheelers (car/jeeps/van) account for a major share of 42.7% and 38% respectively. 3-Wheelers (Autos) and local buses account for about 11.8% and 3.6% respectively, whereas the share of LCV and HCVs together is only about 3.2%.

Table 3.19: Total VKT and Estimated Pollution Load from Different Vehicles in Delhi

Vehicle Type	Vehicle km (in lakhs)	Pollution Load, TPD (% Share)			
		CO	NOx	HC	PM
Cars	300.88 (37.97%)	198.94 (47.16%)	43.15 (39.07%)	35.13 (19.05%)	3.32 (25.96%)
Taxis	6.01 (0.76%)	0.93 (0.22%)	1.81 (1.64%)	0.24 (0.13%)	0.01 (0.09%)
Two Wheelers	338.23 (42.69%)	167.77 (39.77%)	3.89 (3.52%)	111.37 (60.4%)	4.93 (38.56%)
Auto-CNG	71.37 (9.01%)	0.75 (0.18%)	1.88 (1.7%)	15.57 (8.44%)	0.15 (1.18%)
Auto-Petrol	22.20 (2.8%)	18.47 (4.38%)	0.24 (0.22%)	12.68 (6.88%)	0.36 (2.78%)
Goods-Local	14.34 (1.81%)	10.06 (2.39%)	5.24 (4.75%)	0.63 (0.34%)	0.75 (5.89%)
Goods-Inter City	10.80 (1.36%)	7.91 (1.87%)	6.59 (5.97%)	1.03 (0.56%)	1.19 (9.31%)
City Bus (CNG)	10.53 (1.33%)	9.55 (2.26%)	21.60 (19.56%)	5.79 (3.14%)	0.09 (0.7%)
City Bus (Diesel)	11.03 (1.39%)	6.23 (1.48%)	21.73 (19.68%)	1.61 (0.87%)	1.65 (12.94%)
Inter City Bus	6.95 (0.88%)	1.23 (0.29%)	4.31 (3.9%)	0.32 (0.17%)	0.33 (2.58%)
Total	**792.34 (100%)**	**421.84 (100%)**	**110.44 (100%)**	**184.37 (100%)**	**12.77 (100%)**

(Source: Auto Fuel Policy Report, 2002)

The total daily pollution load is estimated to be about 422 MT of CO, 184 MT of HC, 110 MT of NOx and 12.8 MT of particulate matter. Cars and 2-Wheelers together contribute nearly 87% CO, 79% HC and 65% of particulate matter. NOx is contributed mainly by cars (39%) and diesel & CNG buses (together contribute 39%).

3.1.3.1 Vehicular Growth and Present Population

Data relating to different categories of vehicles registered in Delhi was collected from the Transport Department, Delhi and analyzed broadly under eight categories of vehicles, viz. 2 Wheelers, 3 Wheelers, 4 Wheelers (Passenger Cars and Taxi/Cabs etc.), Light Commercial Vehicles (LCVs), Trucks, Buses and Miscellaneous Vehicles. In 2002, the total population of vehicles in Delhi was about 36.87 lakhs, which increased to 52.16 lakhs in 2007. During the last 5 years (2002-2007), increase in 2 and 4-Wheelers is 41.15% and 46.5% respectively. Taxis and buses increased by 89.5% and 27.8% respectively. Trucks recorded a marginal decline of 2.3%. All categories of vehicles increased by about 41%. Composition of different categories of vehicles in 2007 is given in **Fig. 3.17**.

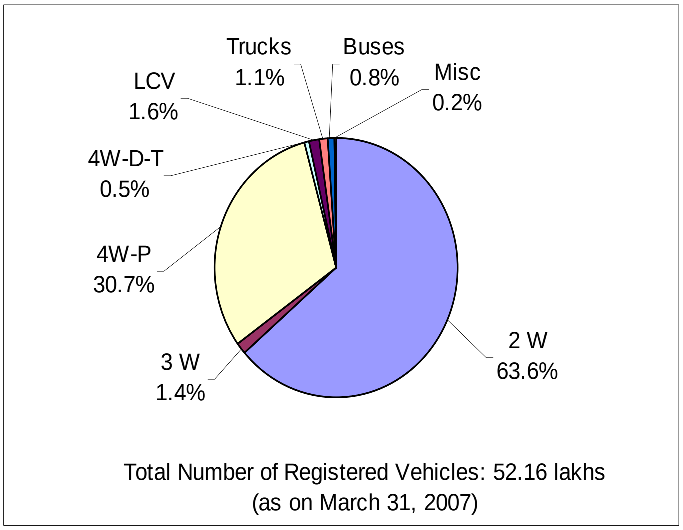


Fig. 3.17: Share of Different Categories of Registered Vehicles: March 2007

As on March 31, 2007, there were 63.6% 2-Wheelers and 30.7% 4-Wheelers, together constituting 94.3% of the vehicles. Rest of all the categories of the vehicles account for about 5.7%.

3.1.3.2 Primary Data Collection Elements and Methodology

Vehicle Count

In order to prepare emission inventory of vehicular (line) sources, primary data on traffic count were collected in the identified study zone, surrounding the air quality monitoring (AQM) stations. All types of vehicles moving on the arterial/ring roads, which are the main carriers of traffic in Delhi, were counted manually round the clock from 8 am to 8 am of the next day. Traffic was also counted on the road nearest to the AQM site (kerbsite locations) for 12 hours duration, between 8 am & 8 pm on non-working day (Sunday). Details of identified traffic count locations on arterial/ring roads within each of the study zones around AQM stations are given in **Table 3.20**.

Table 3.20: Identified Locations for Traffic Count around AQM Sites (Arterial/Ring Road/NH/SH/Major Roads)

Sr. No.	AQM Location	Traffic Count Location	Counting on
1.	Ashram Chowk	towards Badarpur (Mathura Road)	WD & N-WD
		towards Lajpat Nagar	WD
		towards Nizamuddin Rly. Stn.	WD
		towards Sarai Kale Khan	WD
		Over Flyover	WD
2.	Dhaula Kuan	towards Airport	WD & N-WD
		towards AIIMS	WD
		towards Naraina	WD
		towards India Gate	WD
		towards upper Ridge Road	WD
3.	Mayapuri (Lajwanti Garden Chowk)	towards Delhi Cantt.	WD & N-WD
		towards Mayapuri	WD
		towards Tilak Nagar	WD
		towards Sagar Pur	WD
4.	ISBT (T-Point near AAQ site)	towards ISBT	WD & N-WD
		towards Lala Shamnath Marg	WD
		towards Majnu Ka Tilla	WD
5.	Loni Road (Loni Golchakkar)	towards Loni	WD & N-WD
		towards Ghaziabad	WD
		towards Shahdara	WD
		towards Wazirabad	WD
		Over Flyover	WD
6.	Anand Vihar ISBT	towards Gazipur	WD & N-WD
		towards Preet Vihar	WD
		towards Sahibabad	WD
		Telco Chowk to Vivek Vihar	WD
7.	Naraina Industrial Area (Ring Road T-Point)	towards Mayapuri	WD
		towards Dhaula Kuan	WD
		towards Naraina Industrial Area	WD
		Fire brigade Naraian Industrial Area to Loha Mandi	WD & N-WD
8.	GT Karnal Road – Azadpur (GTK bypass – Makraba Chowk)	Towards Model Town	WD & N-WD
		Towards Madhuban Chwok	WD
		Towards Karnal Road	WD
		Towards Wazirabad	WD
9.	Pitampura	Opp. AAQ Site (Santhom Hospital)	WD & N-WD
		Pitampura Road (near BU Block)	WD
		Outer Ring Road (near District Park)	WD
10.	Prahladpur	No arterial/ring road	--

WD: Working Day (Monday to Saturday); N-WD: Non-Working Day (Sunday)

Further, traffic was also counted for limited period during morning, noon and evening hours on main roads (next category of road to the arterial road), feeder roads (including inner roads) within each of the impact zones. Additional traffic count location within each of the study zones is given in **Table 3.21.**

Table 3.21: Additional Traffic Count Locations: Main Roads and Feeder Roads

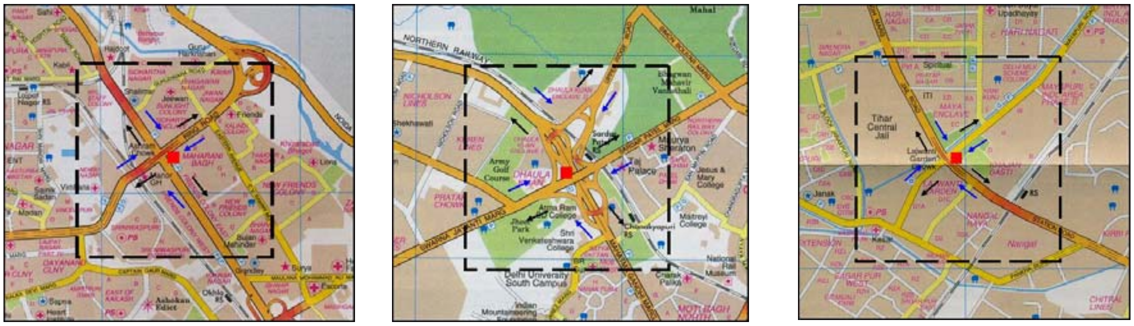
Location	Additional Traffic Count Locations
Ashram Chowk	
Main Roads	East. Avenue to CV Raman Rd, Dayanand Colony Rd
Feeder Roads	Mathura Rd to CV Raman Rd, to Jeevan ngr Rd, to Gurudwara, CV Raman to Khijarabad, Sriniwaspuri Rd, Maharani Bagh - Western Avenue, Maharani Bagh - Central Avenue, Near Rly Line (Below F.O.), Subji Market area
Dhaula Kuan	
Main Roads	Venkateshwara College Road
Feeder Roads	Taj Residency Road, Rly Bridge on SP Marg, Hotel Taj (SP Marg), Army Golf Course
Mayapuri	
Main Roads	Mohan Nagar Rd
Feeder Roads	Mayapuri Industrial Area, Mayapuri Enclave (EA), Pratap Nagar (EB), Nangal Raya, Delhi Milk Scheme
ISBT	
Main Roads	Yamuna Marg, MPCU Road, Rajpur Road
Feeder Roads	MG Road to Old Secretriate
Loni Road	
Main Roads	Wazirabad Rd to Zaffrabad Rd
Feeder Roads	Loni Rd to Ganga Vihar, Ganga Vihar to Wazirabad, Gokulpur to Gokulpuri, Zaffrabad to Atul Marg, Loni Rd to Chitrakoot Colony Rd, Chitrakoot to Mangal Pande Rd, Meenakshi Cinema to Rajnagar Rd, Rajnagar to Meet nagar
Anand Vihar	
Arterial Roads	
Main Roads	Wave Cinema to Maharajpur
Feeder Roads	Gazipur Road to Asha Pushp Vihar, Jagriti Enclave to Harishchandra Rd, Jagriti Enclave to AV Rly Stn., Chanakyapuri Road
Naraina	
Main Roads	Inderpuri Road, Jagir Palace
Feeder Roads	Budh Nagar, Bank Colony, Near Rly Track, Naraina PVR
SSI-GTK	
Main Roads	--
Feeder Roads	Jahangirpuri Ind. Area, Jahangirpuri Red light, Ramagad Road- I Block, Ramagad Road- LIC Flat, Sanjay Gandhi Transport nagar, Ayurvedic nagar
Pitampura	
Main Roads	Prashant Vihar F Block
Feeder Roads	Gyanshakti Mandir, JU Block, BU Block, LU Block, CRPF School
Prahladpur	
Main Roads	Bawana Road, Prahlad Vihar

Vehicles were counted under three major traffic movement categories (fast moving vehicles, goods & passenger vehicles and slow moving vehicles) as given in **Table 3.22**.

Table 3.22: Traffic Classification used in Primary Data Collection

Fast Moving Vehicles	All types of 2 Wheelers	Scooter, Moped, Motorcycle (Petrol)
	All types of 4 Wheelers	Car, Jeep, Van, Taxi etc. (Petrol/Diesel/CNG/LPG)
Goods & Passenger Vehicles	Light Duty Goods Vehicle	LCVs (mini truck, 5 wheelers etc.) - Diesel
	Heavy Duty Goods Vehicle	Trucks, Trailer, Multi-axle trucks (Diesel)
	Light Duty Passenger Vehicles	3 Wheelers – Autos (CNG)
	Heavy Duty Passenger Vehicles	Mini buses (Diesel, CNG)
		Buses (Diesel, CNG)
Slow Moving Vehicles	Non-motorized Vehicles	Cycles, Rickshaws

Traffic count locations on arterial/ring roads around the air quality monitoring stations (marked as red box), are indicated with arrows in **Fig. 3.18.**



Ashram Chowk Dhaula Kuan Mayapuri-Lajwanti Garden Chowk

Ring Road - ISBT Loni Road Anand Vihar - ISBT

Naraina Industrial Area GT Karnal Road-Makbara Chowk Pitampura

Fig. 3.18: Traffic Count Locations within 2km x 2 km Representative Study Zones

Photographs taken during traffic count study are shown below:

Photographs Showing Traffic Count in Delhi

3.1.3.3 Survey of Passenger and Goods Vehicles

In order to study the characteristics of different kinds of vehicles plying in Delhi, representative survey of passenger and goods vehicles was carried out in May-June 2007. The survey was mainly conducted at petrol pumps, bus terminals, taxi stands and parking lots. About 2900 passenger vehicles and about 1200 goods vehicles have been surveyed. Category-wise distribution of vehicles is given in **Table 3.3.2.4.**

Table 3.23: Matrix for Passenger and Goods Vehicles Survey

Passenger Vehicles Survey

No. of Passenger Vehicles Surveyed at each Location							Total Vehicles at 10 locations
2 W	3 W	New Cars	Old Cars	Taxi	Bus	Total	
100	30	50	50	30	30	290	2900

Goods Vehicles Survey

No. of Goods Vehicles Surveyed at each Location				Total Vehicles at 10 locations
LCV	Truck	Multi-axle truck	Total	
60	40	20	120	1200

Survey of passenger and goods vehicles has been conducted using questionnaires given in **Annexure III**, which include basic information on vehicle type, make, usage, fuel consumption and inspection and maintenance details. Besides, details on exhaust emissions obtained through PUC check have also been incorporated in the questionnaire.

Parking lot surveys of passenger and goods vehicles were carried out for more than 4100 vehicles covering all the major categories of the vehicles. Analysis of vehicles survey provided information about vintage of vehicles in the fleet, mileage, daily travel etc. These factors have been considered while estimating the emission loads for different categories of vehicles.

3.1.3.4 Approach for Analysis of Data and Emission Load Estimation

Primary data on traffic counts collected on each road in each of the study zones has been analyzed with respect to the following:

- Total daily traffic volume on major roads (arterial/ring roads)
- Peak hour traffic composition as fast moving vehicles, buses, goods vehicles and slow moving vehicles
- Comparison of peak hour traffic composition on working and non-working days (on the roads nearest to the AQM Sites)
- Estimation of traffic composition on different types of roads (arterial, main and feeder roads) in each 2 km x 2 km study zone
- Estimation of total vehicle kilometer travel (VKT) in each study zone based on traffic data and road length. Length of different types of road categories (arterial roads, main roads and feeder roads) has been estimated from Eicher Map of Delhi City, available in 500 m x 500 m grid size
- Estimation of vehicular emission load in terms of four major pollutants, viz. PM, CO, HC and NOx, in each of the 2 km x 2 km study zones using the traffic count data on each category of road and applicable emission factors (developed by ARAI).
- Estimation of percent emission contribution (in terms of PM, CO, HC and NOx) for each category of road and also for different categories of vehicles in each of the study zones.
- Estimation of SO_2 emission load based on diesel consumption (Sulfur in Diesel - 350 ppm)

- Estimation of re-suspended dust load (in terms of PM10 and PM2.5) due to traffic movement on paved roads for each study zone
- Preparation of overall average traffic emission scenario based on the data collected for the ten 2 km x 2 km study zones

Based on the above analysis, pollutant-wise highest, second highest, lowest and second lowest polluting zones have been identified. Further, pollutant-wise first two vehicle categories contributing to the highest emissions in each of the study zones have been identified, which would facilitate in preparing management plan/ action plan for control of emissions from vehicular sources.

3.1.3.5 Applicable Emission Factors

Emission Factors for different types and makes of vehicles have been developed by Automotive Research Association of India (ARAI), Pune specifically for this study. The emission factors available for more than one vehicle of the same category have been averaged. In case of any particular model year emission factor not available, previous or next model year emission factor has been taken for calculations. The emission factors used in the emission load calculations are summarized in **Annexure III.**

3.1.3.6 Analysis of Primary Data

Total Daily Traffic Volume on Major Roads

The total number of motorized vehicles plying on different major (arterial/ring) roads in each of the study zones is given in **Table 3.24**.

Table 3.24: Total Motorized Traffic Volume on Different Major Roads in the Study Zone

Sr. No.	Study Zone	Traffic Count Location	Total Vehicles (Nos./day)
1.	Ashram Chowk	towards Badarpur (Mathura Road)	115397
		towards Lajpat Nagar	142591
		towards Nizamuddin Rly. Stn.	76043
		towards Sarai Kale Khan	175769
		Over Flyover	105125
2.	Dhaula Kuan	towards Airport-Swaran Jayanti Marg	130124
		towards AIIMS	169321
		towards Naraina	130603
		towards India Gate	71896
		towards upper Ridge Road	41068
3.	Mayapuri (Lajwanti Garden Chowk)	towards Delhi Cantt.	65313
		towards Mayapuri (Main Road)	63675
		towards Tilak Nagar	67236
		towards Sagarpur (Main Road)	37520
4.	ISBT – Ring Road (T-Point near AAQ site)	towards ISBT	109810
		towards Civil Lines (Mian Road)	36186
		towards Majnu Ka Tilla	76835
5.	Loni Road (Loni Golchakkar)	towards Loni (Main Road)	69905
		towards Ghaziabad	69664
		towards Shahdara (Main Road)	58295
		towards Wazirabad	79981
		Over Flyover	37406
6.	Anand Vihar ISBT	towards Gazipur	91200
		towards Preet Vihar	75080
		towards Sahibabad	66777
		Telco Chowk to Vivek Vihar	88682
7.	Naraina Industrial Area (Ring Road T-Point)	towards Mayapuri	168833
		towards Dhaula Kuan	134964
		towards Naraina Industrial Area (Main Road)	68995
		Naraina Industrial Area to Loha Mandi (Main Road)	58051
8.	GT Karnal Road – Azadpur (Makbara Chowk)	Towards Model Town	49214
		Towards Madhuban Chwok	100853
		Towards Karnal Road	96988
		Towards Wazirabad	86373
9.	Pitampura	Opp. AAQ Site (Santhom Hospital)	86978
		Pitampura Road (near BU Block)	33413
		Outer Ring Road (near District Park)	47223
10.	Prahladpur	No significant road/traffic	--

Highest traffic was observed in Dhaula Kuan area and the lowest traffic in Pitampura area. First ten major roads having more than 1 lakh vehicles are summarized in **Table 3.25.**

Table 3.25: Ten Major Roads with High Traffic Flow

Rank	Road Description	Total Daily Traffic	Study Zone
1	Ashram Chowk to Sarai Kale Khan	175769	Ashram Chowk
2	Dhaula Kuan to AIIMS	169321	Dhaula Kuan
3	Naraina T-Point to Mayapuri	168833	Naraina
4	Ashram Chowk to Lajpat Nagar	142591	Ashram Chowk
5	Naraina T-Point to Dhaula Kuan	134964	Naraina
6	Dhaula Kuan to Naraina	130603	Dhaula Kuan
7	Dhaula Kuan to Swaran Jayanti Marg (Airport Road)	130124	Dhaula Kuan
8	Ashram Chowk to Badarpur (Mathura Road)	115397	Ashram Chowk
9	Ring Road towards ISBT	109810	Ring Road (ISBT)
10	SSI-GTK to Madhban Chowk	100853	SSI-GTK

It is clear from the above Table that Ashram Chowk, Dhaula Kuan and Naraina study zone are having maximum traffic activity, followed by ISBT and SSI-GTK area.

Peak Hour Traffic Composition on Major Roads

Peak hour traffic composition has been estimated during morning and evening hours on all the arterial/ring roads in the study zones. The vehicles are categorized into four major categories as fast moving vehicles (all 2W and 4 W), buses, goods vehicles (LCV, trucks) and slow moving vehicles (cycles & rickshaws). Peak hour composition during morning and evening hours at each of the major roads is summarized in **Table 3.26**. Overall fast moving vehicles dominate the traffic movement. At few locations like Loni Road and Mayapuri area, slow moving traffic is also found to be significant, which add to congestion leading to severe air pollution problem.

Table 3.26: Peak Hour Traffic Composition on Major Roads in the Study Zones (24 Hour Traffic Count)

Sr. No.	Name of the Location	Peak Hour Traffic Composition (%)				
		Peak Hour	Total Fast	Total Buses	Total Goods	Total Slow
A.	**Ashram Chowk**					
1	Towards Badarpur	Morn-Peak	92.67	2.30	1.50	3.53
		Even-Peak	90.17	3.82	3.80	2.22
2	Towards Nizamuddin Rly Stn.	Morn-Peak	90.92	3.19	1.27	4.62
		Even-Peak	91.17	3.55	1.02	4.27
3	Towards Sarai Kale Khan	Morn-Peak	93.40	3.62	1.11	1.87
		Even-Peak	94.48	2.63	0.54	2.36
4	Towards Lajpat Nagar	Morn-Peak	90.85	5.88	1.00	2.27
		Even-Peak	90.76	3.33	4.31	1.60
5	Flyover	Morn-Peak	97.31	2.31	0.26	0.12
		Even-Peak	95.38	2.22	2.34	0.06
B.	**Dhaula Kuan**					
6	Swaran Jayanti Marg (AAQ Site)	Morn-Peak	92.12	5.56	0.67	1.65
		Even-Peak	93.48	4.70	0.28	1.54
7	Towards AIIMS (Near Venkateshwara Collage)	Morn-Peak	95.47	2.97	0.60	0.96
		Even-Peak	94.61	2.94	1.10	1.35
8	Towards Naraiana T- Point	Morn-Peak	95.37	1.96	1.20	1.46
		Even-Peak	94.45	2.34	2.38	0.82
9	Towards Sardar Patel Marg (Near Taj Palace)	Morn-Peak	93.37	4.45	1.65	0.53
		Even-Peak	94.04	2.67	1.08	2.22
10	Upper Ridge Road	Morn-Peak	91.92	1.10	6.65	0.32
		Even-Peak	84.48	1.20	12.99	1.32
C.	**Mayapuri (Lajwanti Garden Chowk)**					
11	Towards Delhi Cantt.	Morn-Peak	86.41	2.79	2.84	7.96
		Even-Peak	92.39	1.52	1.10	4.99
12	Towards Maya Puri	Morn-Peak	67.02	2.44	2.34	28.20
		Even-Peak	67.94	3.78	1.72	26.56
13	Towards Tilak Nagar	Morn-Peak	92.93	0.82	1.70	4.55
		Even-Peak	93.96	0.91	0.55	4.59
14	Towards Sagar pur	Morn-Peak	29.63	4.78	0.97	64.62
		Even-Peak	55.25	4.29	4.18	36.28
D.	**Ring Road – Naraina T Point**					
15	Fire Brigade office (Near Loha Mandi ROB)	Morn-Peak	88.72	3.15	0.59	7.54
		Even-Peak	91.21	2.45	2.27	4.08
16	Towards Dhoula Kuan	Morn-Peak	95.89	1.40	1.05	1.65
		Even-Peak	94.80	1.68	1.85	1.67

Table 3.26 (Contd..) : Peak Hour Traffic Composition on Major Roads in the Study Zones (24 Hour Traffic Count)

Sr. No.	Name of the Location	Peak Hour Traffic Composition (%)				
		Peak Hour	Total Fast	Total Buses	Total Goods	Total Slow
17	Towards Mayapuri (Near ROB)	Morn-Peak	90.56	5.59	0.78	3.06
		Even-Peak	94.15	2.09	1.50	2.26
18	Towards Naraiana Industrial Area	Morn-Peak	92.12	1.76	0.43	5.69
		Even-Peak	92.93	1.57	0.48	5.03
E.	**Anand Vihar ISBT**					
19	Towards Gazipur	Morn-Peak	81.13	3.55	0.89	14.44
		Even-Peak	77.92	3.15	1.34	17.59
20	Towards Sahibabad	Morn-Peak	84.84	2.23	0.70	12.22
		Even-Peak	78.98	8.69	0.40	11.94
21	Towards Preet Vihar	Morn-Peak	72.49	3.52	2.36	21.62
		Even-Peak	81.80	3.51	1.23	13.47
22	Towards Vivek Vihar	Morn-Peak	86.11	3.34	2.32	8.24
		Even-Peak	81.40	5.85	0.96	11.79
F.	**Loni Gol Chakker**					
23	Towards Wazirabad	Morn-Peak	63.86	2.95	3.23	29.96
		Even-Peak	63.62	3.37	1.57	31.45
24	Towards Loni Border	Morn-Peak	34.60	0.95	1.15	63.31
		Even-Peak	75.55	1.02	0.83	22.60
25	Towards Sahadara	Morn-Peak	37.27	0.39	1.24	61.10
		Even-Peak	53.53	0.68	0.93	44.86
26	Towards Ghaziabad	Morn-Peak	49.21	4.23	0.97	45.59
		Even-Peak	71.30	4.20	2.87	21.64
27	Flyover	Morn-Peak	90.59	8.44	0.78	0.18
		Even-Peak	71.12	8.47	19.69	0.71
G.	**Ring Road (Near ISBT)**					
28	Towards ISBT	Morn-Peak	78.84	4.39	1.64	15.14
		Even-Peak	82.88	4.74	1.59	10.78
29	Towards Civil Lines	Morn-Peak	92.77	2.33	1.26	3.65
		Even-Peak	88.82	3.53	1.77	5.88
30	Towards Wazirabad	Morn-Peak	70.32	4.27	6.73	18.68
		Even-Peak	52.07	3.77	39.13	5.03
H.	**G.T. Karnal Bypass Chowk**					
31	Towards Madhuban	Morn-Peak	74.06	3.33	4.45	18.16
		Even-Peak	81.78	2.99	5.18	10.06
32	Towards ISBT	Morn-Peak	73.27	4.33	19.02	3.38
		Even-Peak	66.06	4.68	25.67	3.59

Table 3.26 (Contd..) : Peak Hour Traffic Composition on Major Roads in the Study Zones (24 Hour Traffic Count)

Sr. No.	Name of the Location	Peak Hour Traffic Composition (%)				
		Peak Hour	Total Fast	Total Buses	Total Goods	Total Slow
33	Towards Karnal	Morn-Peak	64.98	3.33	23.72	7.97
		Even-Peak	65.46	4.51	19.71	10.32
34	Towards Model Town-Azadpur	Morn-Peak	44.38	5.59	6.16	43.87
		Even-Peak	56.73	6.10	19.59	17.59
I.	**Pitampura**					
35	Opp. AAQ Site (Near Santom Hospital)	Morn-Peak	81.93	2.81	4.45	10.81
		Even-Peak	81.68	3.04	5.25	10.03
36	Pitam Pura Road (Near BU Block)	Morn-Peak	87.12	0.04	3.79	9.05
		Even-Peak	86.78	0.04	1.94	11.24
37	Pitam Pura Outer Ring Road (Near District Park)	Morn-Peak	85.73	0.09	0.91	13.28
		Even-Peak	73.75	0.05	1.31	24.88

Comparison of Traffic on Working and Non-working Days

Traffic movement was also counted on non-working days (between 8 am & 8 pm) at the arterial/major roads nearest to the AQM site, and it has been compared with the traffic on the working day. Traffic volume counted on working and non-working days at the AQM site proximity road is given in **Table 3.27**.

Table 3.27: Comparison of Peak Hour Traffic Composition on Working and Non-Working Days (Traffic Count on the Roads near AQM Sites)

Road nearest to the AQM Site		Working				Non Working			
		Fast	Buses	Goods	Slow	Fast	Buses	Goods	Slow
Ashram Chowk - Mathura Road	Morn-Peak	92.67	2.30	1.50	3.53	89.77	3.44	5.12	1.67
	Even-Peak	90.17	3.82	3.80	2.22	88.07	3.53	6.90	1.50
Dhaula Kuan - Swaran Jayanti Marg	Morn-Peak	92.12	5.56	0.67	1.65	89.07	7.43	2.78	0.73
	Even-Peak	93.48	4.70	0.28	1.54	88.91	5.31	4.10	1.68
Lajwanti Garden Chowk-Mayapuri Rd.	Morn-Peak	67.02	2.44	2.34	28.20	43.38	3.01	0.85	52.76
	Even-Peak	67.94	3.78	1.72	26.56	68.54	2.91	1.83	26.72
Anand Vihar ISBT-Gazipur Road	Morn-Peak	81.13	3.55	0.89	14.44	86.67	5.40	1.42	6.51
	Even-Peak	77.92	3.15	1.34	17.59	86.63	5.21	0.94	7.22

Table 3.27 (Contd..): Comparison of Peak Hour Traffic Composition on Working and Non-Working Days (Traffic Count on the Roads near AQM Sites)

Road nearest to the AQM Site		Working				Non Working			
		Fast	Buses	Goods	Slow	Fast	Buses	Goods	Slow
Outer Ring Road – ISBT(AAQ Site)	Morn-Peak	78.84	4.39	1.64	15.14	83.53	4.85	10.29	1.34
	Even-Peak	82.88	4.74	1.59	10.78	84.99	5.80	6.46	2.75
Naraina Industrial Area-Loha Mandi	Morn-Peak	88.72	3.15	0.59	7.54	87.29	3.38	5.90	3.42
	Even-Peak	91.21	2.45	2.27	4.08	90.48	2.96	2.56	4.00

In general, fast moving traffic dominates at all the locations on both the occasions, however, slow moving traffic is also found to be significant at Lajwanti Garden Chowk-Mayapuri Road on working as well as non-working days.

3.1.3.7 Emission Load Estimation in 2 km x 2 km Study Zone

Road Category-wise Traffic Count

The traffic count data has been analyzed for three types of road categories, viz. arterial/ring roads, main roads (next category to arterial roads) and feeder roads in each study zone. Based on the primary data collected in the study zones, composition of traffic has been calculated under six broad categories of the vehicles, namely; 2W, 3W, 4W, LCVs, trucks and buses. Daily traffic counts on arterial/ring roads, main roads and feeder roads have been estimated based on the primary data for each study zone. Composition of traffic along with total number of vehicles in each study zone is given in **Table 3.28.**

Table 3.28: Road Category-wise Total Daily Traffic and Fleet Composition

Study Zone	Road Type	Total Vehicles	Composition in Fleet, (%)					
			2W	3W	4W	LCVs	Trucks	Buses
Ashram Chowk	Arterial Roads	124225	31.8	10.3	46.8	3.9	3.9	3.4
	Main Roads	40923	33.7	10.6	42.7	6.6	2.7	3.7
	Feeder Roads	10005	39.1	10.7	45.6	2.8	1.0	0.7
Dhaula Kuan	Arterial Roads	123906	29.6	8.3	50.7	4.2	3.6	3.6
	Main Roads	40728	31.4	8.6	46.3	7.2	4.0	2.5
	Feeder Roads	11981	29.9	2.2	61.5	4.3	1.4	0.6
Mayapuri	Arterial Roads	63005	32.3	9.7	53.4	2.0	0.6	2.0
	Main Roads	37390	46.4	10.0	30.9	6.0	0.5	6.2
	Feeder Roads	10283	48.9	9.4	36.8	1.2	0.4	3.3
ISBT	Arterial Roads	87478	27.3	9.4	37.1	13.2	7.8	5.3
	Main Roads	10067	24.1	9.7	39.7	24.9	0.1	1.5
	Feeder Roads	2190	42.0	7.4	46.1	4.5	0.0	0.1

Table 3.29: Road Category-wise Total Daily Traffic and Fleet Composition

Study Zone	Road Type	Total Vehicles	Composition in Fleet, (%)					
			2W	3W	4W	LCVs	Trucks	Buses
Loni Road	Arterial Roads	57145	43.7	15.3	24.9	6.0	4.5	5.6
	Main Roads	38168	44.9	35.0	11.5	4.4	2.1	2.1
	Feeder Roads	4000	73.3	6.5	13.2	4.8	1.1	1.0
Anand Vihar	Arterial Roads	70918	34.7	12.5	41.2	3.5	2.5	5.6
	Main Roads	9285	52.1	3.6	36.0	5.5	0.0	2.8
	Feeder Roads	6439	37.3	3.5	53.2	3.8	1.1	1.0
Naraina	Arterial Roads	79377	30.9	6.9	43.9	10.3	4.7	3.3
	Main Roads	60349	41.5	6.6	43.6	4.1	1.2	2.9
	Feeder Roads	5695	46.6	9.5	40.8	2.9	0.3	0.0
SSI-GTK	Arterial Roads	73679	25.1	8.8	37.6	13.4	10.4	4.7
	Main Roads	0	0	0	0	0	0	0
	Feeder Roads	6567	27.6	2.5	49.5	15.1	4.5	0.9
Pitampura	Arterial Roads	92122	30.0	9.1	46.1	6.3	4.6	3.9
	Main Roads	34684	39.1	7.7	49.2	3.6	0.3	0.2
	Feeder Roads	6227	39.0	7.3	44.0	7.7	1.2	0.8
Prahladpur	Arterial Roads	0	0	0	0	0	0	0
	Main Roads	37473	38.9	12.4	38.0	6.0	1.7	2.9
	Feeder Roads	7043	40.5	6.5	45.7	4.9	1.3	1.1
Overall Average	Arterial Roads	87762	31.2	9.8	43.5	6.8	4.7	4.1
	Main Roads	34341	39.3	12.1	37.9	6.0	1.7	2.9
	Feeder Roads	7043	40.5	6.5	45.7	4.9	1.3	1.1

In terms of total number of vehicles, 2W and 4W constitute the major share, together amounting to 74.7% on arterial roads, 77.2% on main roads and 86.2% on feeder roads. Average composition of vehicles in the fleet on different types of roads is given in **Fig. 3.19**.

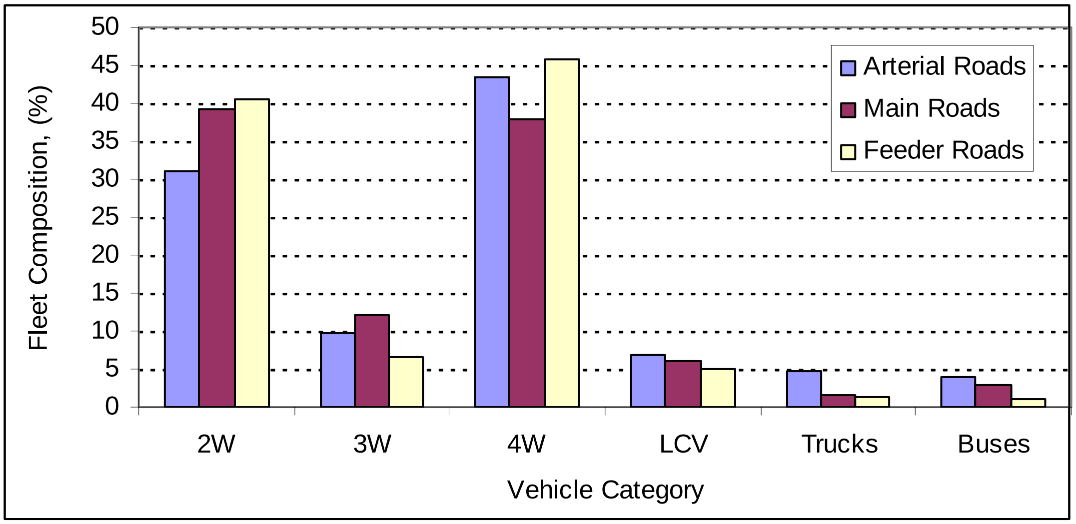


Fig. 3.19: Average Fleet Composition of Different Types of Roads

It can be observed from the above figure, that in the fleet composition 2 and 4 Wheelers are found more on feeder roads, whereas LCV, trucks and buses are highest on arterial roads and lowest on feeder roads, whereas 4 Wheelers on arterial roads are close to feeder roads. 3 Wheelers are found to ply more on main roads, however, its presence on other road types is not too low (ranging between 7-10%).

VKT in Each Study Zone

The total vehicle kilometers travelled in each study zone has been estimated based on the length of different categories of roads, viz. arterial/ring roads, main roads (next category to arterial roads) and feeder roads and categorized traffic count on these roads. Length of each category of road has been measured from the Eicher City Map of Delhi (available in 500 m x 500 m grids), and is given in **Table 3.30**.

Table 3.30: Length of Different Categories of Roads in each Study Zone

Study Zone	Length of Road, (Km)				
	Arterial Roads	Main Roads	Feeder Roads	Minor Roads	Total
Ashram Chowk	5.4	1.4	14.1	27.8	48.7
Dhaula Kuan	5.4	1.4	5.0	18.7	30.5
Mayapuri	3.0	4.0	4.4	30.5	41.9
ISBT	7.3	1.1	4.1	8.0	20.5
Loni Road	2.0	2.6	11.0	44.9	60.5
Anand Vihar	3.8	1.1	4.0	21.7	30.6
Naraina	2.6	4.3	6.6	33.9	47.4
SSI-GTK	4.6	0.0	9.9	31.2	45.7
Pitampura	1.4	1.9	19.3	40.2	62.8
Prahladpur	0.0	2.0	5.9	19.9	27.8

(Note: It is assumed that vehicles on minor road travels only for a short distance of 100-200 m and join either feeder, main or arterial road, hence traffic movement on minor road (street level) is not considered in VKT calculation)

Based on the traffic count and measured road length (arterial, main and feeder roads), total vehicle travel by each category vehicle (2W, 3W, 4W, LCVs, trucks and buses) and their percent contribution on different types of roads is estimated, as presented in **Table 3.31**.

Table 3.31: Road Category-wise Total VKT with % Share of Different Categories of Vehicles

Study Zone & Road Type	Total VKT (km)	Share of Vehicle Category in VKT, (%)						
		2W	3W	4W	LCV	Trucks	Buses	Average
Ashram Chowk								
Arterial	670816	74.1	76.5	77.9	76.9	90.0	87.7	80.5
Main	57292	6.7	6.7	6.1	11.3	5.3	8.2	7.4
Feeder	141067	19.2	16.8	16.0	11.8	4.7	4.0	12.1
Total	869175	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Dhaula Kuan								
Arterial	669091	86.1	91.5	85.5	82.8	90.2	94.2	88.3
Main	44801	6.1	6.3	5.2	9.5	6.6	4.4	6.4
Feeder	59906	7.8	2.1	9.3	7.7	3.2	1.5	5.3
Total	773797	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Mayapuri								
Arterial	189015	40.0	48.8	61.6	28.5	55.7	26.0	43.5
Main	149560	45.5	39.9	28.2	67.5	34.6	63.8	46.5
Feeder	45246	14.5	11.3	10.2	3.9	9.7	10.2	10.0
Total	383821	100.0	100.0	100.0	100.0	100.0	100.0	100.0
ISBT								
Arterial	638586	96.4	97.2	96.5	96.4	100.0	99.5	97.7
Main	11073	1.5	1.7	1.8	3.2	0.0	0.5	1.4
Feeder	8979	2.1	1.1	1.7	0.5	0.0	0.0	0.9
Total	658638	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Loni Road								
Arterial	114289	39.4	31.7	62.3	51.6	66.2	71.9	53.8
Main	99236	35.2	63.1	25.0	32.6	27.3	22.9	34.3
Feeder	44002	25.4	5.2	12.7	15.9	6.5	5.2	11.9
Total	257526	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Anand Vihar								
Arterial	269488	86.2	96.4	86.4	85.8	96.1	96.4	91.2
Main	10214	4.9	1.1	2.9	5.1	0.0	1.9	2.6
Feeder	25756	8.9	2.6	10.7	9.1	3.9	1.7	6.2
Total	305458	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Naraina								
Arterial	206380	33.8	40.6	41.3	64.3	74.7	47.6	50.4
Main	259499	57.0	49.1	51.7	32.4	24.6	52.4	44.5
Feeder	37587	9.3	10.2	7.0	3.3	0.7	0.0	5.1
Total	503466	100.0	100.0	100.0	100.0	100.0	100.0	100.0
SSI-GTK								
Arterial	338923	82.6	94.9	79.8	82.2	92.4	96.5	88.1
Main	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feeder	65011	17.4	5.1	20.2	17.8	7.6	3.5	11.9
Total	403934	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Pitampura								
Arterial	128971	34.8	45.7	41.1	41.2	78.4	83.0	54.0
Main	65900	23.1	19.8	22.4	12.0	2.4	1.9	13.6
Feeder	120176	42.1	34.5	36.5	46.8	19.2	15.1	32.4
Total	315046	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 3.31 (Contd…): Road Category-wise Total VKT with % Share of Different Categories of Vehicles

Study Zone & Road Type	Total VKT (km)	Share of Vehicle Category in VKT, (%)						
		2W	3W	4W	LCV	Trucks	Buses	Average
Prahladpur								
Arterial	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Main	74945	63.4	77.6	60.0	69.0	71.0	82.6	70.6
Feeder	41554	36.6	22.4	40.0	31.0	29.0	17.4	29.4
Total	116499	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Overall Average								
Arterial	358396	57.3	62.3	63.3	61.0	74.4	70.3	64.8
Main	85835	24.3	26.5	20.3	24.3	17.2	23.8	22.7
Feeder	58928	18.3	11.1	16.4	14.8	8.4	5.9	12.5
Total	503159	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Total VKT on arterial roads varies from 1.14 lakh km (at Loni Road) to 6.71 lakh km (at Ashram Chowk), followed by 6.70 lakh km at Dhaula Kuan and 6.39 lakh km at ISBT, with an overall average of 3.58 lakh km. On main roads, total VKT vary from about 10200 km (at Anand Vihar) to 2.6 lakh km (at Naraina), followed by 1.50 lakh km at Mayapuri and 0.99 lakh km at Loni, with an overall average of 0.85 lakh km. On feeder roads, total VKT varies from about 9000 km (at ISBT) to 1.41 lakh km (at Ashram Chowk), followed by 1.20 lakh km at Pitampura and 0.65 lakh km at SSI-GTK, with an overall average of 0.59 lakh km.

Road category-wise percent share of VKT in each of the study zones is presented in **Fig. 3.20**.

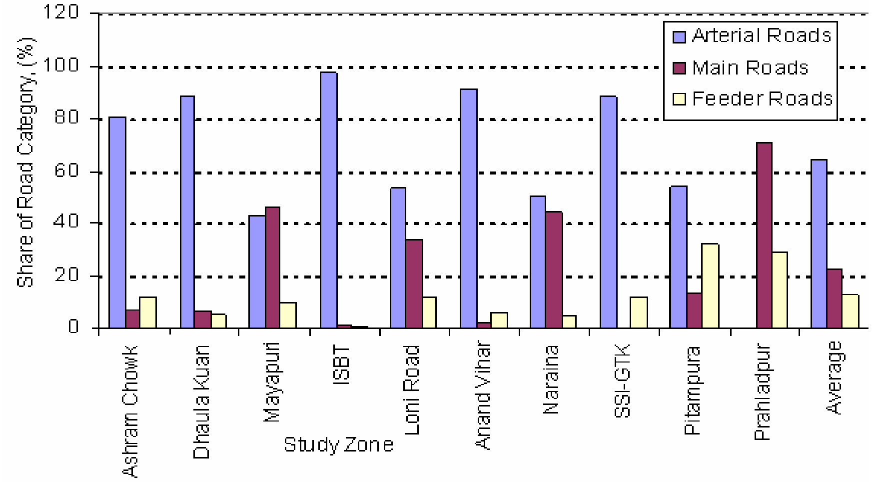


Fig. 3.20: Road category-wise Percent Share of VKT in each Study Zone

Arterial roads in five study zones, namely Ashram Chowk, Dhaula Kuan, ISBT, Anand Vihar and SSI-GTK, contribute more than 80%, highest being at ISBT (97.7%) and lowest at Ashram Chowk (80.5%). Among all the sites, the lowest contribution is observed at Mayapuri (43.5%). Share of main roads varies from 1.4% (at ISBT) to 70.6% at Prahladpur. Similarly, share of feeder roads varies from 0.9% (at ISBT) to 32.4% at Pitampura. The overall average share of arterial, main and feeder roads is calculated to be 64.8%, 22.7% and 12.5%, respectively.

3.1.3.8 Vehicular Emission Load

Assumptions

The following assumptions have been made in order to estimate emission load for different categories, make and model of vehicles. These assumptions are based on primary traffic count data, vehicles survey and number of registered vehicles.

- **Fleet Age Composition:** Age-wise percentage composition of fleet is assumed based on the total number of registered vehicles and the information provided in CPCB document (2001). For the vehicle make, the following composition (**Table 3.32**) has been assumed in the fleet uniformly at all the locations. In general, 85-95% of the vehicles are estimated to be about 10 years. All the autos are considered to be of CNG.

Table 3.32: Year-wise Composition in Total Fleet

Vehicle	1991-1996	1996-2000	2001-2006	2006 onwards
2W-2S	5	40	50	5
2W-4S	0	15	70	15
3W-CNG	0	0	100	0
4W-P	5	40	50	5
4W-D	5	40	50	5
4W-D-T	5	40	50	5
LCV	5	60	30	5
Trucks	5	60	30	5
Buses	0	55	40	5

- **2 Stroke and 4 Stroke 2 Wheelers:** It has been observed from traffic count (through video recording) and vehicle survey that among the total 2 Wheelers, 72% are motorbikes, while the rest 28% are scooters. The same ratio of 72:28 has been considered for 4 Stroke and 2 Stroke 2 Wheelers.

- Among the total 4 Wheelers in the fleet, 92% are petrol vehicles, 5% diesel vehicles and 3% vehicles use CNG.
- Among the total buses in the fleet, 23% use diesel and 77% use CNG.
- Total vehicular emission load has been estimated in terms of 4 major pollutants, viz. PM, CO, HC and NOx using emission factors developed by ARAI.
- Further, emission load for SO_2 has been estimated based on diesel consumption and sulfur content (350 ppm) in diesel.

Estimated Emission Load

Based on the total vehicle movement (VKT) and applicable emission factors, total emission load on different types of roads in each of the study zones has been estimated. Road type wise total Pollutant emission load and percent share of road type is presented in **Table 3.33.**

Table 3.33: Road Category wise Vehicular Emission Load (kg/d) and Percent Share in all the Study Zones and Overall Average

Study Zone/Road Category	Total Emission Load (kg/day)					Share, (%)				
	PM	CO	HC	NOx	SO_2	PM	CO	HC	NOx	SO_2
Ashram Chowk										
Arterial Roads	82.9	1905.9	579.1	746.0	5.72	83.8	79.3	78.0	84.5	83.8
Main Roads	7.0	155.2	51.6	60.2	0.51	7.0	6.5	6.9	6.8	7.5
Feeder Roads	9.1	341.0	112.0	76.7	0.59	9.2	14.2	15.1	8.7	8.7
Dhaula Kuan										
Arterial Roads	80.2	1912.6	556.4	741.8	5.79	86.6	85.5	86.4	87.9	85.4
Main Roads	8.1	165.1	48.7	64.4	0.62	8.8	7.4	7.6	7.6	9.2
Feeder Roads	4.3	159.3	39.1	37.7	0.37	4.7	7.1	6.1	4.5	5.4
Mayapuri										
Arterial Roads	10.1	458.2	142.3	110.0	0.69	39.0	49.2	42.5	39.1	38.4
Main Roads	13.4	366.3	152.2	142.4	0.98	51.7	39.3	45.4	50.7	54.8
Feeder Roads	2.4	107.5	40.6	28.6	0.12	9.3	11.5	12.1	10.2	6.8
ISBT										
Arterial Roads	159.1	2194.3	656.3	1222.5	12.49	98.5	97.8	97.5	98.8	98.1
Main Roads	2.0	28.0	10.0	10.5	0.21	1.2	1.2	1.5	0.8	1.7
Feeder Roads	0.5	21.1	6.9	3.7	0.04	0.3	0.9	1.0	0.3	0.3

Table 3.34: Road Category wise Vehicular Emission Load (kg/d) and Percent Share in all the Study Zones and Overall Average

Study Zone/Road Category	Total Emission Load (kg/day)					Share, (%)				
	PM	CO	HC	NOx	SO_2	PM	CO	HC	NOx	SO_2
Loni Road										
Arterial Roads	18.2	324.4	125.5	158.3	1.21	54.3	50.4	43.8	59.7	59.6
Main Roads	11.4	212.7	115.6	79.6	0.60	34.2	33.0	40.3	30.0	29.3
Feeder Roads	3.9	107.2	45.6	27.1	0.23	11.5	16.6	15.9	10.2	11.1
Anand Vihar										
Arterial Roads	28.6	717.2	254.9	298.1	1.91	92.2	88.7	90.2	93.1	91.0
Main Roads	0.7	24.9	9.1	6.5	0.05	2.2	3.1	3.2	2.0	2.5
Feeder Roads	1.7	66.3	18.6	15.5	0.14	5.6	8.2	6.6	4.8	6.5
Naraina										
Arterial Roads	43.9	1130.3	285.0	404.5	3.31	66.0	60.1	53.3	65.5	67.2
Main Roads	20.6	663.1	219.5	198.3	1.49	31.0	35.3	41.0	32.1	30.3
Feeder Roads	2.0	87.3	30.3	15.1	0.12	3.0	4.6	5.7	2.5	2.5
SSI-GTK										
Arterial Roads	98.9	1273.1	349.4	740.3	7.60	89.0	86.3	87.0	90.3	87.4
Main Roads	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0
Feeder Roads	12.3	201.6	52.2	79.9	1.10	11.0	13.7	13.0	9.7	12.6
Pitampura										
Arterial Roads	19.3	338.5	99.7	148.8	1.55	56.2	42.3	40.5	57.6	56.1
Main Roads	3.6	157.1	49.0	28.7	0.26	10.4	19.6	19.9	11.1	9.6
Feeder Roads	11.5	305.0	97.5	80.9	0.95	33.4	38.1	39.6	31.3	34.4
Prahladpur										
Arterial Roads	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0
Main Roads	4.3	102.2	41.7	40.7	0.33	43.1	39.9	42.2	42.4	43.4
Feeder Roads	5.7	154.1	57.1	55.3	0.44	56.9	60.1	57.8	57.6	56.6
Overall Average										
Arterial Roads	54.1	1025.4	304.9	457.0	4.03	81.3	75.0	71.8	81.3	81.5
Main Roads	7.1	187.5	69.7	63.1	0.51	10.7	13.7	16.4	11.2	10.2
Feeder Roads	5.3	155.0	50.0	42.1	0.41	8.0	11.3	11.8	7.5	8.3

On an average, the contribution of arterial roads for different pollutants varies from 70.6% (for PM) to 81.8% (for NOx). The contribution of main roads varies from 10.2% (for SO2) to 16.9% (for PM), whereas contribution of feeder roads varies from 7.3% (for NOx) to 12.4% for PM. Study zone wise vehicular emission load is summarized in **Table 3.35**.

The overall average vehicular emission load in terms of PM, CO, HC, NOx and SO_2 is estimated to be 65.8, 1355.9, 421.5, 557.4 and 4.9 kg/d respectively. Among all the study zones, minimum vehicular emission in terms of all the five pollutants is estimated at Prahladpur.

Table 3.35: Summary of Total Emission Load in Each Study Zone

Study Zone	Pollutant Emission Load (kg/day)				
	PM	CO	HC	NOx	SO_2
Ashram Chowk	98.9	2402.1	742.6	882.9	6.8
Dhaula Kuan	92.6	2237.1	644.2	843.9	6.8
Mayapuri	26.0	932.1	335.2	280.9	1.8
ISBT	161.6	2243.4	673.2	1236.7	12.7
Loni Road	33.5	644.3	286.7	264.9	2.0
Anand Vihar	31.0	808.4	282.6	320.1	2.1
Naraina	66.5	1880.7	534.8	617.9	4.9
SSI-GTK	111.2	1474.7	401.7	820.2	8.7
Pitampura	34.3	800.7	246.2	258.5	2.8
Prahladpur	10.0	256.3	98.8	96.0	0.8
Overall Average	**665.6**	**13679.8**	**4246**	**5622**	**49.4**

Among the remaining nine study zones, estimated total emission load for PM ranges between 31.0 kg/d (at Anand Vihar) and 161.6 kg/d (at ISBT), CO ranges between 644.3 kg/d (at Loni) and 2402.1 kg/d (at Ashram Chowk), HC ranges between 246.2 kg/d (at Pitampura) and 742.6 kg/d (at Ashram Chowk), NOx ranges between 258.5 kg/d (at Pitampura) and 1236.7 kg/d (at ISBT) and SO_2 ranges between 1.8 kg/d (at Mayapuri) and 12.7 kg/d at ISBT.

Vehicle Category-wise Emissions Contribution

Percentage emissions contribution (in terms of PM, CO, HC and NOx) of different types of vehicles classified under 10 categories as 2W-2S, 2W-4S, 3W, 4W-P, 4W-D, 4W-CNG, LCV, Trucks, Buses-D and Buses-CNG has been calculated for each of the study zones. The vehicle category-wise emission contributions are presented respectively for Ashram Chowk, Dhaula Kuan, Mayapuri, ISBT, Loni Road, Anand Vihar, Naraina, SSI-GT Karnal Road, Pitampura and Prahladpur are given in **Annexure III**. Overall average emission contribution of all the study zones is presented in **Fig. 3.21**.

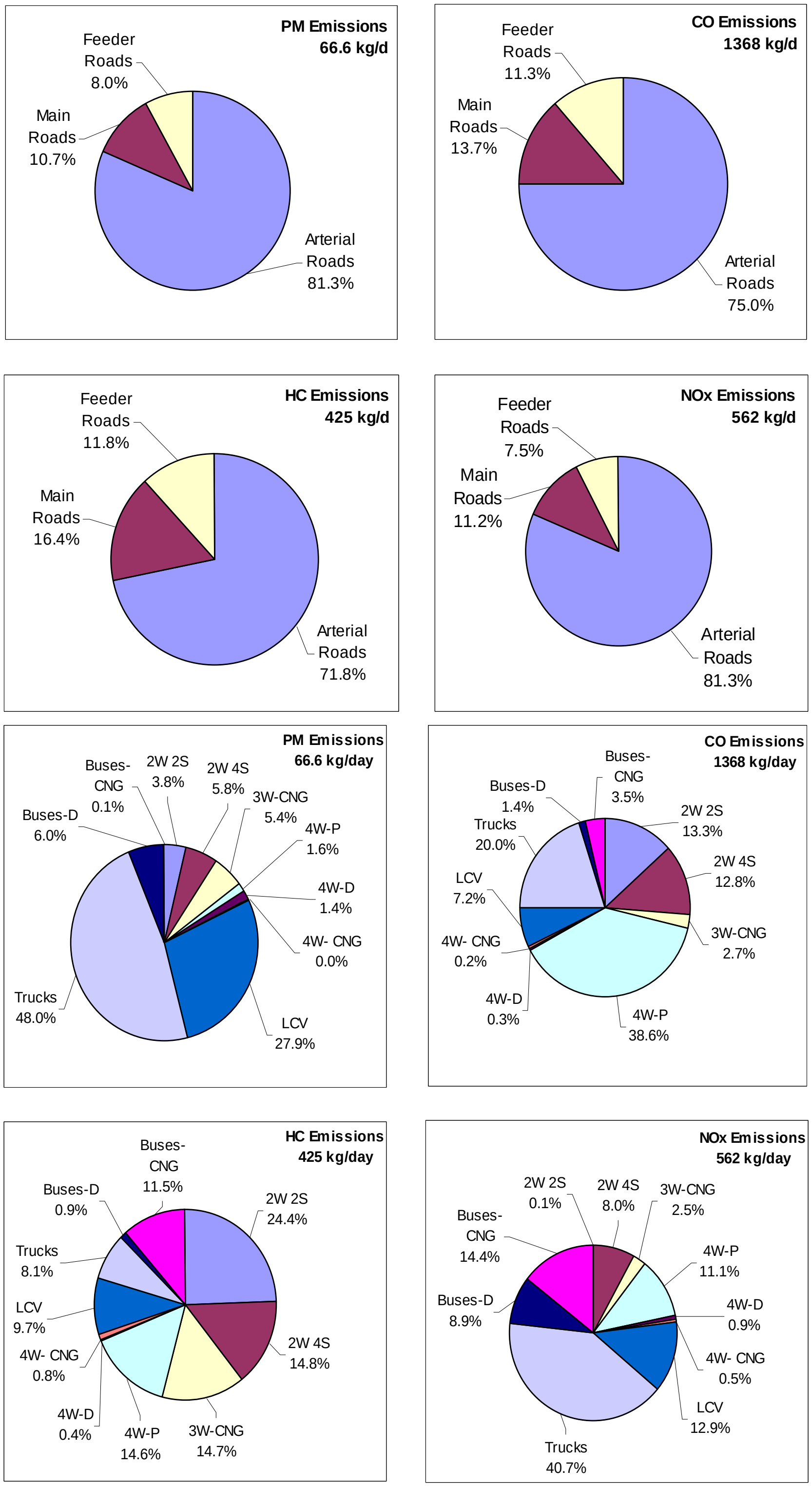


Fig. 3.21: Vehicle Category-wise Emission Contribution: Overall Average of all sites

3.1.4 Contribution of Paved Road Dust Due to Traffic Movement

Re-suspended dust in terms of PM10 and PM2.5 from paved roads has been estimated based on the USEPA methodology, which involves estimation of silt loading (in g/m^2), average weight of vehicles (tons/day), road length, rainfall days etc. Considering different types of roads and different study zone observations, average silt loading has been estimated to be in the range of 0.21 to 7.0 g/m^2 depending on the condition of road. Using the USEPA approach, the re-suspended road dust as PM10 and PM2.5 has been estimated for each type of road category in all the ten study zones. Study zone and road category-wise re-suspended road dust as PM10 and PM2.5 are given in **Tables 3.36 and 3.37** respectively. Share of different categories of roads is also indicated in the Tables, and also shown in **Figs. 3.22** and **3.23.**

Table 3.36: Study Zone and Road Category-wise Estimated Road Dust: PM10 Emissions

Study Zone	**PM10 Emissions (kg/day)**				**Share of Roads (%)**			
	Arterial	Main	Feeder	Total	Arterial	Main	Feeder	Total
Ashram Chowk	421.2	52.2	233.1	706.5	59.6	7.4	33.0	100.0
Dhaula Kuan	439.5	55.6	26.9	522.0	84.2	10.6	5.1	100.0
Mayapuri	44.6	123.2	90.0	257.8	17.3	47.8	34.9	100.0
ISBT	964.3	12.4	1.7	978.4	98.6	1.3	0.2	100.0
Loni Road	96.0	344.6	93.4	533.9	18.0	64.5	17.5	100.0
Anand Vihar	178.7	36.6	88.0	303.4	58.9	12.1	29.0	100.0
Naraina	185.8	141.5	37.6	364.9	50.9	38.8	10.3	100.0
SSI-GTK	596.2	0.0	380.8	977.0	61.0	0.0	39.0	100.0
Pitampura	104.5	13.7	55.0	173.2	60.4	7.9	31.7	100.0
Prahladpur	0.0	48.4	92.9	141.3	0.0	34.2	65.8	100.0

Table 3.37: Study Zone and Road Category-wise Estimated Road Dust: PM2.5 Emissions

Study Zone	**PM2.5 Emissions (kg/day)**				**Share of Roads (%)**			
	Arterial	Main	Feeder	Total	Arterial	Main	Feeder	Total
Ashram Chowk	10.2	3.2	22.9	36.3	28.1	8.8	63.1	100.0
Dhaula Kuan	12.9	3.7	0.0	16.6	77.8	22.2	0.0	100.0
Mayapuri	0.0	6.5	9.5	16.0	0.0	40.5	59.5	100.0
ISBT	90.5	1.0	0.0	91.5	99.0	1.0	0.0	100.0
Loni Road	5.2	42.0	10.1	57.3	9.1	73.3	17.6	100.0
Anand Vihar	5.5	4.5	10.7	20.6	26.4	21.8	51.8	100.0
Naraina	11.2	0.9	2.6	14.6	76.4	5.9	17.6	100.0
SSI-GTK	60.1	0.0	49.8	109.9	54.7	0.0	45.3	100.0
Pitampura	5.3	0.0	0.0	5.3	100.0	0.0	0.0	100.0
Prahladpur	0.0	1.3	10.2	11.5	0.0	11.5	88.5	100.0

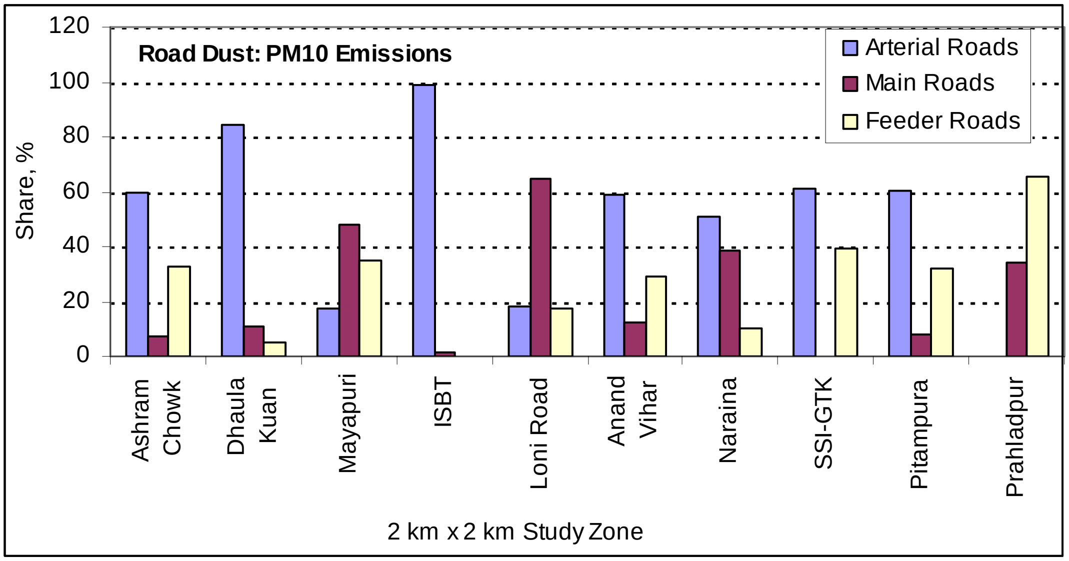


Fig. 3.22 : Site-wise and Road Category-wise Contribution of Re-suspended Road Dust: PM10 Emissions

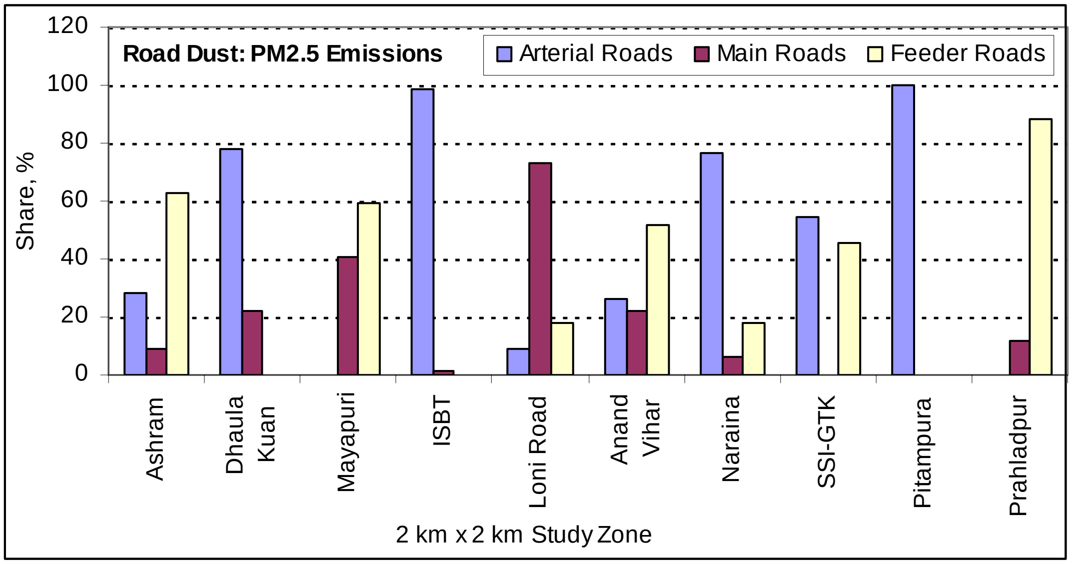


Fig. 3.23: Site-wise and Road Category-wise Contribution of Re-suspended Road Dust: PM2.5 Emissions

Average re-suspended dust as PM10 and PM2.5 is estimated to be 496 kg/d and 38 kg/d respectively. The overall average contribution of re-suspended road dust (PM10 & PM2.5) on arterial, main and feeder roads is estimated to be 49%, 20.5% and 30.5% respectively. Overall average (average of 10 Sites) contribution of re-suspended road dust as PM10 and PM2.5 is shown in **Fig. 3.24**.

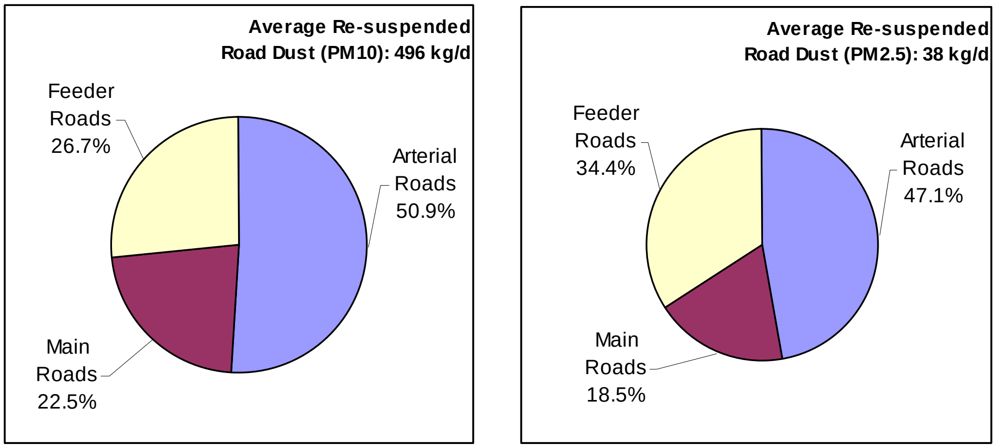


Fig. 3.24: Road Category-wise Average Contribution of Re-suspended Road Dust: PM10 & PM2.5 (Average of 10 Sites)

3.2 Vehicle Emissions Status for Ten Study Zones

Total daily average vehicle km travelled on arterial, main and feeder roads are 358396, 85835, and 58928 respectively. Most of the vehicles in the fleet are 4-wheelers (37.9%-45.7%) and 2-wheelers (31.2%-40.5%) on different categories of roads.Average total VKT is about 5.03 lakh km, of which arterial, main and feeder roads account for 64.8%, 22.7% and 12.5% respectively. 2W, 3W, 4W and LCVs contribute 57.3%-63.3% of total VKT on arterial roads, 20.3%-26.5% on main roads and 11.1%-18.3% on feeder roads. Trucks and buses contribute as much as 74.4% & 70.3% on arterial roads, 17.2% & 23.8% on main roads and 8.4% & 5.9% on feeder roads**.**

Average daily total emission loads at each site in terms of PM, CO, HC, NOx and SO_2 are estimated to be 66.6 kg, 1368 kg, 425 kg, 562 kg and 4.94 kg respectively. Contribution of different pollutants on arterial roads varies between 71.8% (for HC) and 81.5% (for SO_2), whereas on main roads it varies between 10.2% (for SO_2) and 16.4% (for HC). Contribution of feeder roads is between 7.5% (for NOx) and 11.8% (for HC). Pollutant emission load wise major contributors are:

- PM Emissions: Trucks (48.0%), LCVs (27.9%), Buses-D (6.0%) and 2W-4S (5.8%)
- CO Emissions: 4W-P (38.6%), Trucks (20.0%), 2W-2S (13.3%), 2W-4S (12.8%) and LCVs (7.2%)
- HC Emissions: 2W-2S (24.4%), 2W-4S (14.8%), 3W-CNG (14.7%), 4W-P (14.6%), Buses-CNG (11.5%) and LCVs (9.7%)
- NOx Emissions: Trucks (40.7%), Buses-CNG (14.4%), LCVs (12.9%), 4W-P (11.1%) and Buses-D (8.9%)
- SO_2 Emissions: LCV (46.4%), Trucks (34.6%), 4W-D (11.5%), Buses-D (7.5%)

Average re-suspended road dust as PM10 and PM2.5 are estimated to be 495.8 kg/d and 38.0 kg/d. Average contributions of arterial, main and feeder roads are estimated to be about 49.0%, 20.5% and 30.5% respectively. PM2.5 is about 7.7% of the PM10 road dust emissions. Based on the vehicular emission load and re-suspended road dust with respect to different pollutants, first two highest and two lowest polluting study zones are identified as given in **Table 3.38**.

Table 3.38: Pollutant-wise Identified Highest and Lowest Polluting Zones

Pollutant Emissions	Study Zone with Emission Load			
	Highest	**High**	**Low**	**Lowest**
Vehicular				
PM	ISBT	SSI-GTK	Anand Vihar	Prahladpur
CO	Ashram Chowk	ISBT & Dhaula Kuan	Loni Road	Prahladpur
HC	Ashram Chowk	ISBT	Pitampura	Prahladpur
NOx	ISBT	Ashram Chowk	Pitampura & Loni Road	Prahladpur
SO_2	ISBT	SSI-GTK	Mayapuri	Prahladpur
Road Dust				
PM10	ISBT	SSI-GTK	Pitampura	Prahladpur
PM2.5	SSI-GTK	ISBT	Prahladpur	Pitampura

In each of the study zones, major vehicle categories contributing to first two highest percentage emissions with respect to different pollutants (PM, CO, HC and NOx) have been identified and are summarized in **Table 3.39.**

Table 3.39: Pollutant-wise Two Vehicle Categories Contributing to Highest Emissions

Study Zone	Vehicle Category Contributing Highest Emissions							
	PM Emissions		CO Emissions		HC Emissions		NOx Emissions	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Ashram Chowk	Trucks	LCVs	4W-P	Trucks	2W-2S	3W-CNG	Trucks	Buses-CNG
Dhaula Kuan	Trucks	LCVs	4W-P	Trucks	2W-2S	4W-P	Trucks	Buses-CNG
Mayapuri	LCVs	2W-4S	4W-P	2W-2S & 2W-4S	2W-2S	2W-4S	Buses-CNG	4W-P
ISBT	Trucks	LCVs	Trucks	4W-P	2W-2S	LCVs	Trucks	LCVs
Loni Road	Trucks	LCVs	2W-4S & 2W-2S	4W-P & Trucks	2W-2S	3W-CNG	Trucks	Buses-CNG
Anand Vihar	Trucks	LCVs	4W-P	2W-2S & 2W-4S	2W-2S	3W-CNG	Trucks	Buses-CNG
Naraina	Trucks	LCVs	4W-P	Trucks	2W-2S	4W-P	Trucks	4W-P
SSI-GTK	Trucks	LCVs	Trucks	4W-P	LCVs	Trucks & 2W-2S	Trucks	LCVs
Pitampura	LCVs	Trucks	4W-P	2W-2S & 2W-4S	2W-2S	2W-4S	Trucks	LCV
Prahladpur	LCVs	Trucks	4W-P	2W-2S & 2W-4S	2W-2S	3W-CNG	Buses-CNG	LCVs
Overall	Trucks	LCVs	4W-P	Trucks 2W-2S & 2W-4S	2W-2S	2W-4S, 3W-CNG & 4W-P	Trucks	Buses-CNG, LCVs, 4W-P

From the above analysis, it can be concluded that:

PM emissions are mainly emitted by Trucks and LCVs, whereas CO emissions are mainly contributed by 4-Wheelers (Petrol) and 2 & 4 Stroke 2-Wheelers. HC emissions are emitted by 2 Stroke 2-Wheelers and 2W-4 stroke, 3W-CNG as also 4W-Petrol. NOx emissions are mostly contributed by heavy duty vehicles (trucks and buses-CNG). LCVs along with 4W-P also contribute significantly. Share of Re-suspended road dust is considerably high. Depending on the target pollutant, control strategies can be adopted for the specific category of the vehicles.

The emission inventory generated for ten 2 km x 2 km study zones has been used to prepare emission inventory for the whole city. Some of the data obtained in the primary survey for 2 x 2 km study zones have been used in city based inventory preparation of Delhi.

3.3 City Level Emission Inventory

3.3.1 Emission Inventory: Area Source

Data on area source activities in Delhi were collected from various Government and Non-Government departments/agencies as discussed earlier. The required information was collected through interviews with the concerned authorities/persons in respective areas. In addition, fuel consumption data and related information were obtained through primary surveys directly from the sources viz. residences, hotels, restaurants, crematoria etc. Data collected on various source categories were analyzed. Emissions were estimated by applying CPCB recommended [compliance of data from various sources] emissions factors.

3.3.1.1 Approach and Methodology

Data Analysis

I. Demography

Census data such as number and locations of wards/sectors ward wise map and wardwise population etc. was collected from the Office of Registrar General and MCD. According to Census 2001, Delhi state is divided into nine districts and 27 tahsils occupying 1483 sq. km area. Total population of Delhi as per 2001 Census is about 138 lakhs with a population density of 9340 persons per sq.km. Delhi is highly urbanized with 93.18 % population living in urban areas as against the national average of 27.81%. Urban population is 1, 29,05,780 and rural population is 9,44,727. Population in 2001 had increased from 9420644 in 1991 at a decadal growth rate of 46.31%. The population trend of Delhi recorded during 1951-2001 is presented in **Fig. 3.25.**

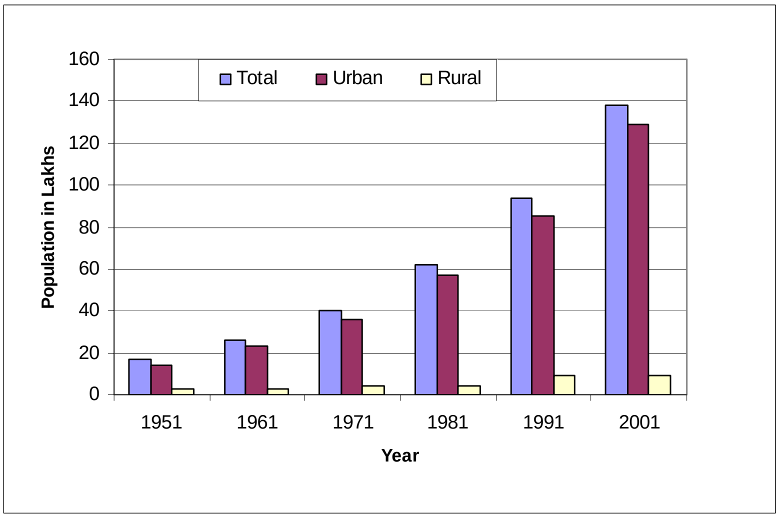


Fig. 3.25: Decadal Population Growth in Delhi

There are three civic bodies in Delhi: Municipal Corporation of Delhi (MCD), New Delhi Municipal Corporation (NDMC) and Delhi Cantonment Board (DCB). As per the 2001 Census, there are 134 wards, which come under MCD, 13 sectors under NDMC, and 7 wards under DCB. Based on 2001 census, ward-wise map and population of Delhi is as presented in **Fig. 3.26**. As per the 2001 census, 13.38 millions reside in MCD, 0.29 millions in NDMC and 0.12 millions in DCB areas.

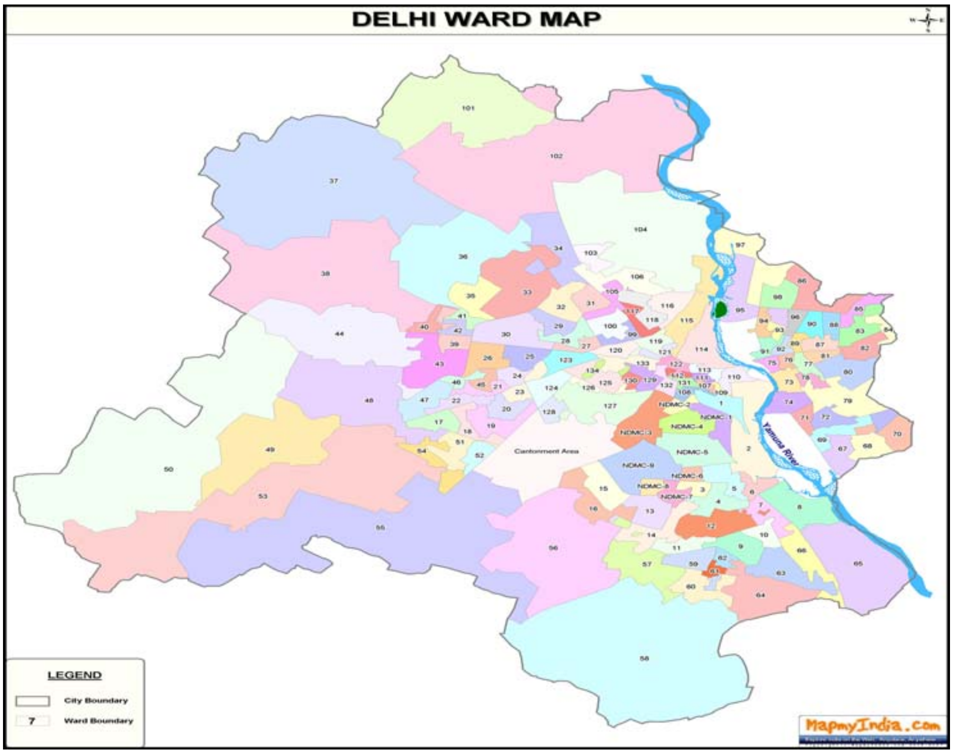


Fig. 3.26: Ward-wise Map of Delhi

Because of acute shortage of affordable shelter, many of the migrants tend to encroach city space in the form of slums. Delhi started witnessing the problem of Jhuggi-Jhopari(JJ) since early sixties and continues to face problems of mushrooming growth of Jhuggi-Jhopari(JJ) Clusters on land pockets belonging to various agencies viz. DDA, MCD, NDMC, DCB, Railways, Government departments, CPWD, and other autonomous organizations. As per census 2001, slum population in urban areas of Delhi is of about 26.6 lakhs, which is approximately 19% of the urban population placing it on third position among the four large metropolitan cites. The estimates of Slum Wing of MCD indicate about 1100 JJ Clusters with 6 lakh households at present in Delhi. Population in different types of settlements is presented in **Table 3.40.**

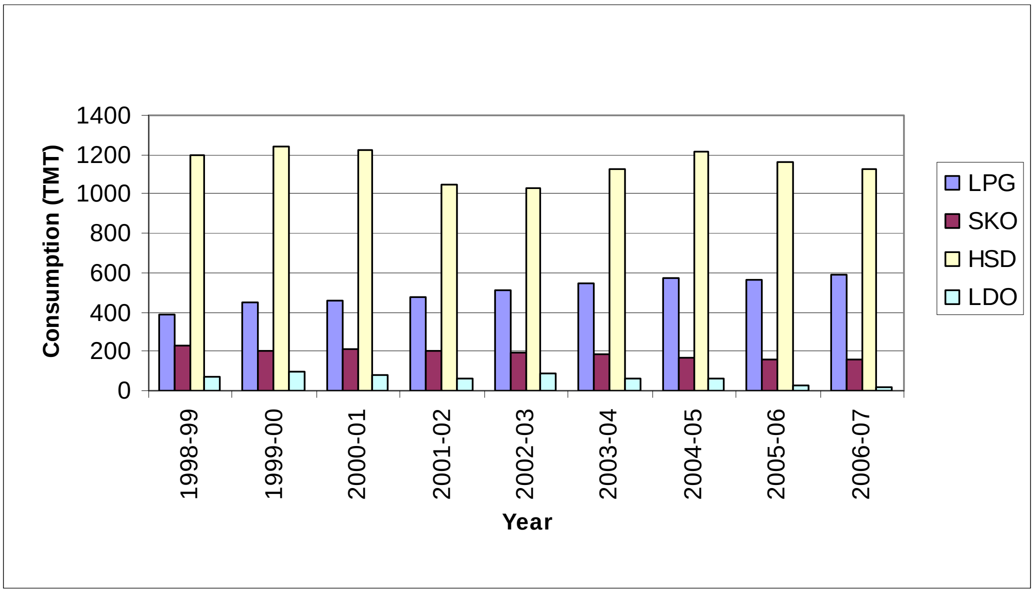
Table 3.40: Population in different Types of Settlements

Sr. No.	Type of Settlement	Estimated population in lakhs in 2000	% of total estimated population
1	JJ Clusters	20.72	14.8
2	Slum Designated Areas	26.64	19.1
3	Unauthorized Colonies	7.40	5.3
4	JJ Resettlements Colonies	17.76	12.7
5	Rural Villages	7.40	5.3
6	Regularized – Unauthorized Colonies	17.76	12.7
7	Urban Villages	8.88	6.4
8	Planned Colonies	33.08	23.7
	Total	**139.64**	**100.00**

Source: Economic Survey of Delhi, 2007-08

II. Fuel Consumption

Data on total Kerosene supply in Delhi was collected from Food Supplies and Consumers Affairs Department. Information on PNG consumption was collected from Indraprastha Gas Limited (IGL). Annual fuel supply with respect to various fuels obtained from Petroleum Planning and Analysis Cell (PPAC) for the period 2001-02 to 2006-07 is presented in **Fig. 3.27**. The total PNG consumption from IGL was around 1 lakh SCM per month in various areas of Delhi in the year 2006-07.



Source: PPAC

Fig. 3.27 : Annual Fuel Consumption in Delhi

3.3.1.2 Emission Estimates

I. Domestic Sector

The data on number of households, which use different types of fuels, was collected from the Office of Registrar General. It indicates that out of total 255419 households, 68% households use LPG, 24% households use kerosene, 4% use wood, 0.1% use coal, 2% use cow dung, 0.7% use crop residue and 0.4% use other fuels such as biogas and electricity. The total LPG and Kerosene supply in Delhi during year 2006-07 were reported as 586 TMT and 162 TMT as obtained from PPAC and Food Supplies and Consumers Affairs Department. Based on the information collected from households survey in different areas of Delhi, it was observed that LPG is the major fuel used in domestic sector. Besides PNG, Kerosene, Coal, Wood and Dung Cakes etc. are also used as fuels in households. The average consumption of various fuels (LPG, PNG, Kerosene, Coal, Wood, Dung Cakes and Crop residue) per family was estimated based on the information collected from households survey. Projected city population for 2007 taken from Census department was used to estimate emissions. Emissions were extrapolated using ward wise population, land-use pattern and fuels consumption pattern in various areas. Estimated emission load from fuel combustion in residential areas and slums are presented in **Tables 3.41 and 3.42.**

Table 3.41: Emission Load from Residential Fuel Combustion

Type of Fuel	**Pollutant Emission (TPD)**				
	PM10	**SO_2**	**NOx**	**CO**	**HC**
LPG	0.64	0.00047	3.92	18.78	23.54
Kerosene	0.03	0.19	0.12	2.98	0.91
Wood	1.00	0.01	0.09	7.54	1.73
Dungcake	0.10	0.02	0.07	1.58	1.52
Cropwaste	7×10^{-3}	4×10^{-4}	1×10^{-3}	2×10^{-1}	5×10^{-2}
Coal	0.17	0.11	0.03	0.21	0.09
PNG	2×10^{-5}	2×10^{-6}	3×10^{-4}	2×10^{-4}	1×10^{-8}

Table 3.42: Emission Load from Slums Fuel Combustion

Type of Fuel	**Pollutant Emission (TPD)**				
	PM10	**SO_2**	**NOx**	**CO**	**HC**
LPG	0.02	0.00	0.13	0.63	0.79
Kerosene	0.07	0.49	0.31	7.58	2.32
Wood	9.61	0.13	0.88	72.49	16.65
Dungcake	0.14	0.04	0.10	2.32	2.23
Coal	0.06	0.04	0.01	0.07	0.03

II. Hotels / Restaurants / Dhabas

Delhi is emerging an international centre of education, health care, tourism, sport and business, which require complimentary facilities such as hotels, restaurants catering to various economic groups. Information on hotels, restaurants, eating houses and dhabas was obtained from the concerned agencies as listed. It is learnt that the hotel industry requires permission from MCD and State Police Department. As per the information collected from MCD, NDMC and DCB around 6611 hotels/restaurants exist in Delhi. Out of these, there are about 937 restaurants, 1356 eating houses and 1217 dhabas. According to fifth economic census report of 2005, there were about 36,000 non agricultural enterprises engaged in hotels / restaurants business in Delhi.

Average emission load from hotels/restaurants in each grid have been estimated. Emission loads from hotels/restaurants in respective grids has been allocated by applying average emission load, based on number and location details of hotels/restaurants supplied by MCD. Estimated emission load from hotels, restaurants, sweet shops, dhabas etc. are summarized in **Table 3.43.**

Table 3.43: Emission Loads from Hotels & Restaurants

Type of Fuel	Pollutant Emission (TPD)				
	PM10	SO_2	NOx	CO	HC
LPG	0.13	$9x10^{-5}$	0.76	3.65	4.58
Kerosene	$1.4x10^{-3}$	0.01	0.01	0.09	0.03
Wood	0.02	$2.9 x10^{-4}$	$2 x10^{-3}$	0.17	0.04
Diesel	1.46	0.97	0.29	1.82	0.77
Coal	$2.9x10^{-4}$	$1.0 x10^{-2}$	$2.9x10^{-4}$	$7.3 x10^{-4}$	$8.2 x10^{-5}$
PNG	$3 x10^{-6}$	$2.5 x10^{-7}$	$4 x10^{-5}$	$3.5 x10^{-5}$	$2.4 x10^{-9}$

III. Bakeries

Number and location of bakeries was obtained from MCD. As per the records of MCD, there are 139 registered bakeries in Delhi. Based on the information collected during survey and discussions held with the authorities of Bakery Association, it was noticed that most of the bakeries use wood as a fuel and average wood consumption in each bakery is approximately 50 kg/day. Based on the above information, emissions from bakeries in respective grids were estimated. Emission load from bakeries are presented in **Table 3.44.**

Table 3.44: Emission Loads from Bakeries

No of Registered Bakeries	Type of Fuel	Pollutant Emission (TPD)				
		PM10	SO_2	NOx	CO	HC
139	Wood	0.12	0.001	0.01	0.87	0.79

IV. Crematoria

There are 274 crematoria, which are operating in various zones of Municipal Corporation of Delhi. Out of these four are electric crematoria. Out of 274, only 62 crematoria are under MCD and rests are managed by private agency. Zone-wise crematoria are listed in **Table 3.45.**

Table 3.45: Zone-wise Cremation Grounds

Zone	Number	Zone	Number
MCD	62	Rohini Zone	11
West Zone	4	South Zone	26
Central Zone	7	Najrafgarh Zone	92
Civil lines Zone	10	Shahadra (South) Zone	5
Narela Zone	49	Shahadra (North) Zone	8
		Grand Total	**274**

Source: MCD

No authentic information was available regarding the number of dead bodies cremated in each crematorium except in a few crematoria. The data on death rate in Delhi for the year 2006 were taken from the Statistical Handbook, 2008 according to which, the total number of registered deaths in 2007 were 101063. Registered deaths in various municipalities in Delhi are presented in **Table 3.46.**

Table 3.46: Registered Deaths in Delhi

Local Body	Deaths in 2004
MCD urban	64498
MCD Rural	4950
MCD Total	69448
NDMC	14415
Delhi Cantt.	1515
Total	**85378**

Source: Department of Economics and Statistics

Based on the population statistics report on religion data of Census of India 2001, total dead bodies cremated using firewood was estimated. It is learnt from the discussions with the authorities of MCD at Nigambodh Ghat that nearly 350 kg of firewood is required to cremate a body. Emission load from few crematoria (respective grids) was estimated based on the available data on number of dead bodies cremated in each crematorium. Emission load for the remaining crematoria is estimated by subtracting these emissions from total emissions. The estimated emission load for the remaining crematoria is distributed in respective grids using location details supplied by MCD. Estimated emission load from crematoria in Delhi are given in **Table 3.47.**

Table 3.47: Emission Load from Crematoria

No of Crematoria	Type of Fuel	Pollutant Emission (TPD)				
		PM10	SO_2	NOx	CO	HC
270*	Wood	1.3	0.02	0.12	9.78	2.25

* Excluding four electric crematoria

V. Waste Incinerators

Around 60 tons of biomedical waste is generated per day in Delhi. This activity is performed by approved private agencies by DPCC Delhi, namely Synergy Waste Management Company, Biocare Technology Services limited and Symbarkey Pvt. Ltd. having their treatment facilities. The first two units operate at Nangloi and Samaipur while last one operates outside Delhi. These units receive waste from private hospitals and Health Care Institutions. About 7 to 8 MT per day of waste is received daily for incineration. Besides, there are some Government and major private hospitals, who have their own biomedical waste incinerators. Most of the incinerators are operated for 6-8 hrs in a day while a few are operated for 2-3 hrs, in a day. Fuels used in incinerator are LDO or HSD. HSD is mostly used in most of the hospitals for waste incineration with an average daily consumption around 2.50 KL. Emission loads from medical waste incinerators in respective grids have been estimated using data on medical waste incinerators and location details given by DPCC. Hospitals and the private agencies having incinerators and their capacity are listed in **Table 3.48**. Estimated pollutant emission loads from medical waste incinerators are presented in **Table 3.49**.

Table 3.48: Waste Incineration Facility at various Hospitals/ Private Agencies

Sr. No.	Name of Hospital	Capacity of Incinerator (Kg/hr)	Quantity of waste burned (kg/day)
1	Army Hospital (R & R unit),Delhi Cantt.	100	135
2	AIIMS, Ansari nagar, ND - 29	230	828
3	Batra Hospital & Medical Research Centre, 1, Tughlakabad Institutional Area, Mehrauli, BadarpurRoad	90	81
4	Guru Tej Bahadur Hospital, Shahdara, Delhi -95	150	405
5	Hindurao Hospital, Rani Jhansi Road, Delhi	150	405
6	Lok Nayak Hospital (LNJP), Jawaharlal Nehru Road, ND - 2	100	1723
7	Maharshi Valmiki J. D. Hospital, Kingsway Camp, Delhi - 9	125	15
8	Ram Manohar Lohiya Hospital, Kharak Singh Marg, New Delhi	125	97

Table 3.48(Contd..) : Waste Incineration Facility at various Hospitals/ Private Agencies

Sr. No.	Name of Hospital	Capacity of Incinerator (Kg/hr)	Quantity of waste burned (kg/day)
9	Safdurjung Hospital, Aurobindo Marg, ND - 29	150	27
10	Sucheta Kriplani Hospital, Panchkuian (sent to Lady Hardinge Hospital)	175	63
11	Swami Dayanand Hospital, Shahdara	65	88
A	Synergy Waste Management Co. Ltd,1/5BAsaf Ali Road, ND - 2	-	1500
B	Biocare Technological Services, 55, Railway Road, Samaipur, Badli Industrial Area, Delhi - 42	-	800

Source : DPCC

Table 3.49: Emission Load from Waste Incinerators

Waste/ Fuel	Pollutant Emissions (TPD)				
	PM10	SO_2	NOx	CO	HC
Waste Burned	0.017	0.008	0.013	0.021	0.001
Diesel	0.001	0.024	0.007	0.002	0.000

VI. Generator Sets

Power demand has been growing rapidly in Delhi. Delhi’s own generation installed capacity is 1699.5 MW. Nearly 38% of Delhi’s power needs are met by its own plants and BTPS and remaining 62% by import from NTPC and other sources. Power generation scenario in Delhi is presented in **Table 3.50.**

Table 3.50 Power Generation in Delhi

Sr.N.	Availability of Power	Installed capacity 2005-06 (MW)	Net Availability of Power-2005-06 (MW)
1.	I.P. Station	247.5	185
2.	Raj Ghat Power House	135	135
3.	Gas Turbine	282	282
4.	Pragati PowerProject	330	330
5.	B.T.P.S.	705	705

Source: Socio-Economic Profile, 2007-08

It is learnt from survey that power failure in Delhi occurs approximately 100 hours per month during summer season and occasionally during rest of the year. During power cut hours, generators sets are operated in residential co-operative societies as well as in commercial shops. Mostly co-operative society flats are situated in Sahibabad (Uttar Pradesh) area which partly falls in the study zone of Anand Vihar. While on an average 2-3 hrs of power failure in most of the parts of the Delhi was observed, it was found that the same is for 6-8 hrs in Sahibabad area. Various capacities of generator sets are used depending on the requirement of power.

Information on number of DG sets supplied during the last 10 years was obtained from Genset suppliers and the average life of Genset has been assumed to be 10 years. Generators sets of different capacities supplied by various manufacturers in Delhi are summarized in **Table 3.51.**

Table 3.51: DG Sets Supplied by Different Suppliers (Total for 10 Years)

Capacity (KVA)	Honda Seil	Birla Yamaha	Total
0.5	14655	21646	36301
1	22325	-	22325
1.5	16900	54115	71015
2	-	32469	32469
2.5	14765	-	14765
Total	**68645**	**108231**	**176876**

Source: Generators sets suppliers

As information on exact number of generator sets in each grid was not available, emission loads from generator sets have been estimated by distributing in proportion to the total emission load per 1000 population. Grid-wise population data of Delhi was used for generator sets emission calculations. Alternatively, total number of generator sets in Delhi was estimated based on the actual synoptic survey data per 1000 population to cross check with the supply data. It is in reasonably good agreement with the supply data.

Based on survey data on number of flats and generator sets operated in co-operative societies, power failure hours, and the data on registered co-operative societies in Delhi obtained from Registrar of Co-operative Societies, emission load from generator sets in co-operative societies was estimated. Based on the number of generator sets, emissions were estimated and are presented in **Table 3.52**.

Table 3.52: Emission Load from Generator sets

Type of Fuel	Pollutant Emissions (TPD)				
	PM10	SO_2	NOx	CO	HC
Diesel/Kerosene	0.534	0.498	7.553	0.594	1.631

Grid-wise emissions were estimated based on the information on locations of co-operative societies.

VII. Solid Waste Disposal/Open burning

Information on solid waste generation in Delhi was obtained from MCD. The total solid waste generated in Delhi is about 6500 Tons/day. This includes waste from households, industries and medical establishments. There is only one large incineration plant in the city which is not operated due to some problems. Delhi has three landfill sites at Gazipur, Okhla and Bhalsawa, which are spread over an area of 150 acres where municipal solid waste is disposed off. None of the landfill sites is having waste burning facilities. However, it was observed that illegal open burning of waste is carried out near some of the AQM sites, viz. Anand vihar and Ashram Chowk. Assuming 1% of total waste generated in Delhi is burned which also includes garden waste emissions from open burning are estimated as given in **Table 3.53.**

Table 3.53: Emission Load from Open Burning

Waste Burned (TPD)	Pollutant Emission (TPD)				
	PM10	**SO_2**	**NOx**	**CO**	**HC**
65	0.0014	0.0001	0.0005	0.0075	0.0038

Per capita emission load from open burning has been estimated and distributed in each grid in proportion to population in grid. Grid-wise population of Delhi has been applied here also for open burning emission calculations.

VIII. Construction Activities

PM10 emissions have been calculated by using AP-42 emission factor. The emission factor used is 1.2 tons of PM_{10} per acre month of activity. Data on building and road construction activities was obtained from Building Construction Department of MCD and PWD. Based on discussions with MCD officials it is assumed that, out of total building construction activities, 75% are new construction works and: 25% are renovation works. From this data, area and duration of construction were obtained and acre-months were estimated. Length/Width of roads was estimated based on information on quantum and type of construction wherever data was not available. The area of land disturbed per km was calculated based on the total width of road. Finally, acre-months were calculated on the basis of area and duration of construction. Following the above approach, PM_{10} emission load from road and building construction activities was estimated to be 12 tons / day. Estimated PM10 emissions from construction activities are presented in **Table 3.54.**

Table 3.54: PM10 Emission Load from Construction Activities

Type of Activity	PM10 Emission Load (TPD)
Flyovers	6.99
Road	0.47
Buildings	4.83

PM10 emission load from flyover and road construction activities in respective grids has been estimated using activities and location details supplied by PWD. Gridwise PM10 emission load from building construction activities has been estimated in proportion to population in grid using data on building construction activities obtained from MCD. Grid-wise population of Delhi has been applied here also for building construction activities emission calculations.

IX. Diesel Locomotives

Information on number of locomotives, diesel consumption and distance traveled in Delhi was obtained from Northern Railways. Total number of diesel locomotives in Delhi is about 189 per day. This includes locos incoming and going out of Delhi. Number of locos incoming and going out of Delhi on different routes are given in **Table 3.55.**

Table 3.55: Total Number of Movements of Locomotives

Direction-route towards/from	Number of Diesel Locomotives					
	Incoming to Delhi			Outgoing from Delhi		
	Passenger	Goods with Load	Goods without Load	Passenger	Goods with Load	Goods without Load
Narela (karnal)	6	0.2	0.03	7	0.35	0.07
Rohtak	21	6.05	0.35	21	4.34	0.13
Rewari	18	0.86	0.09	18	1.18	0.11
Mathura	1	0.65	0.01	1	0.61	0.01
Saharanpur (Shahadra)	10	0.43	-	10	0.5	0.01
Anand Vihar	24	5.83	0.3	23	4.87	0.36

Source: Northern Railway, Delhi

Length of rail line in respective grid has been calculated from the map and emission load from diesel locomotives has been estimated using data on number of locos and diesel consumption applying USEPA -1992 emission factors. Total emissions from diesel locomotives are given in **Table 3.56**.

Table 3.56: Emission Load from Locomotives

Type of Fuel	Pollutant Emissions (TPD)			
	PM10	SO_2	NOx	CO
Diesel	0.021	0.065	0.898	1.140

X. Total Emission Load

Total emission load from various fuels and different source activities: domestic, hotels/restaurants, bakeries, crematoria, incinerators, generator sets and construction activities in Delhi are summarized in **Table 3.57 and Table 3.58.** The total daily area source emission load of different pollutants in Delhi is estimated as: 27.8 MT of PM, 2.6 MT of SO_2, 15.3 MT of NOx 132.5 MT of CO and 60 MT of HC.

Table 3.57: Total Emission Load from Area Source Activities in Delhi

Source/ activity	Emission Load (TPD)				
	PM10	SO_2	NOx	CO	HC
Domestic	1.95	0.35	4.24	31.31	27.84
Domestic Slums	9.91	0.69	1.43	83.09	22.02
Hotels & Restaurants	1.61	0.99	1.06	5.73	5.42
Bakeries	0.12	0.001	0.01	0.87	0.79
Crematoria	1.30	0.02	0.12	9.78	2.25
Hospital Incinerator	0.02	0.03	0.02	0.02	0.001
Generator Sets	0.53	0.50	7.55	0.59	1.63
Construction	12.29	0.00	0.00	0.00	0.00
Open Burning	0.001	0.0001	0.001	0.007	0.004
Locomotives	0.021	0.065	0.898	1.140	0.00
Total	**27.75**	**2.64**	**15.33**	**132.54**	**59.95**

Table 3.58: Total Emission Load from Various Fuels used in Delhi

Fuel	Emission Load (TPD)				
	PM10	SO_2	NOx	CO	HC
LPG	0.79	0.001	4.81	23.06	28.91
PNG	$2x10^{-5}$	$2x10^{-6}$	$3x10^{-4}$	$3x10^{-4}$	$2x10^{-6}$
Coal	1.69	1.13	0.34	2.11	0.89
Kerosene	0.11	0.69	0.43	10.65	3.27
Wood	12.05	0.16	1.10	90.84	21.45
Diesel	0.02	0.08	0.90	1.16	0.01
Dung cake	0.24	0.06	0.18	3.90	3.75
Crop waste	0.01	0.00	0.00	0.21	0.05
Residue/Open Burning	0.79	0.001	4.81	23.06	28.91

Contribution of emissions under different area source categories in Delhi is shown in **Fig. 3.28.** It can be observed from the figures that fuel combustion in domestic segment including slums is dominating the pollutant emissions. However, generators are also other dominating sources by contributing almost half of the total NOx emissions. Hotels and restaurants are also contributing to the emissions. Construction activities show dominance in PM emissions contributing as much as 44% while slums contribute 36% to the total PM emissions. Contribution of other area source activities are found to be less <20%.

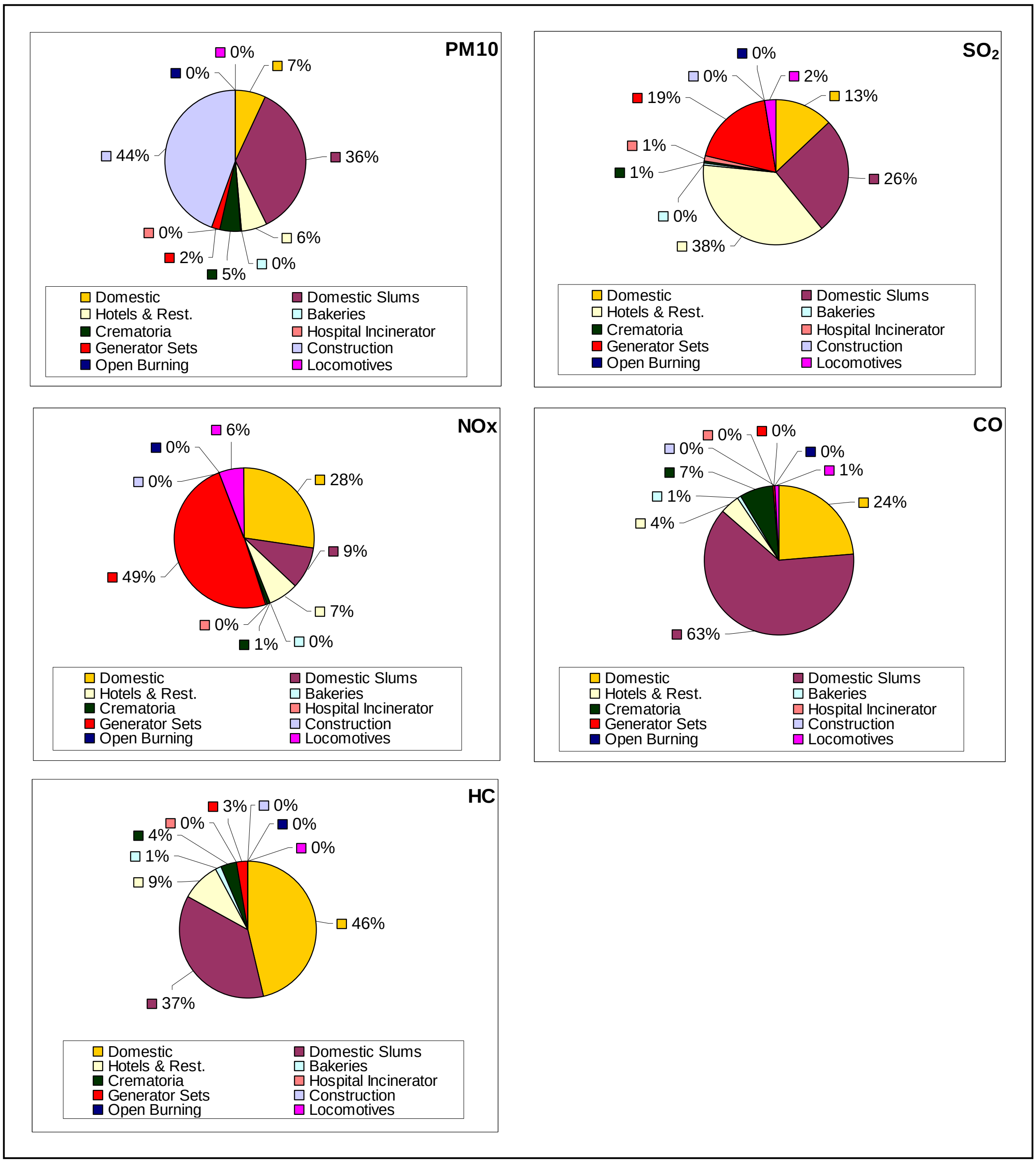


Fig. 3.28: Contribution of Emissions from various Area Source Activities in Delhi

Contribution of emissions from different types of fuels used in area source activities (except construction activity) in Delhi is presented in **Fig. 3.29.** Wood and LPG are observed to be the most significant fuels contributing to the area source emissions in Delhi. Around 50 % of total SO_2 emissions are contributed by coal while 33% is contributed by kerosene.

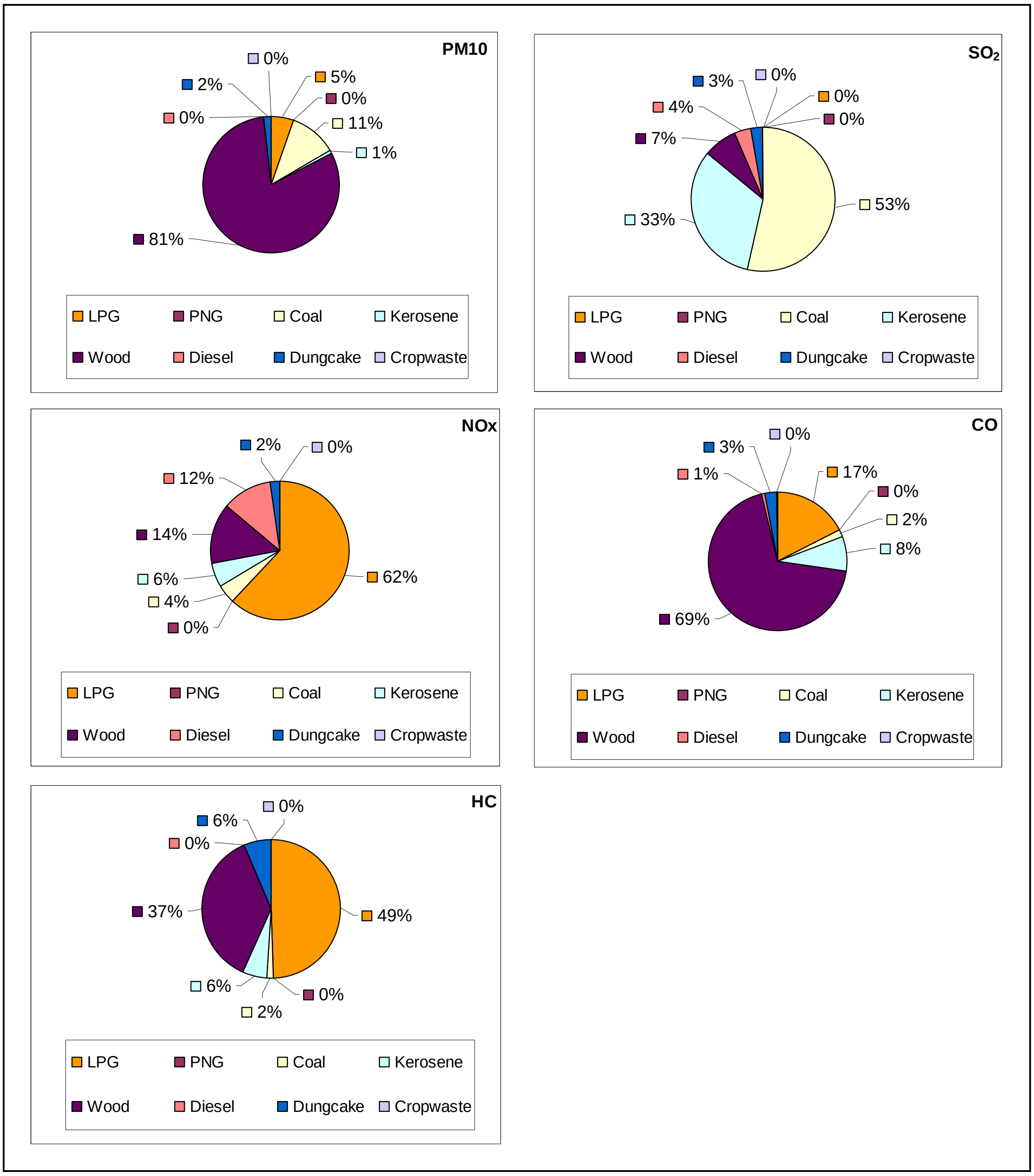
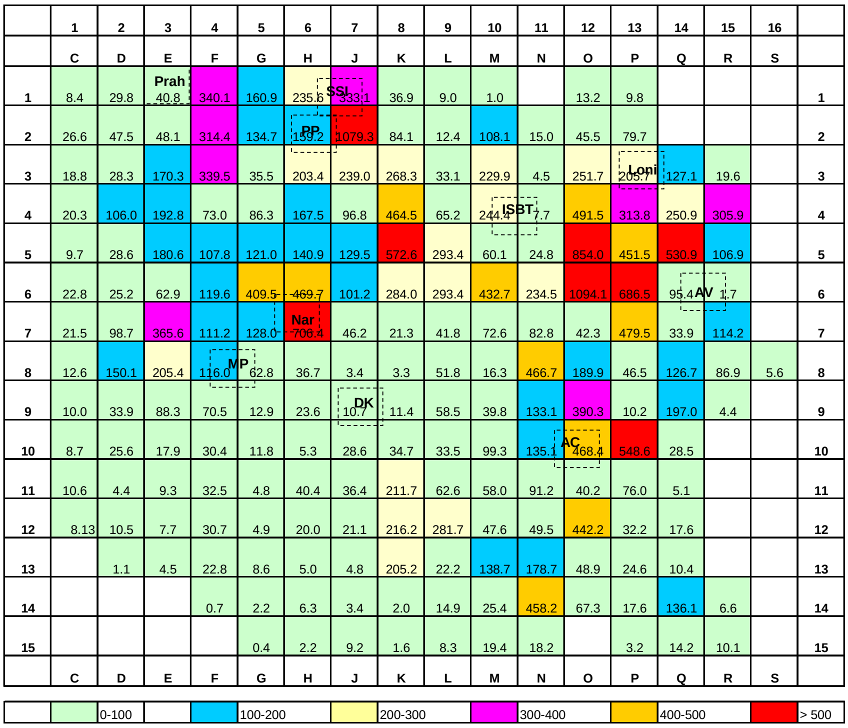


Fig. 3.29: Contribution of various Fuels to Area Source Emissions

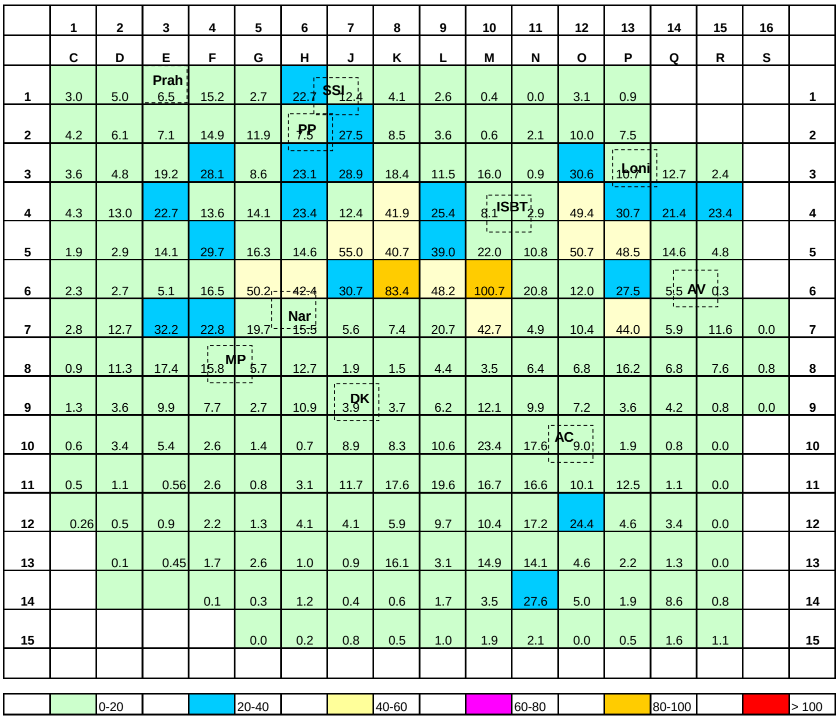
Grid wise emission load from area sources in Delhi is based on ward-wise map. The ward wise map with grids of 2 km x 2 km and the estimated loads in each grid are given in **Annexure III (Table A3.4.1)** marked with study zones**.** Grid-wise emission loads for PM, SO_2, NOx, CO and HC, in Delhi City area are presented respectively in **Figs. 3.30** to **3.34.**



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	C	**D**	**E**	**F**	**G**	**H**	**J**	**K**	**L**	**M**	**N**	**O**	**P**	**Q**	**R**	**S**	
1	8.4	29.8	40.8	340.1	160.9	235.6	333.1	36.9	9.0	1.0		13.2	9.8				**1**
2	26.6	47.5	48.1	314.4	134.7	159.2	1079.3	84.1	12.4	108.1	15.0	45.5	79.7				**2**
3	18.8	28.3	170.3	339.5	35.5	203.4	239.0	268.3	33.1	229.9	4.5	251.7	205.7	127.1	19.6		**3**
4	20.3	106.0	192.8	73.0	86.3	167.5	96.8	464.5	65.2	244.4	7.7	491.5	313.8	250.9	305.9		**4**
5	9.7	28.6	180.6	107.8	121.0	140.9	129.5	572.6	293.4	60.1	24.8	854.0	451.5	530.9	106.9		**5**
6	22.8	25.2	62.9	119.6	409.5	469.7	101.2	284.0	293.4	432.7	234.5	1094.1	686.5	95.4	1.7		**6**
7	21.5	98.7	365.6	111.2	128.0	706.4	46.2	21.3	41.8	72.6	82.8	42.3	479.5	33.9	114.2		**7**
8	12.6	150.1	205.4	116.0	62.8	36.7	3.4	3.3	51.8	16.3	466.7	189.9	46.5	126.7	86.9	5.6	**8**
9	10.0	33.9	88.3	70.5	12.9	23.6	10.7	11.4	58.5	39.8	133.1	390.3	10.2	197.0	4.4		**9**
10	8.7	25.6	17.9	30.4	11.8	5.3	28.6	34.7	33.5	99.3	135.1	468.4	548.6	28.5			**10**
11	10.6	4.4	9.3	32.5	4.8	40.4	36.4	211.7	62.6	58.0	91.2	40.2	76.0	5.1			**11**
12	8.13	10.5	7.7	30.7	4.9	20.0	21.1	216.2	281.7	47.6	49.5	442.2	32.2	17.6			**12**
13		1.1	4.5	22.8	8.6	5.0	4.8	205.2	22.2	138.7	178.7	48.9	24.6	10.4			**13**
14				0.7	2.2	6.3	3.4	2.0	14.9	25.4	458.2	67.3	17.6	136.1	6.6		**14**
15					0.4	2.2	9.2	1.6	8.3	19.4	18.2		3.2	14.2	10.1		**15**
	C	**D**	**E**	**F**	**G**	**H**	**J**	**K**	**L**	**M**	**N**	**O**	**P**	**Q**	**R**	**S**	

🟩	0-100	🟦	100-200	🟨	200-300	🟪	300-400	🟧	400-500	🟥	> 500

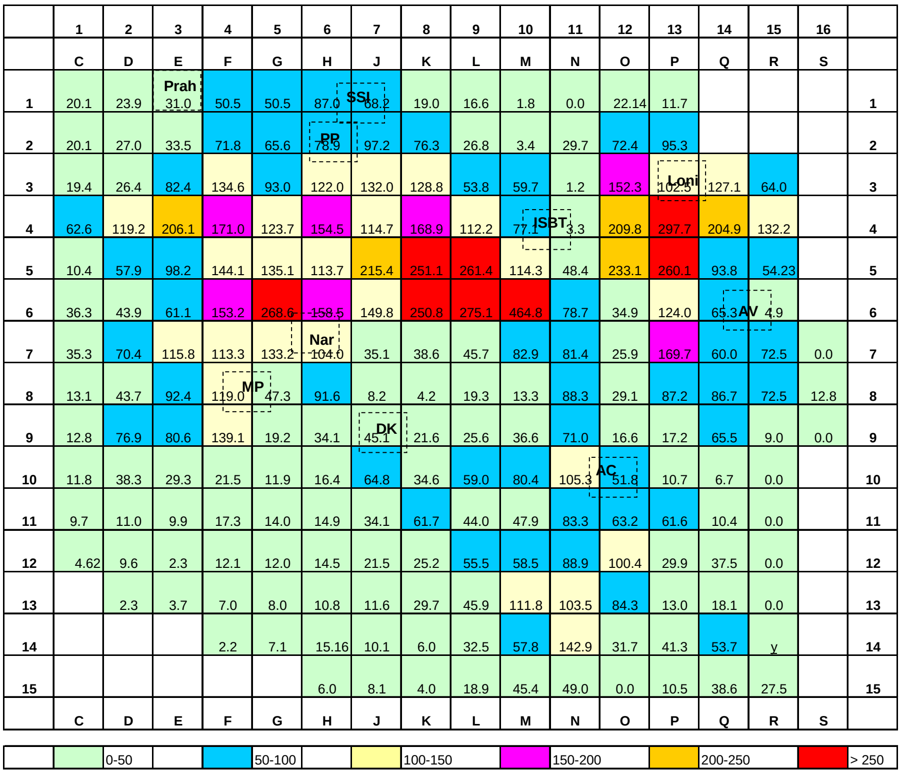
Fig. 3.30 : Grid-wise PM Emission Load (kg/d) in Delhi: Area Sources



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	C	**D**	**E**	**F**	**G**	**H**	**J**	**K**	**L**	**M**	**N**	**O**	**P**	**Q**	**R**	**S**	
1	3.0	5.0	6.5	15.2	2.7	22.7	12.4	4.1	2.6	0.4	0.0	3.1	0.9				**1**
2	4.2	6.1	7.1	14.9	11.9	7.5	27.5	8.5	3.6	0.6	2.1	10.0	7.5				**2**
3	3.6	4.8	19.2	28.1	8.6	23.1	28.9	18.4	11.5	16.0	0.9	30.6	10.7	12.7	2.4		**3**
4	4.3	13.0	22.7	13.6	14.1	23.4	12.4	41.9	25.4	8.1	2.9	49.4	30.7	21.4	23.4		**4**
5	1.9	2.9	14.1	29.7	16.3	14.6	55.0	40.7	39.0	22.0	10.8	50.7	48.5	14.6	4.8		**5**
6	2.3	2.7	5.1	16.5	50.2	42.4	30.7	83.4	48.2	100.7	20.8	12.0	27.5	5.5	0.3		**6**
7	2.8	12.7	32.2	22.8	19.7	15.5	5.6	7.4	20.7	42.7	4.9	10.4	44.0	5.9	11.6	0.0	**7**
8	0.9	11.3	17.4	15.8	5.7	12.7	1.9	1.5	4.4	3.5	6.4	6.8	16.2	6.8	7.6	0.8	**8**
9	1.3	3.6	9.9	7.7	2.7	10.9	3.9	3.7	6.2	12.1	9.9	7.2	3.6	4.2	0.8	0.0	**9**
10	0.6	3.4	5.4	2.6	1.4	0.7	8.9	8.3	10.6	23.4	17.6	9.0	1.9	0.8	0.0		**10**
11	0.5	1.1	0.56	2.6	0.8	3.1	11.7	17.6	19.6	16.7	16.6	10.1	12.5	1.1	0.0		**11**
12	0.26	0.5	0.9	2.2	1.3	4.1	4.1	5.9	9.7	10.4	17.2	24.4	4.6	3.4	0.0		**12**
13		0.1	0.45	1.7	2.6	1.0	0.9	16.1	3.1	14.9	14.1	4.6	2.2	1.3	0.0		**13**
14				0.1	0.3	1.2	0.4	0.6	1.7	3.5	27.6	5.0	1.9	8.6	0.8		**14**
15					0.0	0.2	0.8	0.5	1.0	1.9	2.1	0.0	0.5	1.6	1.1		**15**

🟩	0-20	🟦	20-40	🟨	40-60	🟪	60-80	🟧	80-100	🟥	> 100

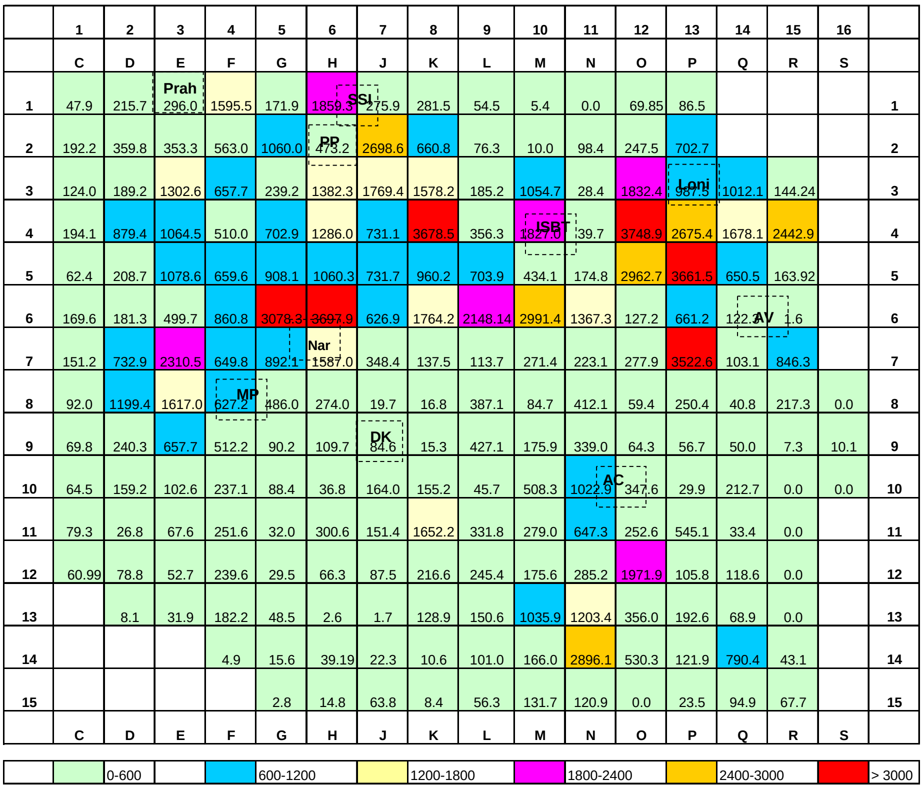
Fig. 3.31: Grid-wise SO_2 Emission Load (kg/d) in Delhi: Area Sources



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1	20.1	23.9	Prah 31.0	50.5	50.5	87.0	SSI 68.2	19.0	16.6	1.8	0.0	22.14	11.7				1
2	20.1	27.0	33.5	71.8	65.6	PP 78.9	97.2	76.3	26.8	3.4	29.7	72.4	95.3				2
3	19.4	26.4	82.4	134.6	93.0	122.0	132.0	128.8	53.8	59.7	1.2	152.3	Loni 102.5	127.1	64.0		3
4	62.6	119.2	206.1	171.0	123.7	154.5	114.7	168.9	112.2	ISBT 77.1	3.3	209.8	297.7	204.9	132.2		4
5	10.4	57.9	98.2	144.1	135.1	113.7	215.4	251.1	261.4	114.3	48.4	233.1	260.1	93.8	54.23		5
6	36.3	43.9	61.1	153.2	268.6	158.5	149.8	250.8	275.1	464.8	78.7	34.9	124.0	AV 65.3	4.9		6
7	35.3	70.4	115.8	113.3	133.2	Nar 104.0	35.1	38.6	45.7	82.9	81.4	25.9	169.7	60.0	72.5	0.0	7
8	13.1	43.7	92.4	MP 119.0	47.3	91.6	8.2	4.2	19.3	13.3	88.3	29.1	87.2	86.7	72.5	12.8	8
9	12.8	76.9	80.6	139.1	19.2	34.1	DK 45.1	21.6	25.6	36.6	71.0	16.6	17.2	65.5	9.0	0.0	9
10	11.8	38.3	29.3	21.5	11.9	16.4	64.8	34.6	59.0	80.4	105.3	AC 51.8	10.7	6.7	0.0		10
11	9.7	11.0	9.9	17.3	14.0	14.9	34.1	61.7	44.0	47.9	83.3	63.2	61.6	10.4	0.0		11
12	4.62	9.6	2.3	12.1	12.0	14.5	21.5	25.2	55.5	58.5	88.9	100.4	29.9	37.5	0.0		12
13		2.3	3.7	7.0	8.0	10.8	11.6	29.7	45.9	111.8	103.5	84.3	13.0	18.1	0.0		13
14				2.2	7.1	15.16	10.1	6.0	32.5	57.8	142.9	31.7	41.3	53.7	y		14
15						6.0	8.1	4.0	18.9	45.4	49.0	0.0	10.5	38.6	27.5		15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

	🟩	0-50		🟦	50-100		🟨	100-150		🟪	150-200		🟧	200-250		🟥	> 250

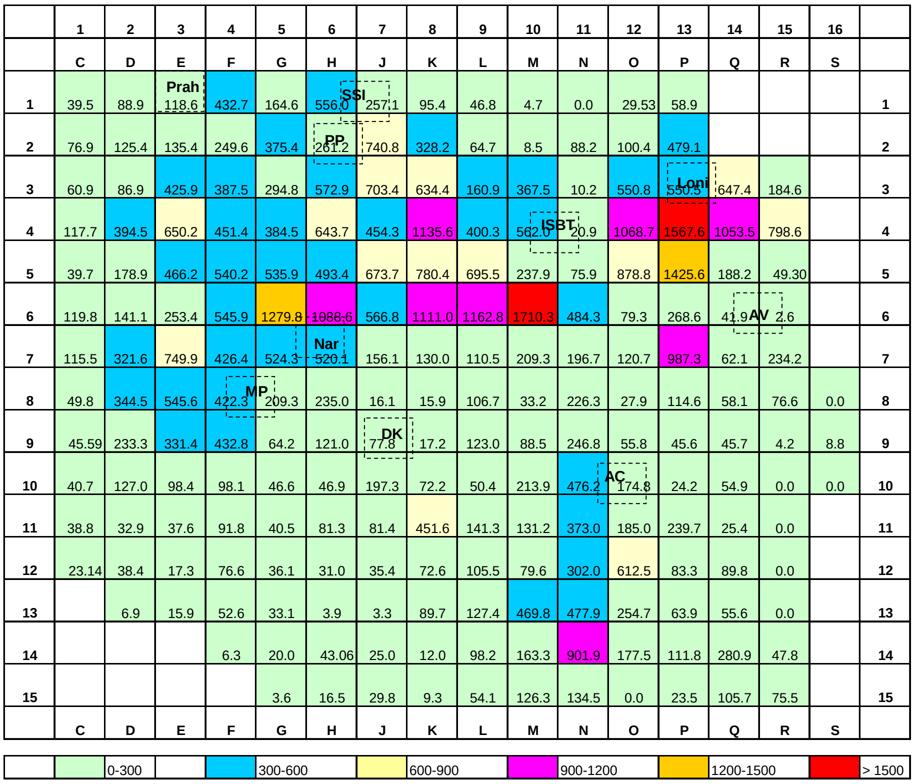
Fig. 3.32: Grid-wise NO_2 Emission Load (kg/d) in Delhi: Area Sources



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1	47.9	215.7	Prah 296.0	1595.5	171.9	1859.3	SSI 275.9	281.5	54.5	5.4	0.0	69.85	86.5				1
2	192.2	359.8	353.3	563.0	1060.0	PP 473.2	2698.6	660.8	76.3	10.0	98.4	247.5	702.7				2
3	124.0	189.2	1302.6	657.7	239.2	1382.3	1769.4	1578.2	185.2	1054.7	28.4	1832.4	Loni 987.5	1012.1	144.24		3
4	194.1	879.4	1064.5	510.0	702.9	1286.0	731.1	3678.5	356.3	ISBT 1827.0	39.7	3748.9	2675.4	1678.1	2442.9		4
5	62.4	208.7	1078.6	659.6	908.1	1060.3	731.7	960.2	703.9	434.1	174.8	2962.7	3661.5	650.5	163.92		5
6	169.6	181.3	499.7	860.8	3078.3	3697.9	626.9	1764.2	2148.14	2991.4	1367.3	127.2	661.2	AV 122.3	1.6		6
7	151.2	732.9	2310.5	649.8	892.1	Nar 1587.0	348.4	137.5	113.7	271.4	223.1	277.9	3522.6	103.1	846.3		7
8	92.0	1199.4	1617.0	MP 627.2	486.0	274.0	19.7	16.8	387.1	84.7	412.1	59.4	250.4	40.8	217.3	0.0	8
9	69.8	240.3	657.7	512.2	90.2	109.7	DK 84.6	15.3	427.1	175.9	339.0	64.3	56.7	50.0	7.3	10.1	9
10	64.5	159.2	102.6	237.1	88.4	36.8	164.0	155.2	45.7	508.3	1022.9	AC 347.6	29.9	212.7	0.0	0.0	10
11	79.3	26.8	67.6	251.6	32.0	300.6	151.4	1652.2	331.8	279.0	647.3	252.6	545.1	33.4	0.0		11
12	60.99	78.8	52.7	239.6	29.5	66.3	87.5	216.6	245.4	175.6	285.2	1971.9	105.8	118.6	0.0		12
13		8.1	31.9	182.2	48.5	2.6	1.7	128.9	150.6	1035.9	1203.4	356.0	192.6	68.9	0.0		13
14				4.9	15.6	39.19	22.3	10.6	101.0	166.0	2896.1	530.3	121.9	790.4	43.1		14
15					2.8	14.8	63.8	8.4	56.3	131.7	120.9	0.0	23.5	94.9	67.7		15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

	🟩	0-600		🟦	600-1200		🟨	1200-1800		🟪	1800-2400		🟧	2400-3000		🟥	> 3000

Fig. 3.33: Grid-wise CO Emission Load (kg/d) in Delhi: Area Sources



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1	39.5	88.9	Prah 118.6	432.7	164.6	SSI 556.0	257.1	95.4	46.8	4.7	0.0	29.53	58.9				1
2	76.9	125.4	135.4	249.6	375.4	PP 261.2	740.8	328.2	64.7	8.5	88.2	100.4	479.1				2
3	60.9	86.9	425.9	387.5	294.8	572.9	703.4	634.4	160.9	367.5	10.2	550.8	Loni 550.5	647.4	184.6		3
4	117.7	394.5	650.2	451.4	384.5	643.7	454.3	1135.6	400.3	ISBT 562.0	20.9	1068.7	1567.6	1053.5	798.6		4
5	39.7	178.9	466.2	540.2	535.9	493.4	673.7	780.4	695.5	237.9	75.9	878.8	1425.6	188.2	49.30		5
6	119.8	141.1	253.4	545.9	1279.8	1088.6	566.8	1111.0	1162.8	1710.3	484.3	79.3	268.6	AV 41.9	2.6		6
7	115.5	321.6	749.9	426.4	524.3	Nar 520.1	156.1	130.0	110.5	209.3	196.7	120.7	987.3	62.1	234.2		7
8	49.8	344.5	545.6	MP 422.3	209.3	235.0	16.1	15.9	106.7	33.2	226.3	27.9	114.6	58.1	76.6	0.0	8
9	45.59	233.3	331.4	432.8	64.2	121.0	DK 77.8	17.2	123.0	88.5	246.8	55.8	45.6	45.7	4.2	8.8	9
10	40.7	127.0	98.4	98.1	46.6	46.9	197.3	72.2	50.4	213.9	476.2	AC 174.8	24.2	54.9	0.0	0.0	10
11	38.8	32.9	37.6	91.8	40.5	81.3	81.4	451.6	141.3	131.2	373.0	185.0	239.7	25.4	0.0		11
12	23.14	38.4	17.3	76.6	36.1	31.0	35.4	72.6	105.5	79.6	302.0	612.5	83.3	89.8	0.0		12
13		6.9	15.9	52.6	33.1	3.9	3.3	89.7	127.4	469.8	477.9	254.7	63.9	55.6	0.0		13
14				6.3	20.0	43.06	25.0	12.0	98.2	163.3	901.9	177.5	111.8	280.9	47.8		14
15					3.6	16.5	29.8	9.3	54.1	126.3	134.5	0.0	23.5	105.7	75.5		15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

	🟩	0-300		🟦	300-600		🟨	600-900		🟪	900-1200		🟧	1200-1500		🟥	> 1500

Fig. 3.34: Grid-wise HC Emission Load (kg/d) in Delhi: Area Sources

3.3.2 Emission Inventory: Industrial Sources

3.3.2.1 Approach and Methodology

For obtaining comprehensive list of different types of air polluting industries in the region, Central Pollution Control Board, Delhi Pollution Control Committee, concerned Government Institutions, Office of Commissioner of Industries, Govt. of NCT, Delhi, District Industrial Centre (DIC) and other organizations in Delhi were approached. Specific information on production capacities, raw materials used, manufacturing processes, fuel consumption etc. were collected from the available secondary data records. Information on fuel shift in industries as well as shifting of polluting industries outside Delhi was also collected from DPCC and CPCB. NEERI team visited all the 36 industrial estates for surveying visible stacks and emissions and collection of primary data from representative industries through questionnaires. The gross emissions have been estimated for all types of industries viz. power plant (5), metallurgical, engineering, food, textile, plastic, rubber, chemical and other industries using appropriate CPCB/AP-42 emission factors.

3.3.2.2 Data Analysis

Thermal power plants (TPP) account for major share of industrial emissions (for SO_2 and NOx) in the region. However, as the major units in TPP are equipped with high efficiency control equipments, viz. ESP and also due to use of clean (beneficiated) coal, its contribution towards particulate air pollution has reduced in comparison to 1995 emissions reported in NCR report. Earlier study conducted by NEERI (1995) also showed that the power plants and others including engineering industries were the major contributors to industrial emissions. SSI units numbering 2252 approx. (predominantly engineering) constitute another group of air polluting industries in the region. The percentage contribution of SO_2, NOx and PM10 from SSI in 36 industrial estates is 1.7%, 6.9% and 6.4 % respectively. The total emission scenario includes contribution from five power plants, nine medium scale Industries as well as from small scale industries.

Large industries Power Plants are the major sources of SO_2 (96.6%) and NOx (93%) emissions in the region. This emission pattern has been arrived at considering the existing industrial structure including the power plants. Emissions estimated for Power Plants are given in **Table 3.59** and their contribution is shown in **Fig. 3.35**.

Table 3.59: Emissions from Power Plants: Delhi, 2006-07

Thermal Power Plant	Emission Load (Kg/day)				
	PM10	**SO_2**	**NOx**	**HC**	**CO**
Rajghat Thermal Power Station	2880	24320	28160	128	640
Pragati Thermal Power Station	4.5	71.4	33331.2	1309.4	9999.4
Indraprastha Power Station	4950	41801.0	48400.0	220.0	1100.0
Gas Turbine Power Station	0.9	13.8	6451.2	253.4	1935.4
Badarpur Thermal Power Station	22410	189240	219120	996	4980
Total	**30245.4**	**255446.2**	**335462.4**	**2906.8**	**18654.8**

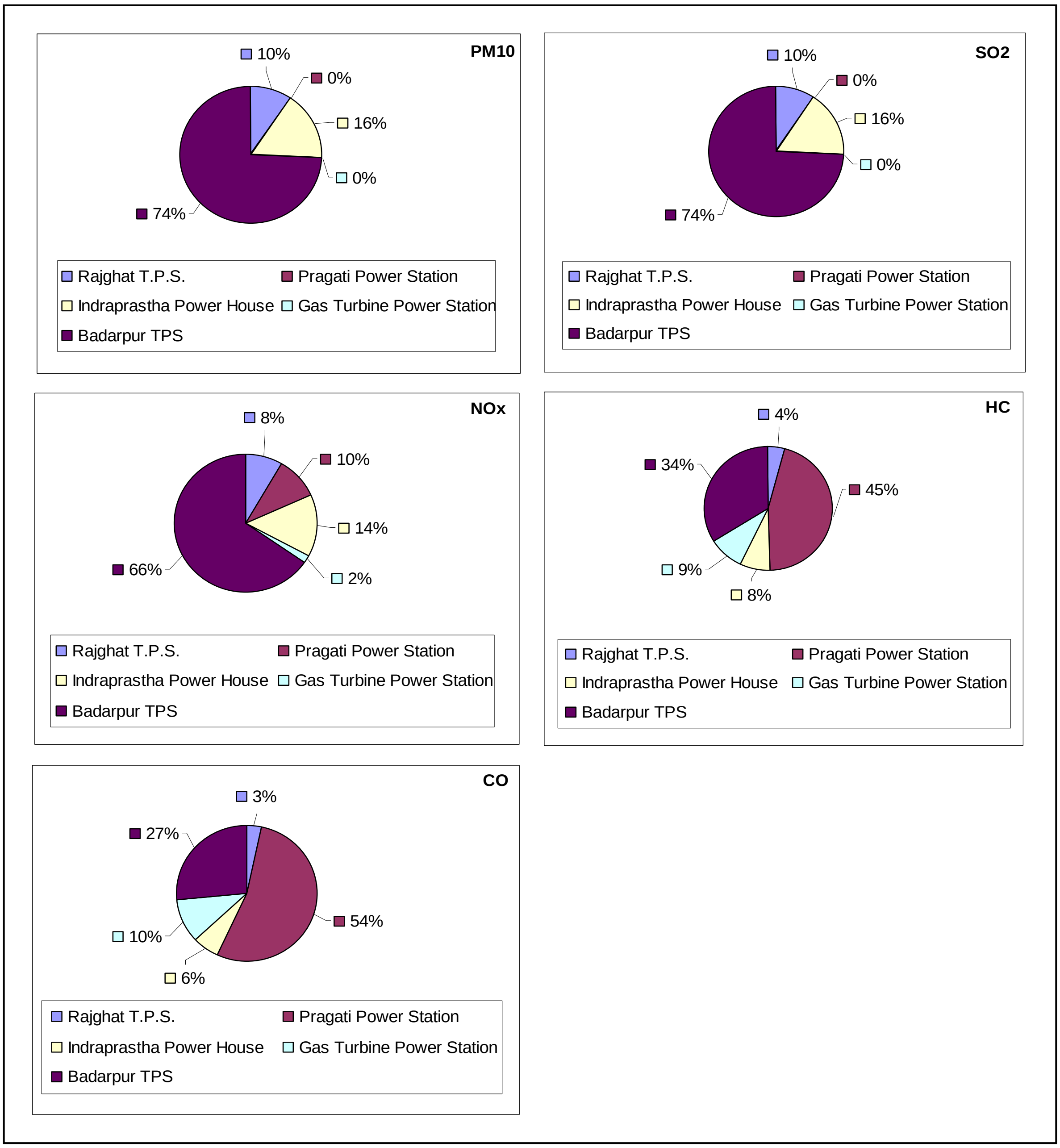


Fig. 3.35: Pollutant-wise % Emissions Contribution of Power Plants: Delhi

Emissions estimated for nine Medium Scale industries are given in **Table 3.60** and their contribution is shown in **Fig. 3.36**.

Table 3.60: Emission Inventory (Medium Scale Industries): Delhi- 2006-07

Sr. No.	Medium scale industries	Emission Load (Kg/day)				
		PM10	SO_2	NOx	HC	CO
1.	Nafed Cold storage, Lawrence Rd	0.07	5.8	0.3	0.04	0.19
2.	Shakti Hosiery, Lawrence Rd	0.0005	0.06	0.002	0.0002	0.0012
3.	Mothers Dairy, Patparganj	28.8	4063.0	144.0	14.4	72.0
4.	Delhi milk scheme,West Patel nagar	1.50	215.30	7.60	0.80	3.80
5.	Dry cleaning, phase III Okhla	1.50	189.60	7.49	0.75	3.74
6.	Pearl drinks ltd, Lawrence Rd	0.01	0.56	0.04	0.00	0.02
7.	Modern Food ltd, Lawrence Rd	0.29	40.63	1.44	0.14	0.72
8.	Kaytis Food processes, Lawrence Rd	112.50	4.75	5.50	0.03	0.13
9.	Brittania Industries ltd, Lawrence Rd	0.55	3.38	19.38	0.77	5.84
	Total	**145.2**	**4523.2**	**185.8**	**16.9**	**86.4**

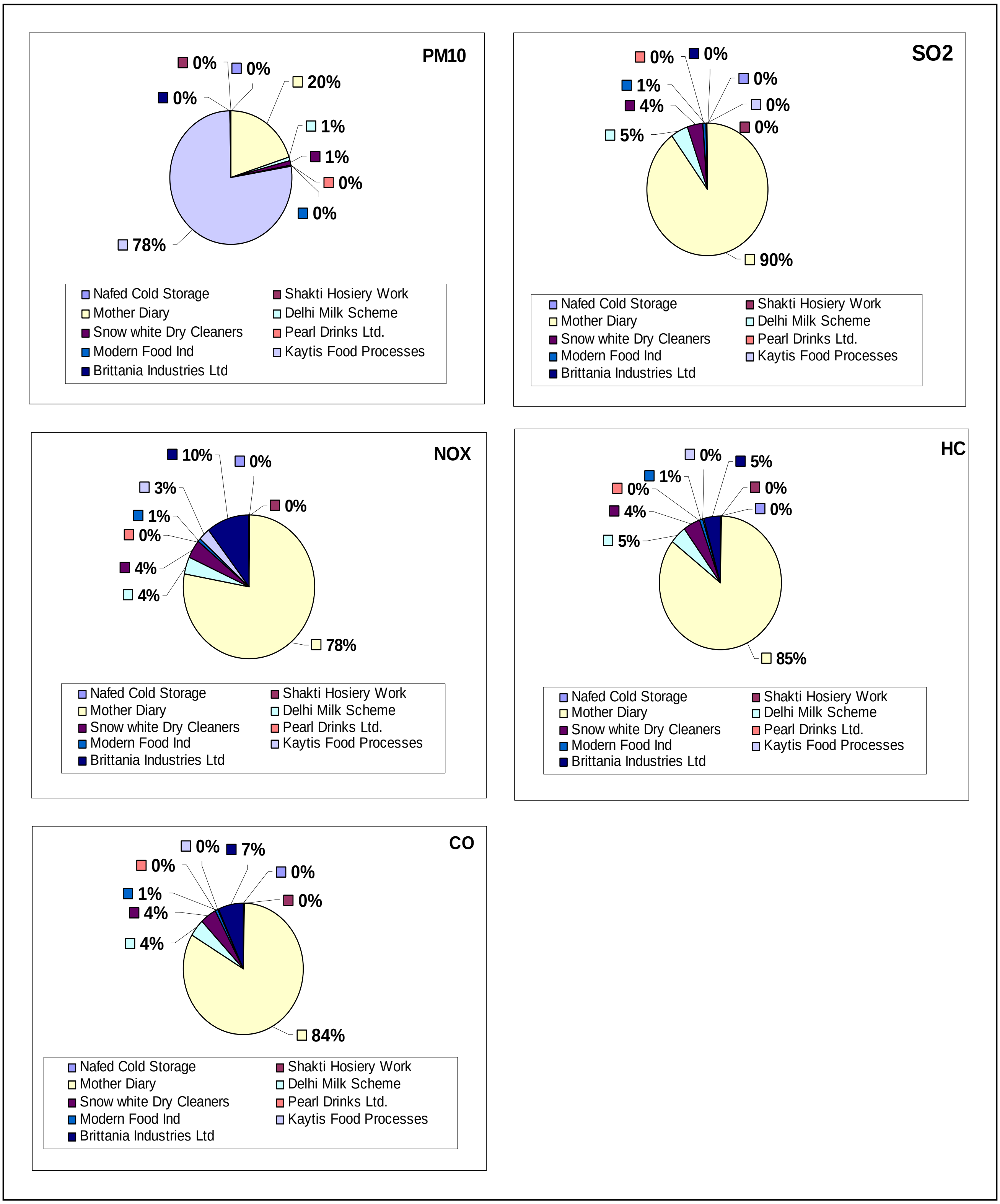


Fig. 3.36: Emissions Contribution of Medium Scale Industries

The emissions estimated for 2252 SSI units located in 36 industrial estates is given in **Table 3.61**.

Table 3.61: Emissions Inventory of SSI Units: Delhi- 2006-07

Industrial Estates	**Emission Load (kg/day)**				
	PM10	**SO_2**	**NOx**	**HC**	**CO**
Anand Parbat	440.0	114.3	204.0	14.6	40.8
Badli	49.4	93.4	694.1	55.4	150.5
Samaipur	21.0	19.6	297.5	23.7	64.3
Kirtinagar	36.1	57.2	507.3	40.5	110.0
Friends Colony	103.0	99.5	1455.5	116.1	314.4
Bawana	1.2	5.3	14.8	1.2	3.2
Okhla Phase I	123.2	209.1	1729.0	137.7	375.1
Okhla Phase II	181.8	197.6	2567.1	205.0	554.9
Okhla Phase III	21.9	22.6	309.5	24.7	66.9
Motinagar	18.3	9.0	166.2	11.7	34.5
Mohan Coperative	39.8	56.1	560.4	44.7	121.4
Wazirpur	171.8	288.2	2412.1	192.6	523.2
Shahadara	2.4	12.8	32.5	2.6	7.2
Jhilmil	56.1	92.6	788.3	62.9	170.9
Tilaknagar	13.0	797.6	91.9	8.4	34.2
Najafgarh	72.8	78.1	1028.3	82.1	222.2
Nangoli	9.8	14.4	138.1	11.0	29.9
Dilshad	15.3	14.3	216.7	17.3	46.8
Mangolpuri Phase I	9.0	20.2	125.8	10.1	27.4
Mangolpuri Phase II	11.5	13.9	162.8	13.0	35.2
Lawrence Road	113.0	1258.3	1461.5	118.1	336.7
Narela	41.0	51.6	579.0	46.2	125.2
Naraina Phase II	28.1	26.2	396.9	31.7	85.7
Shahazabagh	17.6	16.4	248.6	19.8	53.7
GTK	44.7	222.7	610.4	48.9	135.1
SSI	32.7	30.5	462.3	36.9	99.8
SMA	40.9	38.1	577.7	46.1	124.8
Patpargang	41.6	78.7	2379.3	46.6	126.6
Mayapuri phase I	83.8	158.3	1177.4	94.0	255.4
Mayapuri phase II	101.5	155.4	1428.4	114.0	309.6
Naraina Phase I	57.9	69.5	817.1	65.2	176.6
Rajasthan Udyog	87.7	108.1	1236.8	98.7	267.5
Total	**2088.0**	**4429.6**	**24877.4**	**1841.5**	**5029.7**

SSI units in 36 industrial estates are distributed in four zones of Delhi i.e., North, East, South and West. Accordingly, zone-wise emissions are estimated as given in **Table 3.62.**

Table 3.62: Zone-wise Emissions from Different Industries in Delhi

Industrial Estates	Emission Load (kg/day)				
	PM10	SO_2	NOx	HC	CO
North Zone					
Anand Parbat	440.0	114.3	204.0	14.6	40.8
Badli	49.4	93.4	694.1	55.4	150.5
Samaipur	21.0	19.6	297.5	23.7	64.3
Wazirpur	171.8	288.2	2412.1	192.6	523.2
Najafgarh	72.8	78.1	1028.3	82.1	222.2
Narela	41.0	51.6	579.0	46.2	125.2
Bawana	1.2	5.3	14.8	1.2	3.2
Kirtinagar	36.1	57.2	507.3	40.5	110.0
Motinagar	18.3	9.0	166.2	11.7	34.5
Shazadabagh	17.6	16.4	248.6	19.8	53.7
GTK	44.7	222.7	610.4	48.9	135.1
SSI	32.7	30.5	462.3	36.9	99.8
SMA	40.9	38.1	577.7	46.1	124.8
Rajasthan Udyog	87.7	108.1	1236.8	98.7	267.5
East Zone					
Friends Colony	103.0	99.5	1455.5	116.1	314.4
Shahadara	2.4	12.8	32.5	2.6	7.2
Jhilmil	56.1	92.6	788.3	62.9	170.9
Dilshad	15.3	14.3	216.7	17.3	46.8
Patparganj	41.6	78.7	2379.3	46.6	126.6
Shahibabad	121.7	79.4	9.6	0.5	2.5
South Zone					
Okhla Phase I	123.2	209.1	1729.0	137.7	375.1
Okhla Phase II	181.8	197.6	2567.1	205.0	554.9
Okhla Phase III	21.9	22.6	309.5	24.7	66.9
Mohan Cooperative	39.8	56.1	560.4	44.7	121.4
West Zone					
Mayapuri phase I	83.8	158.3	1177.4	94.0	255.4
Mayapuri phase II	101.5	155.4	1428.4	114.0	309.6
Tilaknagar	13.0	797.6	91.9	8.4	34.2
Nangoli	9.8	14.4	138.1	11.0	29.9
Mangolpuri Phase I	9.0	20.2	125.8	10.1	27.4
Mangolpuri Phase II	11.5	13.9	162.8	13.0	35.2
Naraina Phase II	28.1	26.2	396.9	31.7	85.7
Naraina Phase I	57.9	69.5	817.1	65.2	176.6

The contribution of emission loads from SSIs in four zones viz. North, East, South and West is presented respectively in **Annexure III.** Category-wise distribution of SSI units is given in **Table 3.63** and their contributions are shown in **Fig. 3.37 through 3.41**.

Table 3.63: Category wise Emissions from Small Scale Industries at Delhi

Type of Industry	Emission Load (kg/day)				
	PM10	SO_2	NOx	HC	CO
Engineering	462.9	539.4	6742.2	521.2	1412.1
Chemical	299.4	231.6	1857.0	112.5	306.1
Metallurgy	66.9	64.8	1602.2	75.4	204.0
Rubber	101.6	123.2	1433.2	114.4	310.0
Textile	170.1	228.9	2397.1	191.1	518.9
Plastic	140.8	199.6	1982.4	158.2	429.2
Pharma	42.2	42.8	595.8	47.5	128.7
Food	95.7	1253.4	1544.7	98.5	283.9
Others	708.4	1748.5	6723.0	522.6	1436.8

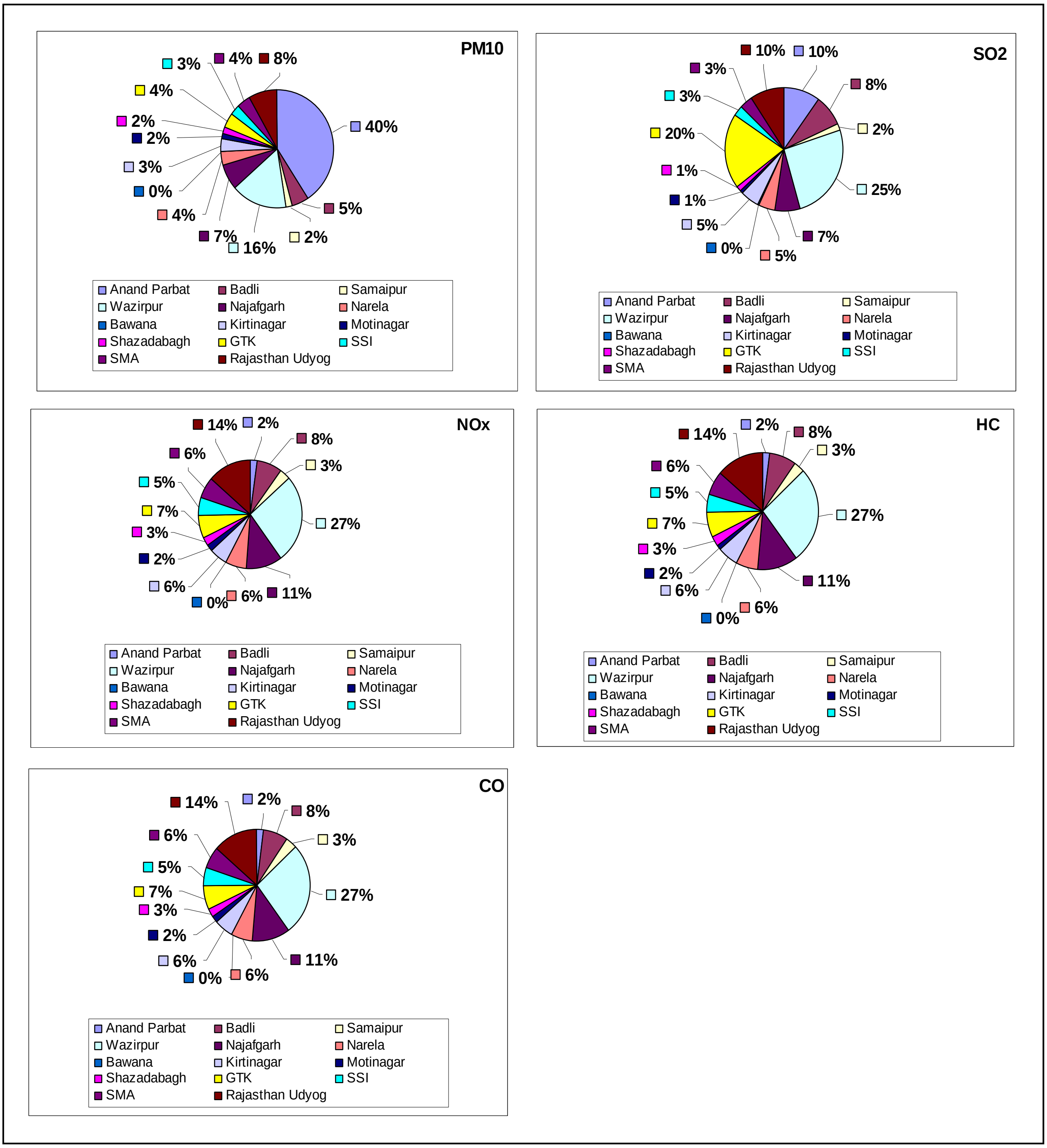


Fig. 3.37 : Pollutant wise % Emissions contribution from SSI Units: North Zone

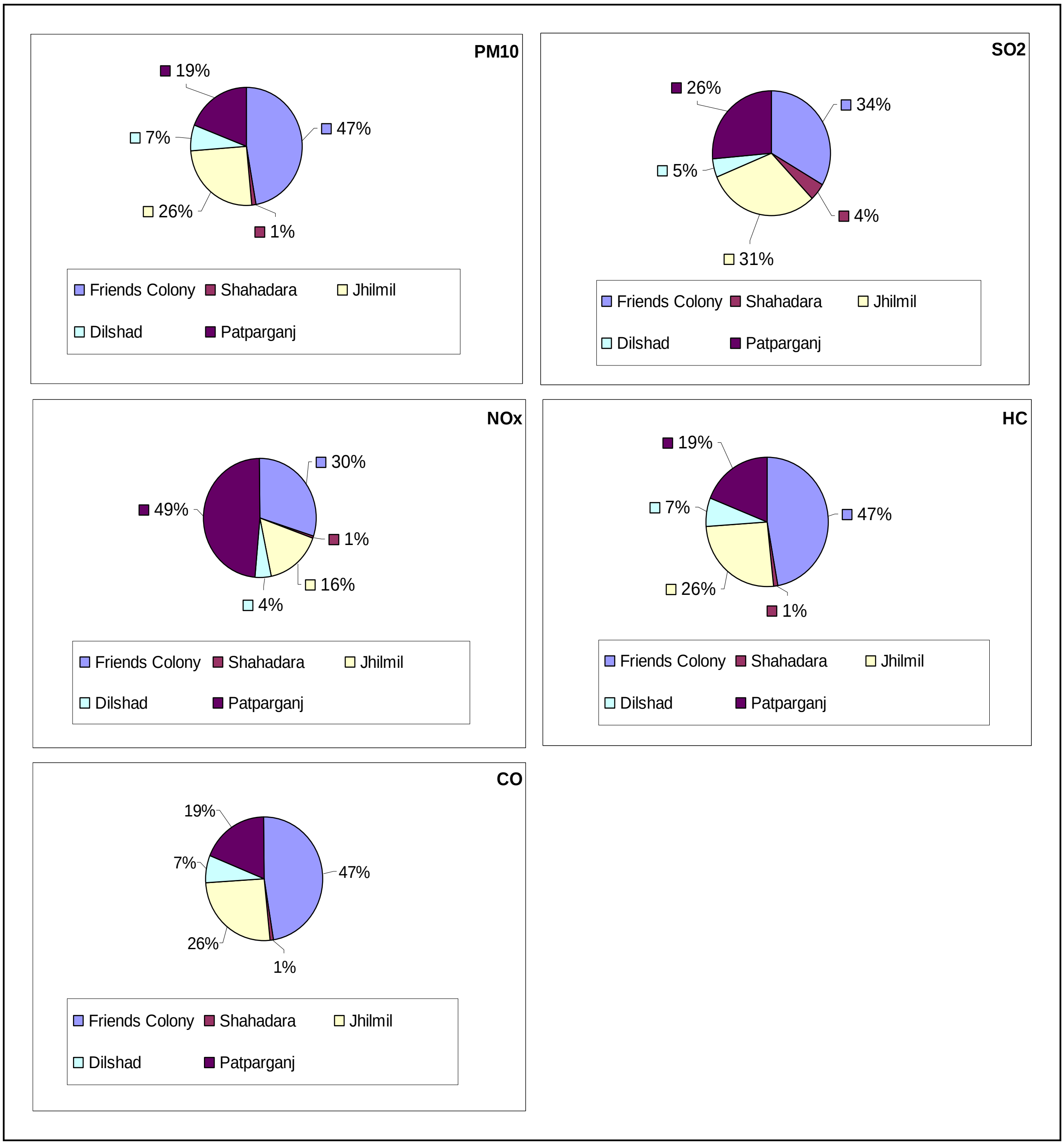


Fig. 3.38 : Pollutant-wise % Emissions contribution from SSI Units: East Zone

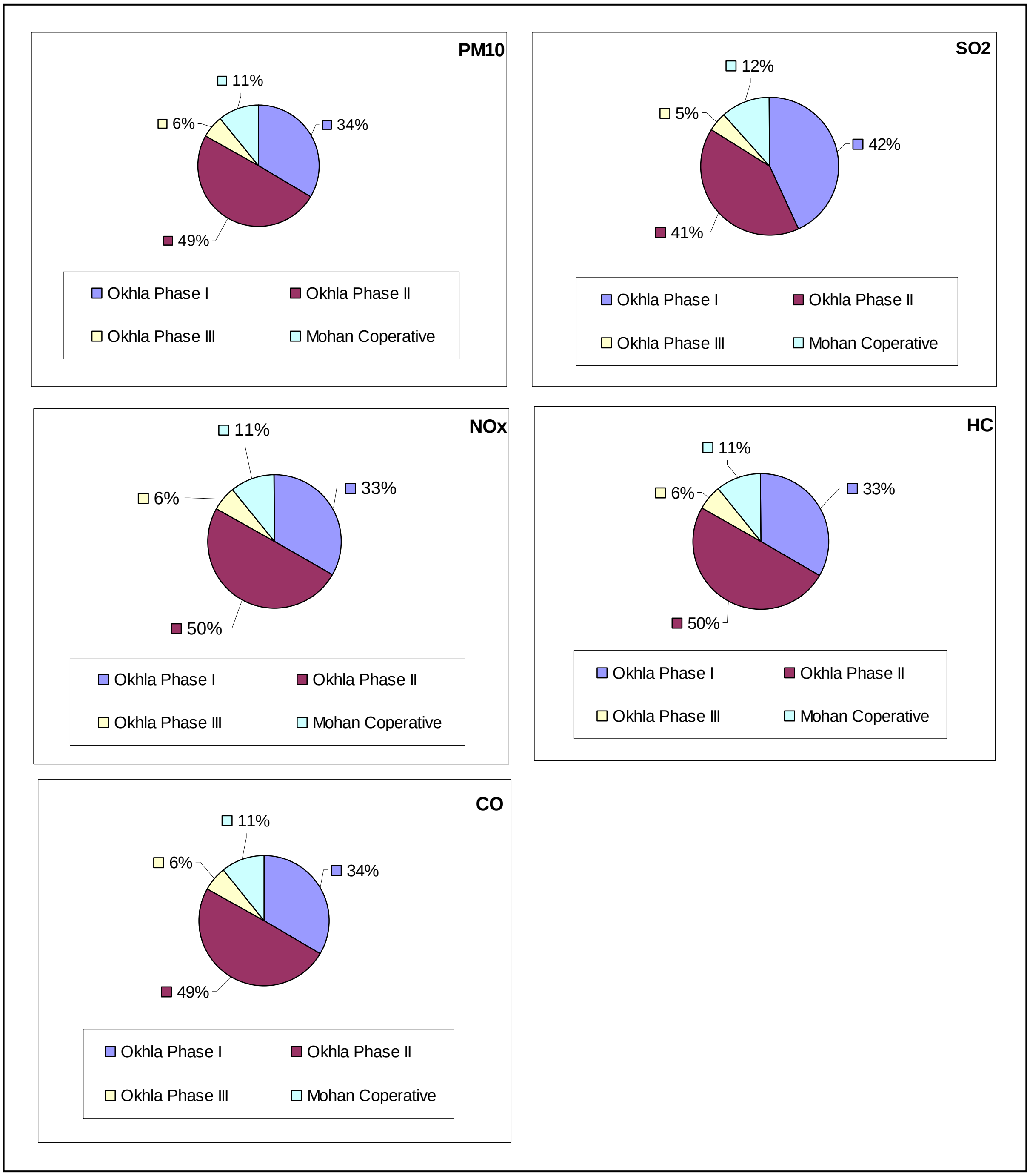


Fig. 3.39: Pollutant-wise % Emissions contribution from SSI Units: South Zone

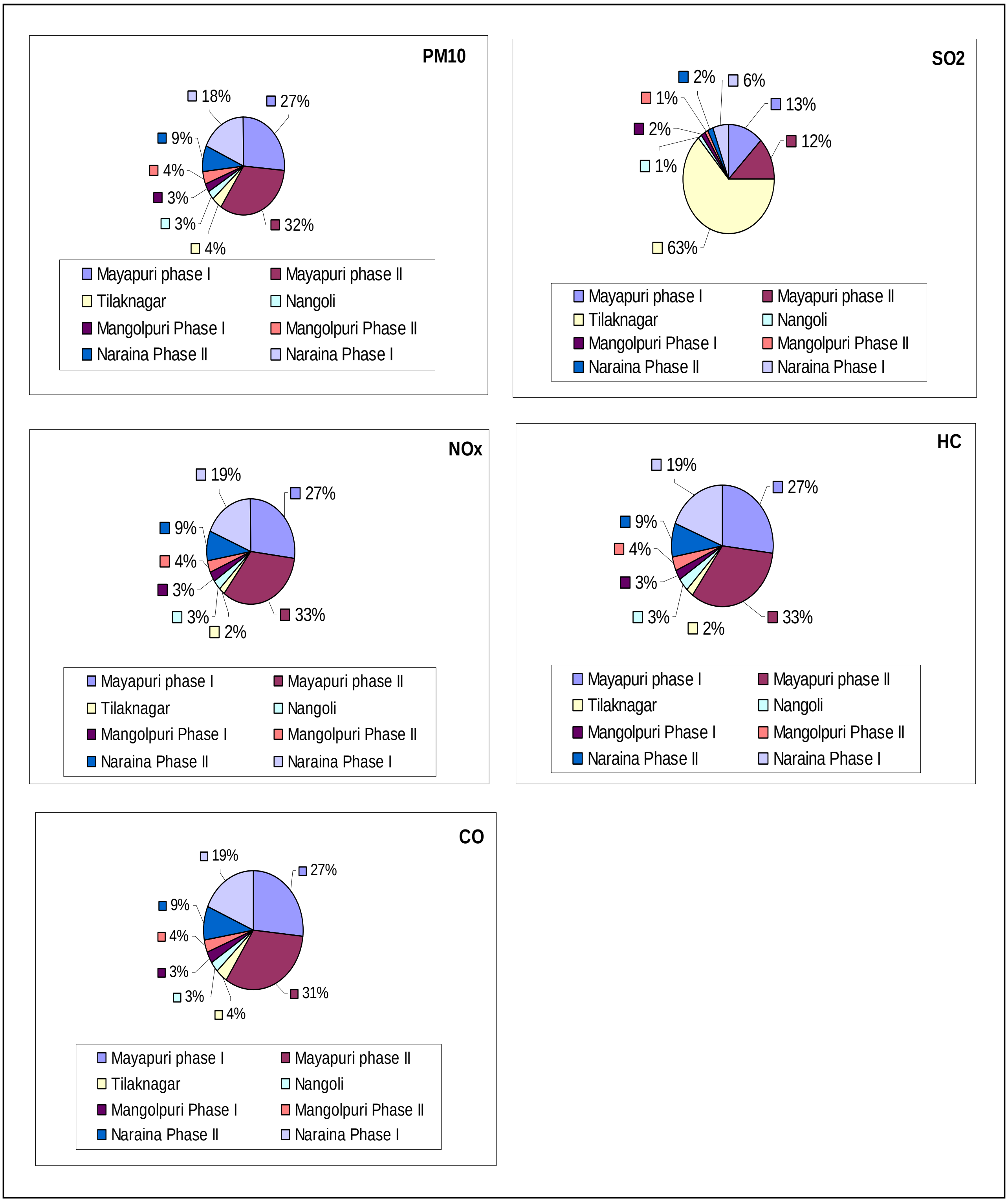


Fig. 3.40: Pollutant-wise % Emissions contribution from SSI Units: West Zone

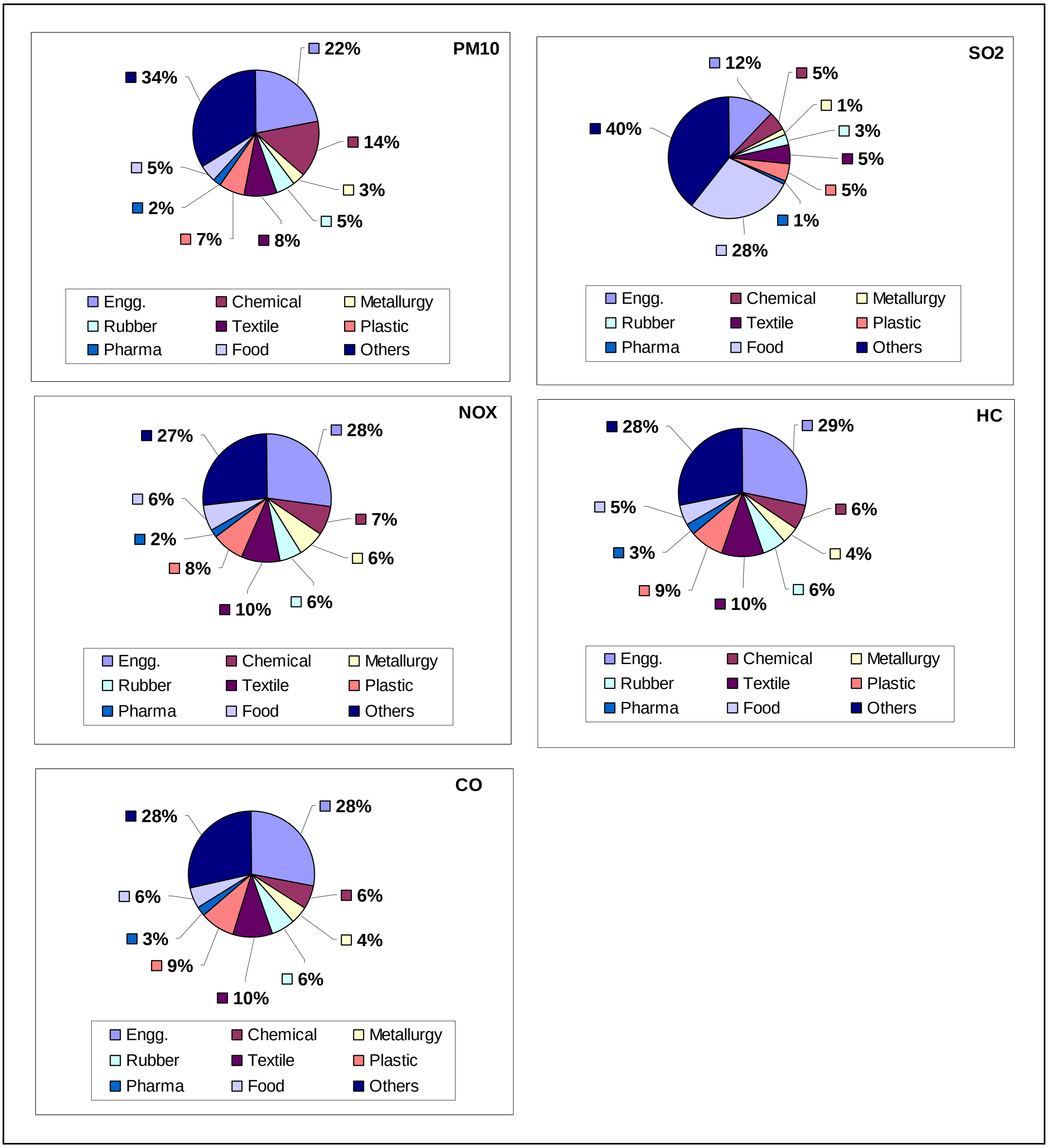


Fig. 3.41: Pollutant and Category wise % Emissions Contribution of SSI Units

Total emission loads from all Point Sources, Power Plants, Medium and Small Scale Industries is presented in **Table 3.64,** while percentage contribution of Emission Load from Point Sources is given in **Table 3.65**.

Table 3.64: Estimated Emission Load from all Industrial Sources: Delhi 2006-07

Type of the Industry	**Emission Load (kg/day)**				
	PM10	**SO$_2$**	**NOx**	**HC**	**CO**
Small Scale Industries	2087.9	4429.6	24877.3	1841.5	5029.7
Medium Scale Industries	145.2	4523.1	185.9	16.9	86.4
Large Scale Industries	30245.4	255446.2	335462.4	2906.8	18654.8
Total	**32478.6**	**264398.9**	**360525.6**	**4765.1**	**23770.9**

Table 3.65: % Contribution of Emission Load from Industrial Sources: Delhi, 2006-07

Pollutant	**LSI (5)**	**MSI (9)**	**SSI (723) (2kmx2km)**
PM10	93.1%	0.4%	6.4%
SO$_2$	96.6%	1.7%	1.7%
NOx	93%	0.1%	6.9%
HC	61%	0.4%	38.6%
CO	78.5%	0.4%	21.2%

Percentage Contribution of Pollutants from Large, Medium and Small Scale Industries for PM10, SO$_2$, NOx, HC and CO is given in **Fig. 3.42.**

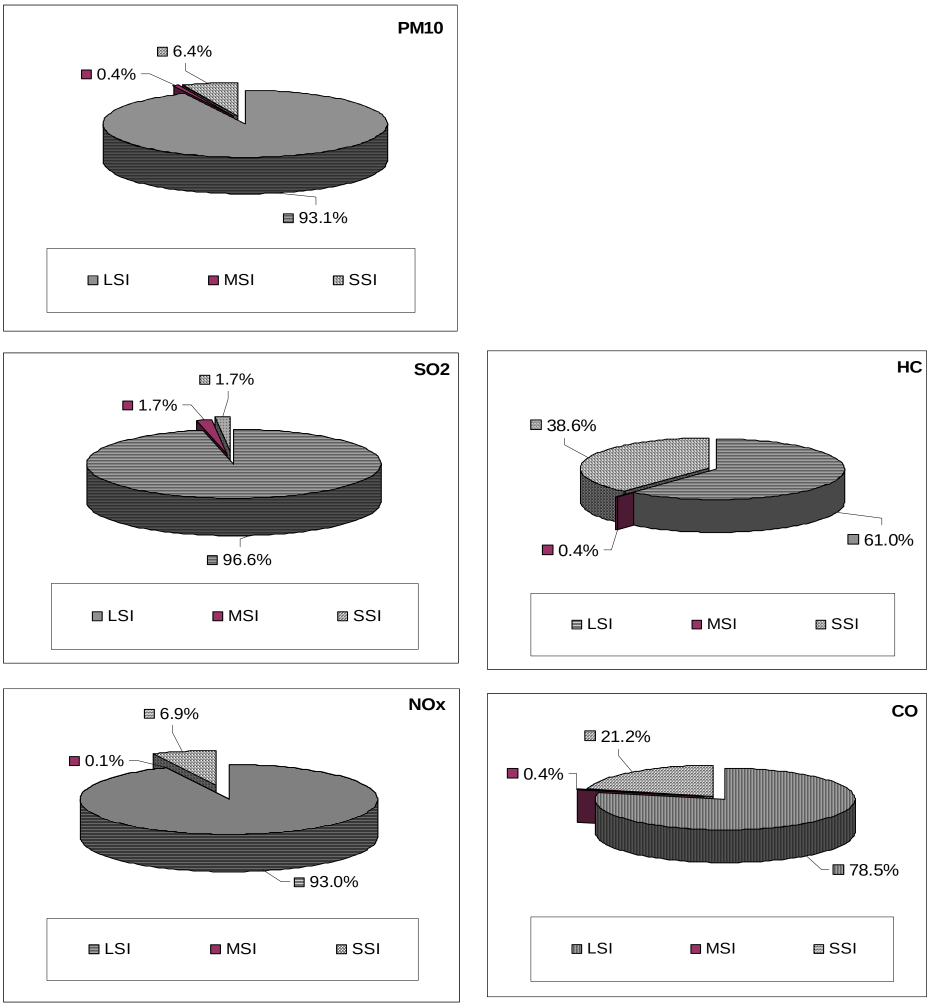
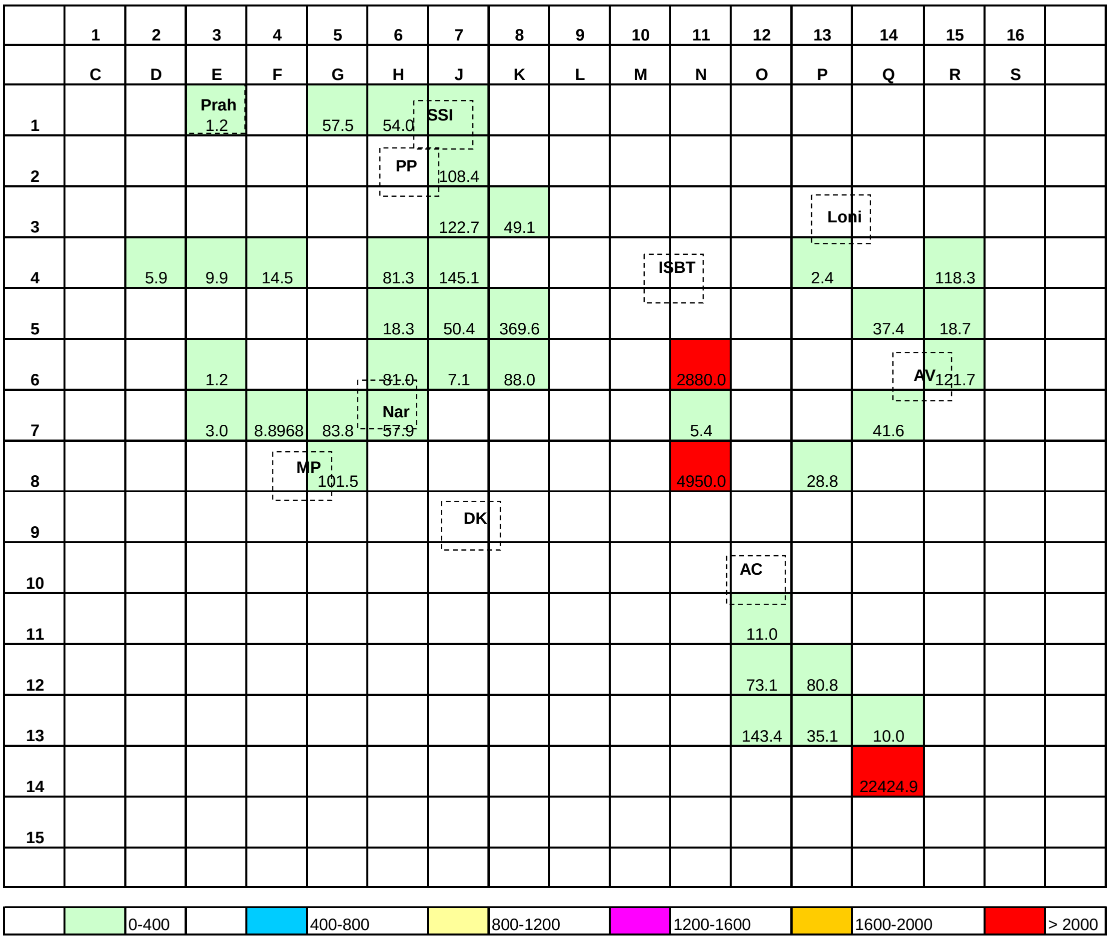


Fig. 3.42: Percentage Contribution of Pollutants from Large, Medium and Small Scale Industries for PM10, SO$_2$, NOx, HC and CO

The contribution of power plants is found to be major and contribution of PM10, SO_2 and NOx emissions with a reported percentage of 93.1, 96.6, & 93% respectively.

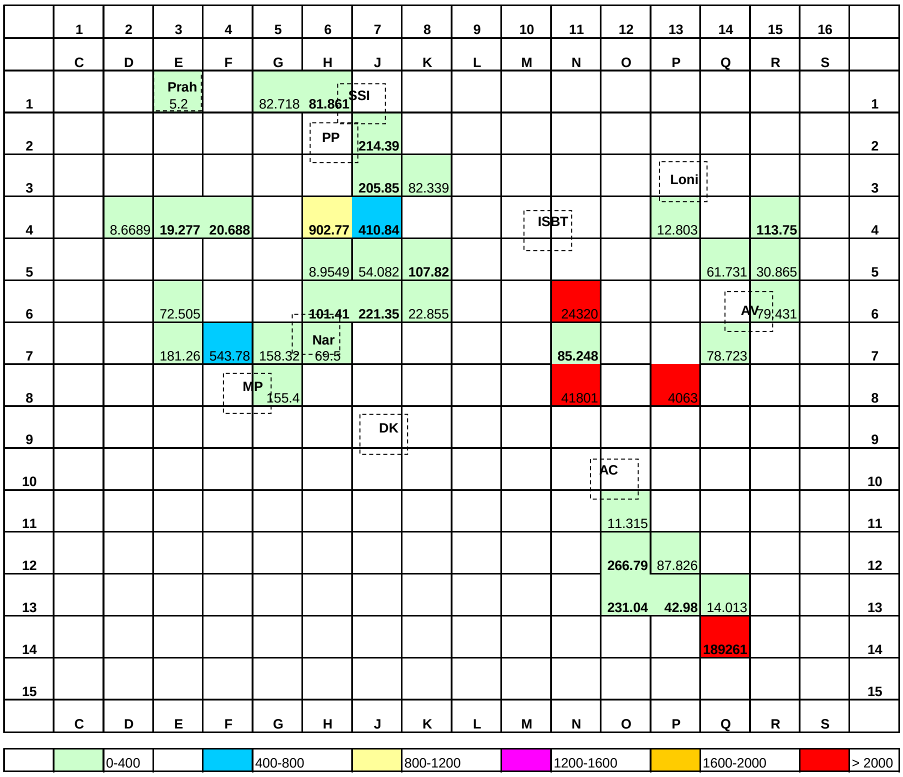
Grid wise emission load from point sources in Delhi is given in **Annexure III (Table A3.4.2)**. Grid-wise emission loads for PM, SO_2, NOx, HC and CO, in Delhi City area are presented respectively **Fig. 3.43** to **3.47**.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1			Prah 1.2		57.5	54.0	SSI										
2						PP	108.4										
3							122.7	49.1					Loni				
4		5.9	9.9	14.5		81.3	145.1			ISBT			2.4		118.3		
5						18.3	50.4	369.6						37.4	18.7		
6			1.2			81.0	7.1	88.0			2880.0			AV	121.7		
7			3.0	8.8968	83.8	Nar 57.9					5.4			41.6			
8				MP	101.5						4950.0		28.8				
9							DK										
10												AC					
11												11.0					
12												73.1	80.8				
13												143.4	35.1	10.0			
14														22424.9			
15																	

	🟩	0-400		🟦	400-800		🟨	800-1200		🟪	1200-1600		🟧	1600-2000		🟥	> 2000

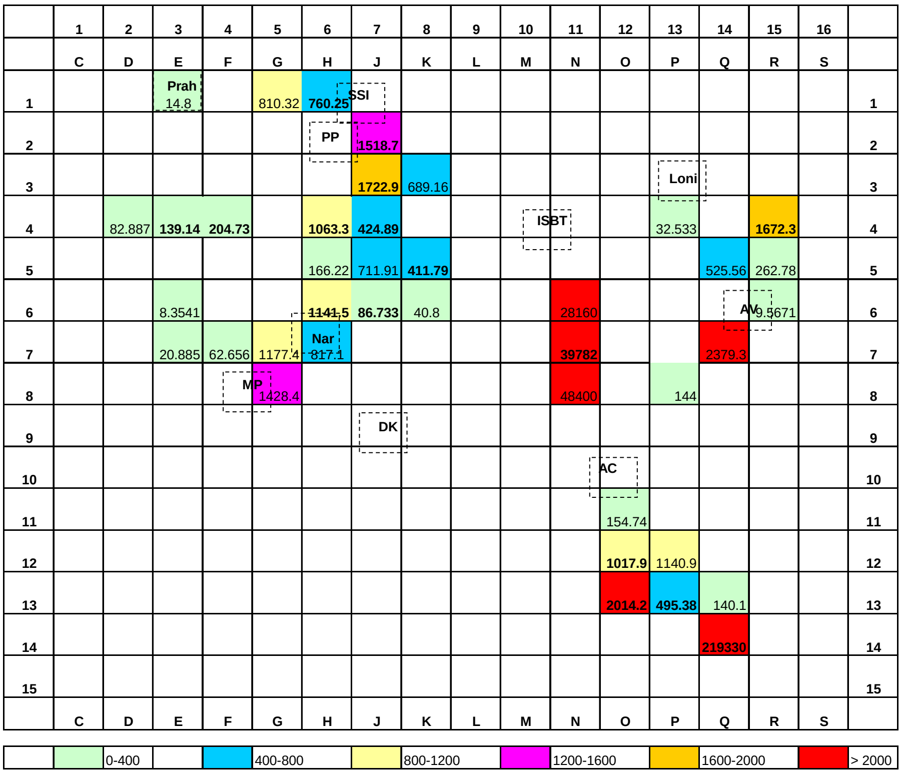
Fig: 3.43: Grid-wise PM10 Emission Load (kg/d) in Delhi: Industrial Sources



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1			Prah 5.2		82.718	81.861	SSI										1
2						PP	214.39										2
3							205.85	82.339					Loni				3
4		8.6689	19.277	20.688		902.77	410.84				ISBT		12.803		113.75		4
5						8.9549	54.082	107.82						61.731	30.865		5
6			72.505			101.41	221.35	22.855			24320				AV 79.431		6
7			181.26	543.78	158.32	Nar 69.5					85.248			78.723			7
8				MP	155.4						41801		4063				8
9							DK										9
10												AC					10
11												11.315					11
12												266.79	87.826				12
13												231.04	42.98	14.013			13
14														189261			14
15																	15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

🟩 0-400 🟦 400-800 🟨 800-1200 🟪 1200-1600 🟧 1600-2000 🟥 > 2000

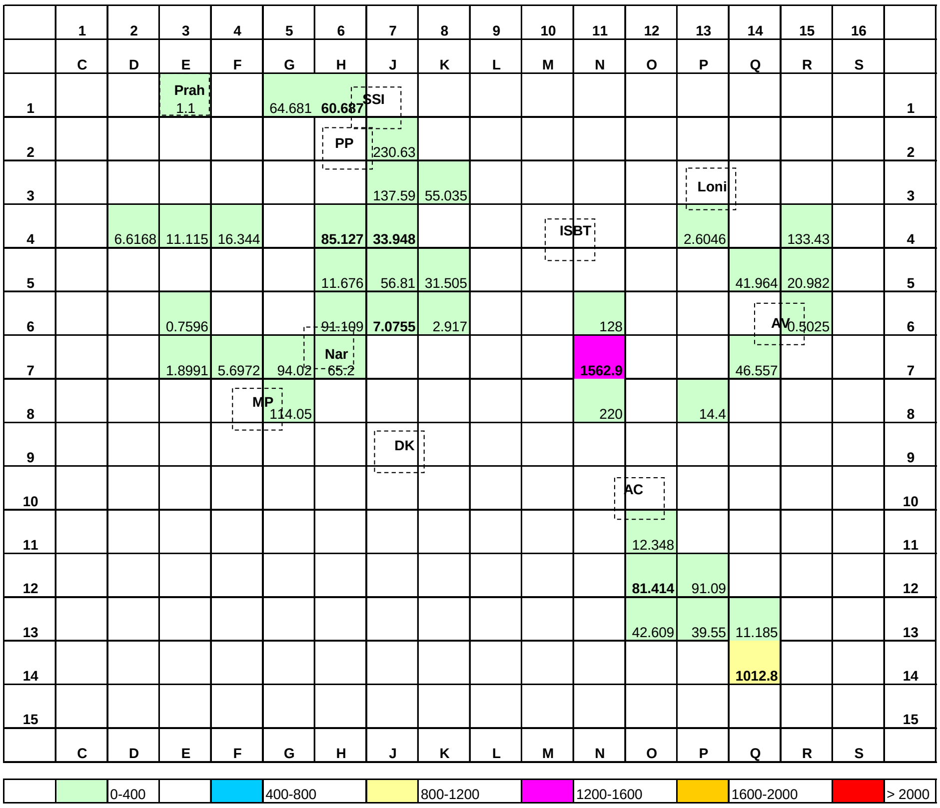
Fig: 3.44 : Grid-wise SO_2 Emission Load (kg/d) in Delhi: Industrial Sources



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1			Prah 14.8		810.32	760.25	SSI										1
2						PP	1518.7										2
3							1722.9	689.16					Loni				3
4		82.887	139.14	204.73		1063.3	424.89				ISBT		32.533		1672.3		4
5						166.22	711.91	411.79						525.56	262.78		5
6			8.3541			1141.5	86.733	40.8			28160				AV 9.5671		6
7			20.885	62.656	1177.4	Nar 817.1					39782			2379.3			7
8				MP	1428.4						48400		144				8
9							DK										9
10												AC					10
11												154.74					11
12												1017.9	1140.9				12
13												2014.2	495.38	140.1			13
14														219330			14
15																	15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

🟩 0-400 🟦 400-800 🟨 800-1200 🟪 1200-1600 🟧 1600-2000 🟥 > 2000

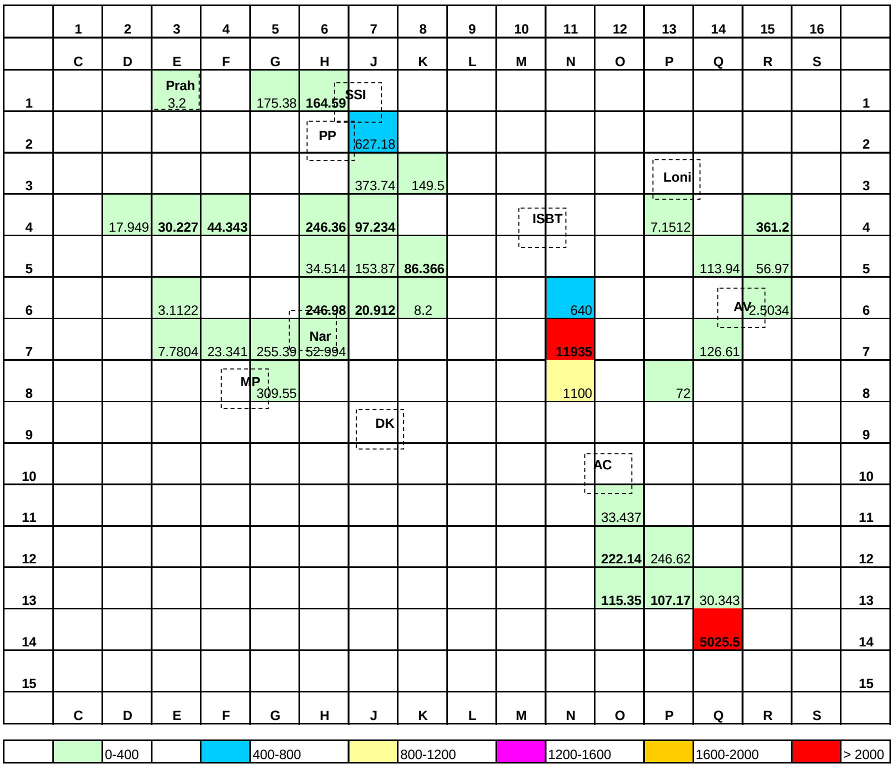
Fig: 3.45 : Grid-wise NO_2 Emission Load (kg/d) in Delhi: Industrial Sources



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1			**Prah** 1.1		64.681	**60.687**	**SSI**										1
2						**PP**	230.63										2
3							137.59	55.035					**Loni**				3
4		6.6168	11.115	16.344		**85.127**	**33.948**				**ISBT**		2.6046		133.43		4
5						11.676	56.81	31.505						41.964	20.982		5
6			0.7596			91.109	**7.0755**	2.917			128				**AV** 0.5025		6
7			1.8991	5.6972	94.02	**Nar** 65.2					**1562.9**			46.557			7
8				**MP**	114.05						220		14.4				8
9							**DK**										9
10												**AC**					10
11												12.348					11
12												**81.414**	91.09				12
13												42.609	39.55	11.185			13
14														**1012.8**			14
15																	15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

🟩	0-400		🟦	400-800	🟨	800-1200	🟪	1200-1600	🟧	1600-2000	🟥 > 2000

Fig: 3.46 :Grid-wise HC Emission Load (kg/d) in Delhi: Industrial Sources



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1			**Prah** 3.2		175.38	**164.59**	**SSI**										1
2						**PP**	627.18										2
3							373.74	149.5					**Loni**				3
4		17.949	**30.227**	**44.343**		**246.36**	**97.234**				**ISBT**		7.1512		**361.2**		4
5						34.514	153.87	**86.366**						113.94	56.97		5
6			3.1122			**246.98**	**20.912**	8.2			640				**AV** 2.5034		6
7			7.7804	23.341	255.39	**Nar** 52.994					**11935**			126.61			7
8				**MP**	309.55						1100		72				8
9							**DK**										9
10												**AC**					10
11												33.437					11
12												**222.14**	246.62				12
13												**115.35**	**107.17**	30.343			13
14														**5025.5**			14
15																	15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

🟩	0-400		🟦	400-800	🟨	800-1200	🟪	1200-1600	🟧	1600-2000	🟥 > 2000

Fig: 3.47 : Grid-wise CO Emission Load (kg/d) in Delhi: Industrial Sources

3.3.2.3 Data Constraints and Assumptions

- The polluting industries were identified in the 36 industrial estates of Delhi with the help of DPCC records. There are 2266 industries in Delhi, of which 2252 are small scales, 9 are medium scale and 5 are large scale industries. The hot mix plant, stone crushers and other large/medium scale industries are either closed or have shifted outside Delhi.
- The information on fuel viz. coal/coke, light diesel oil (LDO), Low Sulfur Heavy Stock (LSHS), Compressed Natural Gas (CNG) supplied to these industries was obtained from power plants, DPCC, Individual industries, project profiles of SSI (approx.) as well as from the supply data available with the oil companies viz., IOCL, BPCL and IBP for the financial year 1999-2000, 2000-2001 & 2001-2002. This along with fuel consumption in Delhi as given in Delhi stat.com site for the year 1995-2002, has been considered
- A wide variation is seen in the data on fuel supplied by the refineries to the industries and the data obtained from the consent forms of DPCC, and individual industries on fuel consumption. It indicates the existence of some other sources of fuel supply and consumption whose details are not easily traceable.

3.3.3 City Level Emission Inventory: Vehicular Sources

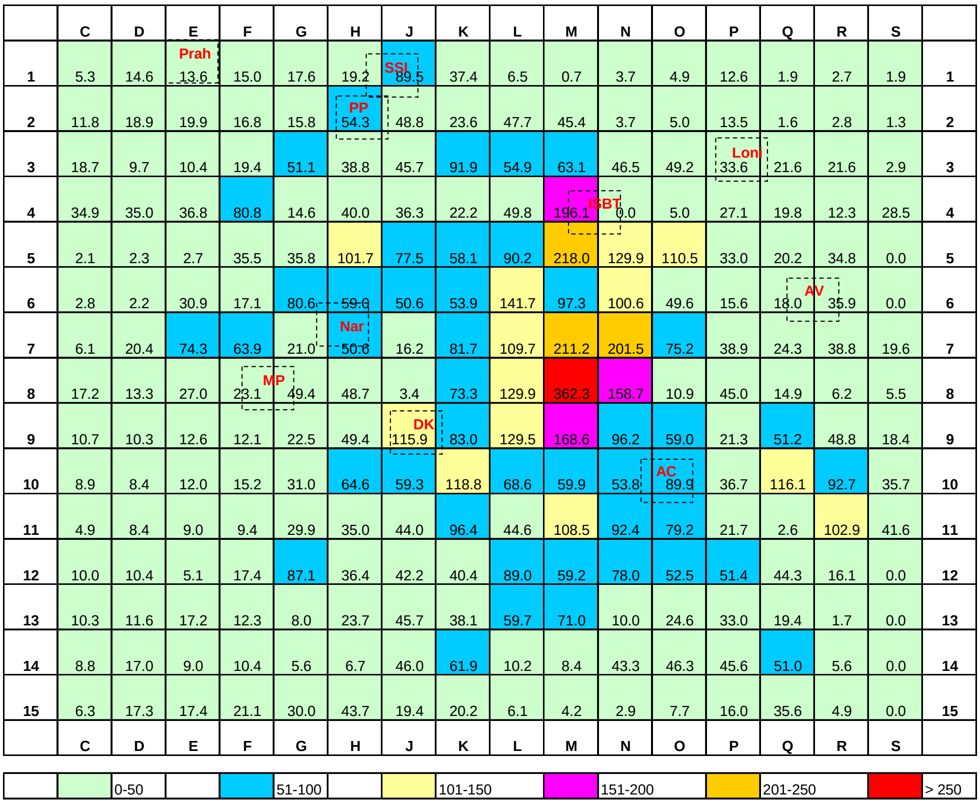
3.3.3.1 Approach and Methodology

In order to estimate emission load from vehicular sources and re-suspended road dust emissions, the following approach has been adopted:

- The vehicular emission load (in terms of PM, CO, HC, NOx and SO_2) estimated for 10 study zones (2 km x 2 km) has been extrapolated for the whole of Delhi city.
- The Eicher City Map of Delhi with 2 km x 2 km grid size has been considered and the same grid configuration has been used.
- Length of arterial, main and feeder roads have been calculated from the map in each 2 km x 2 km grid and emission load (for different pollutants) on these types of roads in each study zone has been estimated per unit road length (gram pollutant/ meter road length).
- As per the map, the total length of arterial/ring roads/NHs is found to be 472 km, main roads (next category roads to arterial roads) 355 km and main feeder roads – 2002 km. Traffic on minor roads/street roads is considered to travel a distance of 100-200 m and it joins any other category of road, hence these types of roads are not considered in the emission load calculations

Grid-wise emission loads for different pollutants is given in **Annexure III.** Total daily vehicular emission load in Delhi for different pollutants is estimated as: 9.75 MT of PM, 217.8 MT of CO, 66.7 MT of HC, 84.2 MT of NOx and 0.72 MT of SO_2. Daily re-suspended road dust emissions in terms of PM10 and PM2.5 is estimated to be 77.3 MT and 5.7 MT.

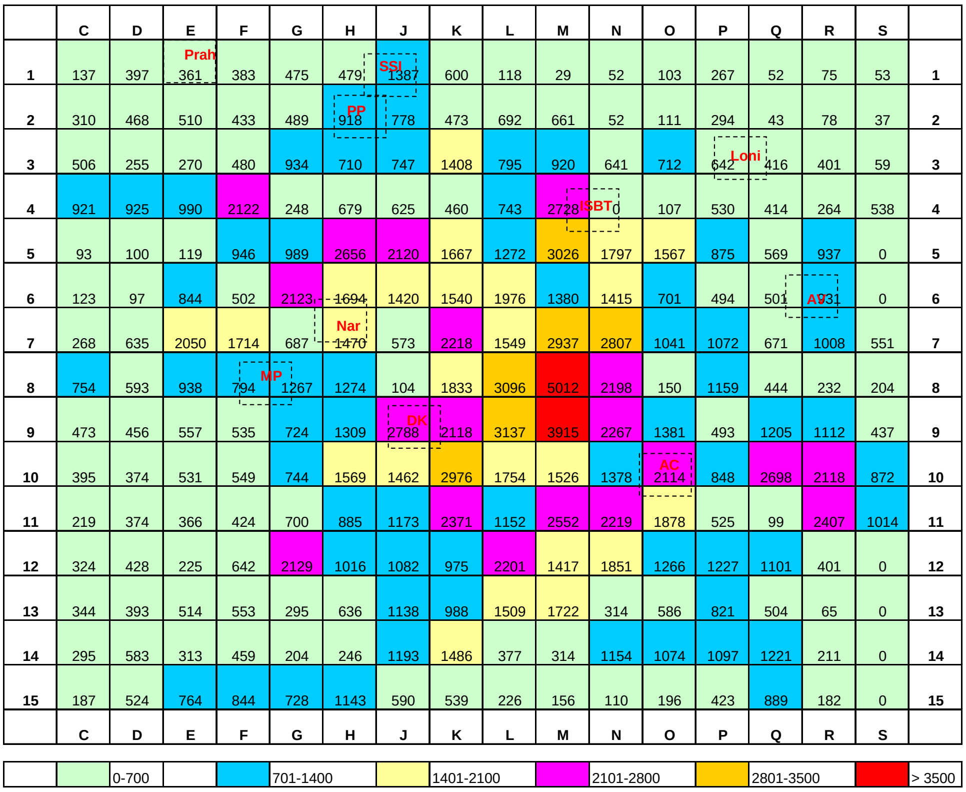
Grid-wise emission loads from vehicles for PM, CO, HC, NOx and SO_2 are presented in **Figs. 3.48** to **3.52**. Grid-wise road dust emission loads for PM10 and PM2.5 are presented in **Figs. 3.53** to **3.54** respectively.



	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1	5.3	14.6	13.6	15.0	17.6	19.2	89.5	37.4	6.5	0.7	3.7	4.9	12.6	1.9	2.7	1.9	1
2	11.8	18.9	19.9	16.8	15.8	54.3	48.8	23.6	47.7	45.4	3.7	5.0	13.5	1.6	2.8	1.3	2
3	18.7	9.7	10.4	19.4	51.1	38.8	45.7	91.9	54.9	63.1	46.5	49.2	33.6	21.6	21.6	2.9	3
4	34.9	35.0	36.8	80.8	14.6	40.0	36.3	22.2	49.8	196.1	0.0	5.0	27.1	19.8	12.3	28.5	4
5	2.1	2.3	2.7	35.5	35.8	101.7	77.5	58.1	90.2	218.0	129.9	110.5	33.0	20.2	34.8	0.0	5
6	2.8	2.2	30.9	17.1	80.6	59.0	50.6	53.9	141.7	97.3	100.6	49.6	15.6	18.0	35.9	0.0	6
7	6.1	20.4	74.3	63.9	21.0	50.6	16.2	81.7	109.7	211.2	201.5	75.2	38.9	24.3	38.8	19.6	7
8	17.2	13.3	27.0	23.1	49.4	48.7	3.4	73.3	129.9	362.3	158.7	10.9	45.0	14.9	6.2	5.5	8
9	10.7	10.3	12.6	12.1	22.5	49.4	115.9	83.0	129.5	168.6	96.2	59.0	21.3	51.2	48.8	18.4	9
10	8.9	8.4	12.0	15.2	31.0	64.6	59.3	118.8	68.6	59.9	53.8	89.9	36.7	116.1	92.7	35.7	10
11	4.9	8.4	9.0	9.4	29.9	35.0	44.0	96.4	44.6	108.5	92.4	79.2	21.7	2.6	102.9	41.6	11
12	10.0	10.4	5.1	17.4	87.1	36.4	42.2	40.4	89.0	59.2	78.0	52.5	51.4	44.3	16.1	0.0	12
13	10.3	11.6	17.2	12.3	8.0	23.7	45.7	38.1	59.7	71.0	10.0	24.6	33.0	19.4	1.7	0.0	13
14	8.8	17.0	9.0	10.4	5.6	6.7	46.0	61.9	10.2	8.4	43.3	46.3	45.6	51.0	5.6	0.0	14
15	6.3	17.3	17.4	21.1	30.0	43.7	19.4	20.2	6.1	4.2	2.9	7.7	16.0	35.6	4.9	0.0	15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

🟩	0-50	🟦	51-100	🟨	101-150	🟪	151-200	🟧	201-250	🟥	> 250

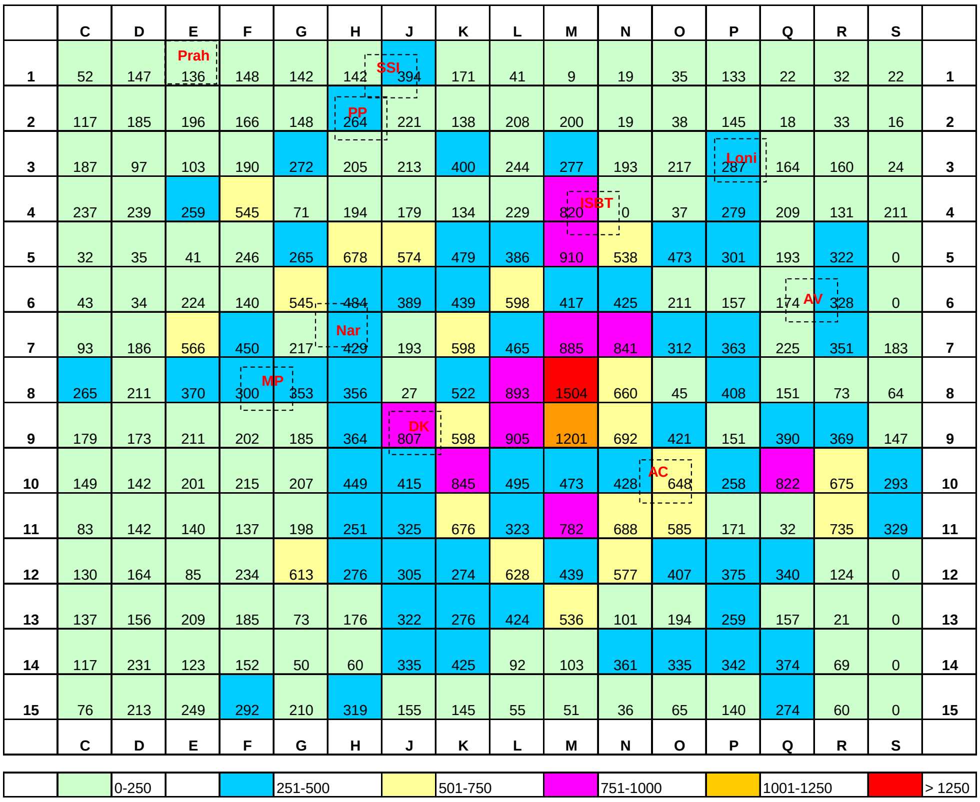
Fig. 3.48: Grid-wise PM Emission Load (kg/d) in Delhi: Vehicular Sources



	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1	137	397	361	383	475	479	1387	600	118	29	52	103	267	52	75	53	1
2	310	468	510	433	489	918	778	473	692	661	52	111	294	43	78	37	2
3	506	255	270	480	934	710	747	1408	795	920	641	712	642	416	401	59	3
4	921	925	990	2122	248	679	625	460	743	2728	0	107	530	414	264	538	4
5	93	100	119	946	989	2656	2120	1667	1272	3026	1797	1567	875	569	937	0	5
6	123	97	844	502	2123	1694	1420	1540	1976	1380	1415	701	494	501	931	0	6
7	268	635	2050	1714	687	1470	573	2218	1549	2937	2807	1041	1072	671	1008	551	7
8	754	593	938	794	1267	1274	104	1833	3096	5012	2198	150	1159	444	232	204	8
9	473	456	557	535	724	1309	2788	2118	3137	3915	2267	1381	493	1205	1112	437	9
10	395	374	531	549	744	1569	1462	2976	1754	1526	1378	2114	848	2698	2118	872	10
11	219	374	366	424	700	885	1173	2371	1152	2552	2219	1878	525	99	2407	1014	11
12	324	428	225	642	2129	1016	1082	975	2201	1417	1851	1266	1227	1101	401	0	12
13	344	393	514	553	295	636	1138	988	1509	1722	314	586	821	504	65	0	13
14	295	583	313	459	204	246	1193	1486	377	314	1154	1074	1097	1221	211	0	14
15	187	524	764	844	728	1143	590	539	226	156	110	196	423	889	182	0	15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

🟩	0-700	🟦	701-1400	🟨	1401-2100	🟪	2101-2800	🟧	2801-3500	🟥	> 3500

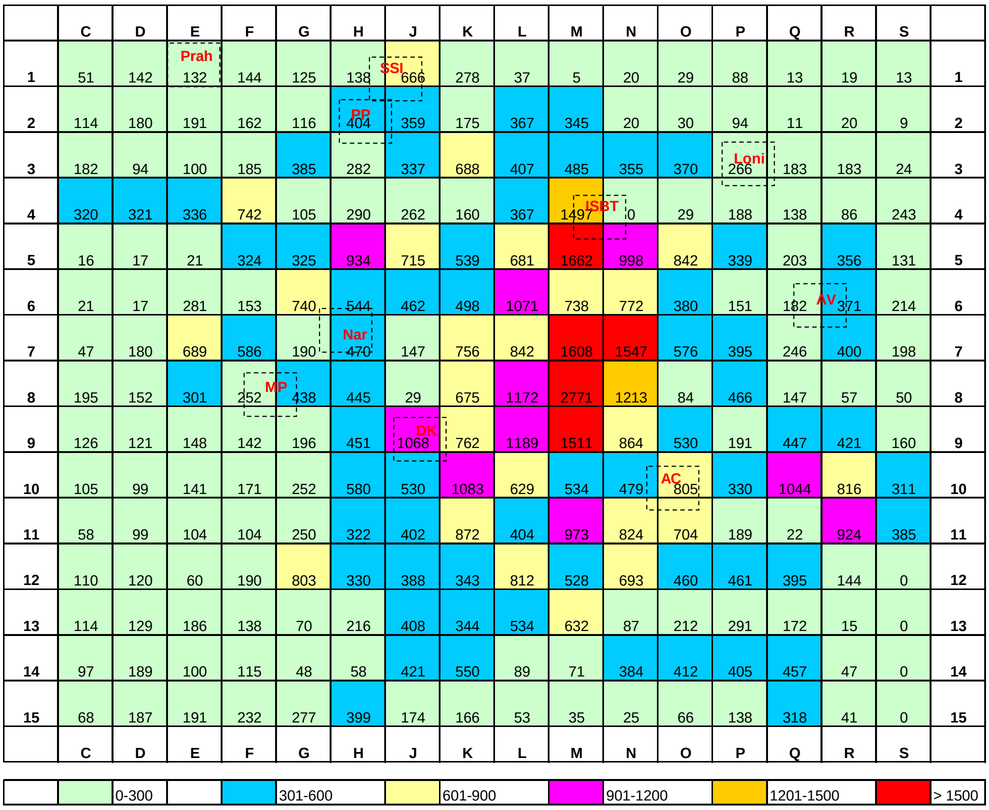
Fig. 3.49: Grid-wise CO Emission Load (kg/d) in Delhi: Vehicular Sources



	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1	52	147	136	148	142	142	394	171	41	9	19	35	133	22	32	22	1
2	117	185	196	166	148	264	221	138	208	200	19	38	145	18	33	16	2
3	187	97	103	190	272	205	213	400	244	277	193	217	287	164	160	24	3
4	237	239	259	545	71	194	179	134	229	820	0	37	279	209	131	211	4
5	32	35	41	246	265	678	574	479	386	910	538	473	301	193	322	0	5
6	43	34	224	140	545	484	389	439	598	417	425	211	157	174	328	0	6
7	93	186	566	450	217	429	193	598	465	885	841	312	363	225	351	183	7
8	265	211	370	300	353	356	27	522	893	1504	660	45	408	151	73	64	8
9	179	173	211	202	185	364	807	598	905	1201	692	421	151	390	369	147	9
10	149	142	201	215	207	449	415	845	495	473	428	648	258	822	675	293	10
11	83	142	140	137	198	251	325	676	323	782	688	585	171	32	735	329	11
12	130	164	85	234	613	276	305	274	628	439	577	407	375	340	124	0	12
13	137	156	209	185	73	176	322	276	424	536	101	194	259	157	21	0	13
14	117	231	123	152	50	60	335	425	92	103	361	335	342	374	69	0	14
15	76	213	249	292	210	319	155	145	55	51	36	65	140	274	60	0	15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

🟩	0-250	🟦	251-500	🟨	501-750	🟪	751-1000	🟧	1001-1250	🟥	> 1250

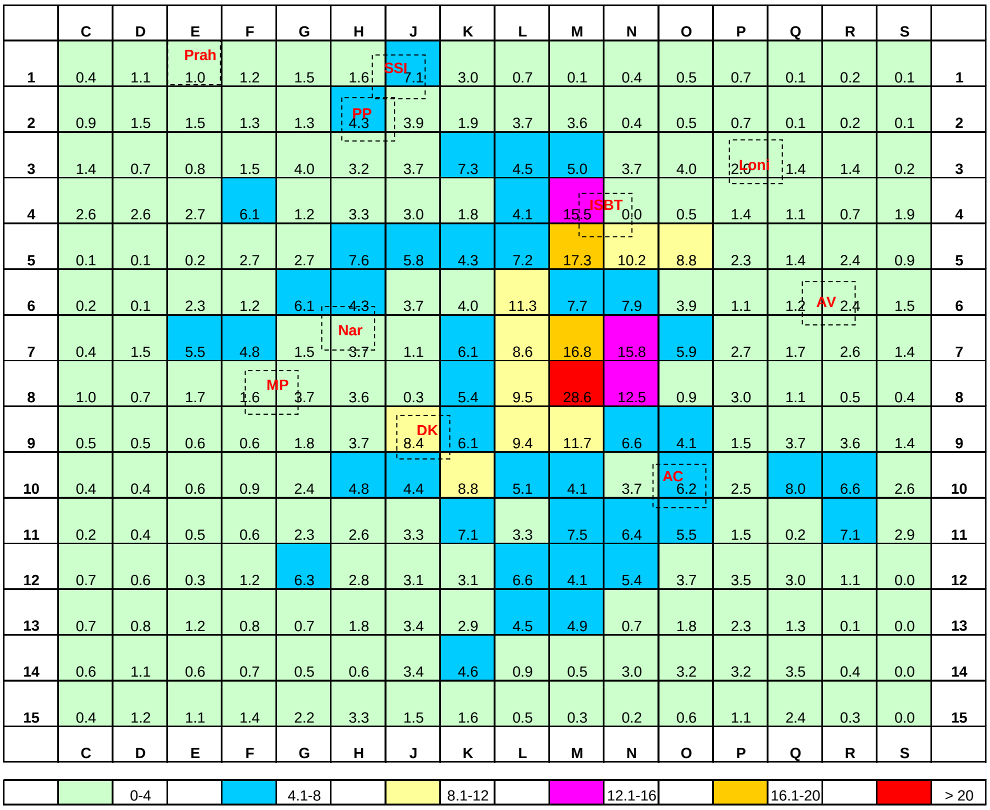
Fig. 3.50: Grid-wise HC Emission Load (kg/d) in Delhi: Vehicular Sources



	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1	51	142	132	144	125	138	666	278	37	5	20	29	88	13	19	13	1
2	114	180	191	162	116	404	359	175	367	345	20	30	94	11	20	9	2
3	182	94	100	185	385	282	337	688	407	485	355	370	266	183	183	24	3
4	320	321	336	742	105	290	262	160	367	1497	0	29	188	138	86	243	4
5	16	17	21	324	325	934	715	539	681	1662	998	842	339	203	356	131	5
6	21	17	281	153	740	544	462	498	1071	738	772	380	151	182	371	214	6
7	47	180	689	586	190	470	147	756	842	1608	1547	576	395	246	400	198	7
8	195	152	301	252	438	445	29	675	1172	2771	1213	84	466	147	57	50	8
9	126	121	148	142	196	451	1068	762	1189	1511	864	530	191	447	421	160	9
10	105	99	141	171	252	580	530	1083	629	534	479	805	330	1044	816	311	10
11	58	99	104	104	250	322	402	872	404	973	824	704	189	22	924	385	11
12	110	120	60	190	803	330	388	343	812	528	693	460	461	395	144	0	12
13	114	129	186	138	70	216	408	344	534	632	87	212	291	172	15	0	13
14	97	189	100	115	48	58	421	550	89	71	384	412	405	457	47	0	14
15	68	187	191	232	277	399	174	166	53	35	25	66	138	318	41	0	15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

🟩	0-300	🟦	301-600	🟨	601-900	🟪	901-1200	🟧	1201-1500	🟥	> 1500

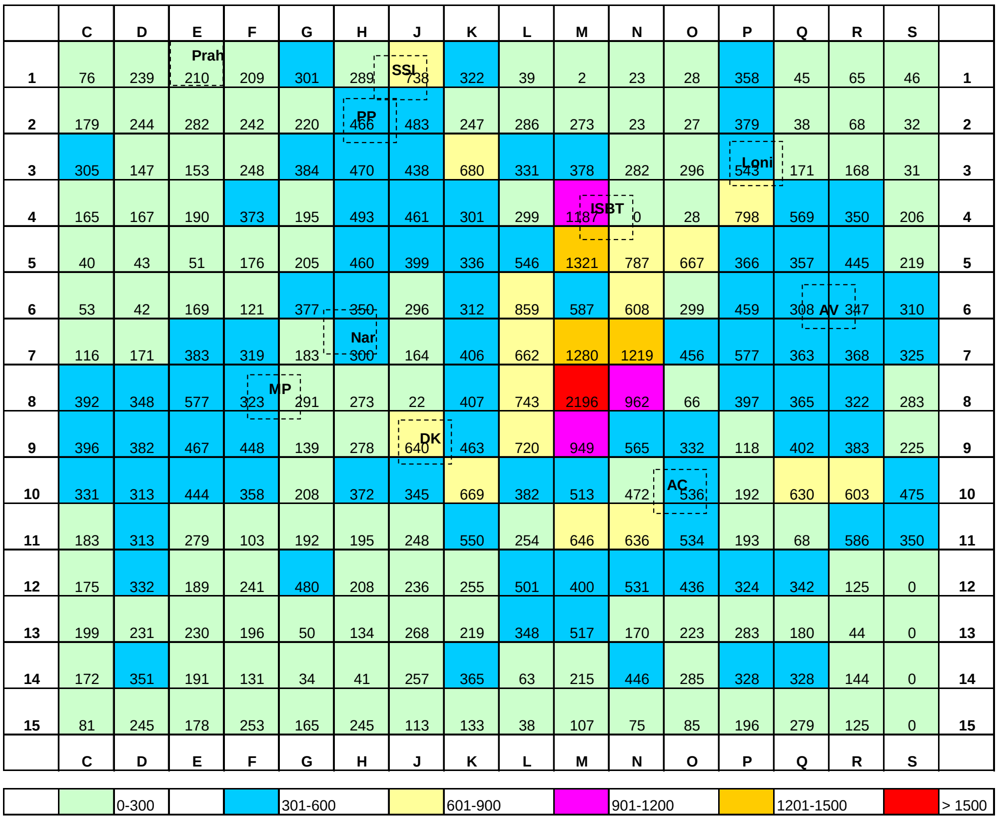
Fig. 3.51: Grid-wise NOx Emission Load (kg/d) in Delhi: Vehicular Sources



	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1	0.4	1.1	1.0	1.2	1.5	1.6	7.1	3.0	0.7	0.1	0.4	0.5	0.7	0.1	0.2	0.1	1
2	0.9	1.5	1.5	1.3	1.3	4.3	3.9	1.9	3.7	3.6	0.4	0.5	0.7	0.1	0.2	0.1	2
3	1.4	0.7	0.8	1.5	4.0	3.2	3.7	7.3	4.5	5.0	3.7	4.0	2.0	1.4	1.4	0.2	3
4	2.6	2.6	2.7	6.1	1.2	3.3	3.0	1.8	4.1	15.5	0.0	0.5	1.4	1.1	0.7	1.9	4
5	0.1	0.1	0.2	2.7	2.7	7.6	5.8	4.3	7.2	17.3	10.2	8.8	2.3	1.4	2.4	0.9	5
6	0.2	0.1	2.3	1.2	6.1	4.3	3.7	4.0	11.3	7.7	7.9	3.9	1.1	1.2	2.4	1.5	6
7	0.4	1.5	5.5	4.8	1.5	3.7	1.1	6.1	8.6	16.8	15.8	5.9	2.7	1.7	2.6	1.4	7
8	1.0	0.7	1.7	1.6	3.7	3.6	0.3	5.4	9.5	28.6	12.5	0.9	3.0	1.1	0.5	0.4	8
9	0.5	0.5	0.6	0.6	1.8	3.7	8.4	6.1	9.4	11.7	6.6	4.1	1.5	3.7	3.6	1.4	9
10	0.4	0.4	0.6	0.9	2.4	4.8	4.4	8.8	5.1	4.1	3.7	6.2	2.5	8.0	6.6	2.6	10
11	0.2	0.4	0.5	0.6	2.3	2.6	3.3	7.1	3.3	7.5	6.4	5.5	1.5	0.2	7.1	2.9	11
12	0.7	0.6	0.3	1.2	6.3	2.8	3.1	3.1	6.6	4.1	5.4	3.7	3.5	3.0	1.1	0.0	12
13	0.7	0.8	1.2	0.8	0.7	1.8	3.4	2.9	4.5	4.9	0.7	1.8	2.3	1.3	0.1	0.0	13
14	0.6	1.1	0.6	0.7	0.5	0.6	3.4	4.6	0.9	0.5	3.0	3.2	3.2	3.5	0.4	0.0	14
15	0.4	1.2	1.1	1.4	2.2	3.3	1.5	1.6	0.5	0.3	0.2	0.6	1.1	2.4	0.3	0.0	15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

	🟩	0-4		🟦	4.1-8		🟨	8.1-12		🟪	12.1-16		🟧	16.1-20	🟥	> 20

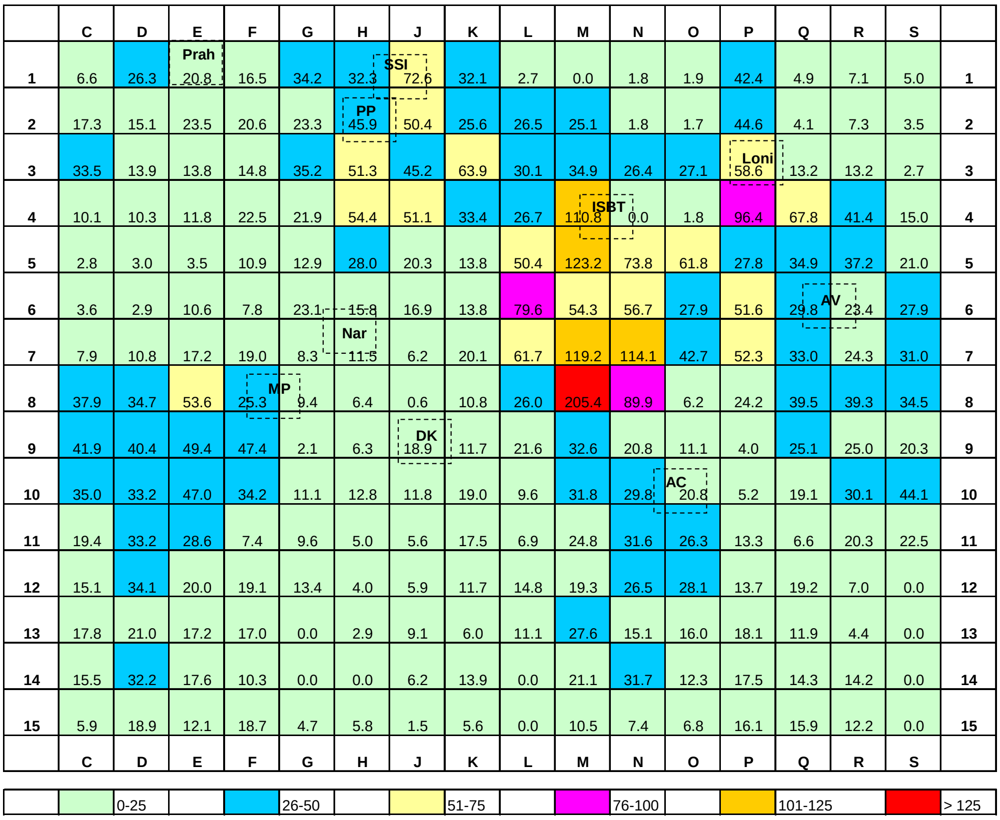
Fig. 3.52: Grid-wise SO_2 Emission Load (kg/d) in Delhi: Vehicular Sources



	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1	76	239	210	209	301	289	738	322	39	2	23	28	358	45	65	46	1
2	179	244	282	242	220	466	483	247	286	273	23	27	379	38	68	32	2
3	305	147	153	248	384	470	438	680	331	378	282	296	543	171	168	31	3
4	165	167	190	373	195	493	461	301	299	1187	0	28	798	569	350	206	4
5	40	43	51	176	205	460	399	336	546	1321	787	667	366	357	445	219	5
6	53	42	169	121	377	350	296	312	859	587	608	299	459	308	347	310	6
7	116	171	383	319	183	300	164	406	662	1280	1219	456	577	363	368	325	7
8	392	348	577	323	291	273	22	407	743	2196	962	66	397	365	322	283	8
9	396	382	467	448	139	278	640	463	720	949	565	332	118	402	383	225	9
10	331	313	444	358	208	372	345	669	382	513	472	536	192	630	603	475	10
11	183	313	279	103	192	195	248	550	254	646	636	534	193	68	586	350	11
12	175	332	189	241	480	208	236	255	501	400	531	436	324	342	125	0	12
13	199	231	230	196	50	134	268	219	348	517	170	223	283	180	44	0	13
14	172	351	191	131	34	41	257	365	63	215	446	285	328	328	144	0	14
15	81	245	178	253	165	245	113	133	38	107	75	85	196	279	125	0	15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

	🟩	0-300		🟦	301-600		🟨	601-900		🟪	901-1200		🟧	1201-1500	🟥	> 1500

Fig. 3.53: Grid-wise Road Dust PM10 Emission Load (kg/d) in Delhi



	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1	6.6	26.3	Prah 20.8	16.5	34.2	32.3	SSI 72.6	32.1	2.7	0.0	1.8	1.9	42.4	4.9	7.1	5.0	1
2	17.3	15.1	23.5	20.6	23.3	PP 45.9	50.4	25.6	26.5	25.1	1.8	1.7	44.6	4.1	7.3	3.5	2
3	33.5	13.9	13.8	14.8	35.2	51.3	45.2	63.9	30.1	34.9	26.4	27.1	Loni 58.6	13.2	13.2	2.7	3
4	10.1	10.3	11.8	22.5	21.9	54.4	51.1	33.4	26.7	ISBT 110.8	0.0	1.8	96.4	67.8	41.4	15.0	4
5	2.8	3.0	3.5	10.9	12.9	28.0	20.3	13.8	50.4	123.2	73.8	61.8	27.8	34.9	37.2	21.0	5
6	3.6	2.9	10.6	7.8	23.1	15.8	16.9	13.8	79.6	54.3	56.7	27.9	51.6	AV 29.8	23.4	27.9	6
7	7.9	10.8	17.2	19.0	8.3	Nar 11.5	6.2	20.1	61.7	119.2	114.1	42.7	52.3	33.0	24.3	31.0	7
8	37.9	34.7	53.6	MP 25.3	9.4	6.4	0.6	10.8	26.0	205.4	89.9	6.2	24.2	39.5	39.3	34.5	8
9	41.9	40.4	49.4	47.4	2.1	6.3	DK 18.9	11.7	21.6	32.6	20.8	11.1	4.0	25.1	25.0	20.3	9
10	35.0	33.2	47.0	34.2	11.1	12.8	11.8	19.0	9.6	31.8	29.8	AC 20.8	5.2	19.1	30.1	44.1	10
11	19.4	33.2	28.6	7.4	9.6	5.0	5.6	17.5	6.9	24.8	31.6	26.3	13.3	6.6	20.3	22.5	11
12	15.1	34.1	20.0	19.1	13.4	4.0	5.9	11.7	14.8	19.3	26.5	28.1	13.7	19.2	7.0	0.0	12
13	17.8	21.0	17.2	17.0	0.0	2.9	9.1	6.0	11.1	27.6	15.1	16.0	18.1	11.9	4.4	0.0	13
14	15.5	32.2	17.6	10.3	0.0	0.0	6.2	13.9	0.0	21.1	31.7	12.3	17.5	14.3	14.2	0.0	14
15	5.9	18.9	12.1	18.7	4.7	5.8	1.5	5.6	0.0	10.5	7.4	6.8	16.1	15.9	12.2	0.0	15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

🟩	0-25	🟦	26-50	🟨	51-75	🟪	76-100	🟧	101-125	🟥	> 125

Fig. 3.54: Grid-wise Road Dust PM2.5 Emission Load (kg/d) in Delhi

3.3.3.2 Summary of Emission Loads

Based on the emission inventory of vehicular sources with respect to different pollutants and road dust generation, top ten grids with very high loads in Delhi city have been identified. These are summarized in **Table 3.66**, along with the vehicular emission load, whereas for re-suspended road dust, these are given in **Table 3.67**.

Table 3.66: Top Ten Vehicular Emission Loads and Affected Grids

Rank	Top Ten Pollution Loads, (kg/d)					Grids Having Highest Pollution				
	PM	CO	HC	NOx	SO_2	PM	CO	HC	NOx	SO_2
1	362	5012	1504	2771	28.6	M8	M8	M8	M8	M8
2	218	3915	1201	1662	17.3	M5	M9	M9	M5	M5
3	211	3137	910	1608	16.8	M7	L9	M5	M7	M7
4	201	3096	905	1547	15.8	N7	L8	L9	N7	N7
5	196	3026	893	1511	15.5	M4	M5	L8	M9	M4
6	169	2976	885	1497	12.5	M9	K10	M7	M4	N8
7	159	2937	845	1213	11.7	N8	M7	K10	N8	M9
8	142	2807	841	1189	11.3	L6	N7	N7	L9	L6
9	130	2788	822	1172	10.2	N5	J9	Q10	L8	N5
10	130	2728	820	1083	9.5	L8	M4	M4	K10	L8

Table 3.67: Top Ten Re-suspended Road Dust Loads and Affected Grids

Rank	Dust Loads, (kg/d)		Grids with Highest Dust Generation	
	PM10	PM2.5	PM10	PM2.5
1	2195.7	205.4	M8	M8
2	1321.0	123.2	M5	M5
3	1280.0	119.2	M7	M7
4	1218.8	114.1	N7	N7
5	1187.2	110.8	M4	M4
6	961.7	96.4	N8	P4
7	948.6	89.9	M9	N8
8	858.7	79.6	L6	L6
9	798.4	73.8	P4	N5
10	787.1	72.6	N5	J1

Based on the emission inventory, the most affected grids with prominent areas and localities are identified, which can be termed as hotspots. These are summarized in **Table 3.68** and **Fig. 3.55**.

Table 3.68: Identified Hotspots due to Vehicular Pollution and Re-suspended Road Dust Emission Loads

Grid	Affected Prominent Areas/Locality
M8	India Gate, Rajpath, Vigyan Bhawan, Udyog Bhawan
M5	ISBT, Kashmere Gate, Tis Hazari Court, Stephens Hospital
M9	Lodi Garden, Lodi Estate, UNO, India Habitat Centre
M7	Connaught Place, Jantar Mantar, Mandi House Chowk
L9	Race Cource, Hotel Ashok, Hotel Samrat, Delhi Gymkhana Club
L8	Central Secretariat, Sansad Bhawan, Rashtrapati Bhawan
N7	Firoz Shah Kotla, ITO, Mandi House, Maulana Azad Medical College, GB Pant Hospital, LNJP Hospital
M4	Delhi University, Timarpur Chowk, Vidhan Sabha
N8	Supreme Court, Pragati Maidan, WHO, Indraprasth, Delhi High Court
K10	Moti Bagh, Netaji Nagar, R.K. Puram
L6	Karol Bagh, Sadar Bazar, Motia Khan, Jhandewalan
J9	Dhaula Kuan Area
Q10	Toll Plaza, Chilla, Alka Cinema
N5	GPO, Indraprasth University, Nigambodh Ghat
P4	Loni Golchakkar, Durgapuri Chowk, Balbir Nagar, Babarpur
J1	Makraba Chowk (SSI-GTK area), Jahangirpuri, Rajiv Nagar

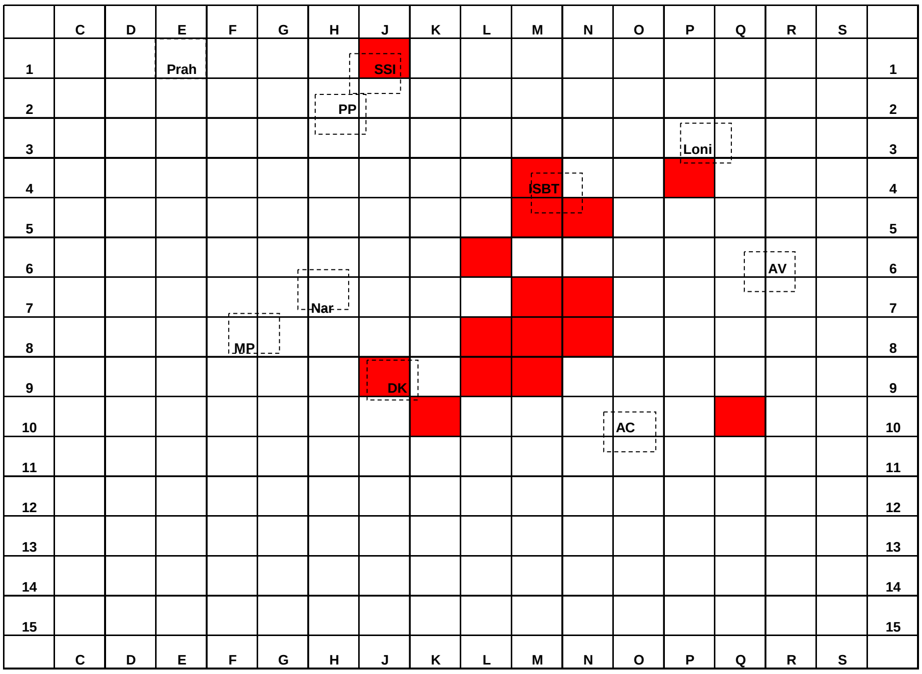


Fig. 3.55 : Identified Hotspots (Highest Polluting Grids)

Following observations emerge :

- The analysis of data and information with regard to area and activities, many places have shown high levels of pollutants.
- Maximum vehicular pollution and road dust loads are estimated to be in the area surrounding India Gate, followed by ISBT, Lodi Road and Connaught Place.
- Maximum vehicular pollution in a 2 km x 2 km grid is estimated to be PM – 362 kg/d, CO – 5012 kg/d, HC – 1504 kg/d, NOx – 2771 kg/d and SO_2 - 28.6 kg/d,
- Maximum road dust re-suspension is estimated to be PM10 – 2195.7 kg/d and PM2.5 – 205.4 kg/d
- Maximum vehicular pollution and road dust generation is estimated in the nearby area of India Gate.

3.4 Summary of Contribution of Various Sources to Total City Emissions

3.4.1 Study Zone-wise

Total emissions from point, area and line sources in study zones around each AQM site are summarized in **Table 3.69.**

Table 3.69 : Emission Load from All the Sources in the Study Zones (Area + Industries + Vehicular + Road dust Re-suspension)

AQM Location	Pollutant Emission Load (kg/day)				
	PM10	SO_2	NOx	CO	HC
Ashram Chowk	859.0	28.6	1017.5	2756.7	905.2
Dhaula Kuan	619.5	10.2	902.7	2285.2	694.8
Mayapuri	405.8	163.8	1752.4	1441.8	626.3
ISBT	1199.2	56.8	1916.0	2442.0	794.7
Loni Road	636.4	8.3	323.3	1438.3	940.9
Anand vihar	527.7	182.7	3036.3	1140.2	498.6
Naraina	900.5	361.9	3435.8	3578.8	1432.0
SSI-GTK	2465.3	442.5	3816.9	3681.8	1089.4
Pitampura	264.7	814.1	548.7	1130.7	547.5
Prahladpur	178.5	20.8	342.0	442.8	195.1

Among all the study zones, highest PM emission load of 2465.3 kg/d is estimated at SSI-GTK area. Highest SO_2 and NOx emission loads are estimated to be 814.1 and 3816.9 kg/d at Pitampura and SSI-GTK respectively. Highest CO and HC emission loads of 3681.8 and 1089.4 kg/d respectively are estimated in SSI-GTK area. Minimum emission load for all pollutants is estimated in Prahladpur area except for NOx which is estimated at Loni Road area. This amply justifies that Prahladpur is the background site.

Among the ten study zones, estimated emission load for PM ranges between 178.5 kg/d (at Prahladpur) and 2465.3 kg/d (at SSI-GTK), SO_2 ranges between 8.3 kg/d (at Loni Road) and 814.1 kg/d (at Pitampura), NOx ranges between 323.3 kg/d (at Loni Road) and 3816.9 kg/d (at SSI-GTK), CO ranges between 442.8 kg/d (at Prahladpur) and 3681.8 kg/d (at SSI-GTK), and HC ranges between 195.1 kg/d (at Prahladpur) and 1432.0 kg/d (at Naraina).

Contribution of emissions under different source categories: industries, domestic, hotels/restaurants, bakeries, crematoria, incinerators, generator sets, construction activities, vehicles and road dust in all the study zones is presented in **Annexure III.**

The emissions inventory shows that at most of the locations, re-suspended dust from roads is dominating the PM emissions. Vehicular sources are dominating at Ashram Chowk, Dhaula Kuan, ISBT, Pitampura, Naraina, and Prahladpur. However, domestic cooking including slums shows dominance in contributing to emissions at Loni Road, Pitampura and Prahladpur. Industries are the most dominating sources at Anand Vihar, SSI-GTK and Naraina, while diesel generators with mainly NOx emissions are contributing to the emissions at ISBT, Pitampura, Naraina and Prahladpur locations.

If seen pollutant wise, at all the sites re-suspended dust from road is the major source of PM emissions contributing to more than 90% of total PM emissions. SO_2 is contributed at Ashram Chowk and Loni Road locations mostly by domestic sources, while at Anand Vihar, SSI-GTK and Naraina, it is dominated by industrial sources. At ISBT and Prahladpur locations, generator sets are the major source of SO_2 emissions. Vehicular source is the major source of NOx emissions at all locations except at Anand Vihar, SSI-GTK and Naraina, which is dominated, by industrial sources. For CO emissions, vehicular source is the major source at all locations, except at Loni Road and SSI-GTK locations where it is dominated by domestic cooking. At Ashram chowk, ISBT, Dhaula Kuan, Mayapuri, Anand Vihar, Naraina and Prahladpur locations, vehicular sources show dominance with respect to HC emissions while at Loni Road, SSI-GTK and Pitampura, HC emissions are dominated by domestic cooking.

3.4.2 Delhi City

Total emissions from point, area and line sources in Delhi are summarized in **Table 3.70**. Estimated emission load from all the sources are PM: 147.2 TPD, SO_2: 267.7 TPD, NOx : 460.1 TPD, CO : 374.1 TPD and HC : 131.4 TPD.

Table 3.70: Summary of Emission Loads from All the Sources in Delhi

Source	Pollutant Emission Rate (kg/day)				
	PM10	**SO_2**	**NOx**	**CO**	**HC**
Industrial	32479	264399	360526	23771	4765
Area	27730	2608	15332	132552	59968
Vehicular	9750	720	84200	217800	66700
Road Dust	77275	-	-	-	-
Total	**147234**	**267727**	**460058**	**374123**	**131433**

Percentage emission contribution has been estimated for major source categories (area, industrial, vehicular and road dust) in terms of different pollutants as presented in **Fig. 3.56**. A combined contribution pie chart is also presented in **Fig. 3.57** for different pollutants.

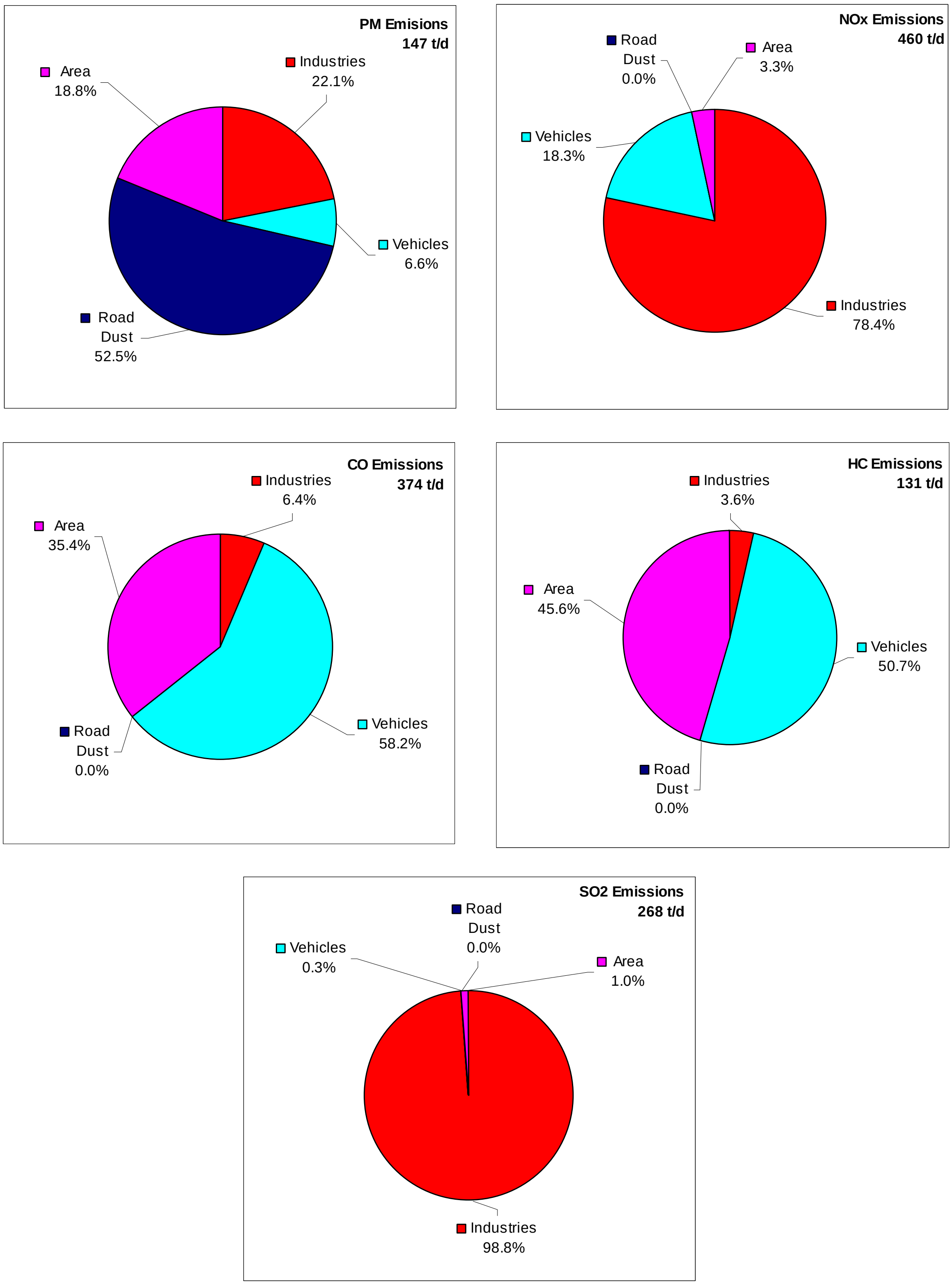
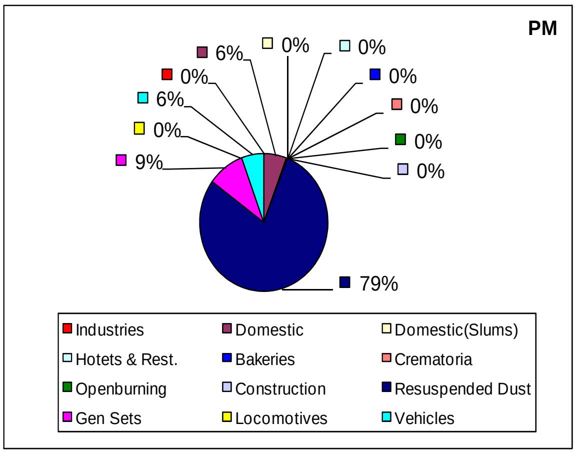
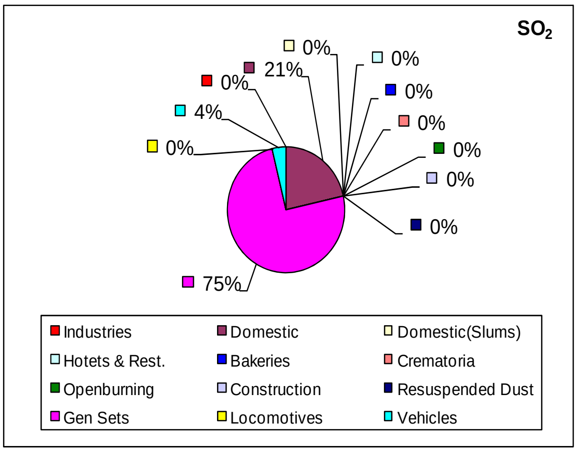
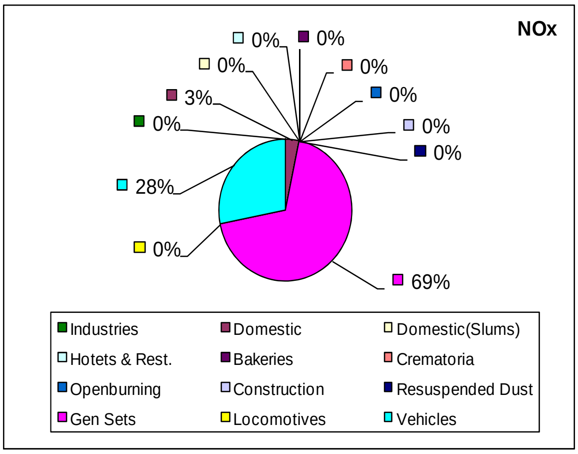
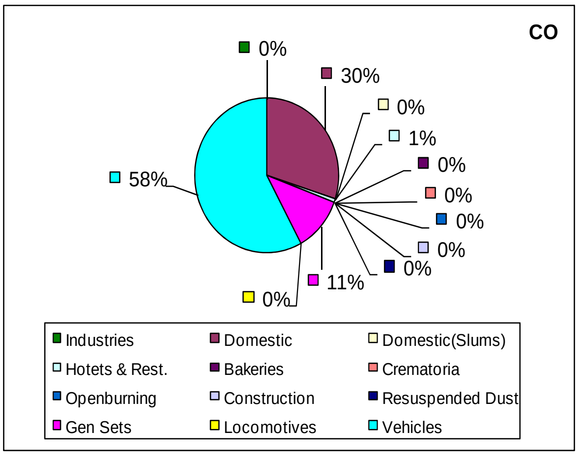


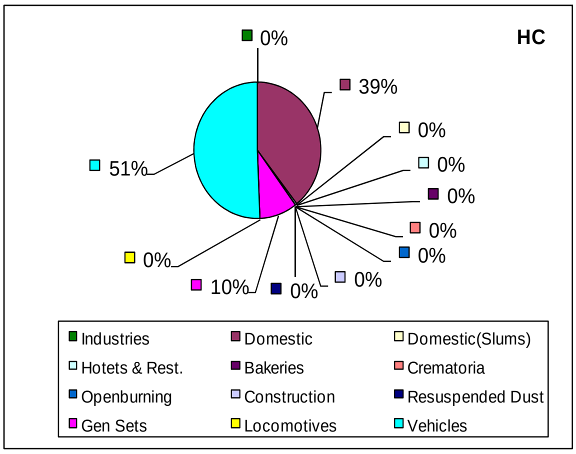
Fig. 3.56: Percent Contribution of Different Source Categories to Total Emission Loads: Delhi











Pollutant		**Major Source**
PM10	:	Re-suspended Dust (79%), Gen Sets (9%), Vehicles (6%), Domestic (6%)
SO$_2$	:	Gen Sets (75%), Domestic (21%), Vehicles (4%)
NOx	:	Gen Sets (69%), Vehicles (28%), Domestic (3%)
CO	:	Vehicles (58%), Domestic (30%), Gen Sets (11%)
HC	:	Vehicles (51%), Domestic (39%), Gen Sets (10%)

Fig. 3.57: Percent Contribution of Different Sources in Total Pollution Load

It is observed that PM10 is dominated by re-suspension of road dust to the extent of 52.5%, whereas vehicles contribute about 6.6% of PM10 emissions. NOx is contributed by the industries (78.4%), mainly power plants, whereas vehicles contribute 18.3% NOx emissions. CO and HC are primarily contributed by vehicular sources to the tune of 58.2% and 50.7% respectively. Area sources, mainly fuel combustion/open burning also contribute significantly to CO (35.4%) and HC (46.6%) emissions. SO_2 to the extent of about 99% is contributed by the industries, mainly power plants and some SSI units.

Emission inventory estimates for ten study zones have been used in dispersion modeling Chapter 5. Whole city inventory has been also used for dispersion modeling with inventory data of 2007 and projected years such as 2012 and 2017.

Chapter 4

Receptor Modeling

4.0 Introduction

Management of air quality requires information about the air pollution levels, possible causes and control measures at source. Ambient air quality can be predicted using mathematical modeling tools (source dispersion model) which require knowledge of physical characteristics of source (emission inventory) and the transport mechanism i.e., meteorology. In an urban setting, both the emission inventory and meteorology cannot be determined precisely due to variable nature of source emission rate, undefined source geometry and non-uniform wind field. In such situations, instead of predicting ambient air pollution levels, the proportionate source contribution to ambient air pollution is determined and then source control measures are implemented. Proportionate source contribution is determined using another modeling tool called receptor modeling. Broadly this tool can be classified into two types, one which uses the exploratory data analysis technique (called factor analysis (FA)) and the other which uses algebraic methodology (also called chemical mass balance (CMB) method). Factor analysis technique uses knowledge of chemical speciation of particulate matter (PM) in the ambient air to determine factor loadings in quantified terms.

4.1 Source Apportionment

The source characteristics are not limited to overall chemical and physical components but to very specific chemical fractions of different metals or ions. Based on the knowledge of signature of sources, they are related to these different factor loadings and their quantified values are considered as the proportionate source contribution to ambient air pollution. In this method of analysis of source contribution, only the chemical speciation of PM in the ambient air is required. On the contrary, CMB approach requires knowledge of chemical speciation of PM in both ambient air and number of possible sources. These sources need not be well defined geometric shapes as in the stacks; instead they may be PM from wind blown dust, re-suspended road dust, waste burning emissions, vehicular emissions etc. Gaseous criteria pollutants like SO_2 and NO_x can not be studied by this methodology (CMB) as once they are mixed in the ambient air, they cannot be separated due to lack of any source specific signature.

In the case of source apportionment study at, Delhi, a survey was carried out to determine possible sources of pollution. Thereafter PM10 and PM2.5 samples were collected from the source and analyzed for various chemical species. Ambient air particulate matter i.e., PM10 and PM2.5 were collected during the three seasons and then analyzed for the same chemical species as those present in source PM. FA tool is applied to PM10 primarily as a screening tool for identifying the possible sources of pollution. These sources were then used in balancing the mass with those of ambient air in CMB methodology.

Ambient air samples (PM10 and PM2.5) were collected from 10 monitoring stations in three seasons and analyzed as per the protocol for CMB. The sites are categorized as given in the **Table 4.1**

Table 4.1: Description of sampling sites

Site description									
Ashram Chowk	Dhaula kuan	Mayapuri	ISBT	Loni Road	Anand Vihar	Naraina	SSI-GTK	Pitampura	Prahladpur
Kerb side	Kerb side	Kerb side	Kerb side	Kerb side	Kerb side	Mixed-use	Industrial	Residential	Background

PM samples from vehicular emissions were collected by Automotive Research Association of India (ARAI), Pune and analyzed for creating the source profile. PM samples from other sources (road dust, waste burning etc.) were collected by Indian Institute of Technology, Bombay (IITB) and analyzed for creating the source profile. Factor Analysis has been perform for all the samples from ten sites with a view to identify major and dominant sources. Later, CMS has been used to assess and apportion masses.

4.1.1 Factor Analysis: Introduction & Methodology

Factor analysis is a statistical technique based on the assumption that the total concentration of each element is made up of the sum of elemental contributions from each of the different pollution source components (Thurston and Spengler, 1985). Factor analysis replaces a large set of inter-correlated variables with a smaller number of independent variables (Factors). The percent variability of each factor represents the total variance explained by that factor. To each species in a factor, factor loadings are associated which are nothing but the correlation of that species with the factor. Each factor indicates the presence of significant source. The identification of the sources associated with the factors is an important task and requires detailed study concerning knowledge of possible sources in the area, strength of the different sources and the type of emissions from the existing sources. The outcome of the factor analysis, therefore requires the knowledge of activities around monitoring sites to infer about the sources of particulate matter.

The factor analysis assumes that the total concentration of each element is made up of the sum of elemental contributions from each of different pollution source components. Hence,

$$Z_{ik} = \sum_{j=1}^{P} W_{ij} P_{jk} \qquad \text{- - - - - (1)}$$

Where P_{jk} is the j^{th} factor's value for each observation k, j=1--p, the number of pollution sources influencing the data, W_{ij} is the coefficient matrix of the components, Z_{ik} is the standardized value of element i for observation k, i=1--n, the total number of elements in the analysis, k=1---m, the total number of observations. Equation (1) can be inverted as,

$$P_{jk} = B_{ji} Z_{ik} \qquad \text{- - - - - (2)}$$

Where $B_{ji}=W_{ji}/\lambda_j$, λ_j is the eigen value associated with P_j. The factor scoring matrix B is derived so that the first factor explains as a large percent of the original variable's total variance as possible. The coefficients of the second factor are chosen so that it explains as large a percent of the remaining variance of the original variables. Factors are uncorrelated with each other. The coefficients B's are mathematically derived from the correlation matrix as,

$$R_{ii} = Z_{ii}\ Z_{ii}^{t} \qquad \text{- - - - - (3)}$$

The diagonalized matrix R gives orthogonal components. The diagonalization finds a matrix Q such that,

$$Q_{ii}^{-1}\ R_{ii}\ Q_{ii} = \lambda_{ii}' \qquad \text{- - - - - (4)}$$

Q contains the corresponding eigen vectors which diagonalize the correlation matrix. These eigen vectors are matrix B which can be used to derive factor score matrix P from Z matrix. In order to reduce the dimensionality in the data set, the new variables i.e. factors must have simple interpretations. But unrotated PCs are often not readily interpretable since they each attempt to explain all remaining variance in the data set. For this reason, a limited number of components are usually subjected to rotation that means, maximization of the variance of the communality normalized loadings. Such rotations tend to drive variable loadings towards either zero or one on a given factor. They preclude the happening of a strong general component by making the variance explained by the individual components more equal, resulting in orthogonal components. Based on the above considerations, the varimax rotated factor analysis technique based on the principal components has been used in the determination of the particulate matter pollution sources. The components or factors rotated had eigen values greater than one after rotation. For factor analysis with varimax rotation, the components with eigen value greater than one are generally retained, as the component with variance of one represents the amount of variance explained by the original variable, so that the component with variance greater than one represents more variance than by the original variable. Factor analysis has been performed using SPSS 7.0. The results of application of factor analysis are discussed in the next section.

Based on the chemical speciation of PM collected at ten air quality monitoring sites, FA was carried out to determine the predominant sources. Since the FA tool has been used by many researchers to arrive at major source categories in the past, its strengths have been used to first establish major source categories. This preliminary information can provide very useful insight into the data. This information, combined with additional site specific knowledge of sources, was used for meaningful interpretation. This is used as a screening method for selecting sources to be considered in CMB. Following **Table 4.2** shows the predominant sources that could be deciphered based on the available information in literature and field observations. The factor loading matrix is given in **Annexure 4.1.1a**.

Table 4.2 : Summary of Factor Analysis Results-PM10 (Identified major factors)

Station	Summer	Post Monsoon	Winter
Ashram Chowk	• Combustion • Resuspended dust • Vehicles	• Combustion • Resuspended dust • Soil dust	• Combustion • Resuspended dust • Soil Dust
Dhaula Kuan	--	• Combustion • Re-suspended dust • Vehicles • Soil dust	• Soil Dust • Combustion • Industries
Mayapuri	• Combustion • Resuspended dust • Industry	• Vehicles • Combustion • Soil dust	--
ISBT	• Vehicles • Soil dust • Industries	--	• Industries • Resuspended dust • Vehicles • Soil dust
Loni Road	• Combustion • Resuspended dust • Vehicles • Soil dust	• Combustion • Soil dust • Smelter	• Combustion • Resuspended dust • Vehicles
Anand Vihar	• Combustion • Resuspended dust • Soil Dust • Vehicles	• Combustion • Resuspended dust • Soil Dust • Smelter	--
Naraina	• Combustion • Resuspended dust • Smelter	• Combustion • Soil dust • Industry • Smelter	• Resuspended dust • Vehicles • Industries • Soil dust
SSI-GTK	• Combustion • Vehicles • Industries • Smelter	• Combustion • Resuspended dust • Secondary aerosol formation	• Soil dust • Combustion • Industries
Pitampura	• Combustion • Vehicles • Resuspended dust	• Combustion • Resuspended dust • Secondary aerosol formation • Vehicles	• Vehicles • Resuspended dust • Soil dust
Prahladpur	• Combustion & Resuspended dust • Soil dust	• Combustion & Resuspended dust • Soil Dust • Vehicles	• Resuspended dust • Vehicles • Secondary aerosol formation • Smelter

***** Data sets not sufficient for analysis

4.1.1. Factor Analysis

Conclusions

Based on the factor analysis, the following conclusions can be drawn:

- Combustion is the most important source contributing to PM10 concentration at all the ten locations during summer and post monsoon.
- Resuspended dust is the other important source of PM10 during summer at kerb side, mixed-use and background stations whereas, at industrial and residential locations, auto exhaust is the second most important source during summer.
- During winter, soil dust or resuspended dust is the most important source at all the locations except at ISBT and Loni Road, where industrial and combustion activities respectively are dominant.
- Secondary aerosol formation is significant only at mixed-use, industrial, residential locations, whereas at kerb side locations, this source is not as significant. This could be due to the fact that formation of secondary aerosol takes longer duration. Some amount of secondary aerosol formation indicated at Pitampura (residential) and Prahladpur (reference) is due to time available for such reactions to take place and also get transported to other places with wind.

4.1.2 Chemical Mass Balance (CMB 8.2) Modeling: Introduction & Methodology

For source apportionment of particulate matter, CMB8.2 software (available via www.epa.gov/scram001/receptor_cmb.htm) has been used. It is window based software that provides much goodness of fit tests to verify the accuracy of the model.

CMB model uses the chemical composition of ambient pollutant samples to estimate the contribution of different source types to the measured pollutant concentrations. The basic principle in chemical mass balance is that composition patterns of emissions from various sources are quite different such that their contributions can be determined by measuring concentrations of many elements collected at a site. The chemical mass balance model requires *a priori* estimates of the number and composition of elements and the knowledge of parameters like number of sources present; the time when analysis was performed; pollutant emitters; variability in emissions composition of each source. The chemical composition of each source-type's emissions (source profile) must also be known to use the model. The CMB model quantifies contributions from chemically distinct source-types rather than contributions from individual emitters. The model cannot separately identify sources, which have similar chemical compositions. The chemical mass balance consists of a least squares solution to a set of linear equations which express each receptor concentration of a chemical species as a linear sum of product of source profile species and source contributions.

The CMB model is derived from physical principles and some of the assumptions include the following:

- The compositions of source emissions are constant over the period of ambient and source sampling
- The chemical species do not react with each other
- All sources with potential for significantly contributing to the receptor have been identified and have had their emissions characterized.
- The number of sources is less than or equal to the number of compounds
- The source profiles are sufficiently different from one another
- Measurement uncertainties are random, uncorrelated and normally distributed

The chemical mass balance consists of a least squares solution to a set of linear equations which express each receptor concentration of a chemical species as a linear sum of product of source profile species and source contributions. The CMB model consists of the following set of equations:

$$C_i = \sum_j m_j x_{ij} \alpha_{ij} \qquad \text{- - - - - (5)}$$

Where C_i = Concentration of species i measured at a receptor site, x_{ij} is the concentration of the i^th^ species from the j^th^ type of source. The term α_{ij} is included as an adjustment for any gain or loss of species i between the source and receptor. The term is assumed to be unity for most chemical species, however for volatile compounds more research is needed to investigate the values of α_{ij} term. The solution of above equation provides the estimate of source strength m_j, that can be obtained by using effective variance least squares method. The equation has a unique solution only when the number of species is equal to or greater than the number of sources. More species reduce the uncertainty of the model. The method minimizes the function

$$\chi^2 = \sum_{i=1}^{n} \frac{\left(C_i - \sum_j m_j x_{ij}\right)^2}{\sigma_{ci}^2 + \sum_j \sigma_{xij}^2 m_j^2} \qquad \text{- - - - - (6)}$$

Where σ_{ci} and σ_{xij} are the uncertainties associated with the measurements.

The normal checks, as specified in the manual by USEPA to accept the model are; t-statistics i.e. source contribution divided by error of source contribution should be greater than 2, χ^2 should be less than 4, R^2 should be greater than 0.8, percentage mass explained should be between 80% and 120%, the ratio of computed and measured concentration of each element (C/M ratio) should be close to 1 and R/U ratio i.e. the ratio of residuals to uncertainty should be less than 2. Although the % mass explained should be in the range of 80-120, a range of 60-120 was considered, as due to variability in the sources and meteorological conditions in Indian scenario, it is not always possible to get >80% mass accounted for. For detailed discussion, CMB 8.2 Users Manual may be referred

As the model requires the source contribution estimates and receptor concentrations in ambient air, significant sources in the area needs to be identified first. It is necessary to make a judicious selection of all major sources in the area for acceptable model predictions.

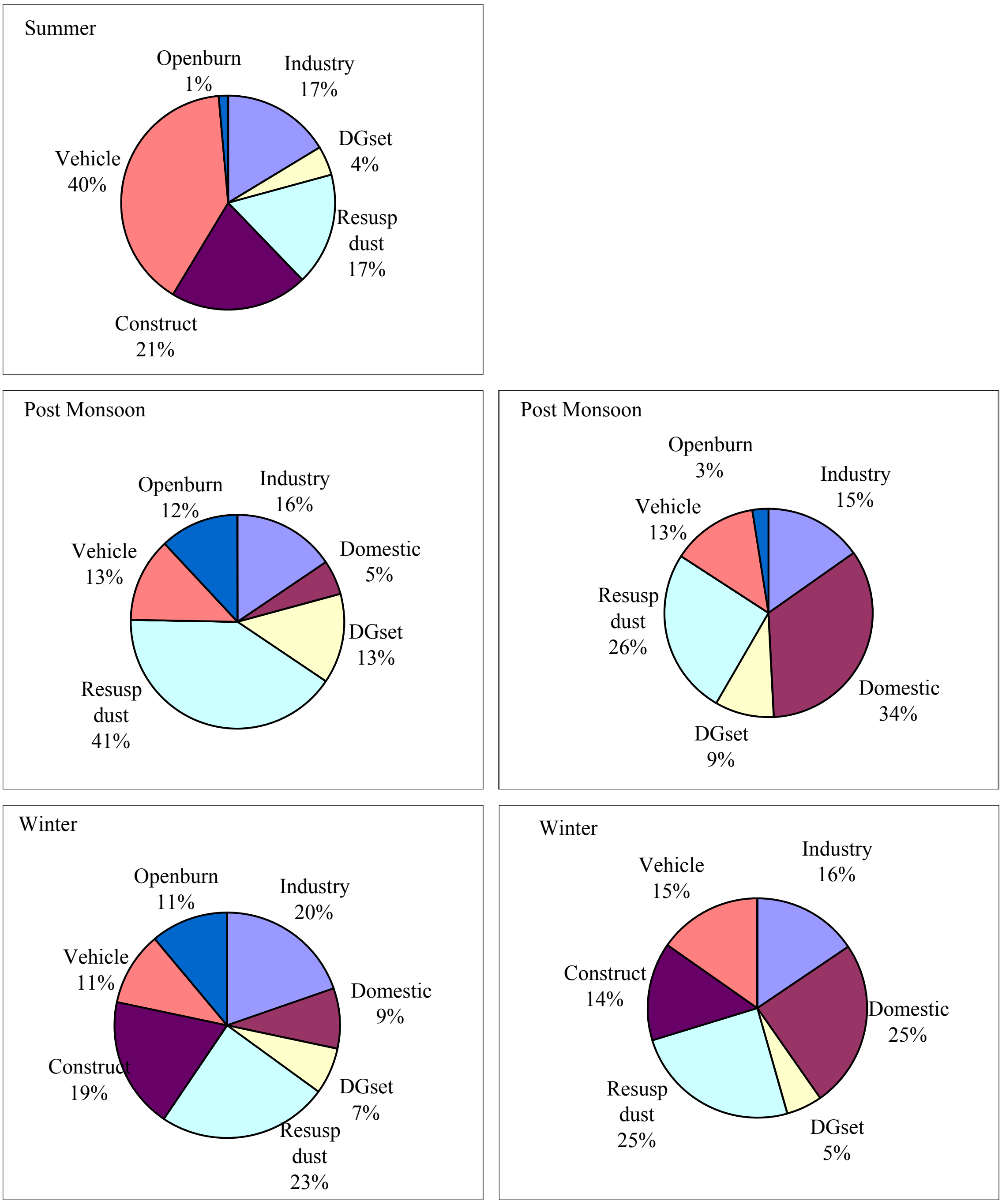
The investigation of sources of particulate matter to be accounted for in CMB model is carried out using emission inventory studies as well as Factor Analysis which provides the initial feedback on presence of dominant sources.. The major air pollution sources in the city are industries, domestic combustion, crematoria, bakeries, construction and vehicular traffic. The respective source profile of each source is taken from IITM and ARAI source profiles database.

4.1.2.1. CMB Application to PM10 source apportionment

Covering as many sources as present in the area, CMB analysis were performed for all the ten air quality monitoring locations on the particulate matter characterization data collected during the three seasons summer, winter and post monsoon. The general category of sources included in the model for all the sites are composites of all the vehicular sources specified by ARAI and Fuel combustion, wood combustion, Chullah, Tandoor, coal combustion power plant, industrial DG set, Kerosene generator (full load), domestic kerosene combustion, soil dust, paved and unpaved road dust, construction, agricultural waste burning, electric arc melting, LPG combustion, metal smelting and solid waste burning by IIT Bombay. The choice of sources however, varies in relation to the activities prevailing in the area and CMB model performance. Similar approach also applies to the selection of species. Efforts were made to include as many species in the model as possible. The choice was, however, restricted based on the model performance.

4.1.2.2 CMB Results

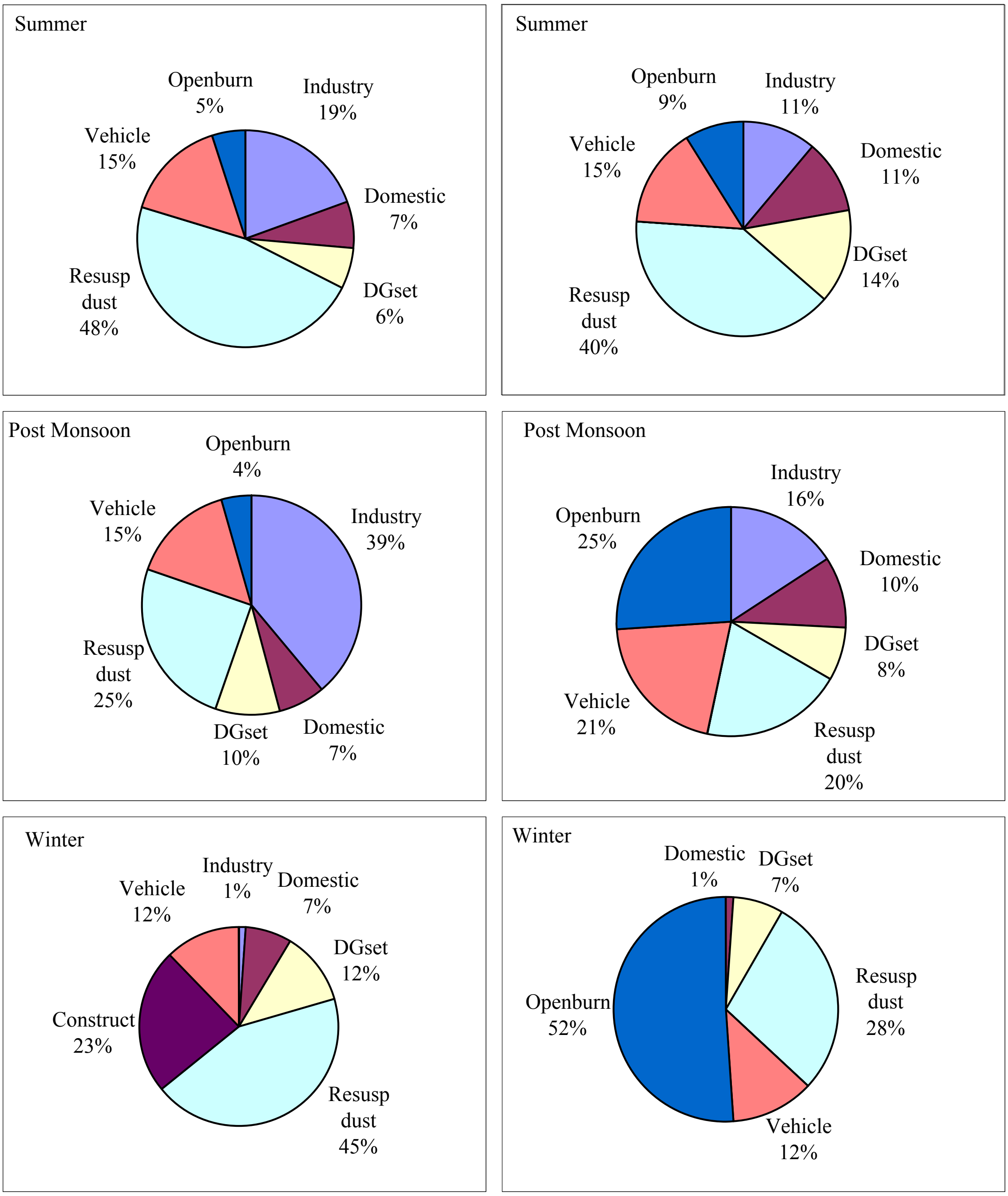
In CMB, an exercise was carried out with the source profile created by ARAI, Pune and IIT, Mumbai. Carbon, ions and metals data were used. Some data on profiles did not match as desired, therefore, the findings were confirmed with molecular markers data. The mass is balanced against a measured value for each species for each season. The results of the CMB application are given in **Figure 4.1 to 4.5**. The average source apportionment results are given in **Table 4.3**. The source categories are combined as per the factor analysis and emission inventory source classification. Model performance of the runs is given in **Annexure 4.1 and 4.2** details the number of days of results based on CMB in different seasons. Figures below show the average values for all valid results for a given season.



Ashram Chowk

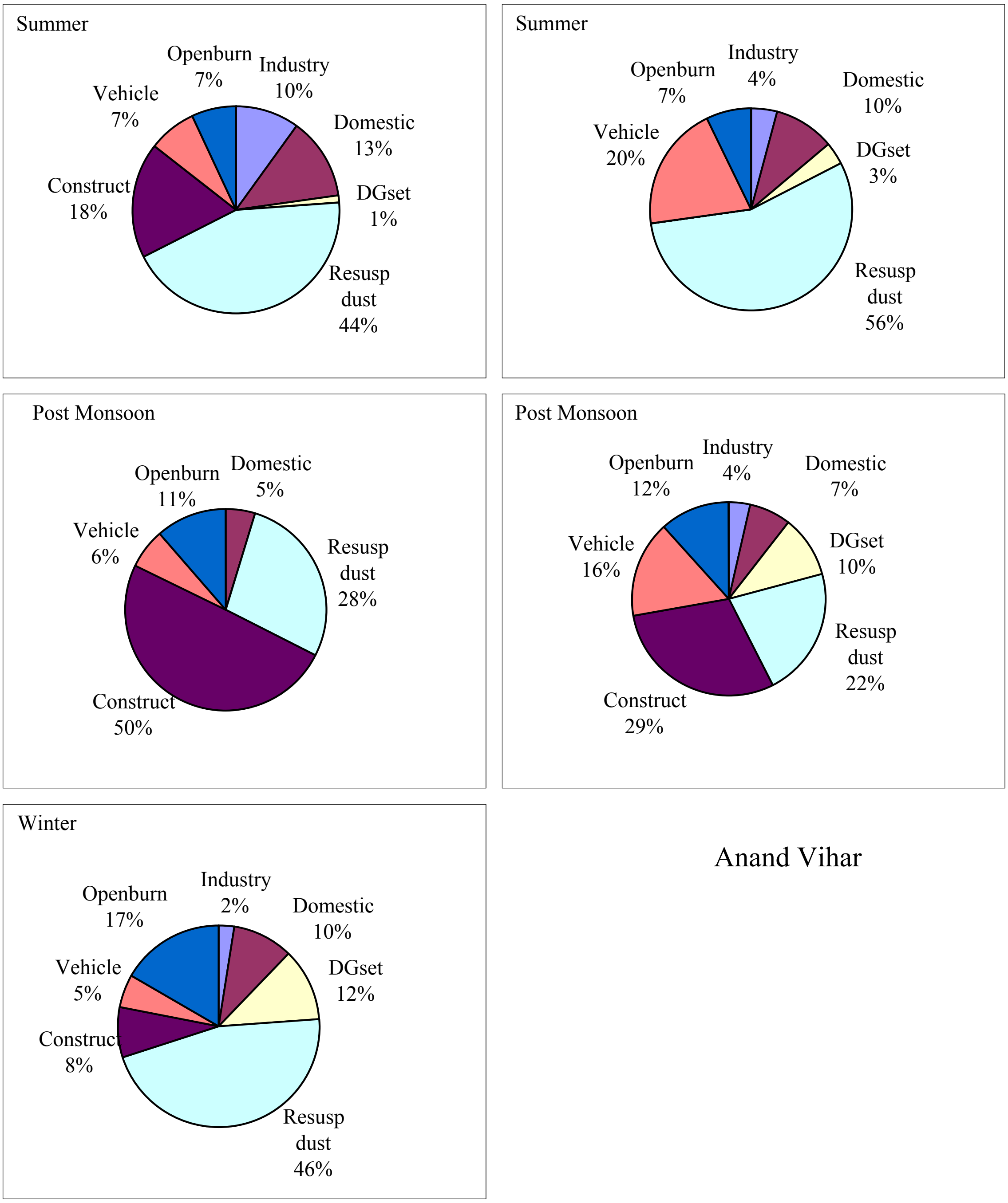
Dhaula kuan

Figure 4.1. Source contribution estimates using CMB model



Mayapuri ISBT

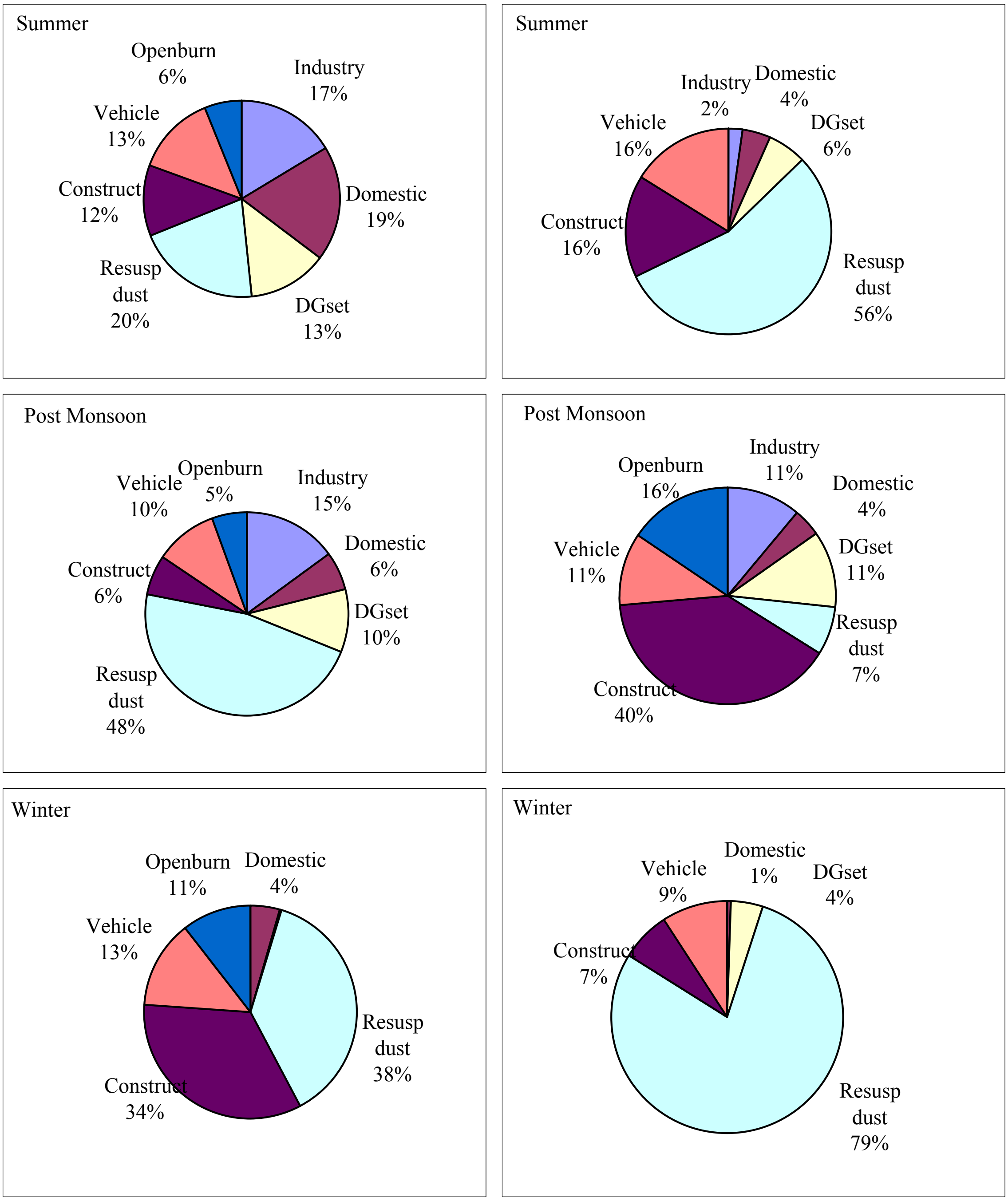
Figure 4.2. Source contribution estimates using CMB model



Anand Vihar

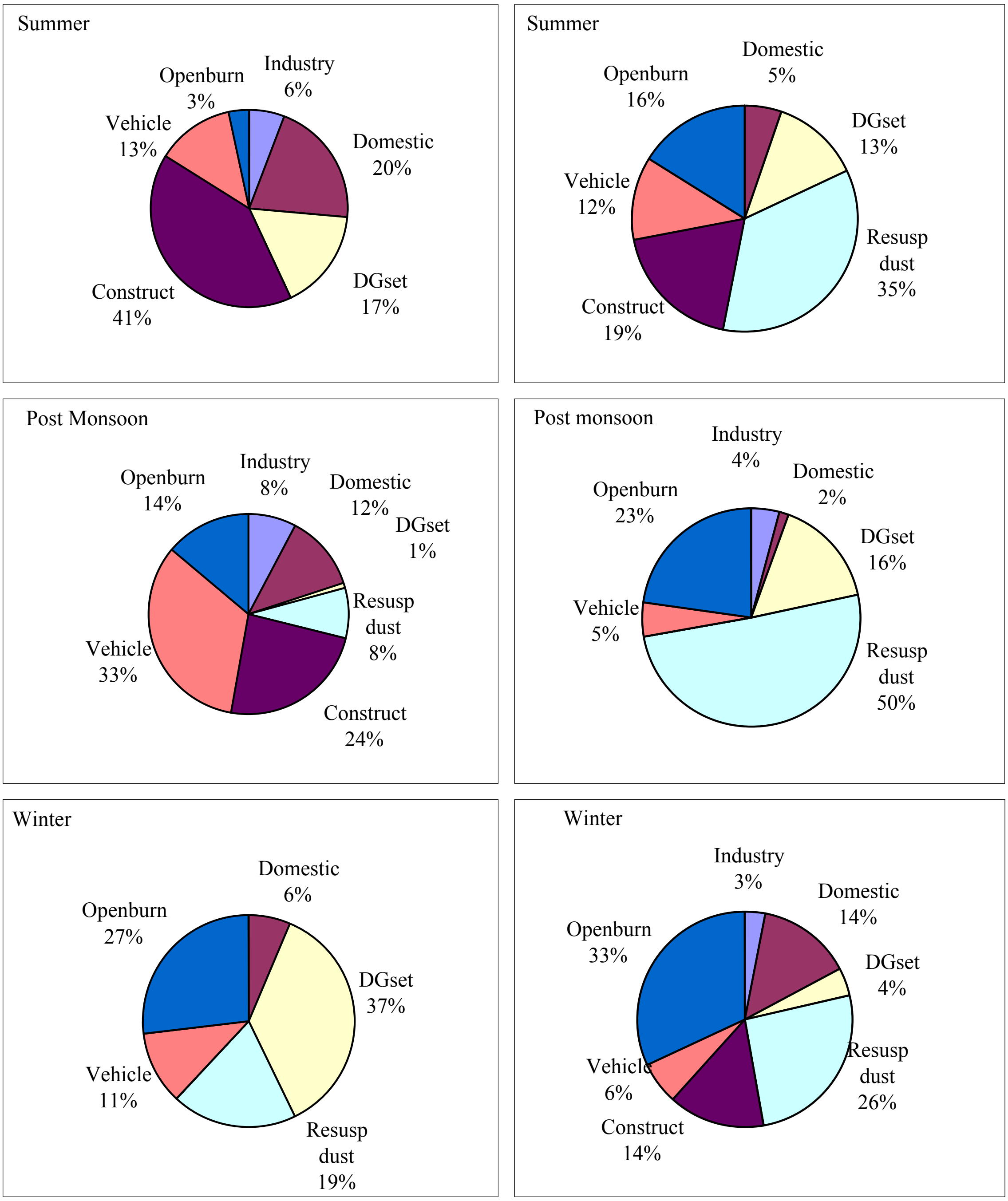
Loni Road

Figure 4.3 Source contribution estimates using CMB model



Naraina SSI-GTK

Figure 4.4 Source contribution estimates using CMB model



Pitampura Prahladpur

Figure 4.5 Source contribution estimates using CMB model

Table 4.3: Summary of CMB Results-PM10 Contribution of Major Sources

Station	Summer	Post monsoon	Winter
Ashram Chowk	▪ Vehicles (40%) ▪ Construction (21%) ▪ Industries (17%) ▪ Resuspended dust (17%)	▪ Resuspended dust (41%) ▪ Vehicles (13%) ▪ DG Set (13%) ▪ Open burning (12%)	▪ Resuspended dust (23%) ▪ Industries (20%) ▪ Construction (19%) ▪ Vehicles (11%) ▪ Open burning (11%)
Dhaula Kuan	--	▪ Domestic (34%) ▪ Resuspended dust (26%) ▪ Industries (15%) ▪ Vehicles (13%) ▪ DG Set (9%)	▪ Domestic (25%) ▪ Resuspended dust (25%) ▪ Industries (16%) ▪ Vehicles (15%) ▪ Construction (14%)
Mayapuri	▪ Resuspended dust (48%) ▪ Industries (19%) ▪ Vehicles (15%)	▪ Industries (39%) ▪ Resuspended dust (25%) ▪ Vehicles (15%) ▪ DG Set (10%)	▪ Resuspended dust (45%) ▪ Construction (23%) ▪ Vehicles (12%) ▪ DG Set (12%)
ISBT	▪ Resuspended dust (40%) ▪ Vehicles (15%) ▪ DG Set (14%) ▪ Industries (11%) ▪ Domestic (11%)	▪ Open burning (25%) ▪ Vehicles (21%) ▪ Resuspended dust (20%) ▪ Industries (16%) ▪ Domestic (10%)	▪ Open burning (52%) ▪ Resuspended dust (28%) ▪ Vehicles (12%) ▪ DG Set (7%)
Loni Road	▪ Resuspended dust (44%) ▪ Construction (18%) ▪ Domestic (13%) ▪ Industries (10%) ▪ Vehicles (7%)	▪ Construction (50%) ▪ Resuspended dust (28%) ▪ Open burning (11%) ▪ Vehicles (6%)	▪ Resuspended dust (46%) ▪ Open burning (17%) ▪ DG Set (12%) ▪ Construction (8%)
Anand Vihar	▪ Resuspended dust (56%) ▪ Vehicles (20%) ▪ Domestic (10%) ▪ Open burning (7%)	▪ Construction (29%) ▪ Resuspended dust (22%) ▪ Vehicles (16%) ▪ Open burning (12%) ▪ DG Set (10%)	--
Naraina	▪ Resuspended dust (20%) ▪ Domestic (19%) ▪ Industries (17%) ▪ Vehicles (13%) ▪ DG Set (13%)	▪ Resuspended dust (48%) ▪ Industries (15%) ▪ Vehicles (10%) ▪ DG Set (10%)	▪ Resuspended dust (38%) ▪ Construction (34%) ▪ Vehicles (13%) ▪ Open burning (11%)
SSI-GTK	▪ Resuspended dust (56%) ▪ Vehicles (16%) ▪ Construction (16%)	▪ Construction (40%) ▪ Open burning (16%) ▪ Vehicles (11%) ▪ DG Set (11%)	▪ Resuspended dust (79%) ▪ Vehicles (9%)
Pitampura	▪ Construction (41%) ▪ Domestic (20%) ▪ DG Set (17%) ▪ Vehicles (13%)	▪ Vehicles (33%) ▪ Construction (24%) ▪ Open burning (14%) ▪ Domestic (12%)	▪ DG Set (37%) ▪ Open burning (27%) ▪ Resuspended dust (19%) ▪ Vehicles (11%)
Prahladpur	▪ Resuspended dust (34%) ▪ Construction (19%) ▪ Open burning (16%) ▪ DG Set (13%) ▪ Vehicles (13%)	▪ Resuspended dust (50%) ▪ Open burning (23%) ▪ DG Set (16%) ▪ Vehicles (5%)	▪ Open burning (33%) ▪ Resuspended dust (26%) ▪ Domestic (14%) ▪ Construction (14%) ▪ Vehicles (6%)

- Data could not converge

The above analysis of source contribution based on CMB results indicates high variability in terms of sources. The analysis indicates that values in different seasons could be highly influenced by the local meteorology as also the intensity of sources in a particular season. The Table of results shown above **(Table 4.3)** also shows the importance of the data available for source profiles created for the Indian conditions. One of the major uncertainties of this analysis is relating to similar levels of source profile chemical speciation and also ambient PM speciation. However, the analysis results obtained can be used as a major indicator of main sources which are present in PH at various sites.

4.2 Summary and Conclusions

Receptor modeling was carried out to arrive at the profile of source contributions of particulate matter in Delhi. Separate season wise analysis was also carried out.Factor analysis and CMB 8.2 were applied to PM10 using carbon, metals and ions data analyzed on different days source contribution where further fine tuned with Molecular Markers data was further used to establish the linkages with different sources. Source apportionment analysis of PM10 using CMB at background station Prahladpur indicates that resuspended dust contribution is around 26-50%and open burning contributes around 16-33%. Construction activities, (although not widely found in post monsoon), contribution is around 14-19%, DG sets contribution is around 13-16% and vehicular contribution is around 5-13% to PM10. Some of these emissions are likely to be contributed by out side the 2 x 2 KM grid.

At residential station Pitampura, the contribution of construction (~24-41%), vehicular (~11-33%), DG sets (~17-37%) and domestic source (~12-20%) activities is significant in summer and post monsoon, whereas in winter, open burning (27%) and DG sets (37%) contributions are significant. Whereas at industrial station SSI-GTK, resuspended dust contribution is significant (~56-79%). Construction, vehicular and open burning are the other sources contributing significantly to PM10.At mixed-use station Naraina, resuspended dust contributes is in the range of 20-48% and vehicles contribute around 10-13% during the three seasons. Other contributions are from industries (15-17%) and DG sets (10-13%) during summer and post monsoon respectively. Construction activities and open burning contribute around 34% and 11%, respectively to PM10 during winter.

At kerb side station Mayapuri, resuspended dust contribution is significant (~25-48%) and vehicular contribution is around 12-15% during three seasons. Industrial contribution is significant during summer and post monsoon (19-39%). DG sets, open burning and domestic activities are the other sources contributing to PM10. At the other kerb side station Loni Road, resuspended dust contribution is around 28-46% and construction activities are significant with a contribution of ~8-50% during the three seasons. This fact corroborates with highly variable and high PM values during monitoring period at Loni Road. Resuspended dust and open burning are the major significant sources with contribution around 20-40% and 25-52% respectively at ISBT. Other significant contribution is from vehicles (12-21%) on the other hand, at Ashram Chowk, resuspended dust contribution is around 17-41%. Industries contribute around 17-20%, vehicles contribute around 11-40% and construction activity contributes around 19-21% of PM10 mass. At Anand Vihar, resuspended dust contribution is 22-56%, vehicles contribute 16-20% during summer and post monsoon and construction activity contribution is

29% during post monsoon. Finally Dhaula kuan an other Kerb side location resuspended dust (~25%) and domestic activities (~25-34%) contribution are significant. Other contributions are from vehicles (~13-15%) and industries (~15%).

PM10 source apportionment analysis, in general, reveals that most of the sites close to road side are highly influenced by resuspension of road dust and vehicular emissions. Background and mixed-use sites are also dominated by resuspended dust. Residential site in Delhi is dominated by construction activities, vehicular sources, DG sets and other domestic sources, whereas Industrial site is dominated by resuspension of road dust with other contributions from construction activities, vehicular sources and open burning. These source strengths are variable in different seasons, however, the pattern remains similar. Using all the above analysis, a conclusive set of major sources that have contributed to the PM10 pollution at different monitoring stations is presented in **Table 4.4**.

Table 4.4: Major source contributions to PM10 at various sites during the three seasons

Station	Summer	Post monsoon	Winter
Prahladpur	**Resuspended dust,** Construction, **Open burning,** DG set, **Vehicle**	**Resuspended dust, Open burning** DG set, **Vehicle**	**Open burning, Resuspended dust**, Domestic, Construction, **Vehicle**
Pitampura	Construction, Domestic DG set, **Vehicle**	**Vehicle**, Construction, Open burning, Domestic	DG set, Open burning, Resuspended dust, **Vehicle**
SSI-GTK	Resuspended dust, **Vehicle**, Construction	Construction, Open burning, **Vehicle**, DG set	Resuspended dust, **Vehicle**
Naraina	**Resuspended dust**, Domestic, Industries, **Vehicle**, DG Set	**Resuspended dust**, Industries, **Vehicle**, DG Set	**Resuspended dust**, Construction, **Vehicle**, Open burning
Dhaula Kuan	--	Domestic, Resuspended dust, Industries, Vehicle, DG set	Domestic, Resuspended dust, Industries, Vehicle, Construction
Ashram Chowk	**Vehicle**, Construction, Industries, **Resuspended dust**	**Resuspended dust**, **Vehicle**, DG set, Open burning	**Resuspended dust**, Industries, Construction, **Vehicle**, Open burning
Mayapuri	**Resuspended dust**, Industries, **Vehicle**	Industries, **Resuspended dust**, **Vehicle**, DG set	**Resuspended dust**, Construction, **Vehicle**, DG set
ISBT	**Resuspended dust**, **Vehicle**, DG set, Industries, Domestic	Open burning, **Vehicle**, **Resuspended dust,** Industries, Domestic	Open burning, **Resuspended dust**, **Vehicle**, DG set
Loni Road	**Resuspended dust**, **Construction**, Domestic, Industries, Vehicle	**Construction**, **Resuspended dust**, Open burning, Vehicle	**Resuspended dust**, Open burning, DG Set, **Construction**
Anand Vihar	Resuspended dust, Vehicle, Domestic, Open burning	Construction, Resuspended dust, Vehicle, Open burning, DG set	--

Bold font indicates the similar sources contributing in three seasons and underline indicates the similar sources contributing in two seasons

As can be seen from the above table, some sources contribute consistently in all three seasons and few others in at least two seasons. It is important to note that though CMB provides the understanding of sources on the basis of their chemical constituents, it is highly dependent on the profile information of all the sources. In absence of complete profile sources show collinearly problems and lead to bunching of sources or complete non-convergence.

The Molecular Marker data indicates widespread biomass burning within the city. Also these markers indicate vehicles contributions in almost all area which could be attributed to large vehicle population in the city. Even residential areas have very high vehicle density.

The report attempts to use this information along with emission inventory and chemical analysis with Molecular Markers to arrive at the sources which need to be addressed for control .CMB, however, only deals with PM apportionment and therefore, for gaseous emission control such as NOx, other information needs to be used for planning its control. PM being a good surrogate of other pollutants, its control will need lead to better air quality.

Chapter 5

Dispersion Modeling: Existing Scenario

5.1 Introduction

Air quality dispersion modeling has been undertaken with a view to identify the important sources and their impact on ambient air quality in Delhi as also at measurement locations. Dispersion modeling tool has been used for the whole city air quality scenario generation for emission loads from different sources. The existing scenario model runs have been carried out to establish the dispersion pattern of pollutants due to local meteorology derived during the study period. Model runs also provide an idea about missing sources or other sources which may have not accounted for the variety of reasons.

Pollutants scenarios for different seasons, locations and sources have been generated to assess the impacts of source contributions and variations. The comparison of concentrations with the existing scenario has been carried out by considering modeled ten concentrations in each case. The option of taking ten highest concentrations (given in annexure) for comparison indicates possible worst conditions under a given scenario.

5.1.1 Model Description

Air quality modeling was carried out for three seasons viz., summer, post monsoon and winter. The USEPA developed/validated ISCST-3 air quality model was used to predict spatial distribution of PM10 and NO_2 concentrations in ambient air (USEPA, 1995). The model has various options including the capability to handle Polar or Cartesian coordinates, simulating point, area, and volume sources, consideration of wet and dry deposition, accounting for terrain adjustment, building downwash algorithm, etc. The data pertaining to source characteristics, meteorological parameters and receptor network required as input to the model include (i) source data: physical dimensions (stack location, stack height, stack top inner diameter), exit velocity, temperature of gas and pollutant emission rate, (ii) hourly meteorological data for the simulation period: wind speed, wind direction, ambient temperature, stability class and mixing height; and (iii) co-ordinates of sources (stacks) and receptors.

The ISCST3 model uses the following steady-state Gaussian plume equations for continuous point and area sources as presented below.

Equation for point source

$$C = \frac{QKVD}{2\,\pi u \sigma_y \sigma_z} \exp(-y^2/2\sigma_y^2) \qquad \ldots(1)$$

where Q is the source strength or emission rate (g s^{-1}), u is the mean wind speed (m s^{-1}), y is the cross wind distance (m), σ_y, σ_z, are the horizontal and vertical dispersion parameters (m), respectively, and K is the scaling coefficient to convert calculated concentrations to desired units. In Eq. (1), V is the term for vertical distribution of Gaussian plume and D is the decay term accounting for the pollutant removal by physical or chemical processes. The model employs Brigg’s formulae to compute plume rise and make use of power law to determine wind speed corresponding to the stack height.

The model runs were carried out separately for industrial, area, vehicular, road dust as also all sources together to quantify their individual contribution as well as cumulative contribution towards the overall ground level concentrations. The industrial sources were considered as independent elevated point sources and the vehicular emissions are considered as adjacent volume sources for input to the model. The 24 hourly variations of vehicular and area source emissions were also considered based on the hourly traffic volume/ intensity and area source emissions. Most of the industrial units within the study area are assumed to be continuous process plants and hence the emission rate through the stacks is considered uniform throughout the day. Specific approach for modeling exercise adopted is discussed while presenting the impact of individual source categories (area, industrial, vehicular and road dust) in the relevant sections.

5.1.2 Modeling Domain

Air Quality modeling was carried out for 2 km x 2 km area around each monitoring site as well as for the whole city of Delhi. For air quality impact predictions, the study area was divided into 16 square grids each of size 0.5 km x 0.5 km. The receptor locations in the study area were configured in a square grid pattern to facilitate coverage of all the important sites located in and around major urban growth centers. The area sources were distributed in a square grid pattern and a uniform distribution of emissions within each grid was assumed. Hourly frequency distributions of wind speed, wind direction, ambient temperature, stability class and mixing height were used in the model. Atmospheric stability was determined using Pasquill modified Turner’s (1964) method. The various stabilities ranging from A to F (Unstable-A, B and C, Neutral-D, Stable-E and F) was determined based on wind speed, solar insolation and cloud cover.

The modeling features are same for all the sources. The salient features of the modeling exercise are given in **Table 5.1.**

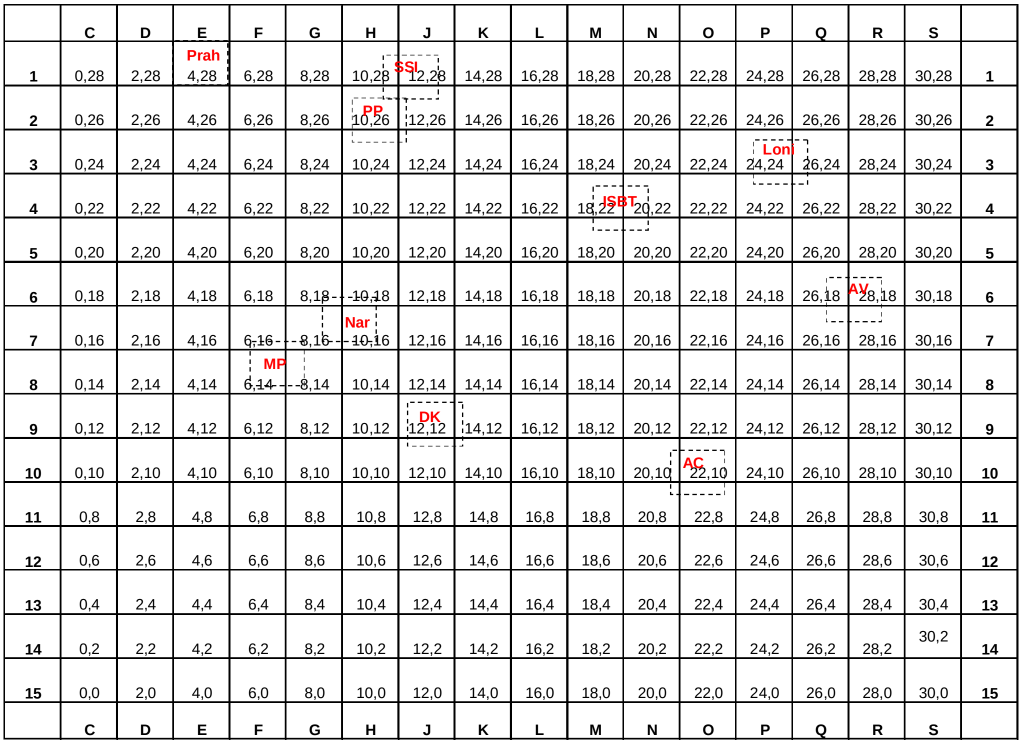
Table 5.1: Salient Features of Modeling Exercise

Parameter	**10 Study Zones (2 km x 2 km)**	**Delhi City**
Sources considered	Area, Industrial, Vehicular, Road dust and all sources together	Area, Industrial, Vehicular, Road dust and all sources together
Pollutants modeled	PM, NOx & RD-PM10	PM, SO_2, NOx & RD-PM10
Emission rate	Hourly variations	Hourly variations
Sources grids	0.5 km x 0.5 km	2 km x 2 km
Surface Met data	Site specific	IMD (Indian Meteorology Departments)
Upper air Met data	CPCB document on mixing height	CPCB document on mixing height
Seasons	Summer, Post Monsoon, Winter	Summer, Post Monsoon, Winter
Model used	ISCST3	ISCST3
Receptors grids	500 m x 500 m	500 m x 500 m
Model Output		
GLC prediction at	1600 receptor locations	3840 receptor locations
Ranked GLCs	First 10 highest values	First 10 highest values
Iso-concentration plots	--	For each pollutant in each season using Surfer 32 graphical software

The schematic diagram showing distribution of 500 m x 500 m grids along with their coordinates in 2 km x 2 km study zone is depicted in **Fig. 5.1,** whereas in **Fig. 5.2,** the study area of Delhi city along with ten 2 km x 2 km study zones and extrapolated zone of influence of the ten study zones are shown.

A4 (-1000,500)	**B4** (-500, 500)	**C4** (0,500)	**D4** (500, 500)
A3 (-1000,0)	**B3** (-500, 0)	**C3** (0,0)	**D3** (500, 0)
A2 (-1000,-500)	**B2** (-500,-500)	**C2** (0, -500)	**D2** (500, -500)
A1 (-1000,-1000)	**B1** (-500, -1000)	**C1** (0, -1000)	**D1** (500, -1000)

Fig. 5.1: Schematic Diagram showing Distribution of Grids along with Coordinates in a 2km x 2 km Study Zone



	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1	0,28	2,28	Prah 4,28	6,28	8,28	10,28	SSI 12,28	14,28	16,28	18,28	20,28	22,28	24,28	26,28	28,28	30,28	1
2	0,26	2,26	4,26	6,26	8,26	PP 10,26	12,26	14,26	16,26	18,26	20,26	22,26	24,26	26,26	28,26	30,26	2
3	0,24	2,24	4,24	6,24	8,24	10,24	12,24	14,24	16,24	18,24	20,24	22,24	Loni 24,24	26,24	28,24	30,24	3
4	0,22	2,22	4,22	6,22	8,22	10,22	12,22	14,22	16,22	JSBT 18,22	20,22	22,22	24,22	26,22	28,22	30,22	4
5	0,20	2,20	4,20	6,20	8,20	10,20	12,20	14,20	16,20	18,20	20,20	22,20	24,20	26,20	28,20	30,20	5
6	0,18	2,18	4,18	6,18	8,18	10,18	12,18	14,18	16,18	18,18	20,18	22,18	24,18	26,18	AV 28,18	30,18	6
7	0,16	2,16	4,16	6,16	8,16	Nar 10,16	12,16	14,16	16,16	18,16	20,16	22,16	24,16	26,16	28,16	30,16	7
8	0,14	2,14	4,14	MP 6,14	8,14	10,14	12,14	14,14	16,14	18,14	20,14	22,14	24,14	26,14	28,14	30,14	8
9	0,12	2,12	4,12	6,12	8,12	10,12	DK 12,12	14,12	16,12	18,12	20,12	22,12	24,12	26,12	28,12	30,12	9
10	0,10	2,10	4,10	6,10	8,10	10,10	12,10	14,10	16,10	18,10	20,10	AC 22,10	24,10	26,10	28,10	30,10	10
11	0,8	2,8	4,8	6,8	8,8	10,8	12,8	14,8	16,8	18,8	20,8	22,8	24,8	26,8	28,8	30,8	11
12	0,6	2,6	4,6	6,6	8,6	10,6	12,6	14,6	16,6	18,6	20,6	22,6	24,6	26,6	28,6	30,6	12
13	0,4	2,4	4,4	6,4	8,4	10,4	12,4	14,4	16,4	18,4	20,4	22,4	24,4	26,4	28,4	30,4	13
14	0,2	2,2	4,2	6,2	8,2	10,2	12,2	14,2	16,2	18,2	20,2	22,2	24,2	26,2	28,2	30,2	14
15	0,0	2,0	4,0	6,0	8,0	10,0	12,0	14,0	16,0	18,0	20,0	22,0	24,0	26,0	28,0	30,0	15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

Fig. 5.2 : Distribution of Grids (as per Eicher Map) in Delhi with marked Study Zone and Grid Coordinates (in km)

5.2 Emission Loads

Emission rates for different pollutants were estimated as per the model requirement using the emission inventory data prepared for different sources of air pollution, as given in Chapter 3. The details of emission data used for modeling exercise along with the grid-wise emission rates for different pollutants for ten 2 km x 2 km study zones are given in Tables in **Annexure V.1** and for the whole Delhi city, in **Annexure V.2.**

5.3 Meteorological Data

Meteorological conditions play a vital role in transport and dispersion of pollutants in the atmosphere. The hourly surface meteorological data viz. wind speed and direction and surface temperature required as input to the model were collected at each of the 10 sites using a continuous wind monitoring instrument round the clock during the air quality monitoring periods. The meteorological data for modeling exercise was taken for the months of May-June (summer season), October-November (post monsoon) and December-January (winter season). Meteorological data was also collected for the corresponding months from IMD, and was used for model runs for Delhi. The mixing height was obtained from the report published by CPCB, whereas stability classes of Pasquill & Gifford (PG) were used.

Wind rose diagrams for summer, post monsoon and winter are prepared for each of the 10 sites and for IMD data. These wind rose diagrams are given in **Annexure V.3**. Site specific IMD data wind rose diagrams in terms of calm duration (%), average wind speed (kmph) and predominant wind direction(s) are summarized for the three seasons in **Table 5.2**.

Table 5.2 : Summary of Station-wise Wind Observation

	Calm duration (%)			**Average WS, (kmph)**			**Predominant WD**		
Station	**Sum**	**PM**	**Win**	**Sum**	**PM**	**Win**	**Sum**	**PM**	**Win**
Ashram Chowk	04	57	43	7.0	1.5	4.0	NW	DWD	NW
Dhaula Kuan	05	55	38	3.0	2.0	2.5	NW, W	DWD	NW
Mayapuri	11	56	27	7.0	2.5	3.0	SW, NE	DWD	NNW, E
ISBT	17	53	35	4.0	2.5	3.0	SE, E	DWD	NW
Loni Road	15	48	34	6.0	2.5	6.0	SE, N	DWD	NW
Anand Vihar	14	54	40	7.0	2.0	5.0	NW, SE	DWD	NW
Naraina	13	54	23	5.0	2.5	6.0	NW, SW	DWD	NW
SSI-GTK	15	47	31	4.0	2.5	3.0	NW, SE	DWD	NW
Pitampura	08	42	28	6.0	2.5	5.0	W	DWD	NNW, SW
Prahladpur	09	39	27	6.0	3.0	4.0	NW	DWD	NW
IMD 2007-08	33	52	46	5.7	3.7	5.1	SE	NW, W	NW

Sum – Summer, PM – Post monsoon, Win – Winter, DWD – Distributed wind directions

Analysis of 10 sites and IMD meteorological data indicates that during summer season calm period prevails around 10% of the time at most of the stations. The wind speed is relatively high varying between 4.0 and 7.0 kmph and wind blows mostly from NW and SE directions. During post monsoon, calm conditions prevail for more than 50% of the time for most of the stations. The wind speed is relatively low at 2.5 kmph and wind spreads in all directions thereby showing no predominance of any particular direction. During winter season, calm conditions prevail for about 30% of the time at most of the stations. The wind speed is moderate, between 3.0 and 6.0 kmph and predominant wind direction is NW.

The major differences between site specific and overall city meteorology (IMD) are related to summer calm values and wind speed. IMD values of calm for summer and winter are higher in comparison with meteorology observed at specific sites. On an average, post monsoon calm conditions are higher for all stations when compared with winter values. This could be attributed to higher post monsoon air pollution levels at most of the stations as discussed in Chapter 2.

5.4 Model Output - Concentration Profiles

5.4.1 Model Results for 2 km x 2 km Study Zones

24 hourly average GLCs of PM and NOx were predicted individually from area, industrial, vehicular sources and road dust re-suspension and their cumulative contributions for each of the study zones, using the respective study zone emission inventory and meteorological data. The model results, in terms of first ten highest GLCs of PM and NOx for each study zone are given in **Annexure V.4**.

24 hourly average GLCs of PM and NOx at the monitoring locations were also predicted during different seasons. The predicted values of PM and NOx (taking all sources together) at each monitoring location during summer, post monsoon and winter have been computed. Seasonal variation in the predicted GLCs of PM and NOx is depicted in **Fig. 5.3** and **Fig. 5.4** respectively. The predicted concentration is taken as the average concentration at 9 receptors points around the monitoring location within 100 m x 100 m area.

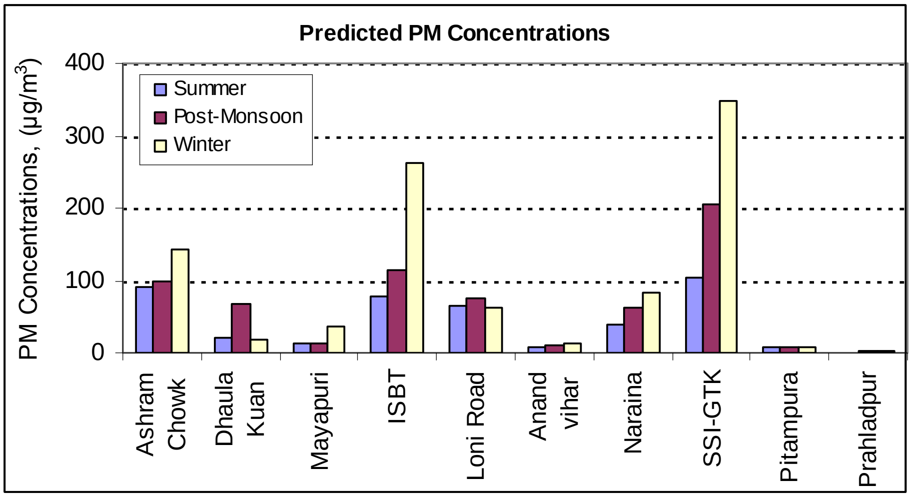


Fig. 5.3: Comparison of Predicted PM Concentrations from All the Sources in Different Seasons: Existing Scenario

Predicted GLCs of PM are found to be the highest during winter, followed by post monsoon and summer at Ashram Chowk, Mayapuri, ISBT, Anand Vihar, Naraina and SSI-GTK. At Dhaula Kuan and Loni Road, highest concentration is observed during post monsoon. At Pitampura and Prahladpur, predicted concentration is very low. At all the monitoring locations, in general, lowest concentration is observed during summer, which can be attributed to the better dispersion conditions. Such variation in model results can be attributed to the fact that wind blown dust and other unaccounted sources of PM can not be integrated in the emission inventory.

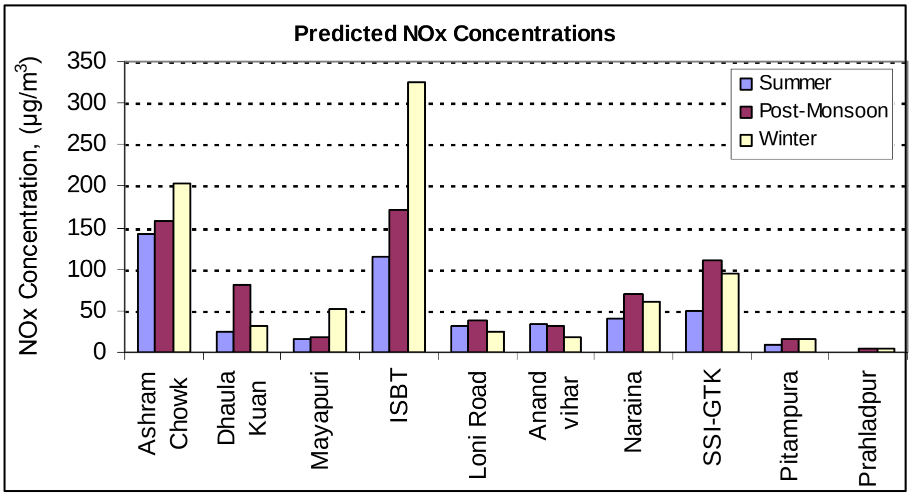


Fig. 5.4: Comparison of Predicted NOx Concentrations from All the Sources in Different Seasons: Existing Scenario

Predicted GLCs of NOx are found to be highest during winter at 3 locations, namely Ashram Chowk, Mayapuri & ISBT, whereas at 3 locations (Dhaula Kuan, Loni Road & SSI-GTK), it is predicted to be slightly more in post monsoon, which may be attributed to the site-specific meteorological conditions. At Prahladpur, predicted concentration is very low. At all the monitoring locations, in general, lowest concentration is observed during summer at most of the locations, which can be attributed to the better dispersion conditions during summer.

Almost similar seasonal trend was observed in measured concentrations of PM and NO_2 values, as also discussed earlier in Chapter 2.

5.4.2 Comparison of Predicted and Measured Concentrations (2 km x 2 km Modeling)

Attempt was made to predict pollutants GLCs at all monitoring locations with a view to compare them with the observed values. Concentrations of PM and NOx have been predicted using respective emission inventory and observed micro-meteorological data of each of the 2 km x 2 km study zones. Predicted concentrations at the air quality monitoring location is taken as the average concentration at 9 receptor locations falling within 100 m x 100 m area around the monitoring location. Predicted total PM and NOx concentration levels at each AAQ site are compared with the corresponding measured PM10 and NO_2 levels in all the three seasons, as presented in **Fig. 5.5.**

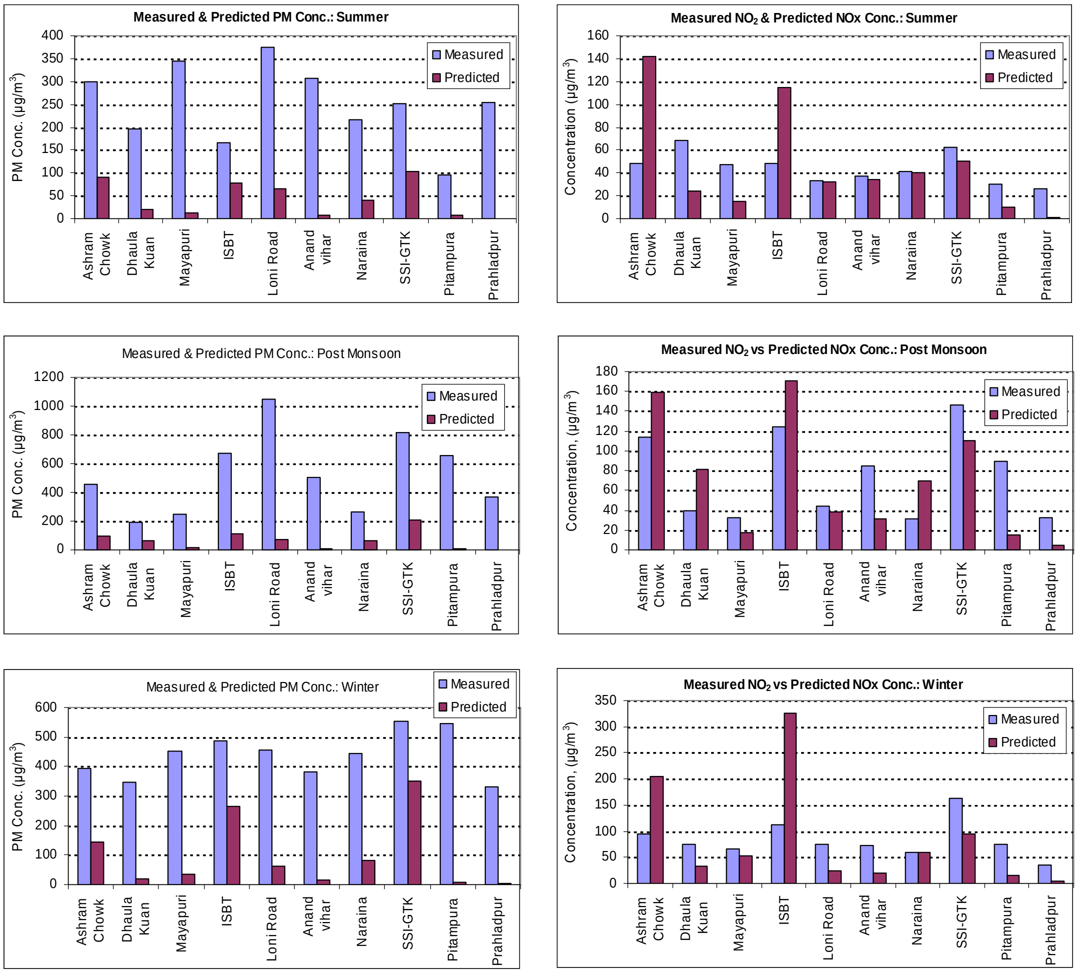


Fig. 5.5: Comparison of Predicted and Measured PM and NOx GLCs at 10 AQM Sites during Summer, Post Monsoon and Winter: Existing Scenario

It is observed that the predicted values of PM10 are much lower as compared to the measured levels, at all the sites and during all seasons. As also discussed earlier in Chapter 2, very high levels of PM are prevalent which can be attributed to wind blown dust, which are not accounted in emission inventory and many other unaccounted infrequent sources prevailing in the study zones. When a comparison is made among the sites, the land use pattern and activity levels around the study zones vary considerably, thereby influencing the predicted levels. Analysis of measured and predicted PM concentration levels reveal dominance of non-anthropogenic sources almost at all the study zones.

When predicted NOx values are compared with the measured NO_2 concentrations, it is observed that except at Ashram Chowk and ISBT, at all other sites, the predicted values are lower or equal to the measured values. High values predicted at the Ashram Chowk and ISBT are mainly attributed to vehicular-NOx as these sites have very high traffic activity in the area.

The over-predicted NOx concentrations at kerbside locations may also be attributed to the fact that vehicles mainly emit NO, which subsequently gets converted into NO_2. This conversion depends on number of factors. As reaction time available at kerbside location is less as compared to residential/mixed use area sites, it results in over-prediction of NOx values. Some of this variation could also be due to uncertainty in the emission factors used in emission inventory estimates.

[Note: It is also pertinent to mention that emission factors for different types of pollution sources are available for NOx (sum of NO and NO_2), whereas measurement in ambient air quality is carried out for NO_2. As per the study carried out in UK, NO_2 could be in the range of 35-40% of NOx in urban sites, and about 83% in rural areas. For roadside locations, NO_2 could be as low as 15% of NOx or so depending upon the traffic activity and other atmospheric conditions. This aspect needs to be kept in mind while comparing the model predicted NOx concentrations with measured ambient NO_2 concentrations. The values mentioned here are indicative and can not be used as correction factors for Indian conditions, unless derived for specific city and atmospheric conditions.]

5.4.3 Influence of Other Emission Sources (beyond 2 km x 2 km) on Predicted Values

Influence of other emission sources beyond 2 km x 2 km study zones has been predicted using the city level emission inventory (detailed modeling results presented in next section). Meteorological data from IMD has been used to normalize the effect of local meteorological variations in city level modeling. The concentrations are predicted at each of the air quality monitoring locations and have been compared with the measured levels for the critical season, winter. Predicted total PM and NOx concentration levels from 2 km x 2 km and city level emission inventory are compared with the corresponding measured PM10 and NO_2 levels at each AAQ site and these are presented in **Fig. 5.6** and **5.7** respectively.

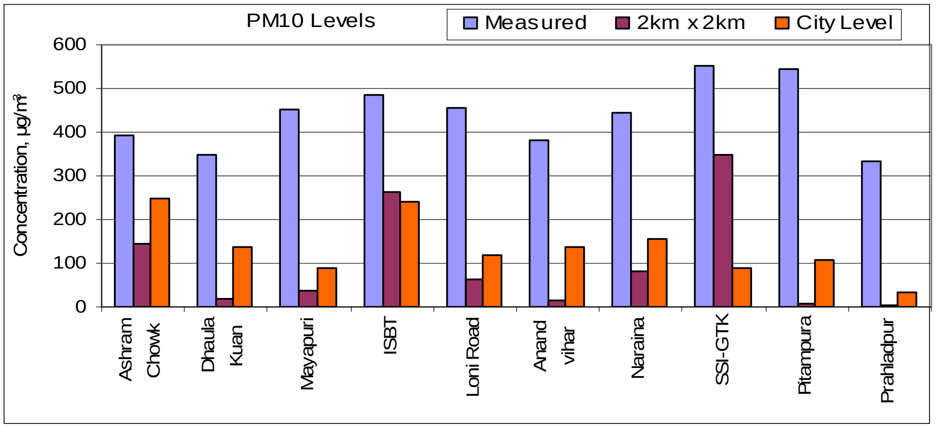


Fig. 5.6: Comparison of Predicted GLCs with Measured Concentrations at 10 AQM Sites during Winter: PM (Existing Scenario)

It can be observed that predicted total PM concentrations are much lower than the measured average PM10 concentrations at all the sites. Model predicted PM10 values using city level emission inventory are found to be much higher as compared to 2 km x 2 km study zone predicted levels, almost at all the sites except at ISBT and SSI-GTK. City level inventory based model showed better closeness to the measured values as compared to the 2 km x 2 km emission inventory. This indicates the influence of activities beyond the study zone of 2 km x 2 km on predicted GLCs. Very high measured concentration levels of PM10 can be attributed to wind blown dust (even for a short time) which can affect the measured values, whereas wind speed record used in model is averaged for an hour. The lower predicted values could be attributed to various factors such as infrequent but distributed biomass burning, road, and other construction activities etc. Observed values are mostly influenced by local unaccounted for sources besides some long and medium range transport of PM.

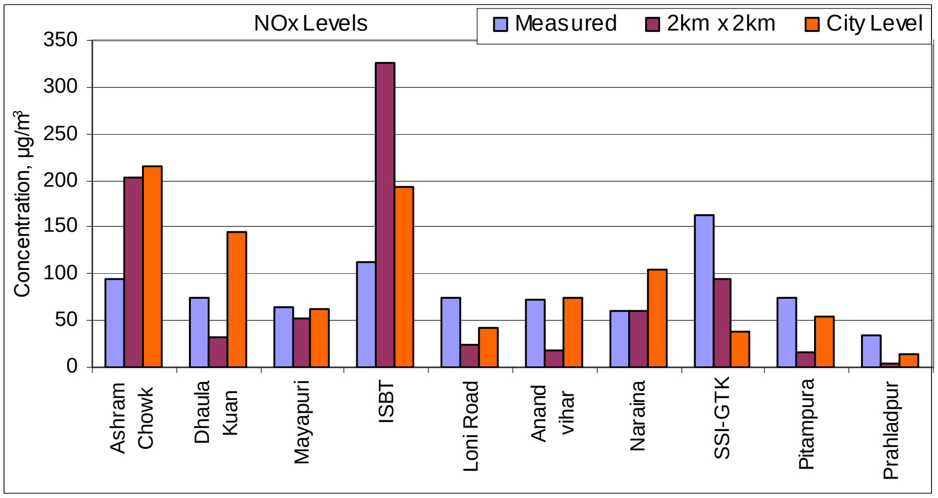


Fig. 5.7: Comparison of Predicted NOx GLCs and Measured NO_2 Concentrations at AQM Sites during Winter: NO_2 (Existing Scenario)

Model results from study zones indicate that predicted NOx levels are higher than the measured NO_2 concentrations at Ashram Chowk and ISBT, whereas, they are lower at Dhaula Kuan, Loni Road, Anand Vihar, SSI-GTK, Pitampura and Prahladpur. At Mayapuri and Naraina, the predicted concentrations compare well with measured values. Predicted NOx concentrations from City Level modeling indicated higher levels as compared to 2 km x 2 km study zones at all the sites, except at SSI-GTK.

High predicted NOx concentrations at Ashram Chowk and ISBT can be attributed to the fact these two sites have very high traffic activity and monitoring location really represents the kerbside location, whereas at other locations namely Mayapuri, Loni Road and Anand Vihar, though monitoring is done at kerbside/roadside, the traffic density on the nearest road has been observed to be much lower as compared to Ashram Chowk, Dhaula Kuan and ISBT.

Therefore, these three sites (Loni Road, Anand Vihar and Mayapuri) can be considered as mixed use activity zones. Further, such variations can be attributed to the prevailing meteorological conditions (mainly wind speed and wind direction) and exact emission releases from different air pollution sources at the time of monitoring. Besides, NOx being reactive species, it goes through chemical transformation as mentioned in previous section. Other reason for such variation could be unknown local sources influencing the concentrations.

Site-wise variation in predicted PM and NOx concentrations from 2 km x 2 km study zone modeling and city level modeling is presented in **Fig. 5.8** and **Fig. 5.9** respectively for PM and NOx.

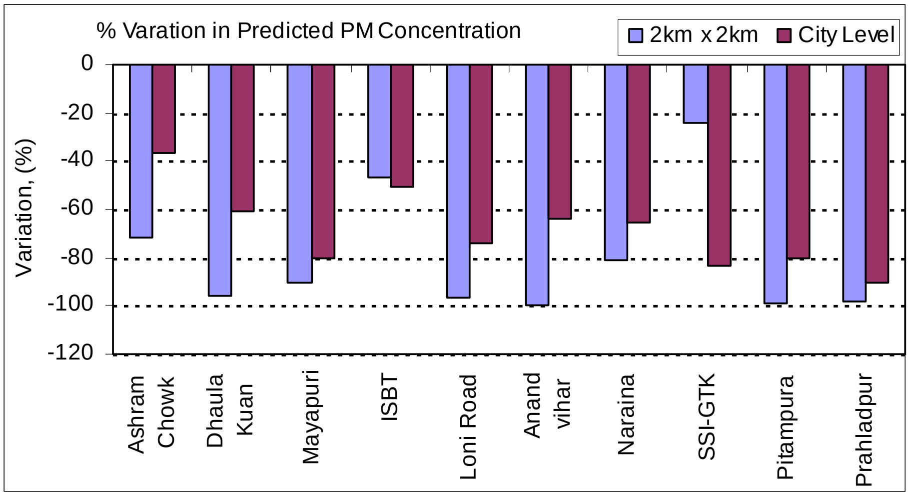


Fig. 5.8: Site-wise Percent Variation in Predicted PM Concentrations with respect to Measured PM10 Values: Winter (Existing Scenario)

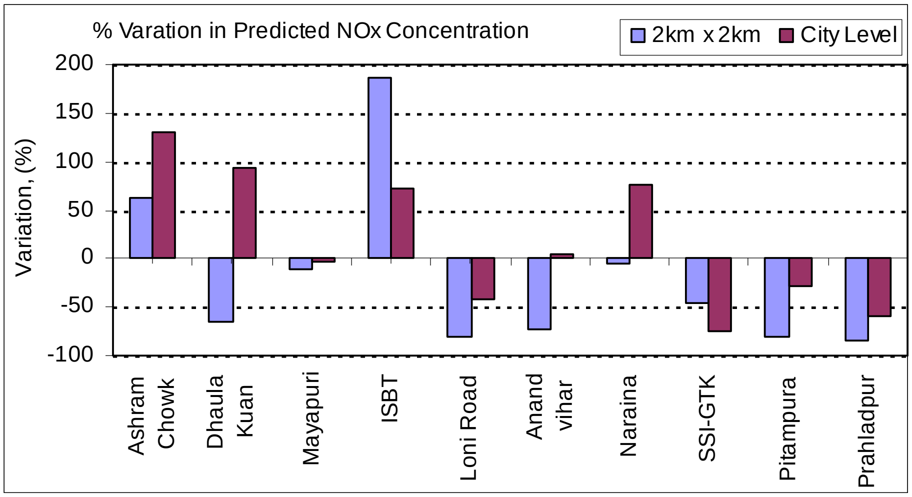


Fig. 5.9: Site-wise Percent Variation in Predicted NOx Concentrations with respect to Measured NO_2 Values: Winter (Existing Scenario)

It can be observed that predicted values of PM are much lower than the measured values at all the sites, varying from about 25% at SSI-GTK to almost 100% at Prahladpur. Predicted NOx values are found to be lower than the measured NO_2 values at all the locations, except at Ashram Chowk and ISBT and also at Dhaula Kuan and Naraina for City level modeling. Overall NOx predictions are better than PM at all locations mainly due to the fact that the latter is highly influenced by natural sources.

5.4.2 City Level Modeling

Occurrence of Maximum GLCs and Iso-concentration Plots: The parameters considered for modeling are PM, NOx, SO_2 and Road Dust-PM10. Pollutants GLCs have been predicted at 3840 receptor locations separately for area, point & line sources and road dust re-suspension. Further, cumulative impact is predicted, wherein total PM includes road dust-PM10 also. Out of the predicted GLC values, first 10 highest concentration values of each pollutant in each season and their occurrence have been tabulated for presenting model results under worst case scenario for area, point and line sources as given in **Annexure V.5**. The maximum GLC (representing a receptor location out of 3840 locations in the city), predicted for different sources during different seasons are summarized along with their occurrence in **Table 5.3.**

Table 5.3: Source Category and Season-wise Predicted Maximum GLCs: Delhi (Existing Scenario)

Pollutant/ Source Category	Summer		Post-Monsoon		Winter	
	MGLC (µg/m^3)	Occurrence of MGLC (E,N) Km	MGLC (µg/m^3)	Occurrence of MGLC (E,N) Km	MGLC (µg/m^3)	Occurrence of MGLC (E,N) Km
PM						
Area	102	12.0, 27.5	132	24.0, 18.5	144	14.0, 26.0
Industrial	38	19.0, 18.5	37	24.5, 13.0	72	24.5, 13.0
Vehicular	28	18.0, 16.0	40	20.0, 14.5	46	20.0, 14.0
Road Dust Re-suspension	214	18.0, 16.0	325	20.0, 14.5	365	20.0, 14.0
Cumulative	**260**	**18.0, 16.0**	**387**	**20.0, 14.5**	**438**	**20.0, 14.0**
NOx						
Area	27	4.0, 24.0	49	20.0, 18.5	56	20.0, 18.0
Industrial	618	19.0, 18.5	605	24.5, 13.0	1153	24.5, 13.0
Vehicular	215	18.0, 16.0	315	20.0, 14.5	355	20.0, 14.0
Road Dust Re-suspension	-		-		-	
Cumulative	**735**	**19.0, 18.5**	**733**	**24.0, 13.5**	**1297**	**24.5, 13.0**

Table 5.3 (Contd…): Source Category and Season-wise Predicted Maximum GLCs: Delhi (Existing Scenario)

Pollutant/ Source Category	Summer		Post-Monsoon		Winter	
	MGLC (µg/m^3)	Occurrence of MGLC (E,N) Km	MGLC (µg/m^3)	Occurrence of MGLC (E,N) Km	MGLC (µg/m^3)	Occurrence of MGLC (E,N) Km
SO_2						
Area	4	18.0, 20.0	8	19.5, 18.5	9	20.0, 18.0
Industrial	360	25.0, 15.5	292	26.5, 14.0	510	24.0, 13.5
Vehicular	2.1	18.0, 16.0	3.2	20.0, 14.5	3.6	20.0, 14.0
Road Dust Re-suspension	-		-		-	
Cumulative	**361**	**25.0, 15.5**	**295**	**26.5, 14.0**	**514**	**24.0, 13.5**

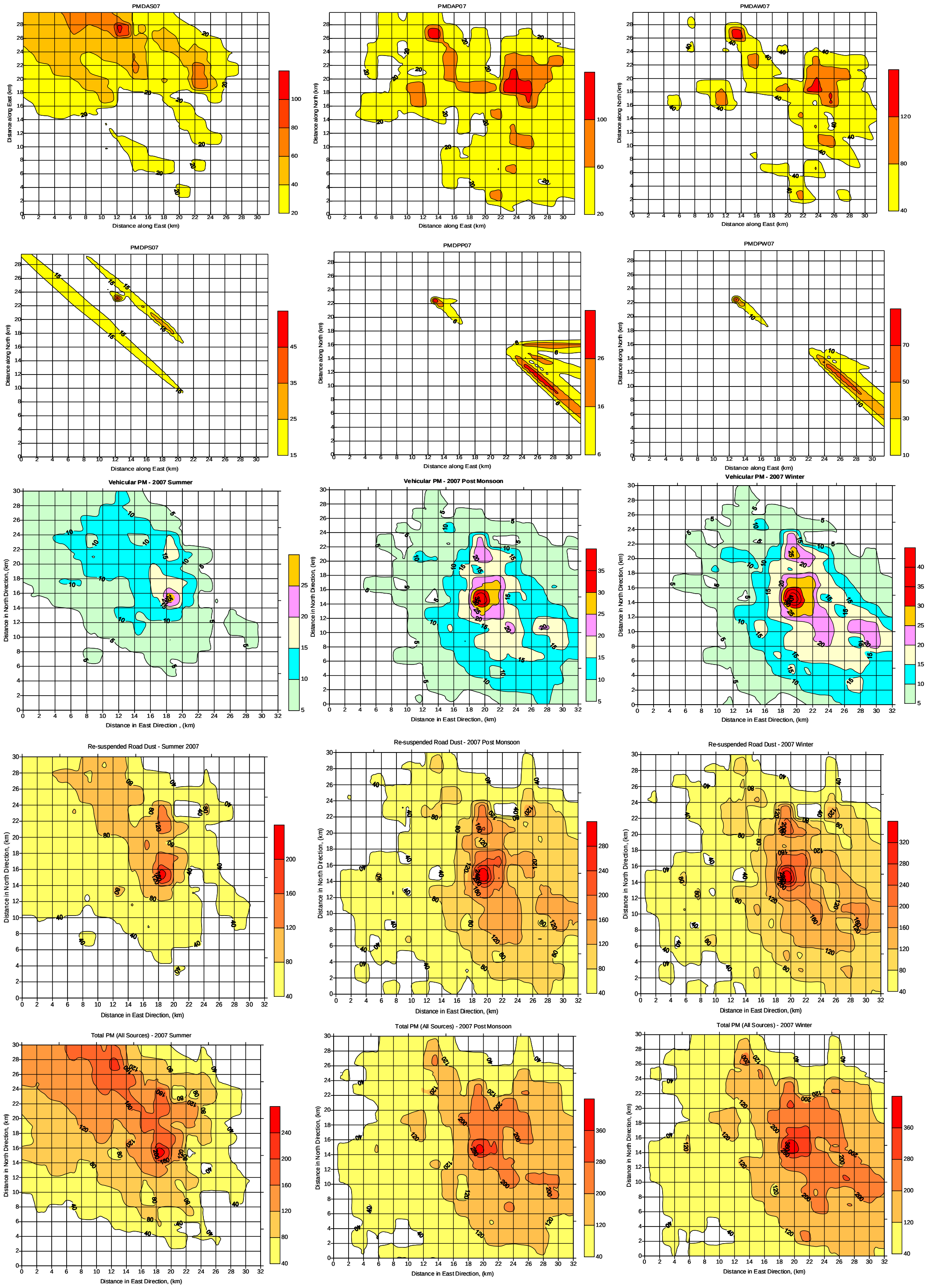
Note: The cumulative maximum GLC is lower than the sum of MGLCs predicted from individual source categories. This is due to the fact that MGLCs from different sources occur at different locations and their cumulative impact can also occur at some other location.

In order to study the spatial dispersion and distribution of pollutants during different seasons in Delhi, iso-concentration plots for different pollutants in each season have been drawn separately depicting impact of area sources, industrial sources, vehicular sources and road dust re-suspension. Further, cumulative plots are drawn taking into account all the sources together. In the cumulative plot of PM, contribution of road dust is also included. These iso-concentration plots are shown in **Figs. 5.10** through **5.12,** respectively for PM, NOx and SO_2.

Note: Model performance was evaluated by comparing predicted concentrations of particulate matter and NOx from 2 km x 2 km and city level modeling with the average measured concentrations during winter. It was judged mainly by index of agreement (d) and root mean square error (RMSE), which indicate the accuracy and error involved in the prediction exercise. For a good model the value of 'd' should be close to 1 and RMSE should be least. For the present analysis of predicted concentrations with measured levels, the model performance parameters calculated are summarized as:

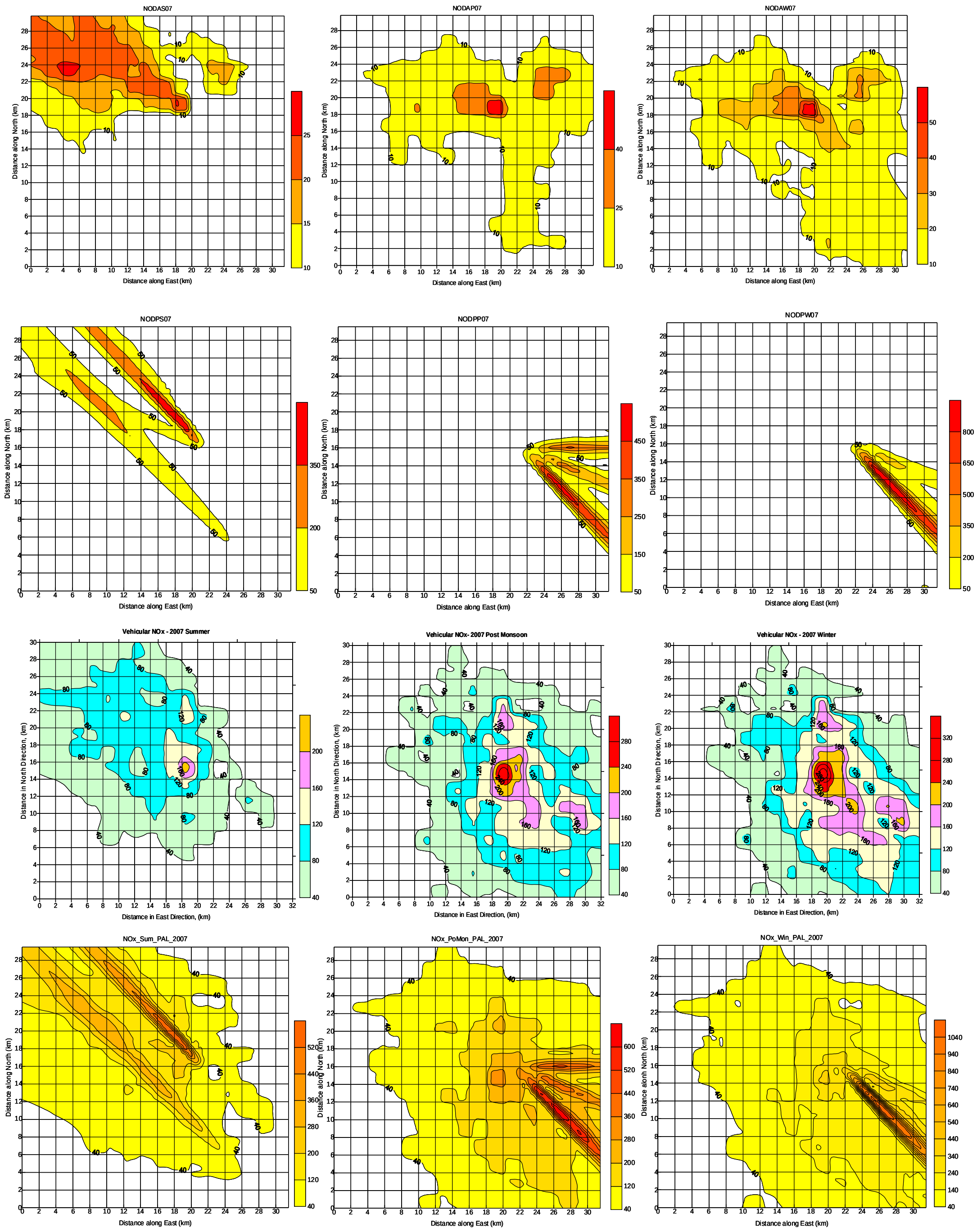
Parameter	**PM10**		**NOx**	
	2km x 2km	**City Level**	**2km x 2km**	**City Level**
Root Mean Square Error (RMSE)	354.0	303.4	85.7	67.4
MAPE	79.5	68.5	73.1	58.6
Index of agreement (d)	0.283	0.347	0.472	0.444

For particulate matter, the value of index of agreement is estimated to be about 28% for 2km x 2 km modeling, which improved to 35% for city level modeling. For NOx, the value of index of agreement is about 47% and 45% respectively for the 2 km x 2 km and city level modeling. Overall, the statistical analyses indicate that the model performance is reasonable.



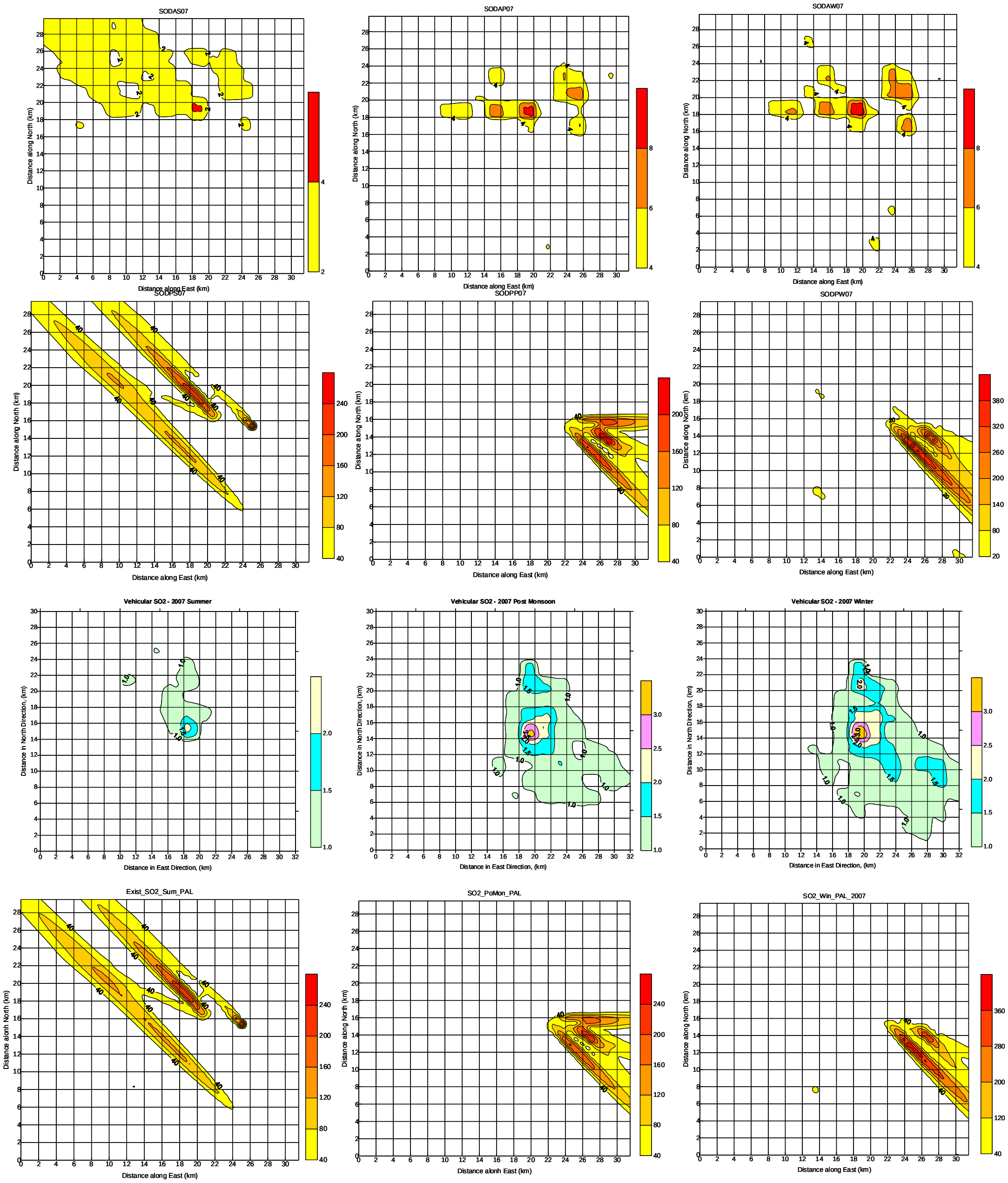
Plots Sequence: 1st Row – Area Sources; 2nd Row – Point Sources, 3rd Row – Line Sources, 4th Row – Road dust re-suspension, 5th Row – Cumulative Impact

Fig. 5.10: Iso-concentration Plots for PM from Area, Point, Line, Road Dust Re-suspension and their Cumulative Impact during Summer, Post Monsoon and Winter (Existing Scenario)



Plots Sequence: 1st Row – Area Sources; 2nd Row – Point Sources, 3rd Row – Line Sources, 4th Row –Cumulative Impact

Fig. 5.11: Iso-concentration Plots for NOx from Area, Point, Line and their Cumulative Impact during Summer, Post Monsoon and Winter (Existing Scenario)



Plots Sequence: 1st Row – Area Sources; 2nd Row – Point Sources, 3rd Row – Line Sources, 4th Row –Cumulative Impact

Fig. 5.12: Iso-concentration Plots for SO_2 from Area, Point, Line and their Cumulative Impact during Summer, Post Monsoon and Winter (Existing Scenario)

5.5 Conclusions

Based on the modeling exercise carried out for 2 km x 2 km ten study zones and the whole Delhi city, the following conclusions can be drawn:

5.5.1 2 km x 2 km Study Zones (10 locations)

- In general, predicted GLCs of PM are found to be the highest during winter, followed by post monsoon and summer at Ashram Chowk, Mayapuri, ISBT, Anand Vihar, Naraina and SSI-GTK. At Dhaula Kuan and Loni Road, highest concentration is observed during post monsoon. It has been seen that at many places, post monsoon calm conditions are higher than winter.
- Predicted GLCs of NOx are found to be highest during winter at 3 locations, namely Ashram Chowk, Mayapuri & ISBT, whereas at 3 locations (Dhaula Kuan, Loni Road & SSI-GTK), it is predicted to be slightly more in post monsoon, which may be attributed to the site-specific meteorological conditions prevailing.
- At all the monitoring locations, In general, lowest concentration is observed during summer at most of the locations, which can be attributed to the better dispersion conditions during summer. Almost similar seasonal trend was observed in measured concentrations of PM and NO_2 values, as also discussed earlier in Chapter 2.
- Comparison of the predicted values with measured PM10 levels indicates that predicted values of PM10 are much lower as compared to the measured levels, at all the sites and during all seasons. As also discussed earlier in Chapter 2, very high levels of PM are mainly attributed to wind blown dust which are not accounted in emission inventory and many other unaccounted infrequent sources prevailing in the study zones. Analysis of measured and predicted PM concentration levels reveal dominance of non-anthropogenic sources almost at all the study zones.
- Comparison of the predicted NOx values with measured NO_2 levels indicates that except at Ashram Chowk and ISBT, at all other sites, the predicted values are lower or equal to the measured values. High values predicted at the Ashram Chowk and ISBT are mainly attributed to vehicular-NOx as these sites have very high traffic activity in the area. The over-predicted NOx concentrations at kerbside locations may also be attributed to the fact that vehicles mainly emit NO, which subsequently gets converted into NO_2. This conversion depends on number of factors and reaction time available. At kerbside location, reaction time is less as compared to residential/mixed use area sites, thereby resulting in over-prediction of NOx values.

5.5.2 City Level

- **Area Sources:** During summer, maximum PM GLC of 102 µg/m^3 is predicted to occur in Uttari Pitampura area. During post-monsoon (132 µg/m^3) and winter (144 µg/m^3), these are found to occur in Jahangirpuri area. Maximum GLC of NOx during summer, post-monsoon and winter is 27, 49 and 56 µg/m^3 respectively, occurring in Nangloi Jat, Turkman Gate and Shismahal area, respectively. Maximum GLC of SO_2 is found to be less than 10 µg/m^3 in any season.

  Iso-concentration plots indicate that PM emissions are due to combustion in slum areas, using wood, kerosene, refuse etc. besides construction activities. NOx emissions from DG sets are the major cause of air pollution under area source category.

- **Industrial Sources:** Predicted maximum GLCs of PM are found to be in the range of 37-72 µg/m^3, occurring mainly in Patparganj Industrial area and Paharganj area. Iso-concentration plots drawn for industrial sources indicate that, even though the predicted GLCs are high, but their spread is limited and follows the wind pattern affecting few grids. High levels of SO_2 and NOx can be attributed to emissions from power plants and generator sets (for NOx) used in the industries.

- **Vehicular Sources and Road Dust Re-suspension:** Maximum GLC of different pollutants (PM, NOx, SO_2 and Road Dust-PM10) in different seasons is found to occur at Connaught Place-India Gate-ITO area. Maximum GLC of PM (from vehicular sources) during different seasons is observed to be in the range of 28-46 µg/m^3, whereas Road Dust (PM10) is predicted to be in the range of 214-365 µg/m^3. This indicates dominance of road dust emissions over the PM emissions emitted by vehicular sources. However, vehicular PM emissions are mainly in fine range (< 2.5 µg/m^3) and their contribution is higher in lower particle size. During different seasons, NOx MGLC is predicted to be in the range of 215-355 µg/m^3. Maximum GLC of SO_2 is predicted to be considerably low in the range of 2.1-3.6 µg/m^3.

  Iso-concentration plots drawn for different pollutants (PM, NOx, SO_2 and Road Dust) during different seasons indicate that Connaught Place-India Gate-ITO area is the most affected area from vehicular pollution point of view, and Road Dust-PM10 and NOx pose serious problem due to vehicular air pollution in Delhi. NOx concentrations are widely distributed as vehicular activities are prevalent in all the areas throughout Delhi.

- **Cumulative Impact:** Maximum GLC of PM (total of all sources) during summer, post-monsoon and winter is observed to be 260, 387 and 438 µg/m^3 respectively, occurring in Connaught Place-India Gate-ITO area. Very high PM concentration levels are due to the fact that contribution of road dust is also included in the total PM.

Very high NOx concentrations occur at specific locations such as Chandni Chowk-Chawri Bazar area (during summer) and in Mayur Vihar-Patparganj area (during post monsoon and winter). These high concentrations values are found to occur at limited number of places.

Iso-concentration plots drawn for total PM (as PM10), NOx and SO_2 for summer, post-monsoon and winter seasons indicate that concentration of PM is well distributed through out the Delhi, with higher levels confining to the area between ISBT and Ashram Chowk along the ring road area. A good spread of high levels of NOx (40 $\mu g/m^3$) can be seen in all the three seasons, but highest levels follow the trend of dispersion from point sources, mainly power plants. Similarly, spread of SO_2 is confined to a few grids which follow the dispersion pattern of power plants.

Influence of other emission sources beyond 2 km x 2 km study zones has also been predicted using the city level emission inventory and meteorological data from IMD. The model results indicate predicted PM concentrations are much lower than the measured average PM_{10} concentrations at all the sites. Model predicted PM_{10} values using city level emission inventory are found to be much higher as compared to 2 km x 2 km study zone predicted levels, almost at all the sites except at ISBT and SSI-GTK. City level inventory based model showed better closeness to the measured values as compared to the 2 km x 2 km emission inventory. This indicates the influence of activities beyond the study zone of 2 km x 2 km on predicted GLCs. Similar trend was observed for NOx, i.e. higher values were predicted from the city level emission inventory as compared to 2 km x 2 km study zone predicted values.

Model results for NOx indicate that among the six kerbside locations (as identified for air quality monitoring), only three sites, namely Ashram Chowk, Dhaula Kuan and ISBT, having high traffic activity represent kerbside location. At the other three locations namely Mayapuri, Loni Road and Anand Vihar, though the monitoring is done at kerbside/ roadside, the traffic density on the nearest road was observed to be much lower as compared to Ashram Chowk, Dhaula Kuan and ISBT, and therefore these three sites (Loni Road, Anand Vihar and Mayapuri) can be considered as mixed use activity zones.

Analysis of all the modeling results indicate the predominance of road dust re-suspension contributing to about 65% of the total PM emissions released from different sources. Vehicular sources are found to be the major contributor of NOx emissions followed by area sources and industrial sources. SO_2 is mainly contributed by power plants and its spread/dispersion is governed by the direction of wind.

It is important to note that though the vehicular sector contributes low PM10 emissions in comparison to crustal or resuspended dust, however, its prevalence is more uniform. Fine fraction of PM (< 2.5) is mainly contributed by vehicles and other combustion sources and the impact of these PM levels are expected to be significant.

Chapter 6

Future Projections and Evaluation of Control Options

6.1 Introduction

Delhi has multiple sources of air pollution such as vehicles, industries, DG sets, domestic burning, biomass-refuse burning and others. Some of the sources are not continuous and not at fixed location. Some of these are construction activities, road paving, repairing, demolition etc. The development of control options warrants that all the sources are understood and analyzed for their future growth. These estimates have also been made with control options. Business as usual scenarios have been generated for each source category based on major trends, which are likely to continue in the time frame of 5 & 10 years, viz. 2012 & 2017. Prominent sources under each category have been discussed with a view to describe the basis for projections.

6.2 Emission Load Projections under BAU (2012 & 2017) Scenarios

6.2.1 Emission Load Projections: Area Sources

Population Growth Projection

Based on the population growth trend from Census 2001, the projected population of Delhi in 2021 will be about 230 lakhs. Projected population for the years 2012 and 2017 and percent increase in population with respect to 2007 is given in **Table 6.1**

Table 6.1: Projected Population of Delhi

Year	Population, (Lakhs)	Increase (%)
2007	165.4	-
2012	190.5	15
2017	219.7	33
2021	230.0	39

Source: Registrar General of India

Due to the phenomenal increase in population, an increasing need for additional civic services, infrastructure and urban development is felt in Delhi. Delhi is also emerging as an international center of education, health care, tourism, sports and business, which warrant complimentary facilities such as hotels, restaurants, bakeries etc. catering to the needs of various economic groups. The forthcoming Commonwealth Games 2010 have added additional urgency to complete various infrastructural facilities in Delhi. Planning/ policy documents prepared by various departments were referred for making future emission projections.

Emission Load Projections for 2012 and 2017

Following assumptions have been made in order to estimate emissions under Business as usual (BAU) scenario for the year 2012 and 2017:

- Normal growth rate in population would result in proportionate increase in different sectors, as also in fuel consumption
- Projected population estimates of Census department for 2012 and 2017 have been used for estimation of emissions.
- Slum population growth in many clusters is as per the estimates made in Economic Survey of Delhi, 2007-08
- Population growth rate has been considered to project future emissions from domestic, hotels/ restaurants, bakeries, crematoria, generator sets and locomotives
- Per capita solid waste generation in Delhi has been used to estimate total biomedical waste generation and open burning
- Existing fuel consumption patterns under different area source categories are also applicable for estimating future emission loads
- Data on existing/continuing and proposed road/flyover and commercial building construction activities obtained from PWD and MCD was used to estimate emissions from construction activities for 2012 and 2017. Population growth rate is taken into account, while estimating emissions from residential building construction activities in 2012 and 2017, since no other data on the same was available.

Keeping in the view the above, pollutants (PM, SO_2 and NOx) emission loads in 2012 and 2017 under BAU scenario are estimated as given in **Table 6.2**

Table 6.2: Projected Pollutants Emission Load in 2012 & 2017

Sources	BAU Emissions 2012 (kg/d)			BAU Emissions 2017(kg/d)		
	PM10	SO_2	NOx	PM10	SO_2	NOx
Domestic	2241.9	397.5	4880.2	2584.6	458.3	5628.7
Domestic Slums	11408.1	793.2	1649.8	13158.8	914.9	1903.0
Hotels & Restaurants	1856.5	1142.6	1225.8	2134.0	1314.5	1412.3
Bakeries	137.5	1.6	10.3	158.6	1.8	11.9
Crematoria	1493.2	19.5	136.6	1722.3	22.5	157.6
Hospital Incinerators	30.6	42.3	30.8	36.5	75.7	43.3
Generator Sets	613.7	572.4	8678.4	706.5	658.9	9990.0
Open Burning	1.6	0.1	0.6	1.9	0.1	0.7
Construction	9554.7	-	-	7290.1	-	-
Locomotives	24.5	75.2	1034.2	28.3	86.8	1192.9
Total	**27362.3**	**3044.4**	**17646.9**	**27821.4**	**3533.6**	**20340.5**

Total emission load of PM, SO_2 and NOx from area sources in Delhi is estimated to be 27.36, 3.04 and 17.6 TPD in 2012 and 27.8, 3.53 and 20.34 TPD in 2017, respectively. Percentage increase in projected emissions from existing level of emissions of various pollutants is shown in **Fig. 6.1**

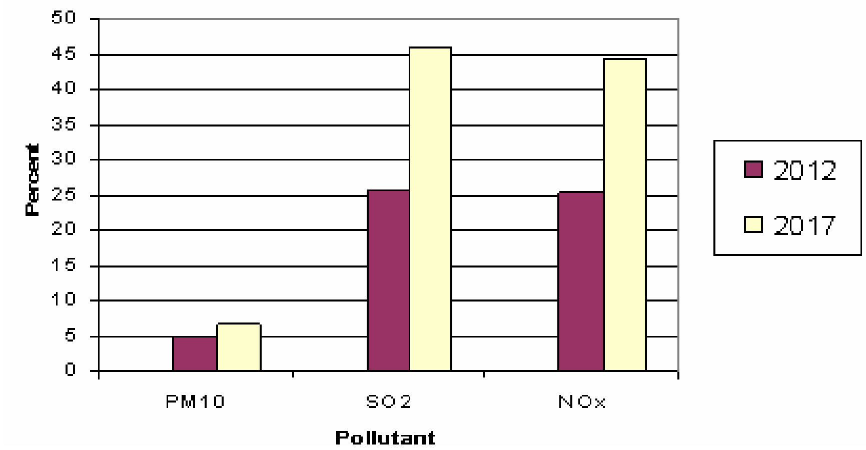
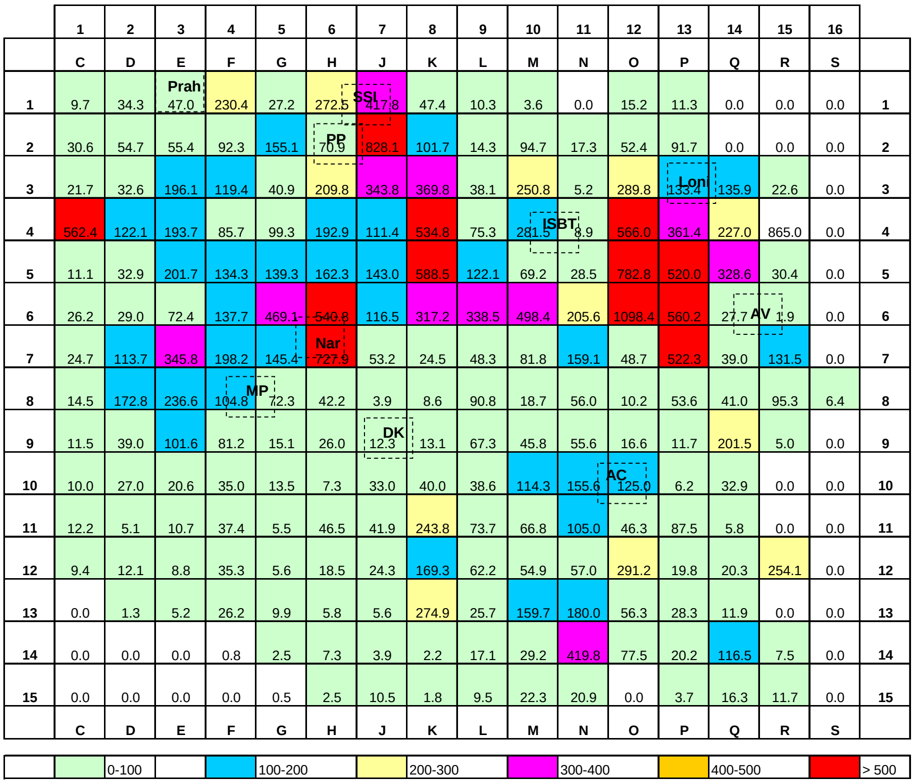


Fig. 6.1: Percentage Increase in Area Source Emissions in Delhi: BAU Scenario 2012 & 2017 compared to 2007

It is evident from the above figure that the increase in the gaseous pollutants by 2012 and 2017 is higher as compared to the particulate emissions. By 2012, an increase of about 4.9% is estimated in PM load, whereas the increase in SO_2 and NOx emissions are expected to be 25.9% and 25.3% respectively. By 2017, the increase would be about 6.7% in the case of PM, whereas increase in SO_2 and NOx could be up to 46.1% and 44.4% respectively. Grid wise emission loads in terms of PM, SO_2 and NOx in Delhi by 2012 and 2017 are presented in **Figs. 6.2** to **6.7**

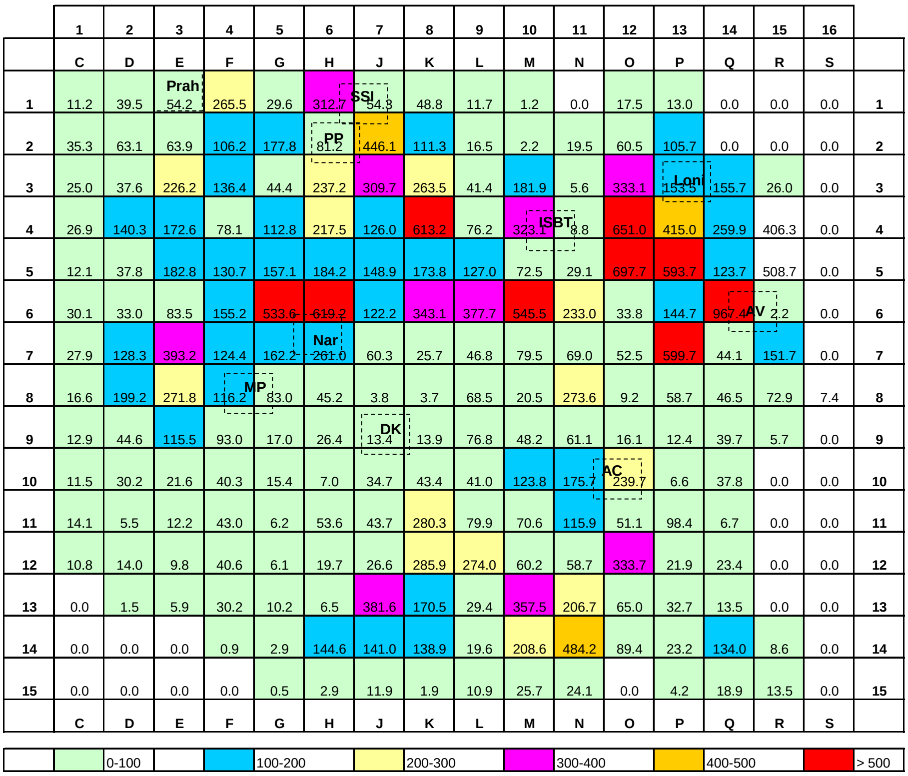


	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1	9.7	34.3	Prah 47.0	230.4	27.2	272.5	SSI 417.8	47.4	10.3	3.6	0.0	15.2	11.3	0.0	0.0	0.0	1
2	30.6	54.7	55.4	92.3	155.1	PP 70.9	828.1	101.7	14.3	94.7	17.3	52.4	91.7	0.0	0.0	0.0	2
3	21.7	32.6	196.1	119.4	40.9	209.8	343.8	369.8	38.1	250.8	5.2	289.8	Loni 133.4	135.9	22.6	0.0	3
4	562.4	122.1	193.7	85.7	99.3	192.9	111.4	534.8	75.3	ISBT 281.5	8.9	566.0	361.4	227.0	865.0	0.0	4
5	11.1	32.9	201.7	134.3	139.3	162.3	143.0	588.5	122.1	69.2	28.5	782.8	520.0	328.6	30.4	0.0	5
6	26.2	29.0	72.4	137.7	469.1	540.8	116.5	317.2	338.5	498.4	205.6	1098.4	560.2	AV 27.7	1.9	0.0	6
7	24.7	113.7	345.8	198.2	145.4	Nar 727.9	53.2	24.5	48.3	81.8	159.1	48.7	522.3	39.0	131.5	0.0	7
8	14.5	172.8	236.6	MP 104.8	72.3	42.2	3.9	8.6	90.8	18.7	56.0	10.2	53.6	41.0	95.3	6.4	8
9	11.5	39.0	101.6	81.2	15.1	26.0	DK 12.3	13.1	67.3	45.8	55.6	16.6	11.7	201.5	5.0	0.0	9
10	10.0	27.0	20.6	35.0	13.5	7.3	33.0	40.0	38.6	114.3	155.6	AC 125.0	6.2	32.9	0.0	0.0	10
11	12.2	5.1	10.7	37.4	5.5	46.5	41.9	243.8	73.7	66.8	105.0	46.3	87.5	5.8	0.0	0.0	11
12	9.4	12.1	8.8	35.3	5.6	18.5	24.3	169.3	62.2	54.9	57.0	291.2	19.8	20.3	254.1	0.0	12
13	0.0	1.3	5.2	26.2	9.9	5.8	5.6	274.9	25.7	159.7	180.0	56.3	28.3	11.9	0.0	0.0	13
14	0.0	0.0	0.0	0.8	2.5	7.3	3.9	2.2	17.1	29.2	419.8	77.5	20.2	116.5	7.5	0.0	14
15	0.0	0.0	0.0	0.0	0.5	2.5	10.5	1.8	9.5	22.3	20.9	0.0	3.7	16.3	11.7	0.0	15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

	🟩	0-100		🟦	100-200	🟨	200-300	🟪	300-400	🟧	400-500	🟥	> 500

Locations of sampling stations are marked in dotted lines in all figures

Fig. 6.2: Grid-wise Area Source PM10 Emission Load (kg/d): BAU Scenario 2012

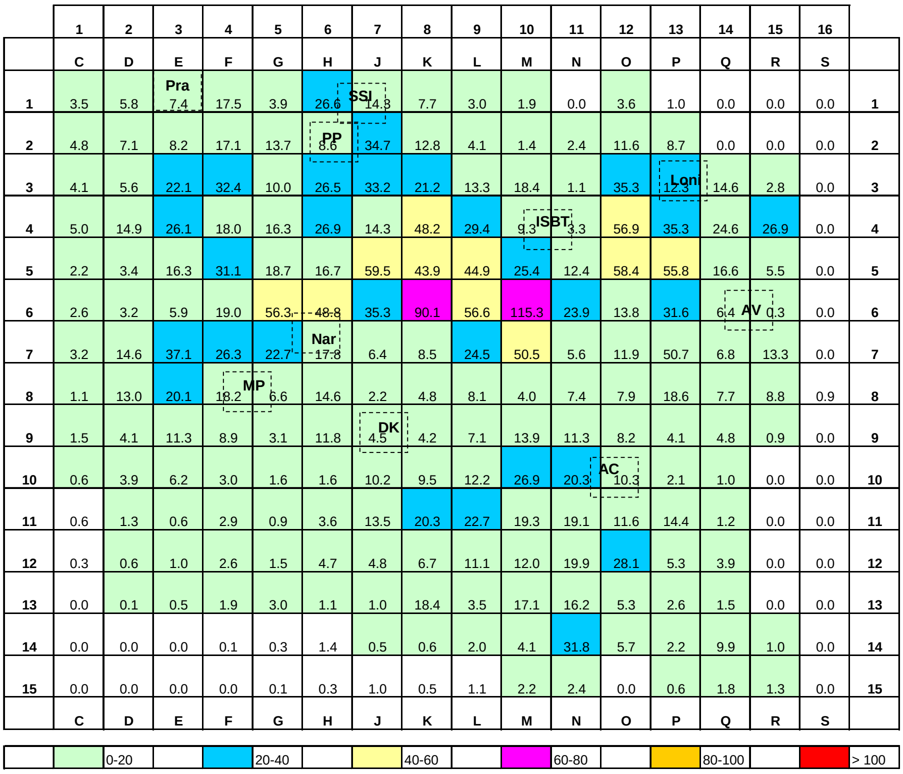


	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1	11.2	39.5	Prah 54.2	265.5	29.6	312.7	SSI 54.3	48.8	11.7	1.2	0.0	17.5	13.0	0.0	0.0	0.0	1
2	35.3	63.1	63.9	106.2	177.8	PP 81.2	446.1	111.3	16.5	2.2	19.5	60.5	105.7	0.0	0.0	0.0	2
3	25.0	37.6	226.2	136.4	44.4	237.2	309.7	263.5	41.4	181.9	5.6	333.1	Loni 153.5	155.7	26.0	0.0	3
4	26.9	140.3	172.6	78.1	112.8	217.5	126.0	613.2	76.2	323.1	ISBT 8.8	651.0	415.0	259.9	406.3	0.0	4
5	12.1	37.8	182.8	130.7	157.1	184.2	148.9	173.8	127.0	72.5	29.1	697.7	593.7	123.7	508.7	0.0	5
6	30.1	33.0	83.5	155.2	533.6	619.2	122.2	343.1	377.7	545.5	233.0	33.8	144.7	967.4	AV 2.2	0.0	6
7	27.9	128.3	393.2	124.4	162.2	Nar 261.0	60.3	25.7	46.8	79.5	69.0	52.5	599.7	44.1	151.7	0.0	7
8	16.6	199.2	271.8	116.2	MP 83.0	45.2	3.8	3.7	68.5	20.5	273.6	9.2	58.7	46.5	72.9	7.4	8
9	12.9	44.6	115.5	93.0	17.0	26.4	DK 13.4	13.9	76.8	48.2	61.1	16.1	12.4	39.7	5.7	0.0	9
10	11.5	30.2	21.6	40.3	15.4	7.0	34.7	43.4	41.0	123.8	175.7	AC 239.7	6.6	37.8	0.0	0.0	10
11	14.1	5.5	12.2	43.0	6.2	53.6	43.7	280.3	79.9	70.6	115.9	51.1	98.4	6.7	0.0	0.0	11
12	10.8	14.0	9.8	40.6	6.1	19.7	26.6	285.9	274.0	60.2	58.7	333.7	21.9	23.4	0.0	0.0	12
13	0.0	1.5	5.9	30.2	10.2	6.5	381.6	170.5	29.4	357.5	206.7	65.0	32.7	13.5	0.0	0.0	13
14	0.0	0.0	0.0	0.9	2.9	144.6	141.0	138.9	19.6	208.6	484.2	89.4	23.2	134.0	8.6	0.0	14
15	0.0	0.0	0.0	0.0	0.5	2.9	11.9	1.9	10.9	25.7	24.1	0.0	4.2	18.9	13.5	0.0	15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

	🟩	0-100		🟦	100-200		🟨	200-300		🟪	300-400		🟧	400-500		🟥	> 500

Locations of sampling stations are marked in dotted lines in all figures

Fig. 6. 3: Grid-wise Area Source PM10 Emission Load (kg/d): BAU Scenario 2017

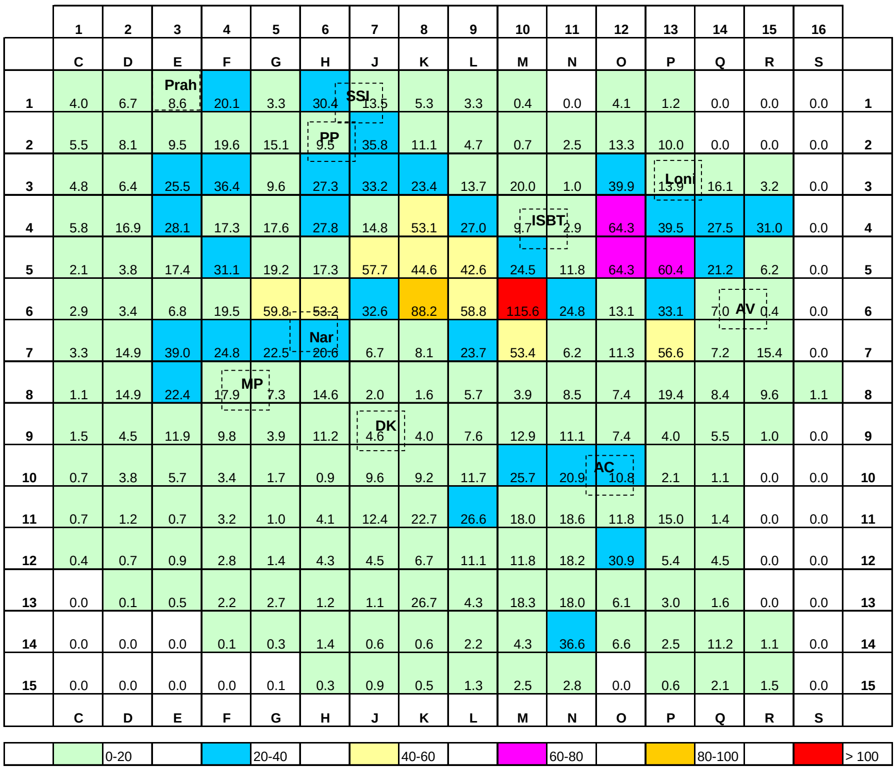


	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1	3.5	5.8	Pra 7.4	17.5	3.9	26.6	SSI 14.3	7.7	3.0	1.9	0.0	3.6	1.0	0.0	0.0	0.0	1
2	4.8	7.1	8.2	17.1	13.7	PP 8.6	34.7	12.8	4.1	1.4	2.4	11.6	8.7	0.0	0.0	0.0	2
3	4.1	5.6	22.1	32.4	10.0	26.5	33.2	21.2	13.3	18.4	1.1	35.3	Loni 12.3	14.6	2.8	0.0	3
4	5.0	14.9	26.1	18.0	16.3	26.9	14.3	48.2	29.4	9.3	ISBT 3.3	56.9	35.3	24.6	26.9	0.0	4
5	2.2	3.4	16.3	31.1	18.7	16.7	59.5	43.9	44.9	25.4	12.4	58.4	55.8	16.6	5.5	0.0	5
6	2.6	3.2	5.9	19.0	56.3	48.8	35.3	90.1	56.6	115.3	23.9	13.8	31.6	6.4	AV 0.3	0.0	6
7	3.2	14.6	37.1	26.3	22.7	Nar 17.8	6.4	8.5	24.5	50.5	5.6	11.9	50.7	6.8	13.3	0.0	7
8	1.1	13.0	20.1	18.2	MP 6.6	14.6	2.2	4.8	8.1	4.0	7.4	7.9	18.6	7.7	8.8	0.9	8
9	1.5	4.1	11.3	8.9	3.1	11.8	DK 4.5	4.2	7.1	13.9	11.3	8.2	4.1	4.8	0.9	0.0	9
10	0.6	3.9	6.2	3.0	1.6	1.6	10.2	9.5	12.2	26.9	20.3	AC 10.3	2.1	1.0	0.0	0.0	10
11	0.6	1.3	0.6	2.9	0.9	3.6	13.5	20.3	22.7	19.3	19.1	11.6	14.4	1.2	0.0	0.0	11
12	0.3	0.6	1.0	2.6	1.5	4.7	4.8	6.7	11.1	12.0	19.9	28.1	5.3	3.9	0.0	0.0	12
13	0.0	0.1	0.5	1.9	3.0	1.1	1.0	18.4	3.5	17.1	16.2	5.3	2.6	1.5	0.0	0.0	13
14	0.0	0.0	0.0	0.1	0.3	1.4	0.5	0.6	2.0	4.1	31.8	5.7	2.2	9.9	1.0	0.0	14
15	0.0	0.0	0.0	0.0	0.1	0.3	1.0	0.5	1.1	2.2	2.4	0.0	0.6	1.8	1.3	0.0	15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

	🟩	0-20		🟦	20-40		🟨	40-60		🟪	60-80		🟧	80-100		🟥	> 100

Locations of sampling stations are marked in dotted lines in all figures

Fig. 6. 4: Grid-wise Area Source SO_2 Emission Load (kg/d): BAU Scenario 2012

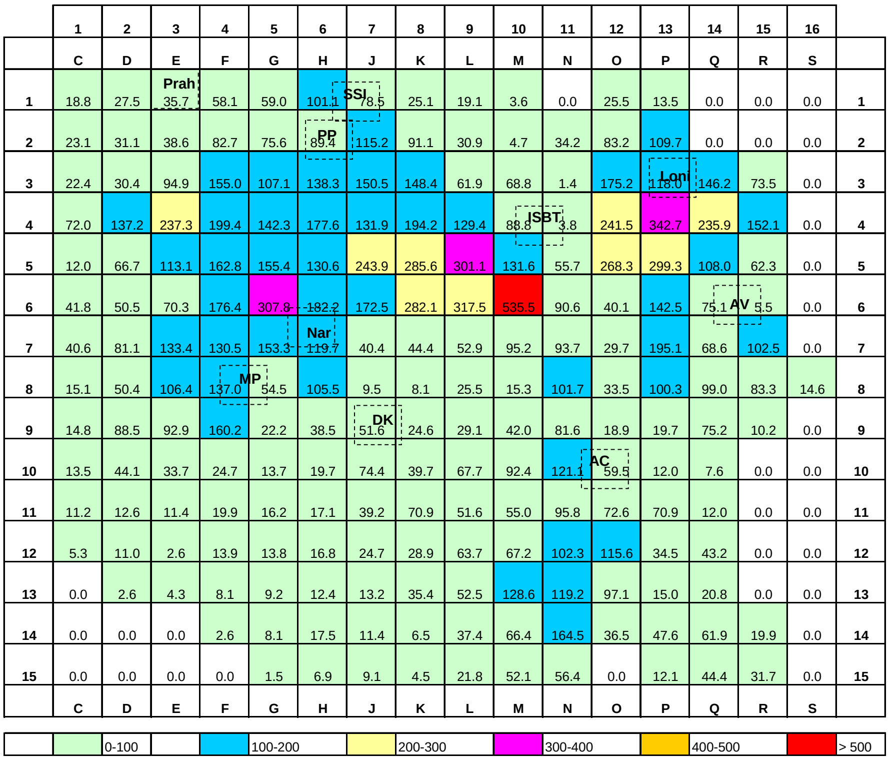


	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1	4.0	6.7	8.6	20.1	3.3	30.4	13.5	5.3	3.3	0.4	0.0	4.1	1.2	0.0	0.0	0.0	1
2	5.5	8.1	9.5	19.6	15.1	9.5	35.8	11.1	4.7	0.7	2.5	13.3	10.0	0.0	0.0	0.0	2
3	4.8	6.4	25.5	36.4	9.6	27.3	33.2	23.4	13.7	20.0	1.0	39.9	13.9	16.1	3.2	0.0	3
4	5.8	16.9	28.1	17.3	17.6	27.8	14.8	53.1	27.0	9.7	2.9	64.3	39.5	27.5	31.0	0.0	4
5	2.1	3.8	17.4	31.1	19.2	17.3	57.7	44.6	42.6	24.5	11.8	64.3	60.4	21.2	6.2	0.0	5
6	2.9	3.4	6.8	19.5	59.8	53.2	32.6	88.2	58.8	115.6	24.8	13.1	33.1	7.0	0.4	0.0	6
7	3.3	14.9	39.0	24.8	22.5	20.6	6.7	8.1	23.7	53.4	6.2	11.3	56.6	7.2	15.4	0.0	7
8	1.1	14.9	22.4	17.9	7.3	14.6	2.0	1.6	5.7	3.9	8.5	7.4	19.4	8.4	9.6	1.1	8
9	1.5	4.5	11.9	9.8	3.9	11.2	4.6	4.0	7.6	12.9	11.1	7.4	4.0	5.5	1.0	0.0	9
10	0.7	3.8	5.7	3.4	1.7	0.9	9.6	9.2	11.7	25.7	20.9	10.8	2.1	1.1	0.0	0.0	10
11	0.7	1.2	0.7	3.2	1.0	4.1	12.4	22.7	26.6	18.0	18.6	11.8	15.0	1.4	0.0	0.0	11
12	0.4	0.7	0.9	2.8	1.4	4.3	4.5	6.7	11.1	11.8	18.2	30.9	5.4	4.5	0.0	0.0	12
13	0.0	0.1	0.5	2.2	2.7	1.2	1.1	26.7	4.3	18.3	18.0	6.1	3.0	1.6	0.0	0.0	13
14	0.0	0.0	0.0	0.1	0.3	1.4	0.6	0.6	2.2	4.3	36.6	6.6	2.5	11.2	1.1	0.0	14
15	0.0	0.0	0.0	0.0	0.1	0.3	0.9	0.5	1.3	2.5	2.8	0.0	0.6	2.1	1.5	0.0	15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

	🟩	0-20		🟦	20-40		🟨	40-60		🟪	60-80		🟧	80-100	🟥	> 100

Locations of sampling stations are marked in dotted lines in all figures

Fig. 6. 5: Grid-wise Area Source SO_2 Emission Load (kg/d): BAU Scenario 2017

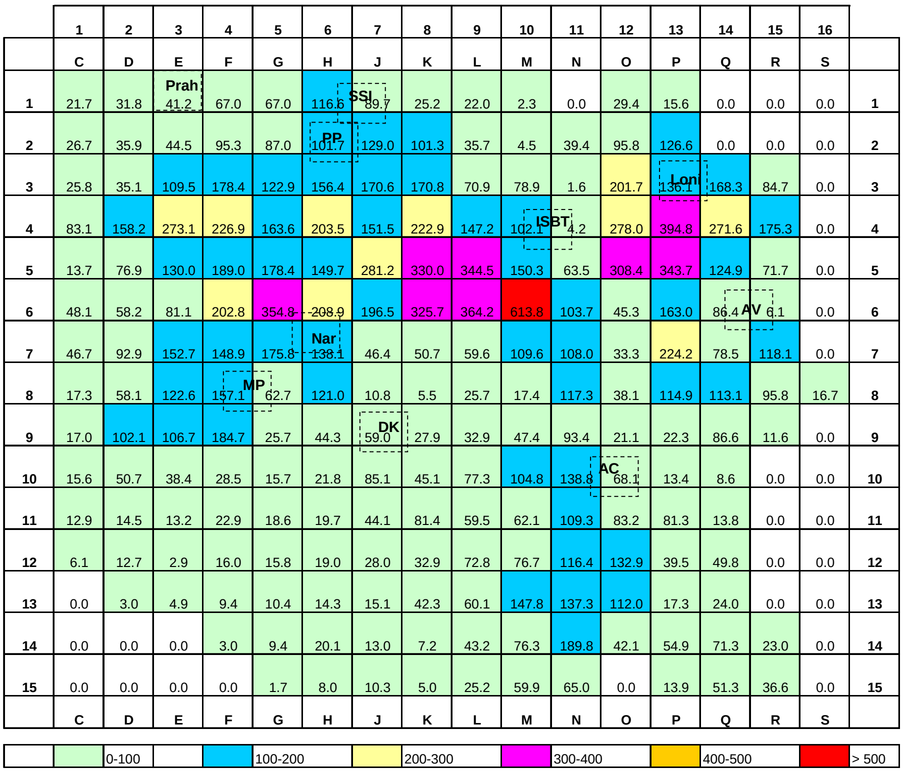


	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1	18.8	27.5	35.7	58.1	59.0	101.1	78.5	25.1	19.1	3.6	0.0	25.5	13.5	0.0	0.0	0.0	1
2	23.1	31.1	38.6	82.7	75.6	89.4	115.2	91.1	30.9	4.7	34.2	83.2	109.7	0.0	0.0	0.0	2
3	22.4	30.4	94.9	155.0	107.1	138.3	150.5	148.4	61.9	68.8	1.4	175.2	118.0	146.2	73.5	0.0	3
4	72.0	137.2	237.3	199.4	142.3	177.6	131.9	194.2	129.4	88.8	3.8	241.5	342.7	235.9	152.1	0.0	4
5	12.0	66.7	113.1	162.8	155.4	130.6	243.9	285.6	301.1	131.6	55.7	268.3	299.3	108.0	62.3	0.0	5
6	41.8	50.5	70.3	176.4	307.8	182.2	172.5	282.1	317.5	535.5	90.6	40.1	142.5	75.1	5.5	0.0	6
7	40.6	81.1	133.4	130.5	153.3	119.7	40.4	44.4	52.9	95.2	93.7	29.7	195.1	68.6	102.5	0.0	7
8	15.1	50.4	106.4	137.0	54.5	105.5	9.5	8.1	25.5	15.3	101.7	33.5	100.3	99.0	83.3	14.6	8
9	14.8	88.5	92.9	160.2	22.2	38.5	51.6	24.6	29.1	42.0	81.6	18.9	19.7	75.2	10.2	0.0	9
10	13.5	44.1	33.7	24.7	13.7	19.7	74.4	39.7	67.7	92.4	121.1	59.5	12.0	7.6	0.0	0.0	10
11	11.2	12.6	11.4	19.9	16.2	17.1	39.2	70.9	51.6	55.0	95.8	72.6	70.9	12.0	0.0	0.0	11
12	5.3	11.0	2.6	13.9	13.8	16.8	24.7	28.9	63.7	67.2	102.3	115.6	34.5	43.2	0.0	0.0	12
13	0.0	2.6	4.3	8.1	9.2	12.4	13.2	35.4	52.5	128.6	119.2	97.1	15.0	20.8	0.0	0.0	13
14	0.0	0.0	0.0	2.6	8.1	17.5	11.4	6.5	37.4	66.4	164.5	36.5	47.6	61.9	19.9	0.0	14
15	0.0	0.0	0.0	0.0	1.5	6.9	9.1	4.5	21.8	52.1	56.4	0.0	12.1	44.4	31.7	0.0	15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

	🟩	0-100		🟦	100-200	🟨	200-300	🟪	300-400	🟧	400-500	🟥	> 500

Locations of sampling stations are marked in dotted lines in all figures

Fig. 6.6: Grid-wise Area Source NOx Emission Load (kg/d): BAU Scenario 2012



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1	21.7	31.8	41.2	67.0	67.0	116.6	89.7	25.2	22.0	2.3	0.0	29.4	15.6	0.0	0.0	0.0	1
2	26.7	35.9	44.5	95.3	87.0	101.7	129.0	101.3	35.7	4.5	39.4	95.8	126.6	0.0	0.0	0.0	2
3	25.8	35.1	109.5	178.4	122.9	156.4	170.6	170.8	70.9	78.9	1.6	201.7	136.1	168.3	84.7	0.0	3
4	83.1	158.2	273.1	226.9	163.6	203.5	151.5	222.9	147.2	102.1	4.2	278.0	394.8	271.6	175.3	0.0	4
5	13.7	76.9	130.0	189.0	178.4	149.7	281.2	330.0	344.5	150.3	63.5	308.4	343.7	124.9	71.7	0.0	5
6	48.1	58.2	81.1	202.8	354.8	208.9	196.5	325.7	364.2	613.8	103.7	45.3	163.0	86.4	6.1	0.0	6
7	46.7	92.9	152.7	148.9	175.8	138.1	46.4	50.7	59.6	109.6	108.0	33.3	224.2	78.5	118.1	0.0	7
8	17.3	58.1	122.6	157.1	62.7	121.0	10.8	5.5	25.7	17.4	117.3	38.1	114.9	113.1	95.8	16.7	8
9	17.0	102.1	106.7	184.7	25.7	44.3	59.0	27.9	32.9	47.4	93.4	21.1	22.3	86.6	11.6	0.0	9
10	15.6	50.7	38.4	28.5	15.7	21.8	85.1	45.1	77.3	104.8	138.8	68.1	13.4	8.6	0.0	0.0	10
11	12.9	14.5	13.2	22.9	18.6	19.7	44.1	81.4	59.5	62.1	109.3	83.2	81.3	13.8	0.0	0.0	11
12	6.1	12.7	2.9	16.0	15.8	19.0	28.0	32.9	72.8	76.7	116.4	132.9	39.5	49.8	0.0	0.0	12
13	0.0	3.0	4.9	9.4	10.4	14.3	15.1	42.3	60.1	147.8	137.3	112.0	17.3	24.0	0.0	0.0	13
14	0.0	0.0	0.0	3.0	9.4	20.1	13.0	7.2	43.2	76.3	189.8	42.1	54.9	71.3	23.0	0.0	14
15	0.0	0.0	0.0	0.0	1.7	8.0	10.3	5.0	25.2	59.9	65.0	0.0	13.9	51.3	36.6	0.0	15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

	🟩	0-100		🟦	100-200		🟨	200-300		🟪	300-400		🟧	400-500	🟥	> 500

Locations of sampling stations are marked in dotted lines in all figures

Fig. 6.7: Grid-wise Area Source NOx Emission Load (kg/d): BAU Scenario 2017

6.2.2 Emission Load Projections: Industrial Sources

Emission Load Projections for 2012 and 2017

In order to estimate future emissions under Business As Usual (BAU) scenario in the year 2012 and 2017 following assumptions are made.

- The present total availability of power in Delhi is 3170 MW including its own installed generation capacity of 994.5 MW. Availability of power from Badarpur TPS is 705 MW. Remaining requirement of power is met through Central Sector sources. As reported in NCR Planning Report-2001, Central Electricity Authority (CEA) has projected a peak load requirement of 5836 MW and 7865 MW in 2012 and 2017 respectively. In order to meet this additional demand in Delhi, the projects under consideration by Delhi Government are: Pragati-II: 330 MW Gas based power plant, Pragati-III: 1500 MW Gas based power project at Bawana, and 1500 MW & 750 MW gas based power projects at Bamnauili in South West Delhi area. Emissions from these power plants are considered under the 2017 BAU scenario. Consumption of natural gas is estimated based on calorific value basis.
- No further growth of air polluting (small and medium scale) Industries in 2012 and 2017 is assumed as per MPD (Master Plan of Delhi) Document.

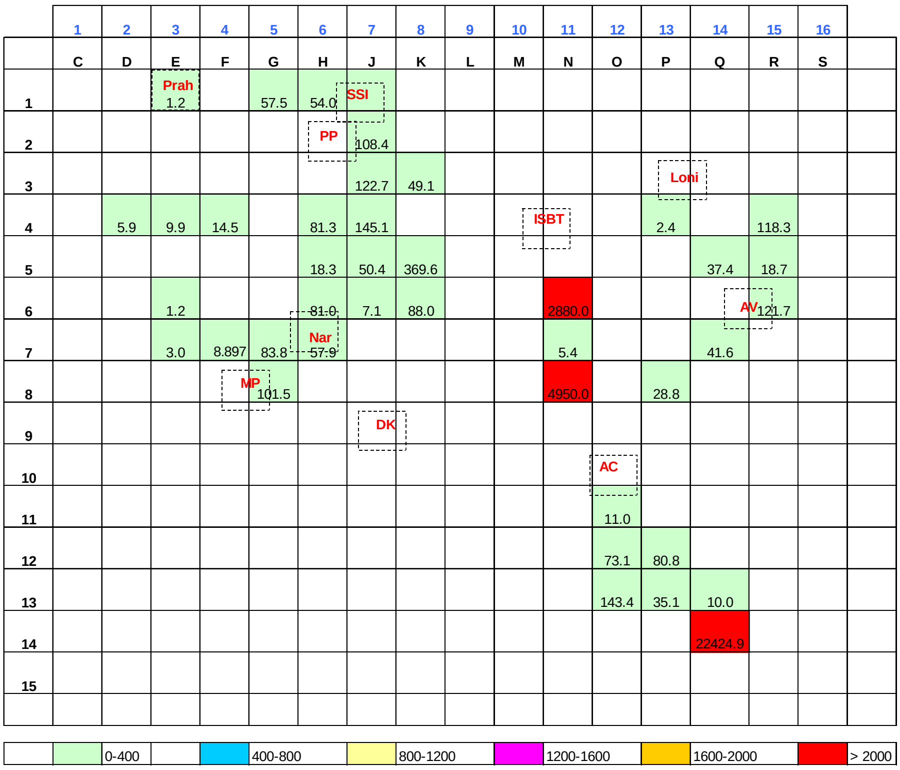
Keeping in view the above, pollutants (PM, SO_2 and NOx) emission load in 2012 and 2017 under BAU scenario for 2012 and 2017 are estimated, as given in **Table 6.3.**

Table 6.3: Projected Pollutants Emission Load in 2012 and 2017

Type of Industries	**Emission Load 2012, (Kg/d)**			**Emission Load 2017, (Kg/d)**		
	PM10	**SO_2**	**NOx**	**PM10**	**SO_2**	**NOx**
Large Scale	30245.4	255446.2	335462.4	30257.9	255644.2	427880.7
Medium Scale	145.2	4523.1	185.8	145.2	4523.1	185.8
Small Scale	2087.	4429.5	24877.3	2087.9	4429.5	24877.3
Total	**32478.6**	**264398.9**	**360525.6**	**32491.2**	**264597**	**452944**

Total point source emission loads of PM, SO_2 and NOx are estimated to be 32.5, 264.4 and 360.5 TPD in 2012 and 32.5, 264.6 and 452.9 TPD in 2017 respectively.

It can be observed that in 2012 and 2017 PM and SO_2 emissions can be maintained at the 2007 emissions level as load from gas power plants will add negligible PM and SO_2. NOx emissions remain constant till 2012, but could increase by about 25.4% by 2017. Grid wise emission loads estimated in terms of PM, SO_2 and NOx in Delhi city for 2012 and 2017 from industrial sources are presented in **Figs. 6.8** to **6.13.**

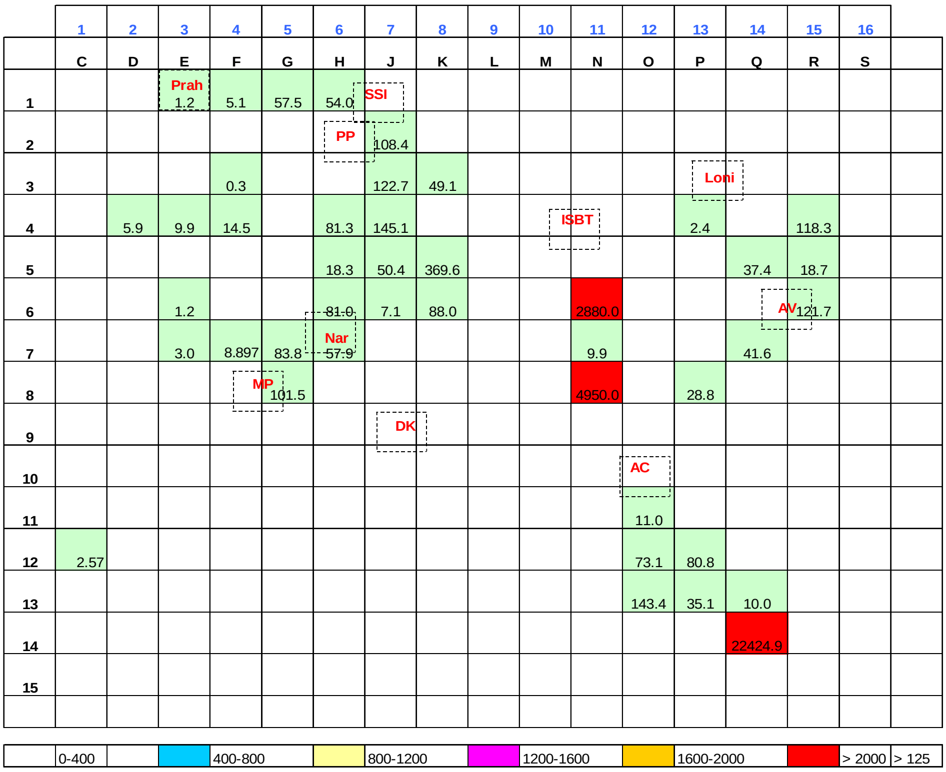


	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S
1			1.2		57.5	54.0										
2							108.4									
3							122.7	49.1								
4		5.9	9.9	14.5		81.3	145.1						2.4		118.3	
5						18.3	50.4	369.6						37.4	18.7	
6			1.2			81.0	7.1	88.0			2880.0				121.7	
7			3.0	8.897	83.8	57.9					5.4			41.6		
8					101.5						4950.0		28.8			
9																
10																
11												11.0				
12												73.1	80.8			
13												143.4	35.1	10.0		
14														22424.9		
15																

🟩 0-400	🟦 400-800	🟨 800-1200	🟪 1200-1600	🟧 1600-2000	🟥 > 2000

Locations of sampling stations are marked in dotted lines in all figures

Fig. 6.8 : Grid-wise Industrial Source PM10 Emission Load (kg/d): 2012

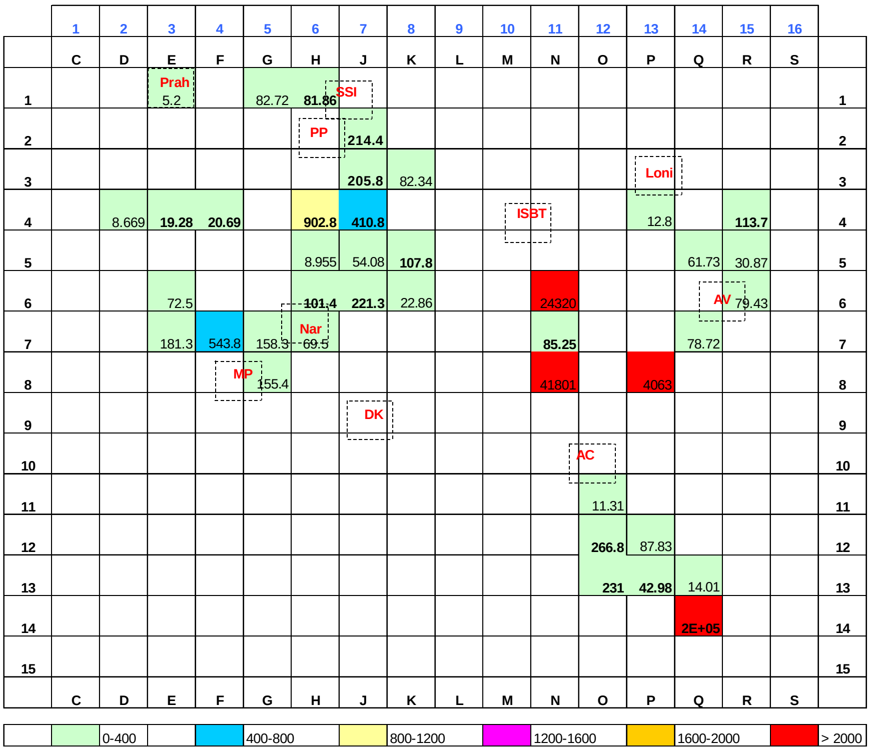


	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S
1			1.2	5.1	57.5	54.0										
2							108.4									
3				0.3			122.7	49.1								
4		5.9	9.9	14.5		81.3	145.1						2.4		118.3	
5						18.3	50.4	369.6						37.4	18.7	
6			1.2			81.0	7.1	88.0			2880.0				121.7	
7			3.0	8.897	83.8	57.9					9.9			41.6		
8					101.5						4950.0		28.8			
9																
10																
11												11.0				
12	2.57											73.1	80.8			
13												143.4	35.1	10.0		
14														22424.9		
15																

⬜ 0-400 | 🟦 400-800 | 🟨 800-1200 | 🟪 1200-1600 | 🟧 1600-2000 | 🟥 > 2000 | > 125

Locations of sampling stations are marked in dotted lines in all figures

Fig. 6.9 : Grid-wise Industrial Source PM10 Emission Load (kg/d): 2017

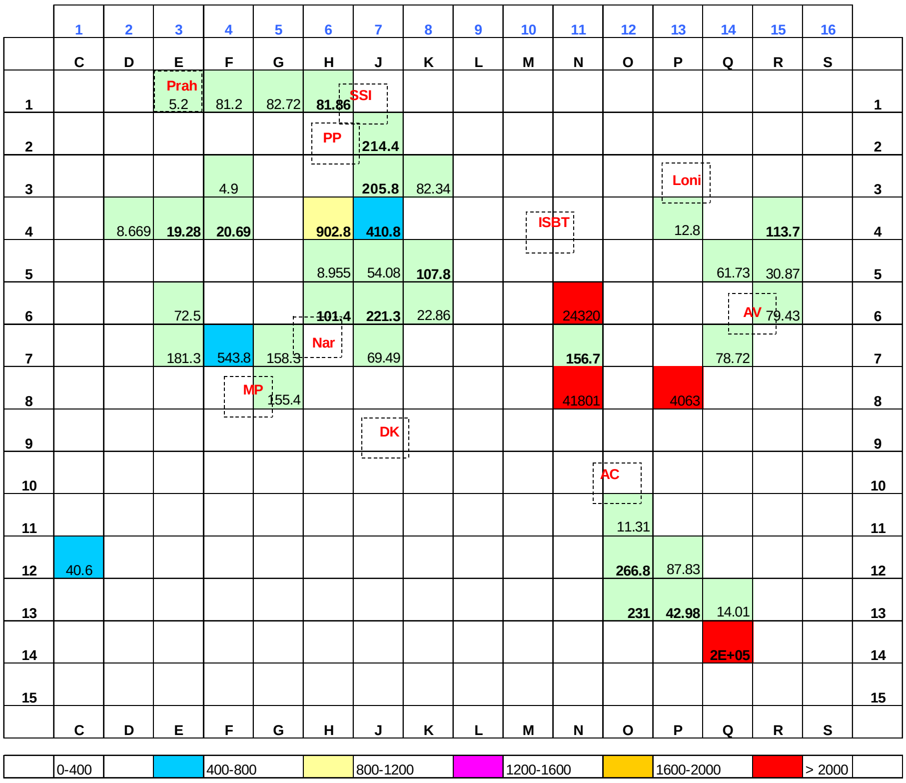


	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1			5.2		82.72	**81.86**											1
2							**214.4**										2
3							**205.8**	82.34									3
4		8.669	**19.28**	**20.69**		**902.8**	**410.8**						12.8		**113.7**		4
5						8.955	54.08	**107.8**						61.73	30.87		5
6			72.5			**101.4**	**221.3**	22.86			24320				79.43		6
7			181.3	543.8	158.3	69.5					**85.25**			78.72			7
8					155.4						41801		4063				8
9																	9
10																	10
11												11.31					11
12												**266.8**	87.83				12
13												**231**	**42.98**	14.01			13
14														**2E+05**			14
15																	15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

🟩 0-400 | 🟦 400-800 | 🟨 800-1200 | 🟪 1200-1600 | 🟧 1600-2000 | 🟥 > 2000

Locations of sampling stations are marked in dotted lines in all figures

Fig. 6.10: Grid-wise Industrial Source SO_2 Emission Load (kg/d): 2012

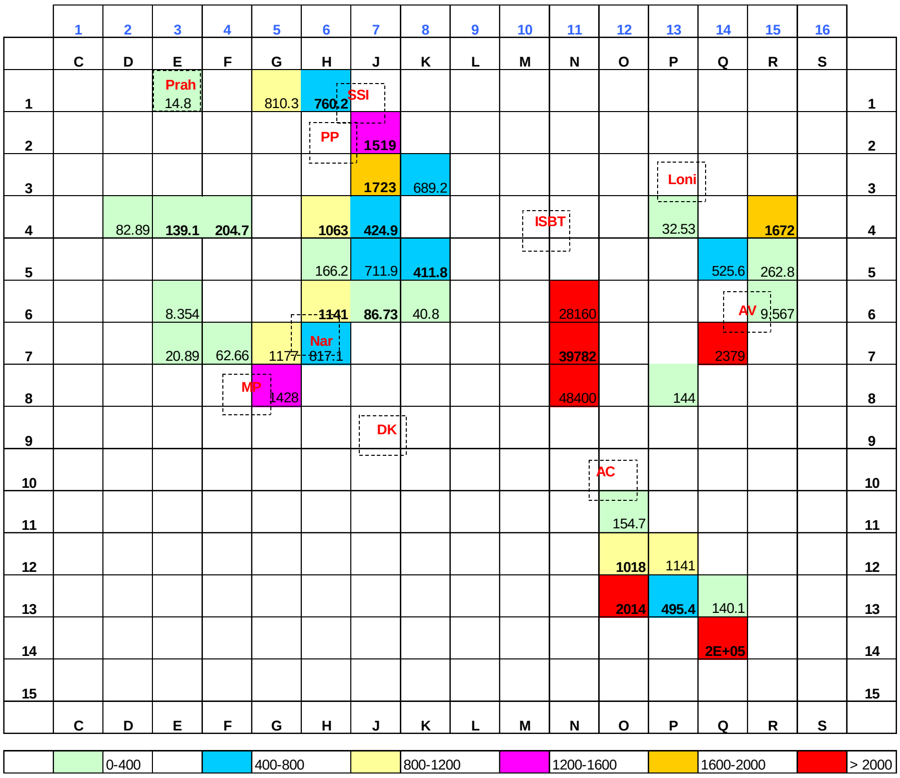


	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1			Prah 5.2	81.2	82.72	81.86	SSI										1
2						PP	214.4										2
3				4.9			205.8	82.34					Loni				3
4		8.669	19.28	20.69		902.8	410.8			ISBT			12.8		113.7		4
5						8.955	54.08	107.8						61.73	30.87		5
6			72.5			101.4	221.3	22.86			24320			AV	79.43		6
7			181.3	543.8	158.3	Nar	69.49				156.7			78.72			7
8				MP	155.4						41801		4063				8
9							DK										9
10												AC					10
11												11.31					11
12	40.6											266.8	87.83				12
13												231	42.98	14.01			13
14														2E+05			14
15																	15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

🟩 0-400 🟦 400-800 🟨 800-1200 🟪 1200-1600 🟧 1600-2000 🟥 > 2000

Locations of sampling stations are marked in dotted lines in all figures

Fig. 6.11 : Grid-wise Industrial Source SO_2 Emission Load (kg/d): 2017

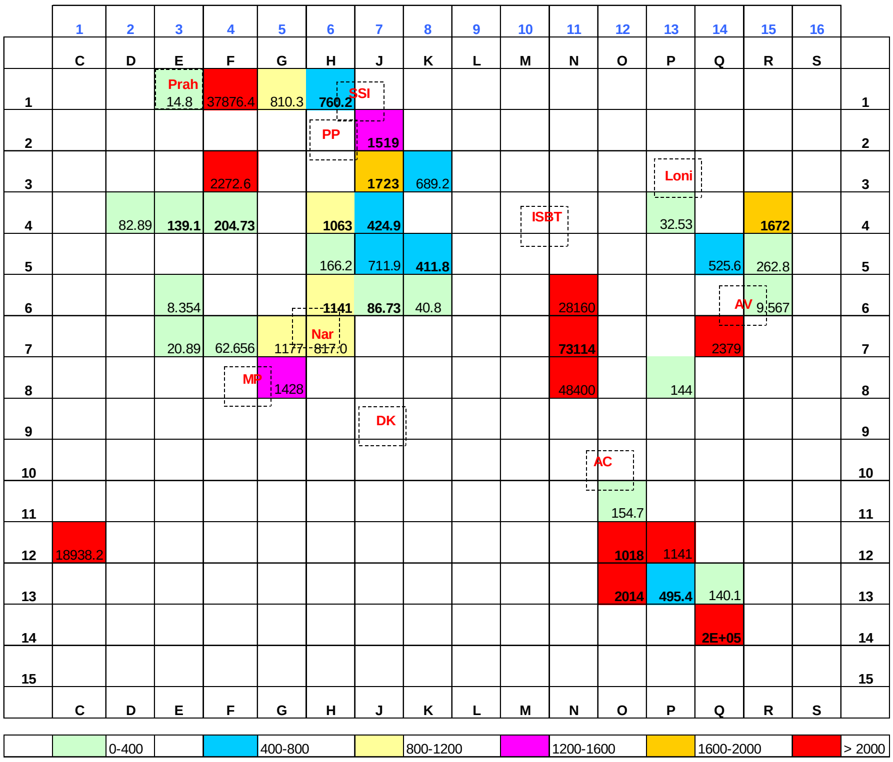


	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1			Prah 14.8		810.3	760.2	SSI										1
2						PP	1519										2
3							1723	689.2					Loni				3
4		82.89	139.1	204.7		1063	424.9			ISBT			32.53		1672		4
5						166.2	711.9	411.8						525.6	262.8		5
6			8.354			1141	86.73	40.8			28160			AV	9.567		6
7			20.89	62.66	1177	Nar 817.1					39782			2379			7
8				MP	1428						48400		144				8
9							DK										9
10												AC					10
11												154.7					11
12												1018	1141				12
13												2014	495.4	140.1			13
14														2E+05			14
15																	15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

🟩 0-400 🟦 400-800 🟨 800-1200 🟪 1200-1600 🟧 1600-2000 🟥 > 2000

Locations of sampling stations are marked in dotted lines in all figures

Fig. 6.12 : Grid-wise Industrial Source NOx Emission Load (kg/d): 2012



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1			14.8	37876.4	810.3	760.2											1
2							1519										2
3				2272.6			1723	689.2									3
4		82.89	139.1	204.73		1063	424.9						32.53		1672		4
5						166.2	711.9	411.8						525.6	262.8		5
6			8.354			1141	86.73	40.8			28160				9.567		6
7			20.89	62.656	1177	817.0					73114			2379			7
8					1428						48400		144				8
9																	9
10																	10
11												154.7					11
12	18938.2											1018	1141				12
13												2014	495.4	140.1			13
14														2E+05			14
15																	15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

🟩	0-400	🟦	400-800	🟨	800-1200	🟪	1200-1600	🟧	1600-2000	🟥	> 2000

Locations of sampling stations are marked in dotted lines in all figures

Fig. 6.13 : Grid-wise Industrial NOx Source Emission Load (kg/d): 2017

6.2.3 Emission Load Projections: Vehicular Sources and Road Dust Re-suspension

Vehicle Growth Projections

Data relating to different categories of vehicles registered in Delhi was collected from the Transport Department, Delhi and analyzed broadly under eight categories of vehicles, viz. 2 Wheelers, 3 Wheelers, 4 Wheelers (Passenger Cars and Taxi/Cabs etc.), Light Commercial Vehicles (LCVs), Trucks, Buses and Miscellaneous Vehicles. In 2002, the total population of vehicles in Delhi was about 36.87 lakhs, which increased to 52.16 lakhs in 2007. The total numbers of registered vehicles under different categories as on March 31 in 2002 and 2007, along with percentage increase during 2002-2007 are given in **Table 6.4**

Table 6.4 : Total Registered Vehicles in Delhi: 2002 and 2007

Vehicle Category	Number of Vehicles Registered		Percentage Increase during 2002-2007
	2002	**2007**	
2 Wheelers (All types)	2350489	3317659	41.15
3 Wheelers	70410	75603	7.38
4 Wheelers (Passenger Cars)	1093145	1601699	46.52
4 Wheelers (Taxi, Cabs etc.)	13459	25509	89.53
Light Commercial Vehicles (LCVs)	55296	82158	48.58
Trucks	60476	59065	-2.33
Buses (Diesel & CNG)	34064	43539	27.82
Miscellaneous	10119	10531	4.07
Total	**3687458**	**5215763**	**40.89**

During the last 5 years (2002-2007), population of 2 and 4-wheelers increased by 41.15% and 46.5% respectively. Highest growth was witnessed in the Taxi category which grew by 89.5% in 5 years. Trucks recorded a marginal decline of 2.3%. The number of vehicles (all categories) increased by about 41%. The above vehicle categories have been further classified into sub-categories such as: 2 Wheelers as 2 Stroke and 4 Stroke, 4 Wheelers (Passenger Cars) as petrol and diesel vehicles, and Buses as Diesel & CNG.

The growth rates have been taken on the basis of growth rate witnessed and rounded off. Trucks growth rate is slightly negative, however based on the growth rate of buses; it is likely that its growth will follow the similar trend as population growth will necessary take growth of trucks as well. Based on the above growth rate witnessed in last five years (2002-2007) as also considering the possibility of some normalization in growth, projections in vehicle population for 2012 and 2017 have been made as given in **Table 6.5**

Table 6.5: Projected growth of Different Categories of Vehicle in 2002 and 2007

Vehicle Category	Growth rate	2012	2017
2 Wheelers	50%	4976488	7464732
3 Wheelers	10%	83163	91480
4 Wheelers (Pass Cars)	50%	2402548	3603823
4 Wheelers (Taxi, cabs)	100%	51018	102036
Light Commercial Vehicles (LCVs)	50%	123237	184856
Trucks	30%	76785	99820
Buses and others	30%	56600	73581

Emission Load Projection for 2012 and 2017

Estimation of total emission load was first carried out for the 2 km x 2 km ten study zones using the same vehicular growth rate. It was extrapolated to whole of the city adopting the approach presented in earlier chapter on emission inventory. The projected total emission load in terms of different pollutants (PM, CO, HC, NOx and SO_2) and re-suspended road dust (PM10 and PM2.5) by 2012 and 2017, along with the present loads (2007) and % increase in emission loads are summarized in **Table 6.6**. Percentage increase in emission load by 2012 and 2017 is depicted in **Fig. 6.14.**

Table 6.6: Baseline and Projected Emission Loads: Vehicular and Road Dust

Pollutant	**Emission Load, (kg/d)**			**Remarks**
	2007 Baseline Status	**2012 BAU Scenario**	**2017 BAU Scenario**	• it is assumed that fuels levels would continue to be at current levels • the current fuel and emissions standards would continue
Vehicular Emissions				
PM	9747	12587	15425	
CO	217791	277069	336207	
HC	66741	85686	104608	
NOx	84194	111124	138096	
SO_2	722	1057	1393	
Road Dust Re-suspension				
PM10	77275	102246	127637	

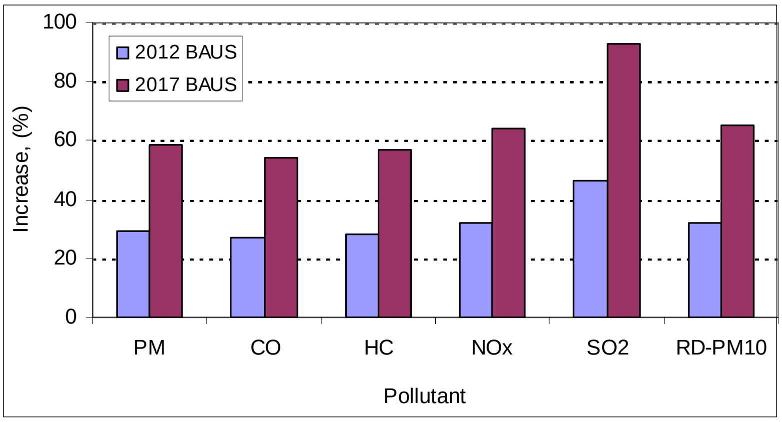


Fig. 6.14: Percentage Increase in Emission Loads (Vehicular & Road Dust): 2012 and 2017

Emission load estimation under BAU scenarios indicate that by 2012, an increase of about 29%, 27%, 28% and 32% in PM, CO, HC and NOx respectively will take place when compared to 2007 levels. Increase in SO_2 could be about 46.5%. By 2017, the increase could be about 58%, 54%, 47% and 64% for PM, CO, HC and NOx, respectively. Though in SO_2 emission percentage increase is higher, its total load is lowest amongst other pollutants. Increase in road dust re-suspension is estimated to be 32.3% by 2012 and 65.2% by 2017.

6.3 Air Quality Projections under BAU (2012 & 2017) Scenario

Impact of area, industrial, vehicular sources and road dust re-suspension are estimated separately and cumulatively under business as usual scenario for the years 2012 and 2017. Dispersion modeling for PM, SO_2 and NOx and modeling exercises have been carried out under different meteorological scenario for different seasons. Meteorological data sets considered predicting the impacts for the year 2012 and 2017is the one used for baseline 2007 model runs. First ten highest 24 hourly concentrations (GLCs) of PM, SO_2 and NOx are tabulated along with the point of its occurrences for each model run are given in **Annexure 6.1**. Iso-concentration plots are drawn for each pollutant during each season.

6.3.1 Model Results – Occurrence of Maximum GLCs in the city and at Ten sites

Pollutant and season-wise predicted maximum GLCs and their occurrence in 2012 and 2017 is summarized for area, industrial & vehicular sources (including road dust re-suspension) along with the cumulative impact of all the sources in **Tables 6.7** through **6.10** respectively. The GLCs at the ten locations are also given in subsequent **Tables 6.11 through 6.16** for critical season of winter.

Table 6.7: Pollutant and Season-wise Predicted MGLC$_S$ and their Occurrence in 2012 and 2017: BAU Scenario – Area Sources

Pollutant/ Year	Summer		Post Monsoon		Winter	
	MGLCs (µg/m^3)	Area of MGLC Occurrence	MGLCs (µg/m^3)	Area of MGLC Occurrence	MGLCs (µg/m^3)	Area of MGLC Occurrence
PM						
2012	91.6	SSI-GTK and Gaonri (near Bhajanpura)	138	Shastri Nagar (near Geeta Colony)	143	Shastri Nagar (near Geeta Colony)
2017	73.3	SSI-GTK and Gaonri (near Bhajanpura)	132.3	Anand Vihar	146	Patparganj Industrial area
SO$_2$						
2012	4.7	Sadar bazar	9.4	Ajmeri gate	10.4	Turkman Gate area
2017	5.5	Sadar bazar	11.0	Ajmeri gate	12.1	Turkman Gate area
NOx						
2012	32.1	Sultanpuri	58	Sitaram bazar	65.4	Turkman Gate area
2017	37.1	Sultanpuri	67.5	Sitaram bazar	75.6	Turkman Gate area

Table 6.8 : Pollutant and Season-wise Predicted MGLC$_S$ and their Occurrence in 2012 and 2017: BAU Scenario – Industrial Sources

Pollutant/ Year	Summer		Post Monsoon		Winter	
	MGLCs (µg/m^3)	Area of MGLC Occurrence	MGLCs (µg/m^3)	Area of MGLC Occurrence	MGLCs (µg/m^3)	Area of MGLC Occurrence
PM						
2012	38.3	Paharganj area	37.1	Patparganj Industrial area	71.1	Patparganj Industrial area
2017	38.3		37.1		71.1	
SO$_2$						
2012	360	Patparganj area	292	Patparganj area	510	Patparganj area
2017	360		292		511	
NOx						
2012	618	Paharganj and Patparganj area	605	Paharganj and Patparganj area	1153	Paharganj and Patparganj area
2017	794		796		1505	

Table 6.9 : Pollutant and Season-wise Predicted MGLC$_S$ and their Occurrence in 2012 and 2017: BAU Scenario – Vehicular Sources

Pollutant/ Year	Summer		Post Monsoon		Winter	
	MGLCs (µg/m^3)	Area of MGLC Occurrence	MGLCs (µg/m^3)	Area of MGLC Occurrence	MGLCs (µg/m^3)	Area of MGLC Occurrence
PM						
2012	35	Connaught Place –India Gate -ITO area	52	Connaught Place –India Gate -ITO area	58	Connaught Place –India Gate -ITO area
2017	43		63		71	
SO$_2$						
2012	3.1	Connaught Place –India Gate -ITO area	4.5	Connaught Place –India Gate -ITO area	5.1	Connaught Place –India Gate -ITO area
2017	4.0		5.9		6.7	
NOx						
2012	279	Connaught Place –India Gate -ITO area	409	Connaught Place –India Gate -ITO area	461	Connaught Place –India Gate -ITO area
2017	344		504		556	
RD-PM10						
2012	279	Connaught Place –India Gate -ITO area	424	Connaught Place –India Gate -ITO area	476	Connaught Place –India Gate -ITO area
2017	345		524		590	

Table 6.10 : Pollutant and Season-wise Predicted MGLC$_S$ and their Occurrence in 2012 and 2017: BAU Scenario – Cumulative Impact of All Sources

Pollutant/ Year	Summer		Post Monsoon		Winter	
	MGLCs (μg/m^3)	Area of MGLC Occurrence	MGLCs (μg/m^3)	Area of MGLC Occurrence	MGLCs (μg/m^3)	Area of MGLC Occurrence
PM*						
2012	319	Connaught Place –India Gate area	499	Connaught Place –India Gate area	564	Connaught Place –India Gate area
2017	398		611		690	
SO$_2$						
2012	361	Pandav nagar-Ganesh nagar	296	Naya Bans (River Belt)	515	ISBT- Sarai Kalekhan area
2017	362	Mayur Vihar (River Belt)	297	Mayur Vihar (River Belt)	517	ISBT- Sarai Kalekhan
NOx						
2012	770	Paharganj	776	ISBT	1342	ISBT
2017	975	Paharganj	1012	Naya Bans (River Belt)	1732	ISBT- Sarai Kalekhan area

- includes RD-PM10

Table 6.11: Predicted Particulate Matter Concentrations (μg/m^3) at ten AQM sites in Delhi : 2007 (Winter)

AQM Location	Point	Area	Line	Road Dust	Total
Ashram Chowk	0.8	60.9	22.6	164	**248.3**
Dhaula Kuan	0.3	18.3	13.9	104	**136.5**
Mayapuri	0.02	26.4	5	57	**88.42**
ISBT	0.3	23.4	23.4	194	**241.1**
Loni Road	0	29.8	4.1	84	**117.9**
Anand vihar	0.4	49.1	6.9	82	**138.4**
Naraina	0.4	85.4	8.5	61	**155.3**
SSI-GTK	0	18.3	4.9	67	**90.2**
Pitampura	0.1	27.7	5.9	73	**106.7**
Prahladpur	0	4.9	1.2	27	**33.1**

Table 6.12: Predicted Particulate Matter Concentrations (μg/m3) at ten AQM sites in Delhi : 2012 (Winter)

AQM Location	Point	Area	Line	Road Dust	Total
Ashram Chowk	0.8	34.7	29	215	**279.5**
Dhaula Kuan	0.3	21.6	17.8	135	**174.7**
Mayapuri	0.02	30.8	6.5	75	**112.32**
ISBT	0.3	51.1	30.1	254	**335.5**
Loni Road	0	24.4	5.3	110	**139.7**
Anand vihar	0.4	46.6	8.9	109	**164.9**
Naraina	0.4	95.4	11	81	**187.8**
SSI-GTK	0	23	6.3	89	**118.3**
Pitampura	0.1	17.6	7.7	98	**123.4**
Prahladpur	0	6	1.6	37	**44.6**

Table 6.13 : Predicted Particulate Matter Concentrations (µg/m^3) at ten AQM sites in Delhi : 2017 (Winter)

AQM Location	Point	Area	Line	Road Dust	Total
Ashram Chowk	0.9	46.6	35.4	267	**349.9**
Dhaula Kuan	0.3	21	21.7	168	**211**
Mayapuri	0.03	30.3	8.8	93	**132.13**
ISBT	0.3	52	36.8	315	**404.1**
Loni Road	0	26.3	6.5	136	**168.8**
Anand vihar	0.5	90.3	10.9	136	**237.7**
Naraina	0.5	64.2	13.5	102	**180.2**
SSI-GTK	0	2.8	7.7	111	**121.5**
Pitampura	0.1	20.3	9.4	123	**152.8**
Prahladpur	0.1	6.9	2	48	**57**

Table 6.14: Predicted NO_2Concentrations (µg/m^3) at ten AQM sites in Delhi : 2007 (Winter)

AQM Location	Point	Area	Line	Total
Ashram Chowk	4.6	14.2	197	**215.6**
Dhaula Kuan	4.4	13.3	128	**145.4**
Mayapuri	0.2	13.6	49	**62.8**
ISBT	4.4	10.7	179	**193.8**
Loni Road	0	10.6	32	**42.4**
Anand vihar	0.9	13.1	61	**75.2**
Naraina	6.4	20.9	78	**105.6**
SSI-GTK	0	2.9	36	**39.2**
Pitampura	1.8	7.6	44	**53.6**
Prahladpur	0.09	2	12	**14.19**

Table 6.15 : Predicted NO_2Concentrations (µg/m^3) at ten AQM sites in Delhi : 2012(Winter))

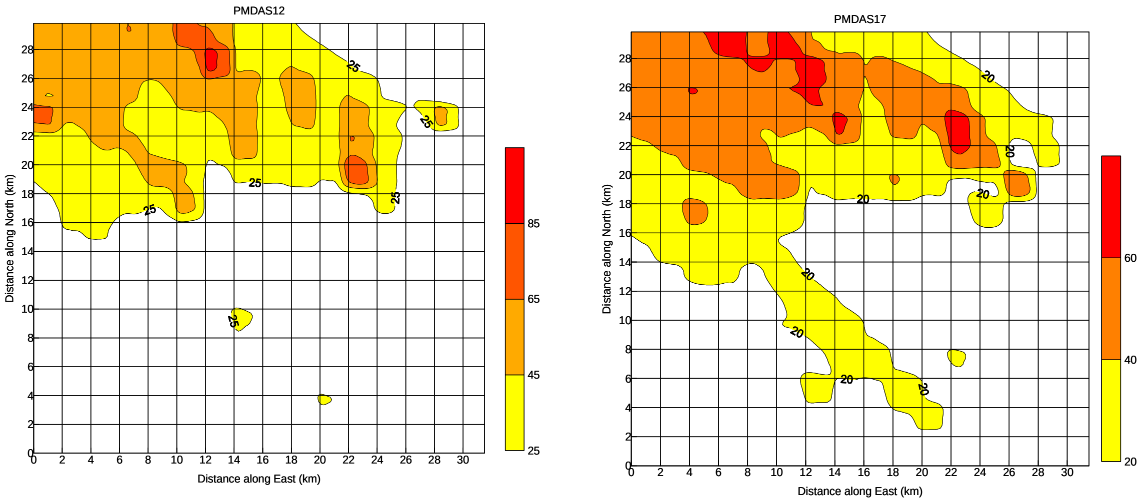
AQM Location	Point	Area	Line	Total
Ashram Chowk	4.6	16.7	266	**287.3**
Dhaula Kuan	4.4	15.6	172	**192**
Mayapuri	0.2	15.8	68	**84**
ISBT	4.4	15.9	239	**259.3**
Loni Road	0.05	12.3	44	**56.3**
Anand vihar	0.9	15.3	83	**99.2**
Naraina	6.4	24.6	107	**138**
SSI-GTK	0.05	3.3	49	**52.3**
Pitampura	1.8	9	60	**70.8**
Prahladpur	0.09	2.4	17	**19.49**

Table 6.16 : Predicted NO_2Concentrations (µg/m^3) at ten AQM sites in Delhi : 2017 (Winter)

AQM Location	Point	Area	Line	Total
Ashram Chowk	75	19.3	320	**413.8**
Dhaula Kuan	4.5	18	207	**229.7**
Mayapuri	0.2	18.2	83	**101.2**
ISBT	23.1	17.1	286	**326**
Loni Road	0.05	14.2	55	**68.7**
Anand vihar	17.1	17.6	101	**135.4**
Naraina	6.6	28.4	129	**163.6**
SSI-GTK	0.01	3.9	59	**62.51**
Pitampura	41.3	10.3	73	**124.5**
Prahladpur	0.1	2.8	21	**23.5**

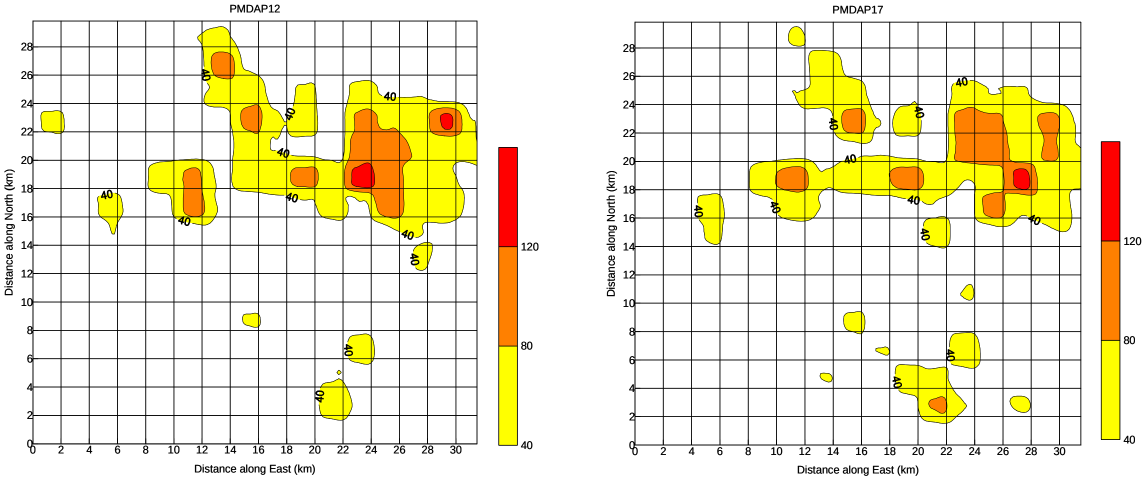
6.3.2 Model Results - Iso-concentration Plots

Iso-concentration plots for PM, NOx and SO_2 during summer, post-monsoon and winter seasons in 2012 and 2017 are presented respectively for area, industrial and vehicular (including road dust re-suspension) along with cumulative impact of all the sources in **Figs.6.15** through **6.27.** These results have been used to derive highest concentrations at ten grids within the city. Also, predicted values have been obtained for all the ten sites.



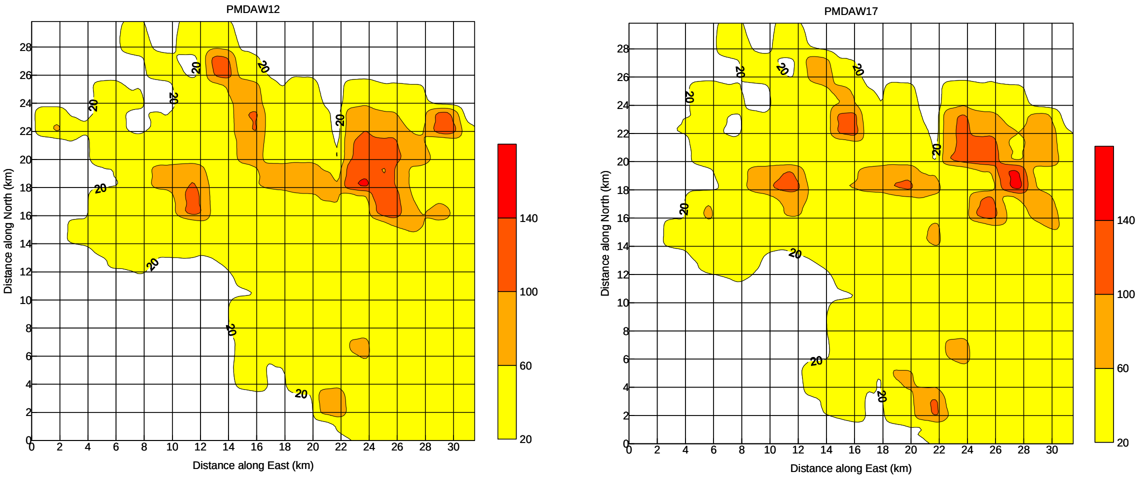
Summer 2012

Summer 2017



Post Monsoon 2012

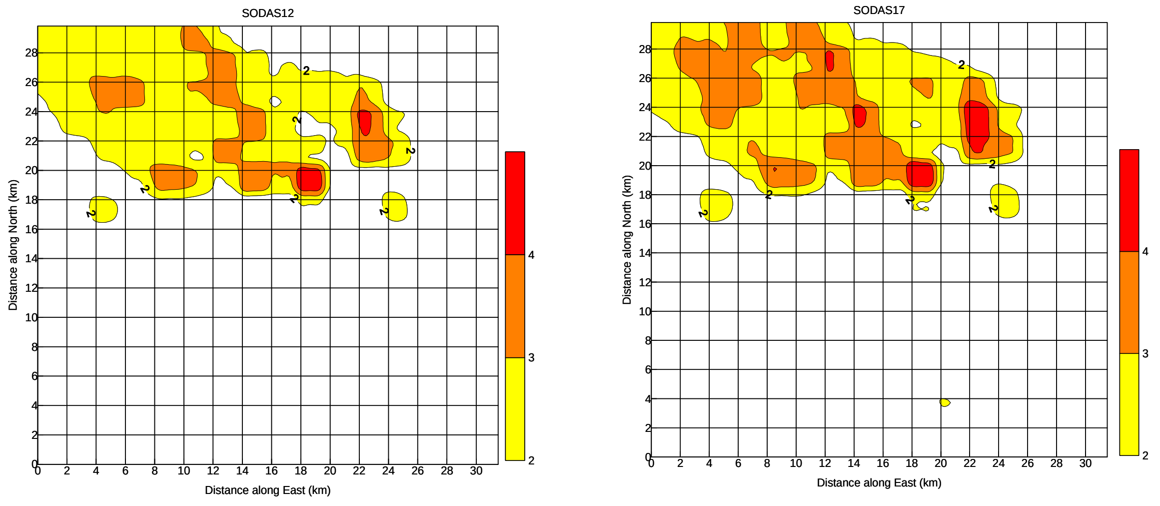
Post Monsoon 2017



Winter 2012

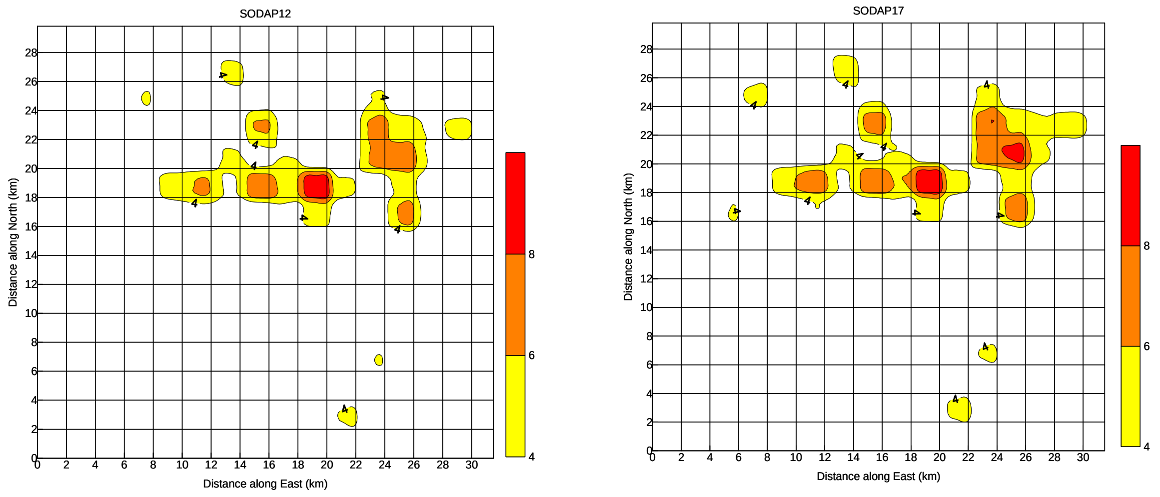
Winter 2017

Fig. 6.15: Predicted Iso-concentration Plots for PM: 2012 & 2017 BAU Scenarios – Area Sources



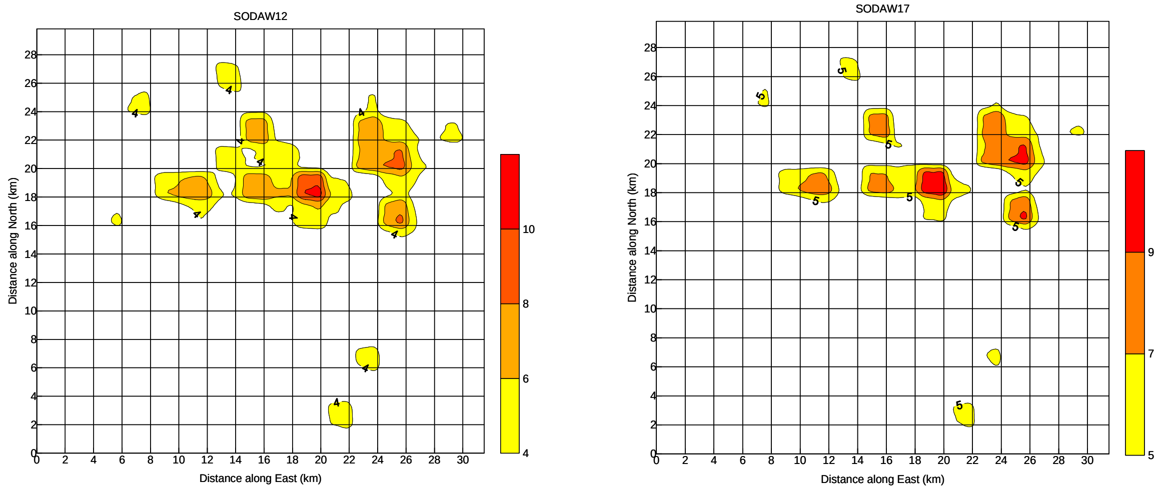
Summer 2012

Summer 2017



Post Monsoon 2012

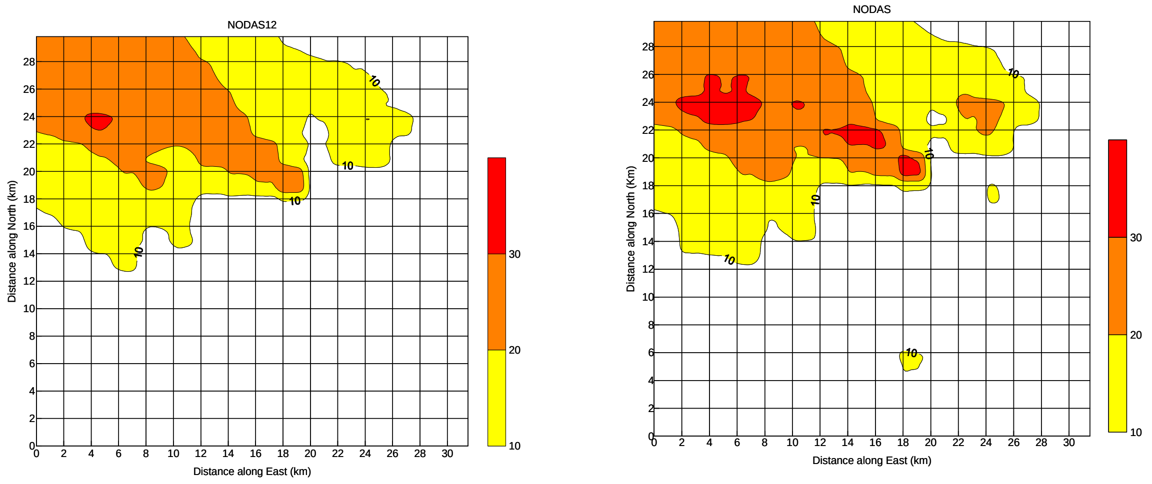
Post Monsoon 2017



Winter 2012

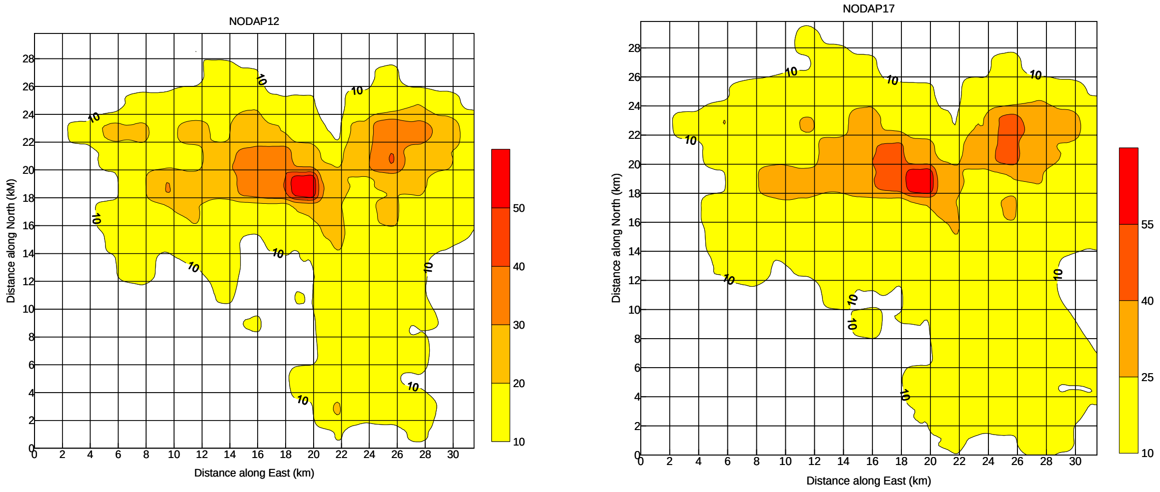
Winter 2017

Fig. 6.16: Predicted Iso-concentration Plots for SO_2: 2012 & 2017 BAU Scenarios – Area Sources



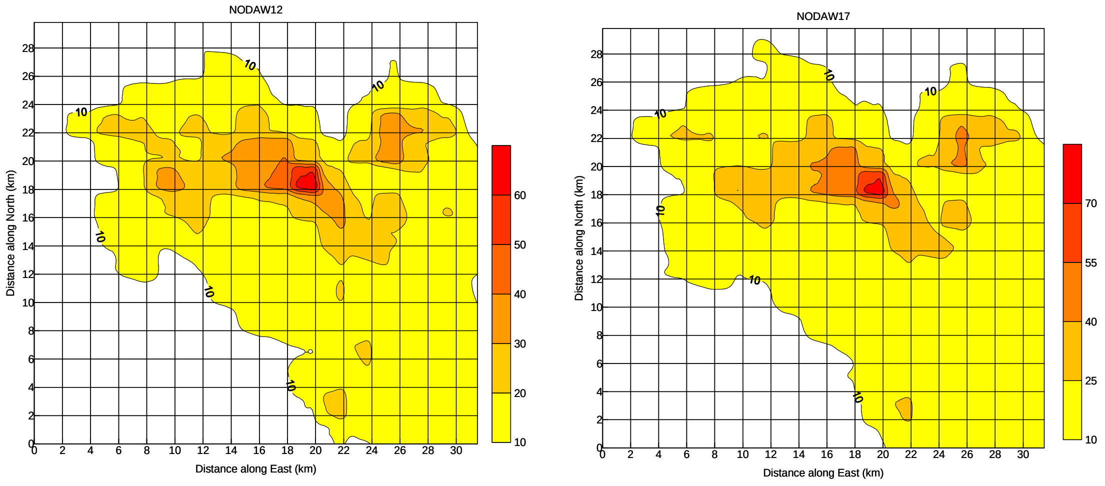
Summer 2012

Summer 2017



Post Monsoon 2012

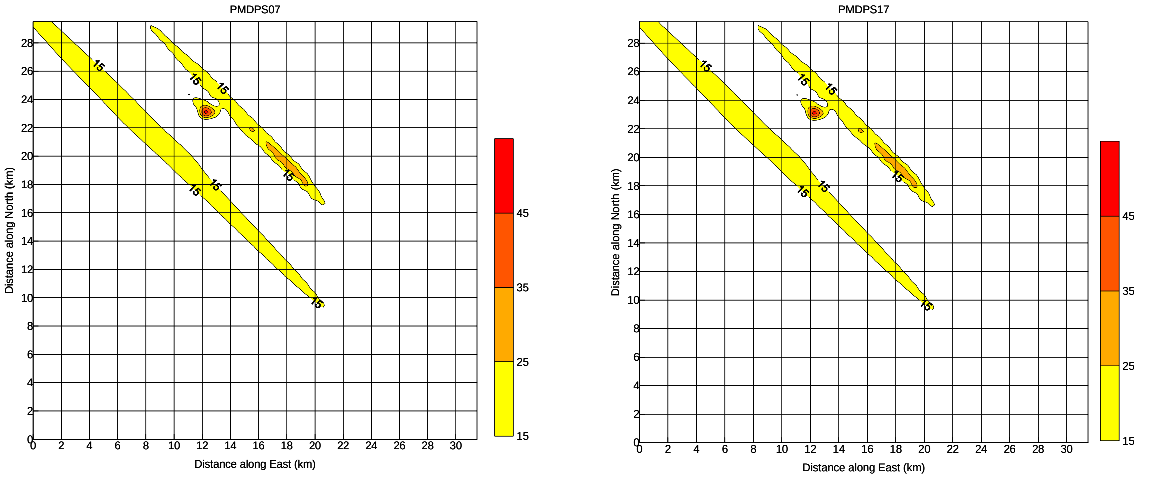
Post Monsoon 2017



Winter 2012

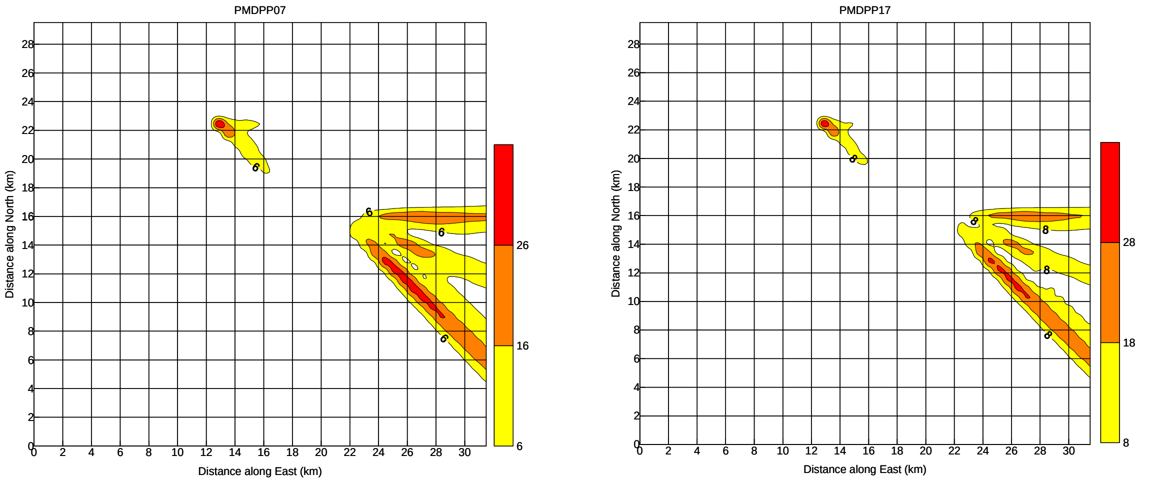
Winter 2017

Fig. 6.17 : Predicted Iso-concentration Plots for NOx: 2012 & 2017 BAU Scenarios – Area Sources



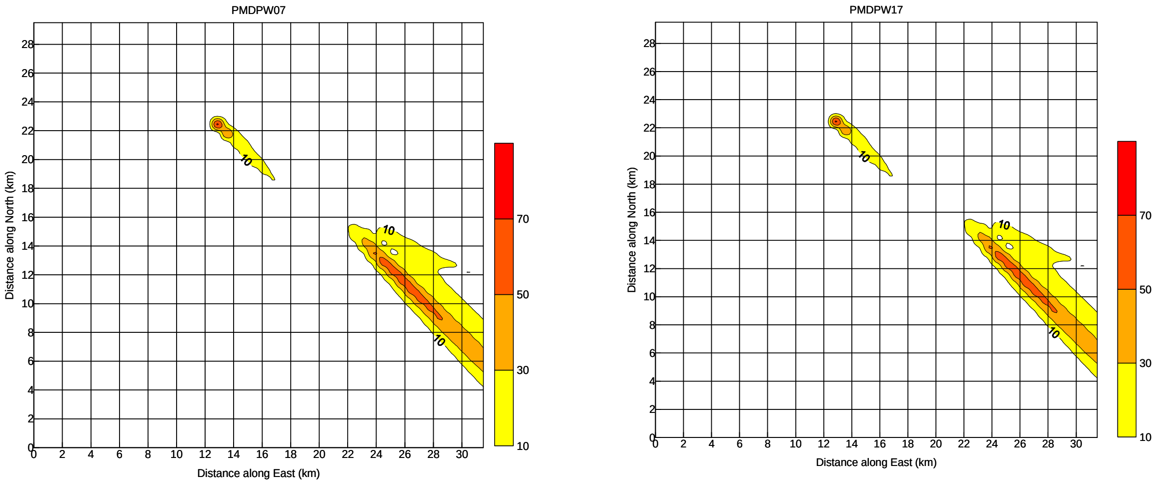
Summer 2012

Summer 2017



Post Monsoon 2012

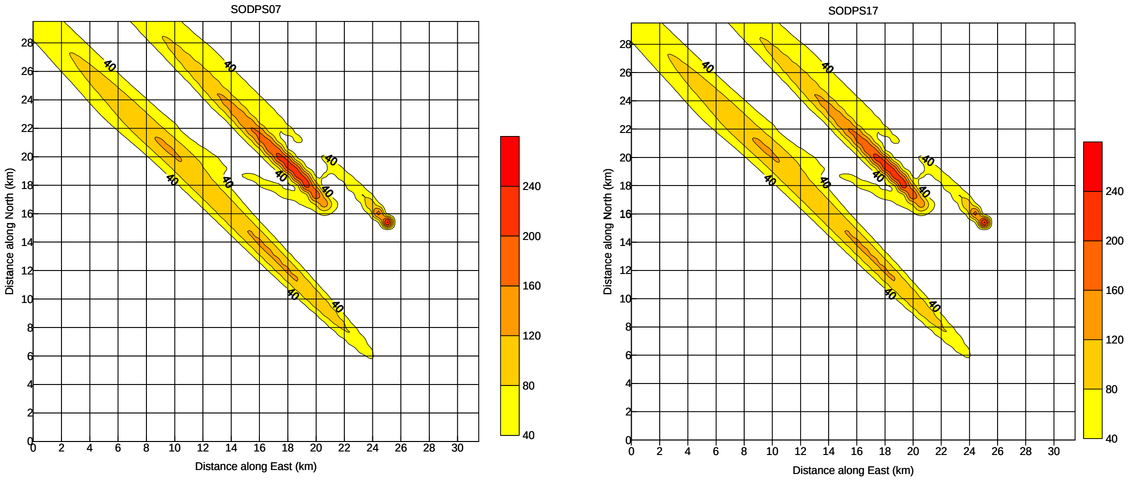
Post Monsoon 2017



Winter 2012

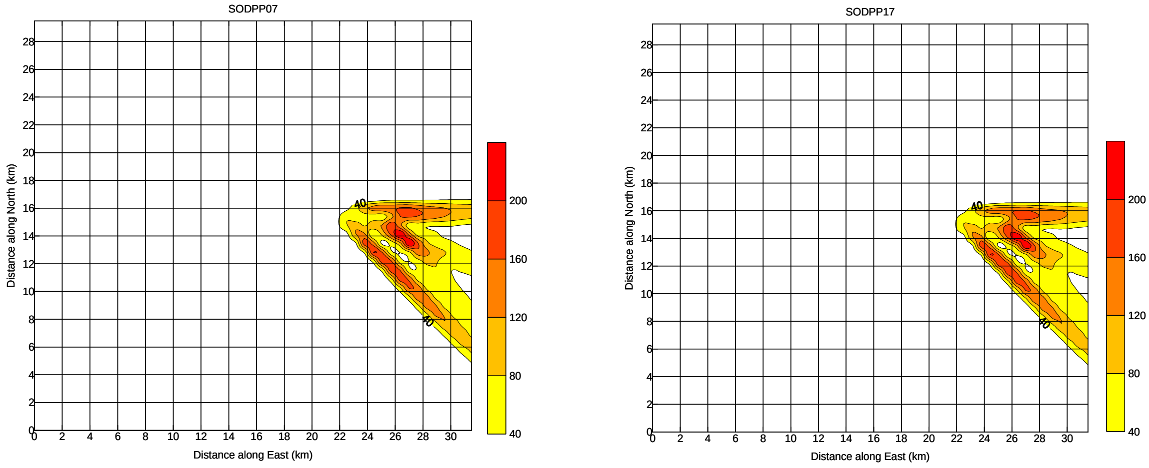
Winter 2017

Fig. 6.18 : Predicted Iso-concentration Plots for PM: 2012 & 2017 BAU Scenarios – Industrial Sources



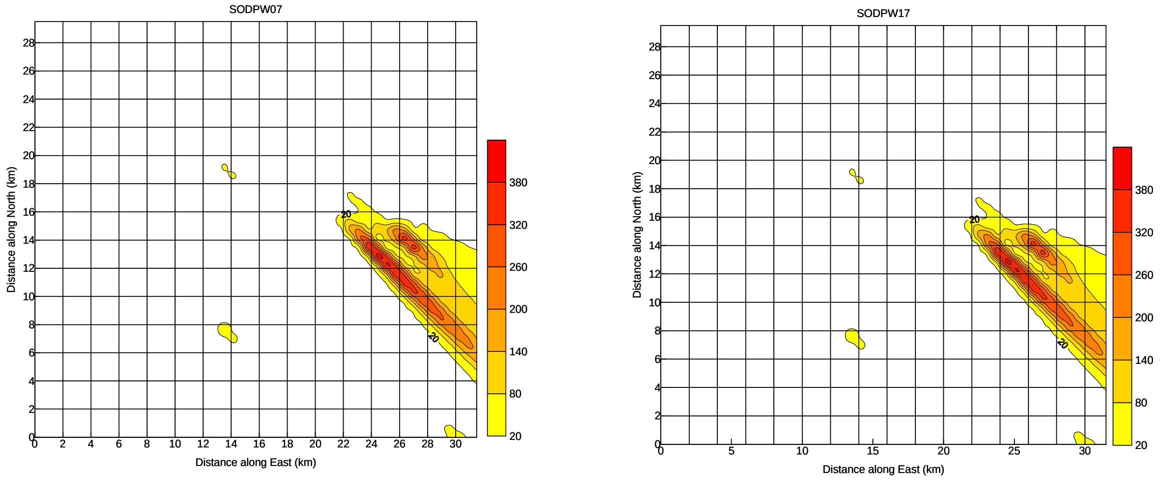
Summer 2012

Summer 2017



Post Monsoon 2012

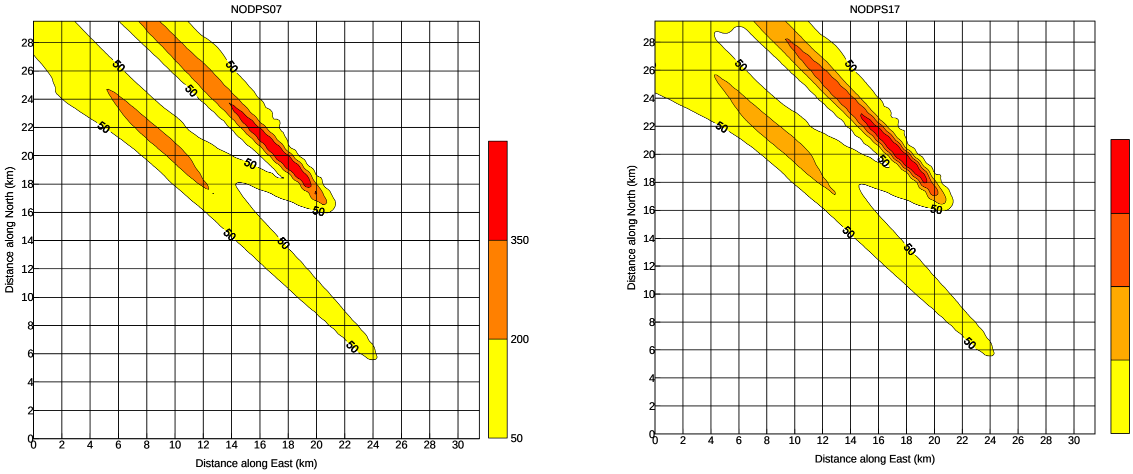
Post Monsoon 2017



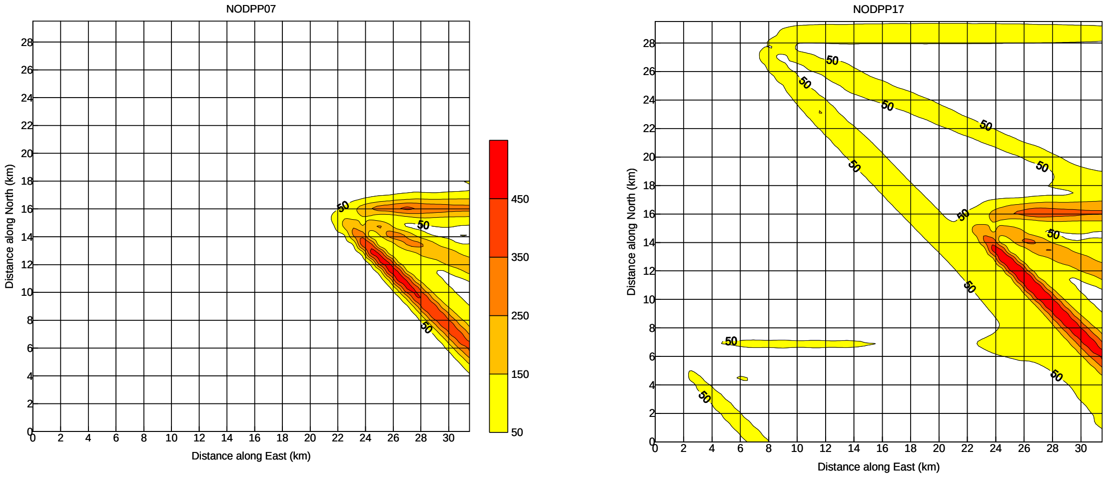
Winter 2012

Winter 2017

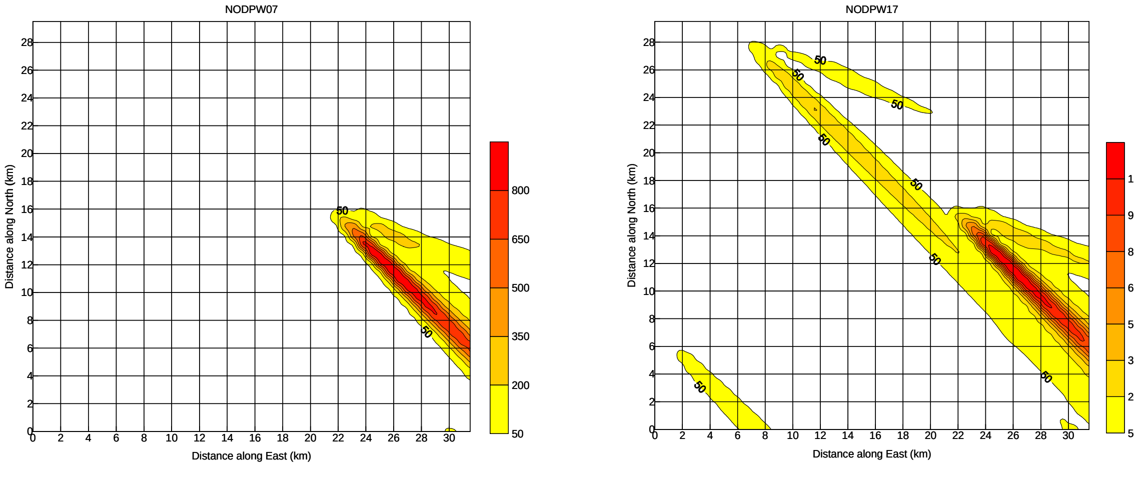
Fig. 6.19 : Predicted Iso-concentration Plots for SO_2: 2012 & 2017 BAU Scenarios - Industrial Sources



Summer 2012 Summer 2017



Post Monsoon 2012 Post Monsoon 2017



Winter 2012 Winter 2017

Fig. 6.20 : Predicted Iso-concentration Plots for NOx: 2012 & 2017 BAU Scenarios - Industrial Sources

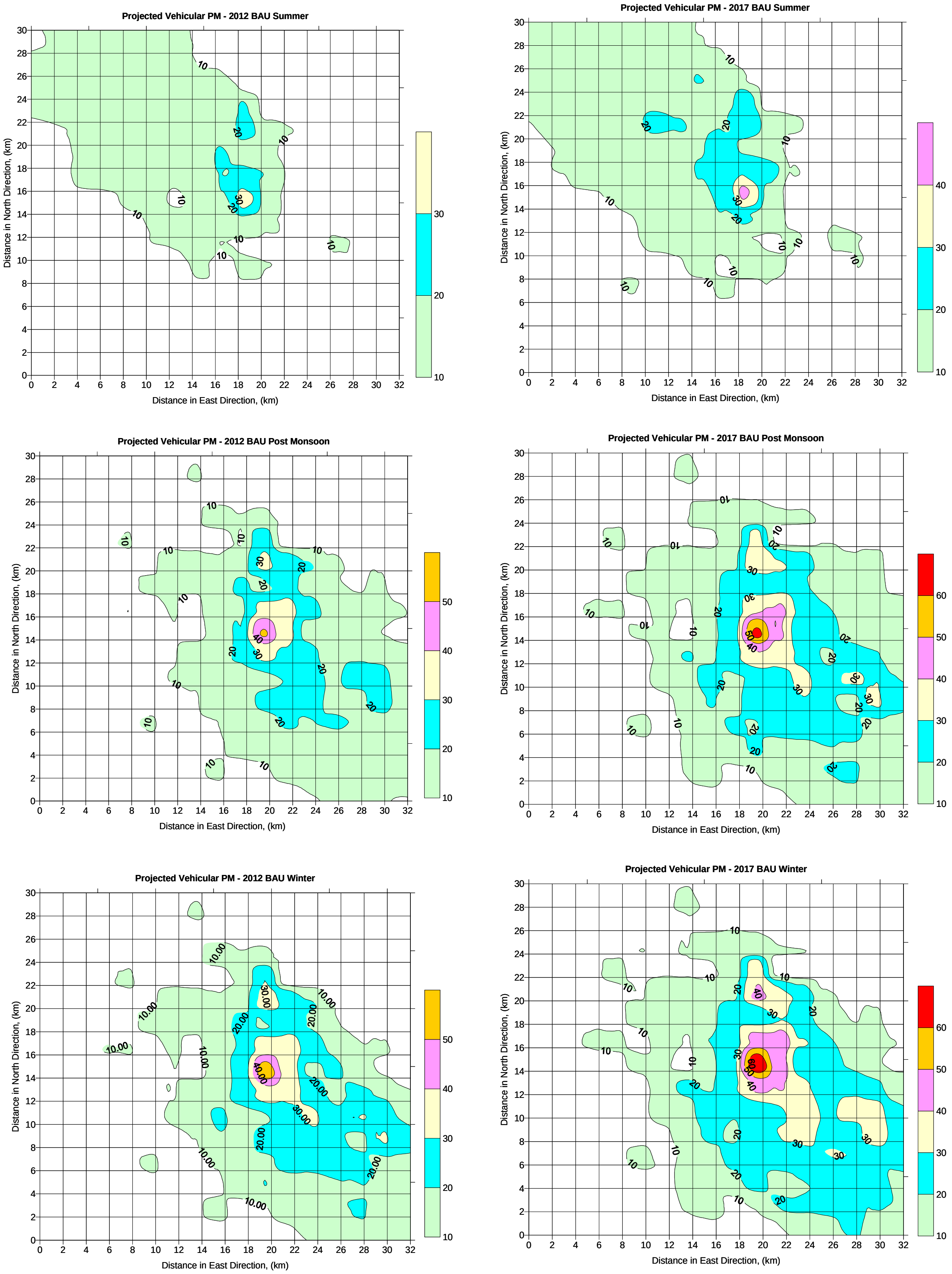
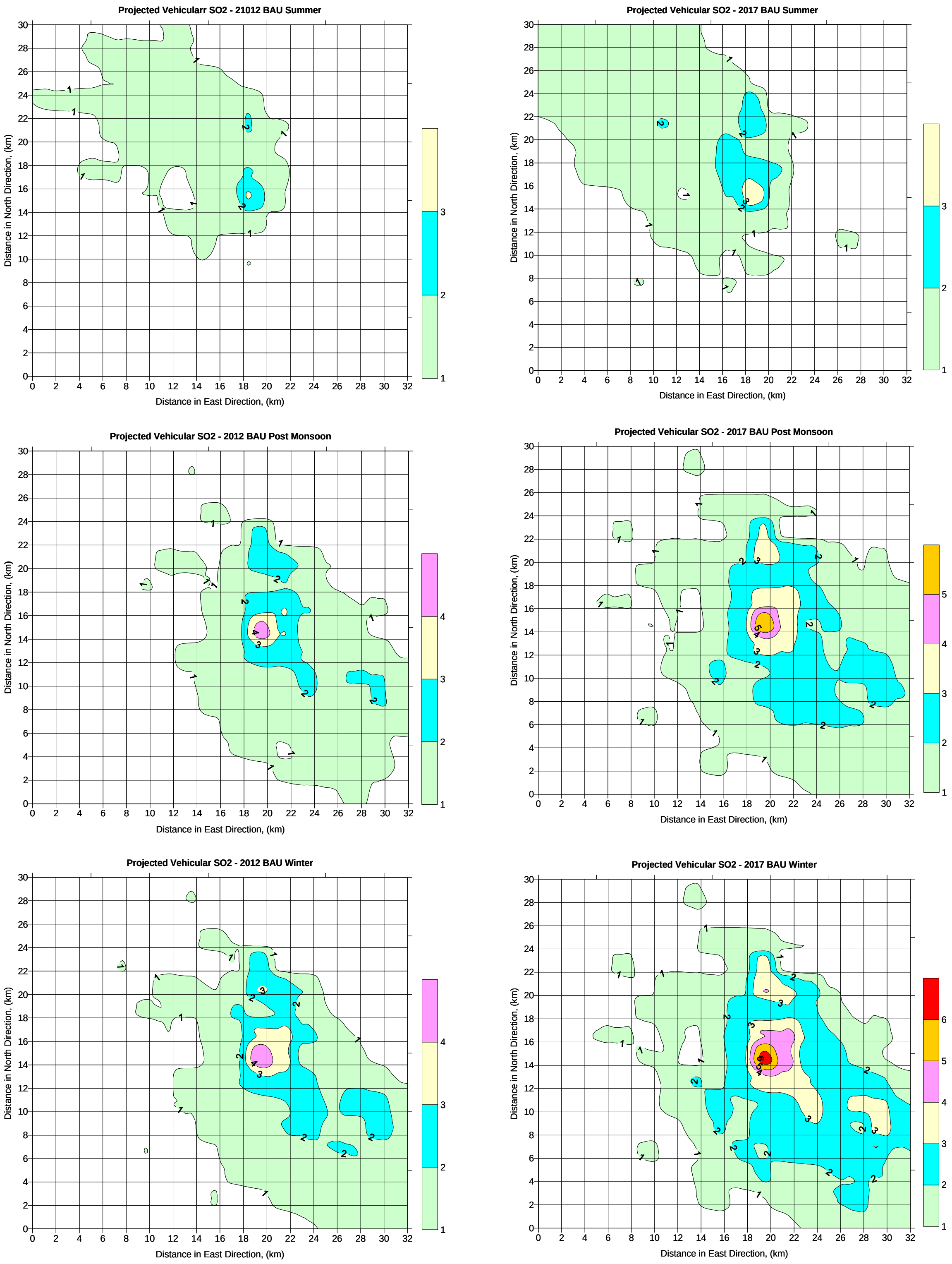


Fig. 6.21 : Predicted Iso-concentration Plots for PM: 2012 & 2017 BAU Scenarios – Vehicular Sources



Projected Vehicularr SO2 - 21012 BAU Summer

Projected Vehicular SO2 - 2017 BAU Summer

Projected Vehicular SO2 - 2012 BAU Post Monsoon

Projected Vehicular SO2 - 2017 BAU Post Monsoon

Projected Vehicular SO2 - 2012 BAU Winter

Projected Vehicular SO2 - 2017 BAU Winter

Fig. 6.22 : Predicted Iso-concentration Plots for SO_2: 2012 & 2017 BAU Scenarios – Vehicular Sources

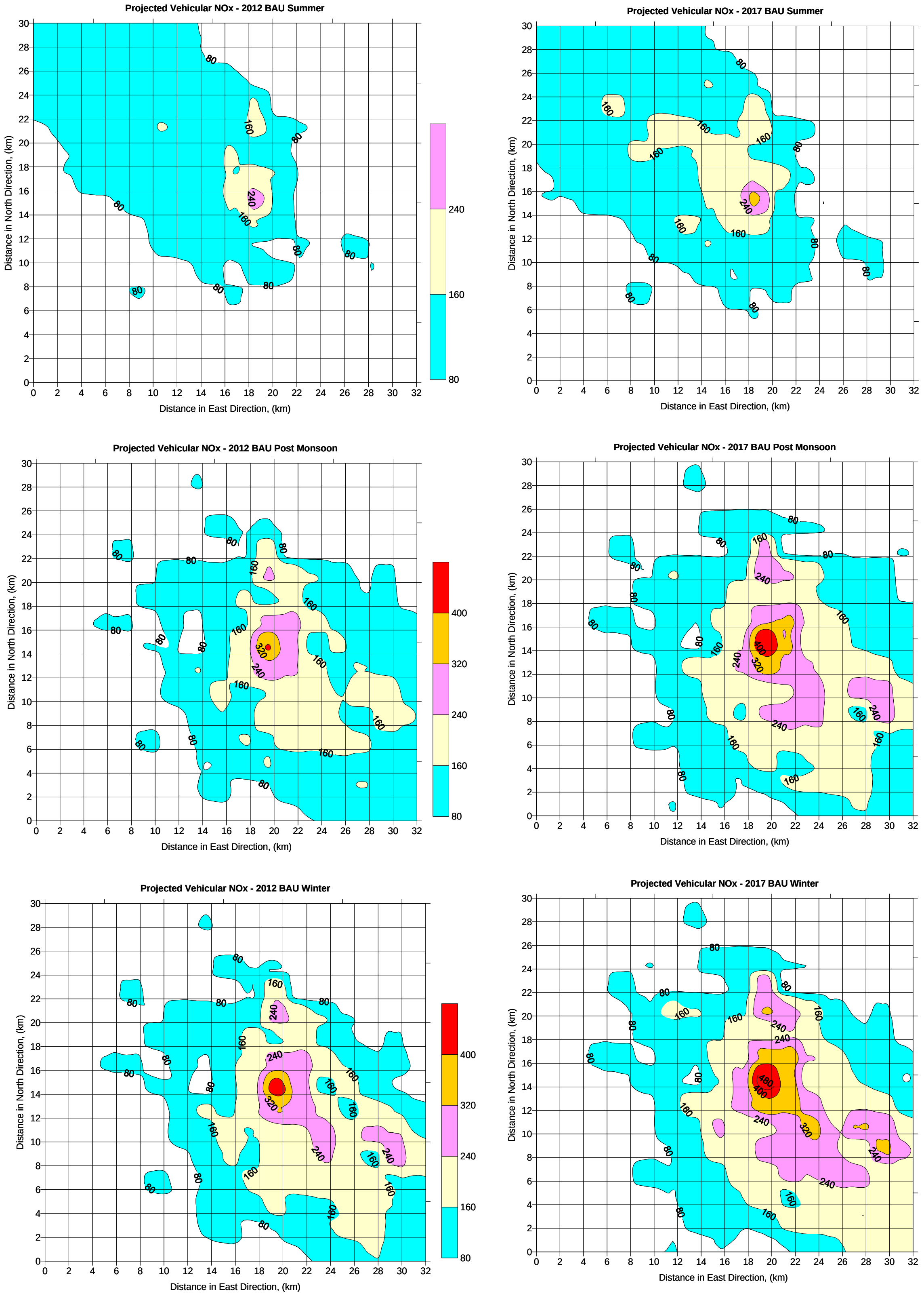


Fig. 6.23 : Predicted Iso-concentration Plots for NOx: 2012 & 2017 BAU Scenarios - Vehicular Sources

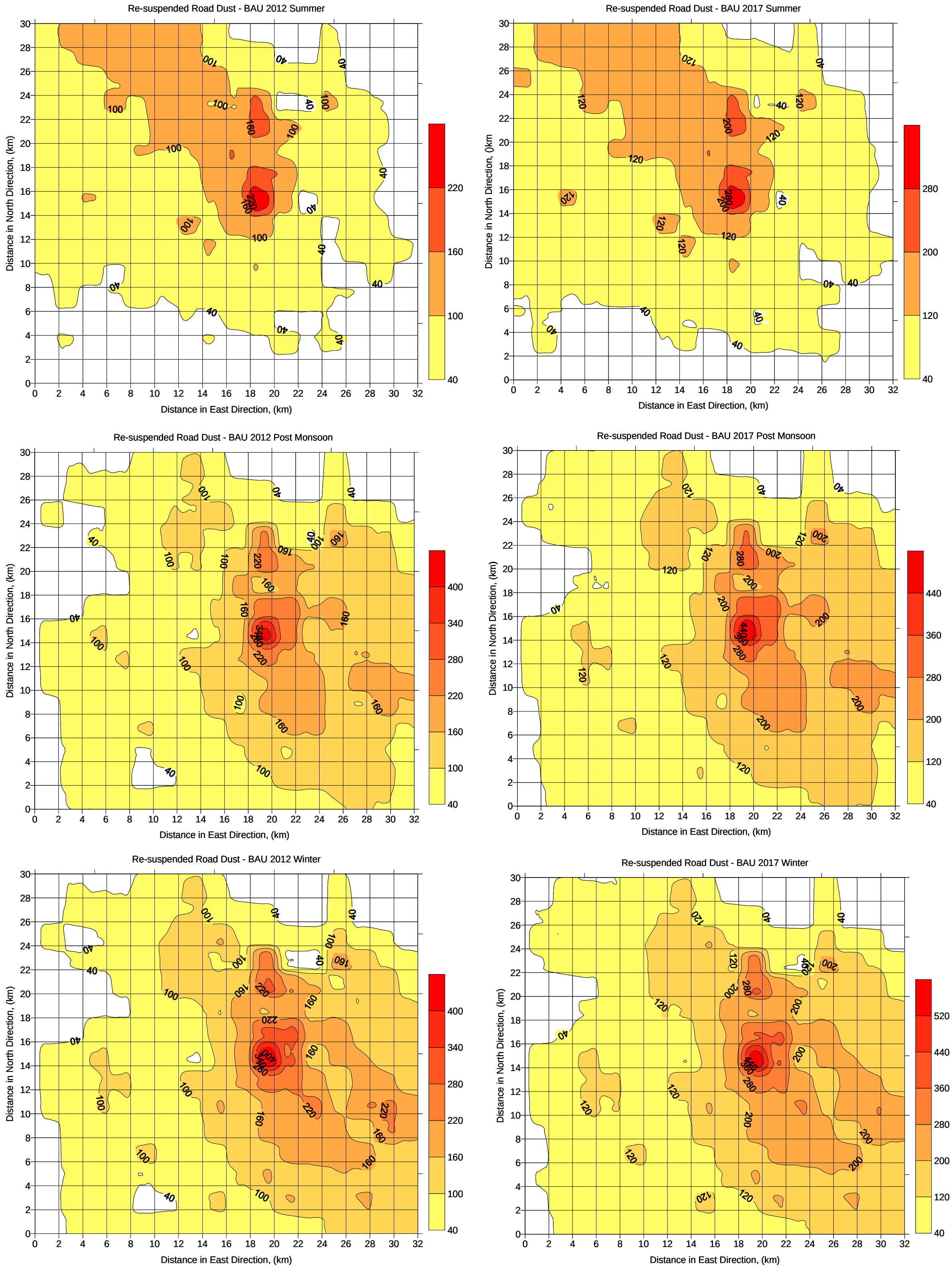
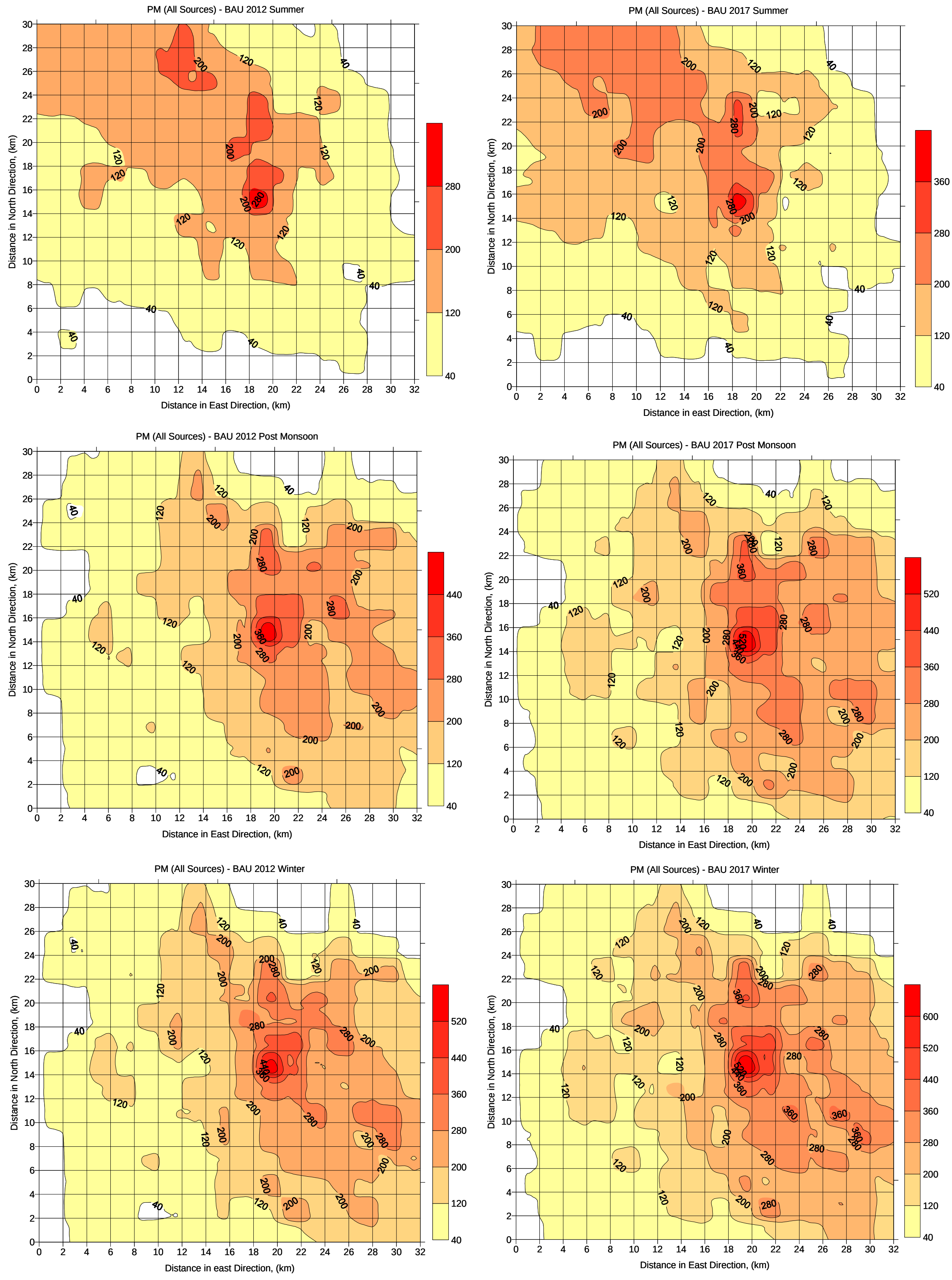


Fig. 6.24 : Predicted Iso-concentration Plots for PM10: 2012 & 2017 BAU Scenarios – Road Dust Re-suspension


PM (All Sources) - BAU 2012 Summer

PM (All Sources) - BAU 2017 Summer

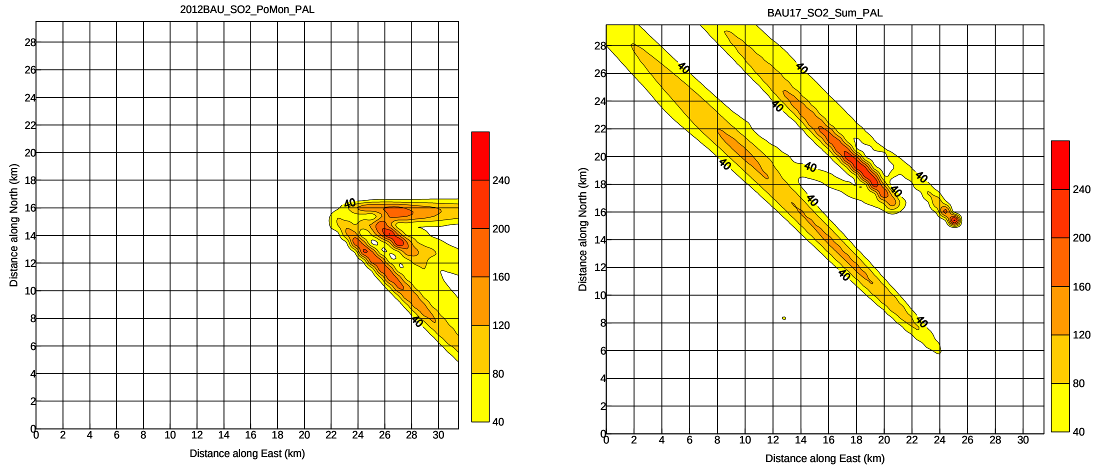
PM (All Sources) - BAU 2012 Post Monsoon

PM (All Sources) - BAU 2017 Post Monsoon

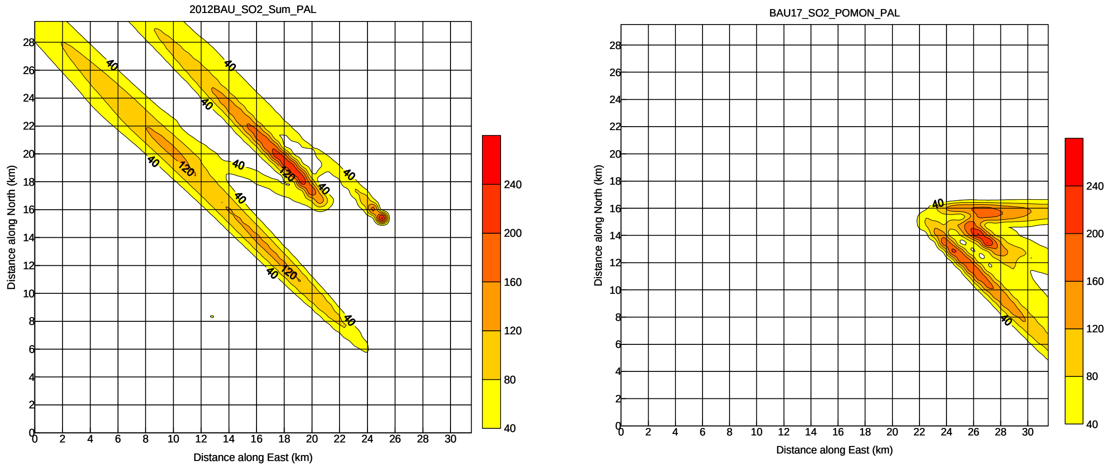
PM (All Sources) - BAU 2012 Winter

PM (All Sources) - BAU 2017 Winter

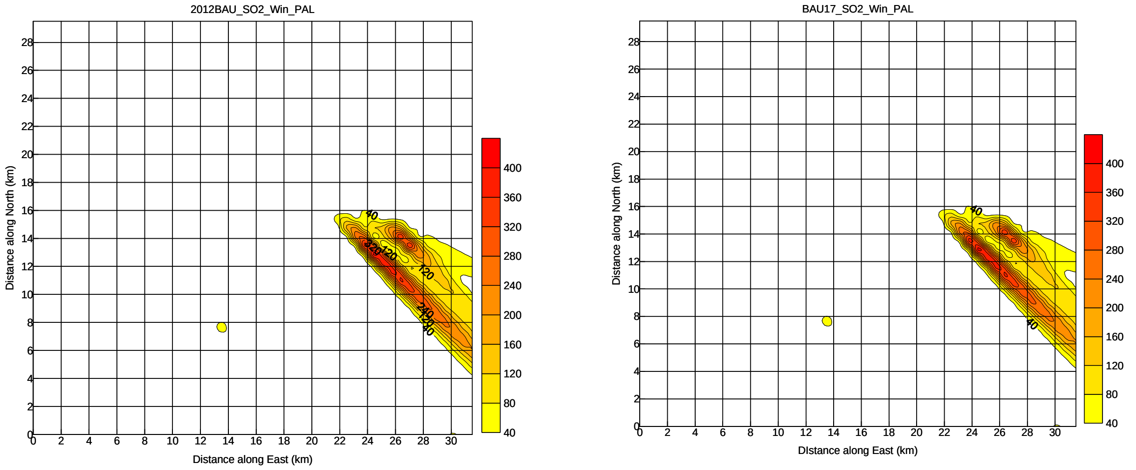
Fig. 6.25 : Predicted Iso-concentration Plots for PM during Different Seasons: 2012 & 2017 BAU Scenarios – Cumulative Impact of All Sources



Summer 2012 **Summer 2017**

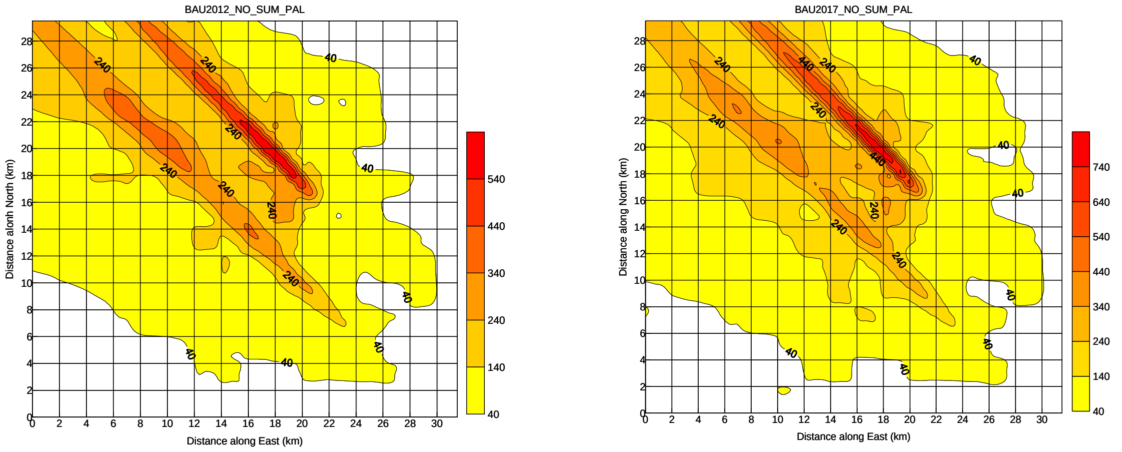


Post Monsoon 2012 **Post Monsoon 2017**

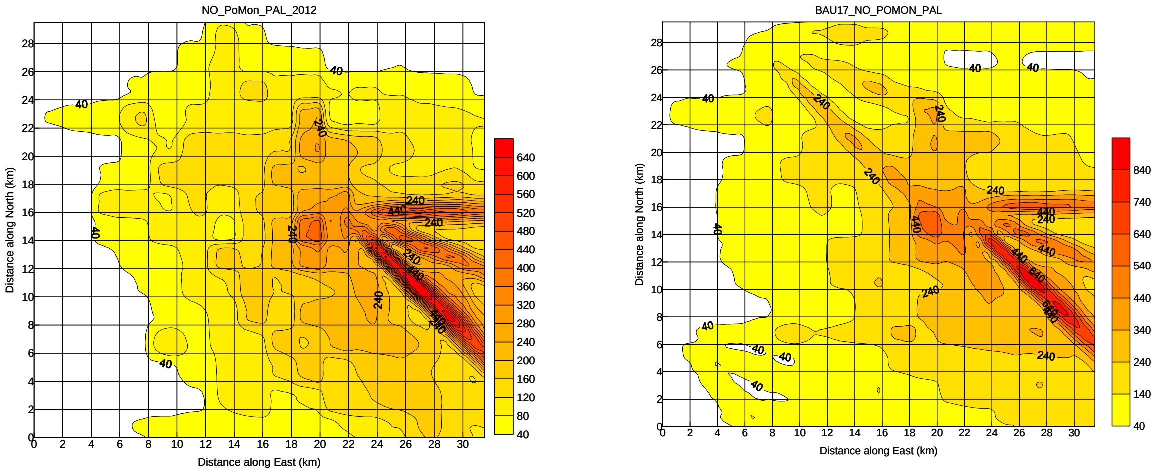


Winter 2012 **Winter 2017**

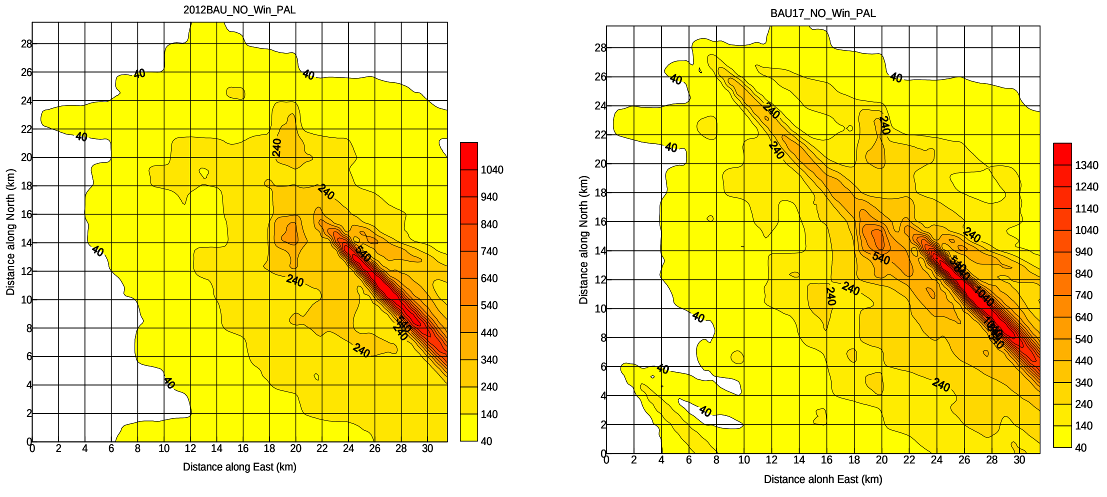
Fig. 6.26 : Predicted Iso-concentration Plots for SO_2 during Different Seasons: 2012 & 2017 BAU Scenarios – Cumulative Impact of All Sources



Summer 2012 **Summer 2017**



Post Monsoon 2012 **Post Monsoon 2017**



Winter 2012 **Winter 2017**

Fig. 6.27 : Predicted Iso-concentration Plots for NOx during Different Seasons: 2012 & 2017 BAU Scenarios – Cumulative Impact of All Sources

Cumulative Impact of All the Sources: Perusal of iso-concentration plots indicate that concentration of PM is well distributed through out Delhi with higher levels confining to the area between ISBT and Ashram Chowk. In general, a good spread of high levels of NOx (40 µg/m^3) can be seen in all the three seasons, but highest levels are following the trend of dispersion from the point sources, mainly power plants. Similarly, spread of SO_2 is limited to confined grids and follows mainly the dispersion pattern from point sources. Higher levels of SO_2 is predicted in Mayur Vihar area during post monsoon and winter, whereas in summer its spread is more and observed along the Chandini Chowk-Chawri Bazaar- Ashok Vihar-SSI-GTK-Pitampura.

6.4 Emission Control Options and Analysis

6.4.1 Area Sources

6.4.1.1 Methodology, Assumptions and Control Options

In order to minimize the emissions from area sources, different control options for various source activities viz. domestic, hotels/ restaurants, bakeries crematoria, medical waste incinerators, construction activities etc. were identified and analyzed. Control options have been later analysed for their effectiveness.

Population Holding Capacity and its Distribution

To accommodate the projected population of 230 lakhs, Master Plan of Delhi (MPD- 2021) recommends: i) to encourage the population distribution in NCR towns, ii) to increase the population holding capacity of the area within existing urban limits through redevelopment; and iii) extension of the present urban limits to the extent necessary. The area within existing urbanisable limits of Delhi Urban Area-2001 consists of the planning zones A to H and the Dwarka, Rohini, Narela Sub-city projects. The immediate urban extension could be in the zone of J to L, N & P (I&II). **Figure 6.28** presents various zones in Delhi as given in MPD-2021**.**

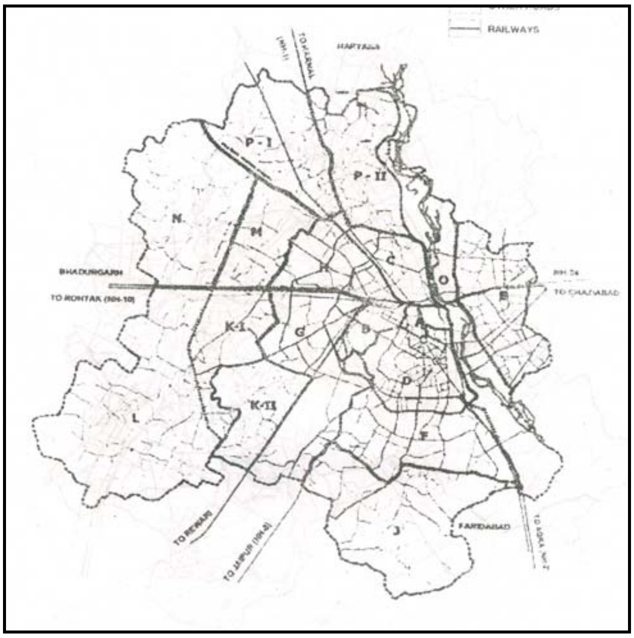


Figure 6.28 : Various Zones in Delhi

Population holding capacity of different zones given in MPD- 2021 has been taken into account for allocating/ distributing the total population in different zones/areas of Delhi. Estimated population holding capacity of various zones in Delhi is presented in **Table 6.17.**

Table 6.17: Estimated Zone wise Population Holding Capacity

Zone/area	Holding Capacity in 2001 (Lakhs)	Actual Population 2001 (Lakhs)	Holding Capacity 2021 (Lakhs)
A	4.20	5.70	5.70
B	6.30	6.24	6.30
C	7.51	6.79	7.88
D	7.55	5.87	8.13
E	17.89	27.98	28.00
F	12.78	17.17	19.75
G	14.90	16.29	19.55
H	18.65	12.26	18.65
Subtotal	**89.78**	**98.30**	**114.00**
Dwarka	NA	5.97	13.00
Rohini III	NA	0.96	16.0
Rohini IV & V	NA	1.98	8.20
Narela	NA	1.79	16.20
Subtotal	**32.22**	**10.70**	**39.00**
Total	**122.00**	**109.00**	**153.00**
Villages	NA	29.0	77.00*
Grand Total		**138.00**	**230.00**

NA - not available * remaining population to be accommodated in villages

Source: MPD-2021

- **Cleaner Fuel**

LPG is considered to be the cleaner fuel as compared to coal, wood and kerosene in domestic cooking and commercial sectors viz. hotels/restaurants and bakeries. Requirement of cleaner fuel is estimated based on its calorific value as a basis. No emissions are estimated in the case of electrically operated crematoria and locomotives.

- **Air Pollution Control Equipment**

To control PM and SO_2 emissions from medical waste incinerator, wet scrubber with control efficiency of 60% is considered as control option.

- **Adequate Power Supply**

The total consumption of power in Delhi is about 3170 MW, whereas total power generation capacity is 1700 MW. Remaining requirement of power is met through Central Sector sources. As reported in NCR Planning Report -2001, Central Electricity Authority (CEA) has projected a peak load requirement of 5836 MW and 7865 MW in 2012 and 2017 respectively. In order to meet this additional demand in Delhi, the projects under consideration by Delhi Government include Pragati-II 330 MW Gas based power plant, Pragati-III 1500 MW Gas based power project at Bawana, 1500 MW coal based power plant at Jhajjar (Haryana) and 750 MW gas based power project at Bamnauili in South West Delhi. The remaining power is proposed to be met from allocated share from the grid system. Keeping in view the time taken for completion of these projects, use of DG sets up to 2012 have been considered and accordingly emissions are estimated. Considering improvement in future power generation scenario, use of DG sets is not envisaged by 2017 and hence no emissions from DG sets are considered.

- **Construction Activities**

To minimise PM emissions from construction activities, better construction practices viz. proper loading/unloading of materials including water spraying are considered as one of the options. 50% reduction in PM emissions is considered by this control option.

- **Refuse and biomass burning**

Though there is ban on open burning, is Delhi, yet it is not being enforced strictly. Refuse burning at landfill requires high level of monitoring and control by local authorities. However, refuse or biomass burning by poor population needs awareness and availability of clean fuels at economical prices to such people.

Various control options analyzed for different area source activities (domestic, hotels/ restaurants, bakeries, crematoria, medical waste incinerator, construction etc.) under BAU scenarios for 2012 and 2017 are summarized in **Table 6.18.**

Table 6.18: Area Source Control Options for Emission Scenario in 2012 and 2017

Source Category	Control Options	Scenario for 2012	Scenario for 2017
Domestic	Use of cleaner fuels viz. LPG/ NG	50% solid fuel, kerosene for domestic use to be shifted to LPG/NG	100% solid fuel, kerosene for domestic use to be shifted to LPG/NG
Hotels, Restaurants Bakeries	Use of cleaner fuels viz. LPG/ NG	100% to be shifted to LPG/NG	100% to be shifted to LPG/NG
Crematoria	Use of cleaner fuels viz. electricity	50% to be operated on electricity	100% to be operated on electricity
Incinerators	Installation of control equipment viz. wet scrubber	100% units to install	100% to be installed
DG sets	Adequate supply of grid power	Use of generator sets till adequate grid power available	No use of generator sets
Open burning	Strict compliance with ban on open burning	100% compliance	100% compliance
Locomotives	Use of cleaner fuels viz. electricity	100% to be operated on electricity	100% to be operated on electricity
Construction	Better construction practices viz. proper loading and unloading of materials, water spraying etc.	50% reduction from construction activities	100% reduction from construction activities

6.4.1.2 Emission Load Projection for 2012 and 2017 under Control Option Scenario

Based on the above approach, gridwise pollutants (PM, SO_2 and NOx) emission load in 2012 and 2017 under control scenario have been estimated. Source wise estimated pollutants (PM, SO_2 and NOx) emission load and percent reduction under control scenario for 2012 and 2017 are presented in **Tables 6.19 and 6.20** respectively.

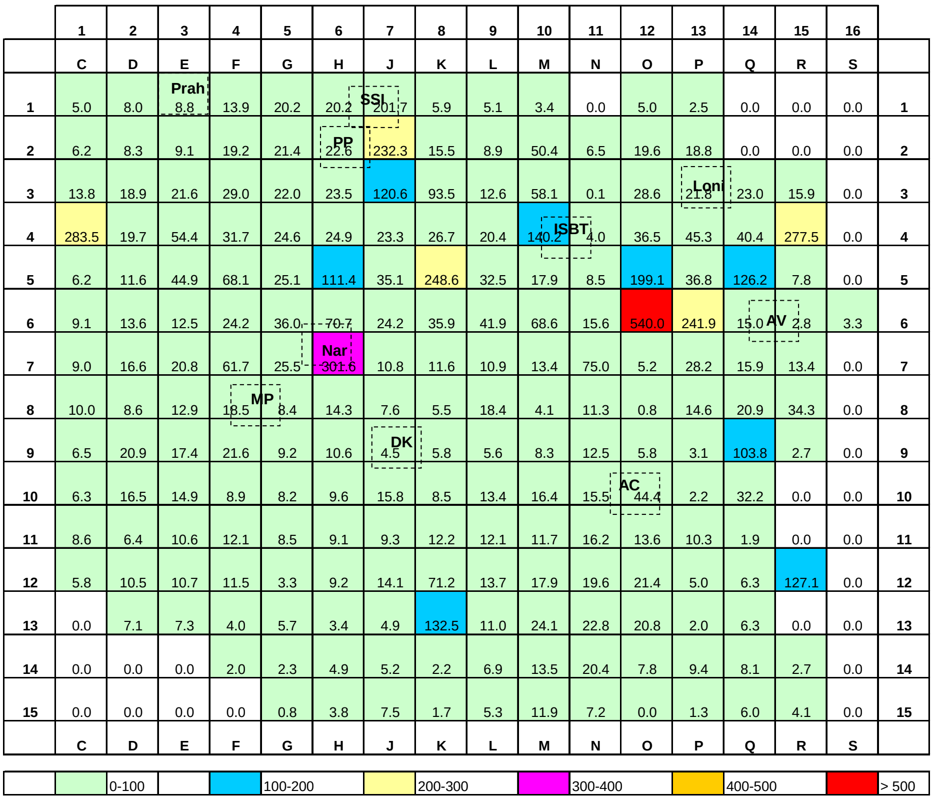
Table 6.19: Emission Loads and % Reduction - Area Sources Control Scenario 2012

Sources	Controlled Emissions (kg/day) 2012			% Reduction		
	PM10	SO_2	NOx	PM10	SO_2	NOx
Domestic	734.2	0.5	4471.2	67.3	99.9	8.4
Domestic Slums	125.1	0.1	761.9	98.9	100.0	53.8
Hotels & Restaurants	165.1	0.1	1005.4	91.1	100.0	18.0
Bakeries	1.4	0.0	8.3	99.0	99.9	20.2
Crematoria	902.5	11.8	82.6	39.6	39.6	39.6
Hospital Incinerators	12.3	16.9	30.8	60.0	60.0	0.0
Generator Sets	613.7	572.4	8678.4	-	-	-
Open Burning	0.0	0.0	0.0	100.0	100.0	100.0
Construction	4777.3	-	-	50.0	-	-
Locomotives	0.0	0.0	0.0	100.0	100.0	100.0
Total	7331.6	601.9	15038.5	73.2	80.2	14.8

Table 6.20: Emission Loads and % Reduction- Area Sources Control Scenario 2017

Sources	Controlled Emissions (kg/day) 2017			% Reduction		
	PM10	SO_2	NOx	PM10	SO_2	NOx
Domestic	868.3	0.6	5287.5	66.4	99.9	6.1
Domestic Slums	260.0	0.2	1583.1	98.0	100.0	16.8
Hotels & Restaurants	184.8	0.1	1125.4	91.3	100.0	20.3
Bakeries	1.3	0.0	8.2	99.2	99.9	31.4
Crematoria	0.0	0.0	0.0	100.0	100.0	100.0
Hospital Incinerators	14.6	30.3	43.3	60.0	60.0	0.0
Generator Sets	0.0	0.0	0.0	100.0	100.0	100.0
Open Burning	0.0	0.0	0.0	100.0	100.0	100.0
Construction	3645.0	-	-	50.0	-	-
Locomotives	0.0	0.0	0.0	100.0	100.0	100.0
Total	4974.0	31.3	8047.5	82.1	99.1	60.4

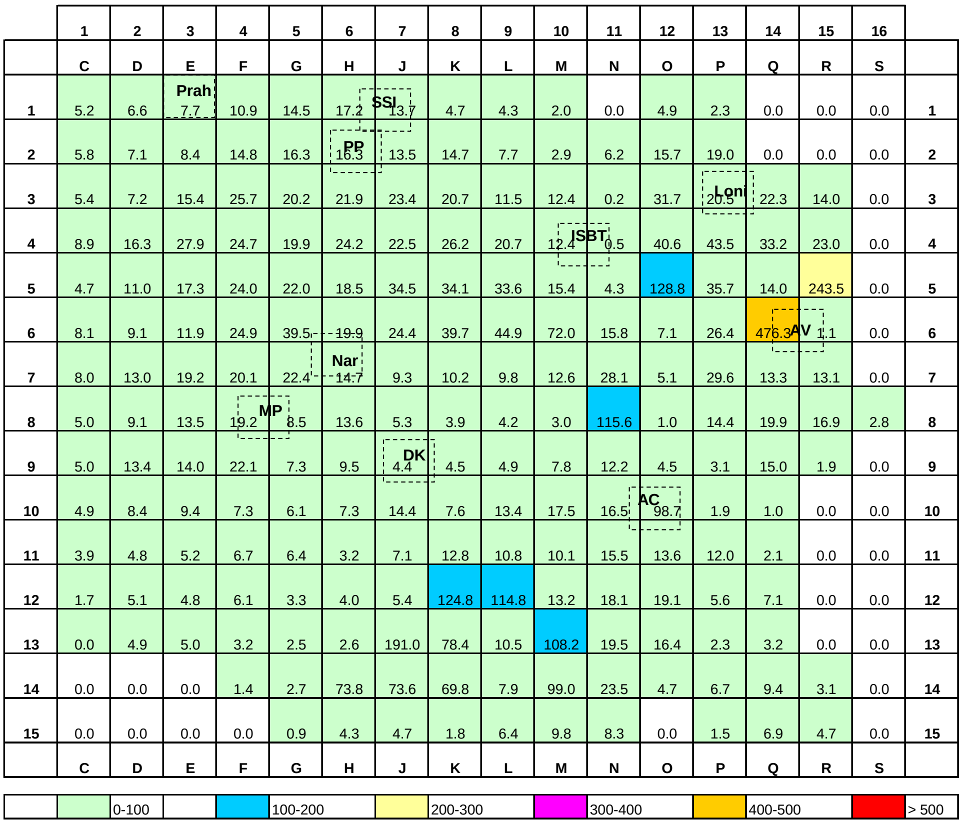
Perusal of these tables indicate that if all control options are applied, total PM and SO_2 emissions can be reduced by 73.2% and 80.2%, while NOx emissions can be reduced only by 14.8% in 2012. In 2017, there will be substantial reduction in emission loads. PM, SO_2 and NOx emission loads could be reduced by 82.1%, 99.1% and 60.4% respectively. Grid wise emissions loads under control option scenarios for 2012 and 2017 are shown in **Figs. 6. 29 to 6.34**.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1	5.0	8.0	8.8	13.9	20.2	20.2	201.7	5.9	5.1	3.4	0.0	5.0	2.5	0.0	0.0	0.0	1
2	6.2	8.3	9.1	19.2	21.4	22.6	232.3	15.5	8.9	50.4	6.5	19.6	18.8	0.0	0.0	0.0	2
3	13.8	18.9	21.6	29.0	22.0	23.5	120.6	93.5	12.6	58.1	0.1	28.6	21.8	23.0	15.9	0.0	3
4	283.5	19.7	54.4	31.7	24.6	24.9	23.3	26.7	20.4	140.2	4.0	36.5	45.3	40.4	277.5	0.0	4
5	6.2	11.6	44.9	68.1	25.1	111.4	35.1	248.6	32.5	17.9	8.5	199.1	36.8	126.2	7.8	0.0	5
6	9.1	13.6	12.5	24.2	36.0	70.7	24.2	35.9	41.9	68.6	15.6	540.0	241.9	15.0	2.8	3.3	6
7	9.0	16.6	20.8	61.7	25.5	301.6	10.8	11.6	10.9	13.4	75.0	5.2	28.2	15.9	13.4	0.0	7
8	10.0	8.6	12.9	18.5	8.4	14.3	7.6	5.5	18.4	4.1	11.3	0.8	14.6	20.9	34.3	0.0	8
9	6.5	20.9	17.4	21.6	9.2	10.6	4.5	5.8	5.6	8.3	12.5	5.8	3.1	103.8	2.7	0.0	9
10	6.3	16.5	14.9	8.9	8.2	9.6	15.8	8.5	13.4	16.4	15.5	44.4	2.2	32.2	0.0	0.0	10
11	8.6	6.4	10.6	12.1	8.5	9.1	9.3	12.2	12.1	11.7	16.2	13.6	10.3	1.9	0.0	0.0	11
12	5.8	10.5	10.7	11.5	3.3	9.2	14.1	71.2	13.7	17.9	19.6	21.4	5.0	6.3	127.1	0.0	12
13	0.0	7.1	7.3	4.0	5.7	3.4	4.9	132.5	11.0	24.1	22.8	20.8	2.0	6.3	0.0	0.0	13
14	0.0	0.0	0.0	2.0	2.3	4.9	5.2	2.2	6.9	13.5	20.4	7.8	9.4	8.1	2.7	0.0	14
15	0.0	0.0	0.0	0.0	0.8	3.8	7.5	1.7	5.3	11.9	7.2	0.0	1.3	6.0	4.1	0.0	15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

🟩	0-100	🟦	100-200	🟨	200-300	🟪	300-400	🟧	400-500	🟥	> 500

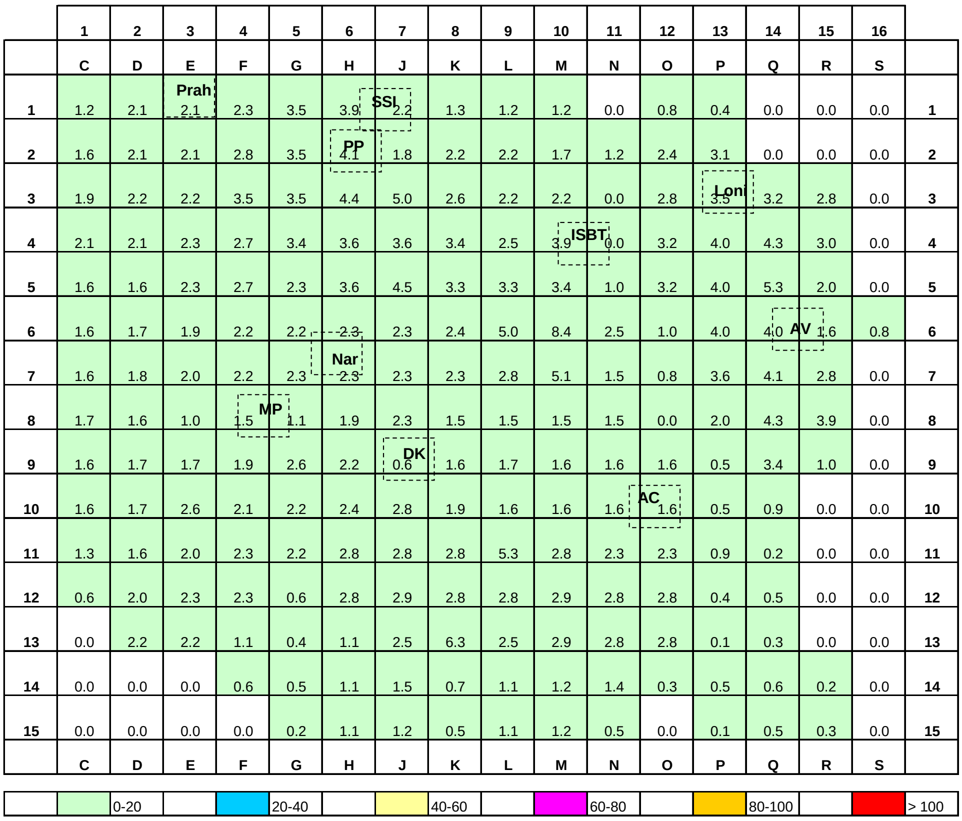
Fig. 6.29: Grid wise PM10 Emissions Rate (kg/d): Area Sources Control Scenario 2012



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1	5.2	6.6	Prah 7.7	10.9	14.5	17.2	SSI 13.7	4.7	4.3	2.0	0.0	4.9	2.3	0.0	0.0	0.0	1
2	5.8	7.1	8.4	14.8	16.3	PP 16.3	13.5	14.7	7.7	2.9	6.2	15.7	19.0	0.0	0.0	0.0	2
3	5.4	7.2	15.4	25.7	20.2	21.9	23.4	20.7	11.5	12.4	0.2	31.7	Loni 20.5	22.3	14.0	0.0	3
4	8.9	16.3	27.9	24.7	19.9	24.2	22.5	26.2	20.7	12.4	ISBT 0.5	40.6	43.5	33.2	23.0	0.0	4
5	4.7	11.0	17.3	24.0	22.0	18.5	34.5	34.1	33.6	15.4	4.3	128.8	35.7	14.0	243.5	0.0	5
6	8.1	9.1	11.9	24.9	39.5	19.9	24.4	39.7	44.9	72.0	15.8	7.1	26.4	476.3	AV 1.1	0.0	6
7	8.0	13.0	19.2	20.1	22.4	Nar 14.7	9.3	10.2	9.8	12.6	28.1	5.1	29.6	13.3	13.1	0.0	7
8	5.0	9.1	13.5	19.2	MP 8.5	13.6	5.3	3.9	4.2	3.0	115.6	1.0	14.4	19.9	16.9	2.8	8
9	5.0	13.4	14.0	22.1	7.3	9.5	DK 4.4	4.5	4.9	7.8	12.2	4.5	3.1	15.0	1.9	0.0	9
10	4.9	8.4	9.4	7.3	6.1	7.3	14.4	7.6	13.4	17.5	16.5	AC 98.7	1.9	1.0	0.0	0.0	10
11	3.9	4.8	5.2	6.7	6.4	3.2	7.1	12.8	10.8	10.1	15.5	13.6	12.0	2.1	0.0	0.0	11
12	1.7	5.1	4.8	6.1	3.3	4.0	5.4	124.8	114.8	13.2	18.1	19.1	5.6	7.1	0.0	0.0	12
13	0.0	4.9	5.0	3.2	2.5	2.6	191.0	78.4	10.5	108.2	19.5	16.4	2.3	3.2	0.0	0.0	13
14	0.0	0.0	0.0	1.4	2.7	73.8	73.6	69.8	7.9	99.0	23.5	4.7	6.7	9.4	3.1	0.0	14
15	0.0	0.0	0.0	0.0	0.9	4.3	4.7	1.8	6.4	9.8	8.3	0.0	1.5	6.9	4.7	0.0	15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

🟩 0-100 🟦 100-200 🟨 200-300 🟪 300-400 🟧 400-500 🟥 > 500

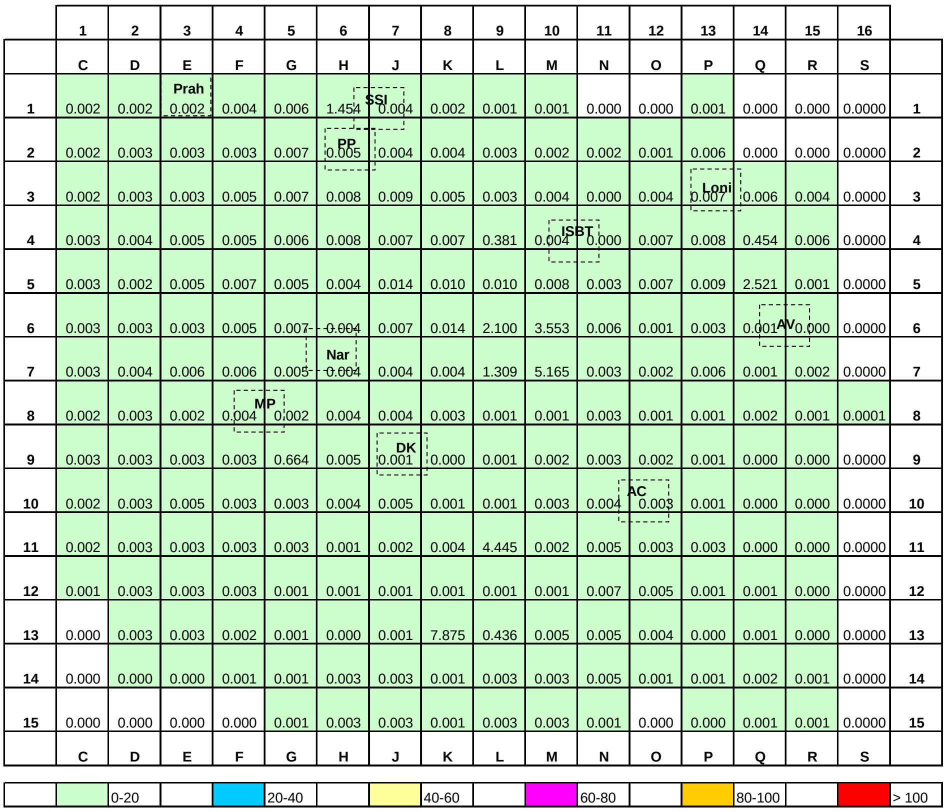
Fig. 6.30: Grid wise PM10 Emissions Rate (kg/d): Area Sources Control Scenario 2017



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1	1.2	2.1	Prah 2.1	2.3	3.5	3.9	SSI 2.2	1.3	1.2	1.2	0.0	0.8	0.4	0.0	0.0	0.0	1
2	1.6	2.1	2.1	2.8	3.5	PP 4.1	1.8	2.2	2.2	1.7	1.2	2.4	3.1	0.0	0.0	0.0	2
3	1.9	2.2	2.2	3.5	3.5	4.4	5.0	2.6	2.2	2.2	0.0	2.8	Loni 3.5	3.2	2.8	0.0	3
4	2.1	2.1	2.3	2.7	3.4	3.6	3.6	3.4	2.5	3.9	ISBT 0.0	3.2	4.0	4.3	3.0	0.0	4
5	1.6	1.6	2.3	2.7	2.3	3.6	4.5	3.3	3.3	3.4	1.0	3.2	4.0	5.3	2.0	0.0	5
6	1.6	1.7	1.9	2.2	2.2	2.3	2.3	2.4	5.0	8.4	2.5	1.0	4.0	4.0	AV 1.6	0.8	6
7	1.6	1.8	2.0	2.2	2.3	Nar 2.3	2.3	2.3	2.8	5.1	1.5	0.8	3.6	4.1	2.8	0.0	7
8	1.7	1.6	1.0	1.5	MP 1.1	1.9	2.3	1.5	1.5	1.5	1.5	0.0	2.0	4.3	3.9	0.0	8
9	1.6	1.7	1.7	1.9	2.6	2.2	DK 0.6	1.6	1.7	1.6	1.6	1.6	0.5	3.4	1.0	0.0	9
10	1.6	1.7	2.6	2.1	2.2	2.4	2.8	1.9	1.6	1.6	1.6	AC 1.6	0.5	0.9	0.0	0.0	10
11	1.3	1.6	2.0	2.3	2.2	2.8	2.8	2.8	5.3	2.8	2.3	2.3	0.9	0.2	0.0	0.0	11
12	0.6	2.0	2.3	2.3	0.6	2.8	2.9	2.8	2.8	2.9	2.8	2.8	0.4	0.5	0.0	0.0	12
13	0.0	2.2	2.2	1.1	0.4	1.1	2.5	6.3	2.5	2.9	2.8	2.8	0.1	0.3	0.0	0.0	13
14	0.0	0.0	0.0	0.6	0.5	1.1	1.5	0.7	1.1	1.2	1.4	0.3	0.5	0.6	0.2	0.0	14
15	0.0	0.0	0.0	0.0	0.2	1.1	1.2	0.5	1.1	1.2	0.5	0.0	0.1	0.5	0.3	0.0	15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

🟩 0-20 🟦 20-40 🟨 40-60 🟪 60-80 🟧 80-100 🟥 > 100

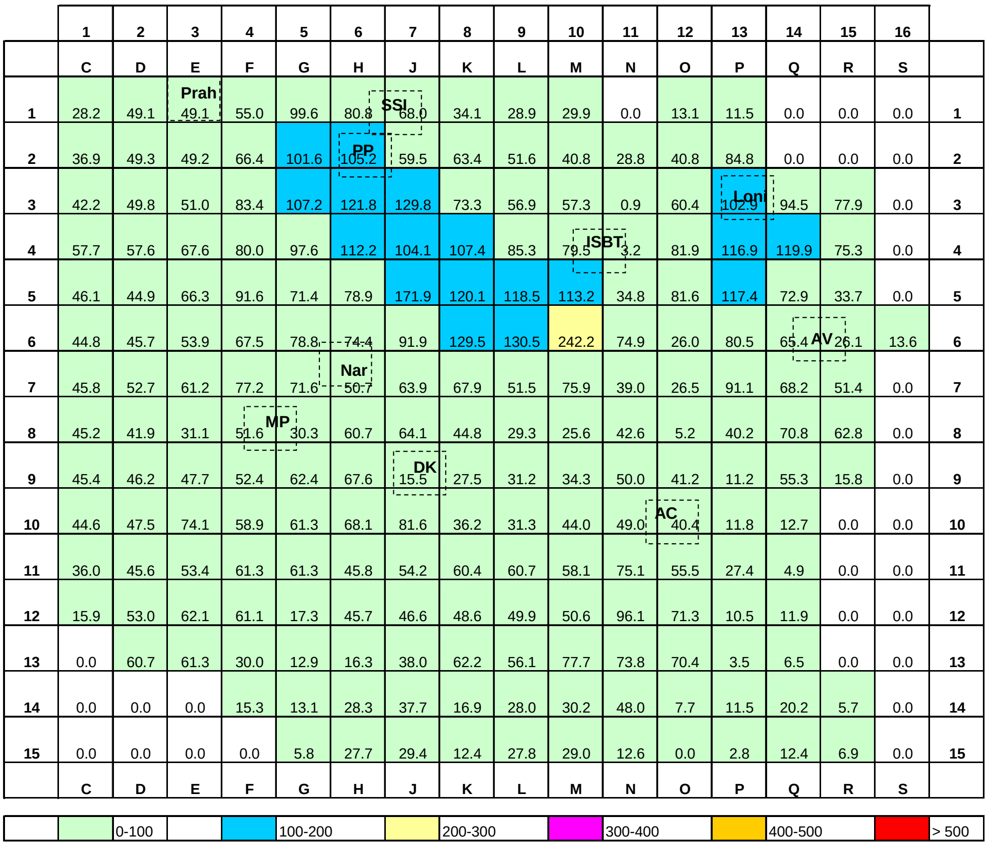
Fig. 6.31: Grid wise SO_2 Emissions Rate (kg/d): Area Sources Control Scenario 2012



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1	0.002	0.002	Prah 0.002	0.004	0.006	1.454	SSI 0.004	0.002	0.001	0.001	0.000	0.000	0.001	0.000	0.000	0.0000	1
2	0.002	0.003	0.003	0.003	0.007	PP 0.005	0.004	0.004	0.003	0.002	0.002	0.001	0.006	0.000	0.000	0.0000	2
3	0.002	0.003	0.003	0.005	0.007	0.008	0.009	0.005	0.003	0.004	0.000	0.004	Loni 0.007	0.006	0.004	0.0000	3
4	0.003	0.004	0.005	0.005	0.006	0.008	0.007	0.007	0.381	ISBT 0.004	0.000	0.007	0.008	0.454	0.006	0.0000	4
5	0.003	0.002	0.005	0.007	0.005	0.004	0.014	0.010	0.010	0.008	0.003	0.007	0.009	2.521	0.001	0.0000	5
6	0.003	0.003	0.003	0.005	0.007	0.004	0.007	0.014	2.100	3.553	0.006	0.001	0.003	AV 0.001	0.000	0.0000	6
7	0.003	0.004	0.006	0.006	0.005	Nar 0.004	0.004	0.004	1.309	5.165	0.003	0.002	0.006	0.001	0.002	0.0000	7
8	0.002	0.003	0.002	MP 0.004	0.002	0.004	0.004	0.003	0.001	0.001	0.003	0.001	0.001	0.002	0.001	0.0001	8
9	0.003	0.003	0.003	0.003	0.664	0.005	DK 0.001	0.000	0.001	0.002	0.003	0.002	0.001	0.000	0.000	0.0000	9
10	0.002	0.003	0.005	0.003	0.003	0.004	0.005	0.001	0.001	0.003	0.004	AC 0.003	0.001	0.000	0.000	0.0000	10
11	0.002	0.003	0.003	0.003	0.003	0.001	0.002	0.004	4.445	0.002	0.005	0.003	0.003	0.000	0.000	0.0000	11
12	0.001	0.003	0.003	0.003	0.001	0.001	0.001	0.001	0.001	0.001	0.007	0.005	0.001	0.001	0.000	0.0000	12
13	0.000	0.003	0.003	0.002	0.001	0.000	0.001	7.875	0.436	0.005	0.005	0.004	0.000	0.001	0.000	0.0000	13
14	0.000	0.000	0.000	0.001	0.001	0.003	0.003	0.001	0.003	0.003	0.005	0.001	0.001	0.002	0.001	0.0000	14
15	0.000	0.000	0.000	0.000	0.001	0.003	0.003	0.001	0.003	0.003	0.001	0.000	0.000	0.001	0.001	0.0000	15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

🟩	0-20	🟦	20-40	🟨	40-60	🟪	60-80	🟧	80-100	🟥	> 100

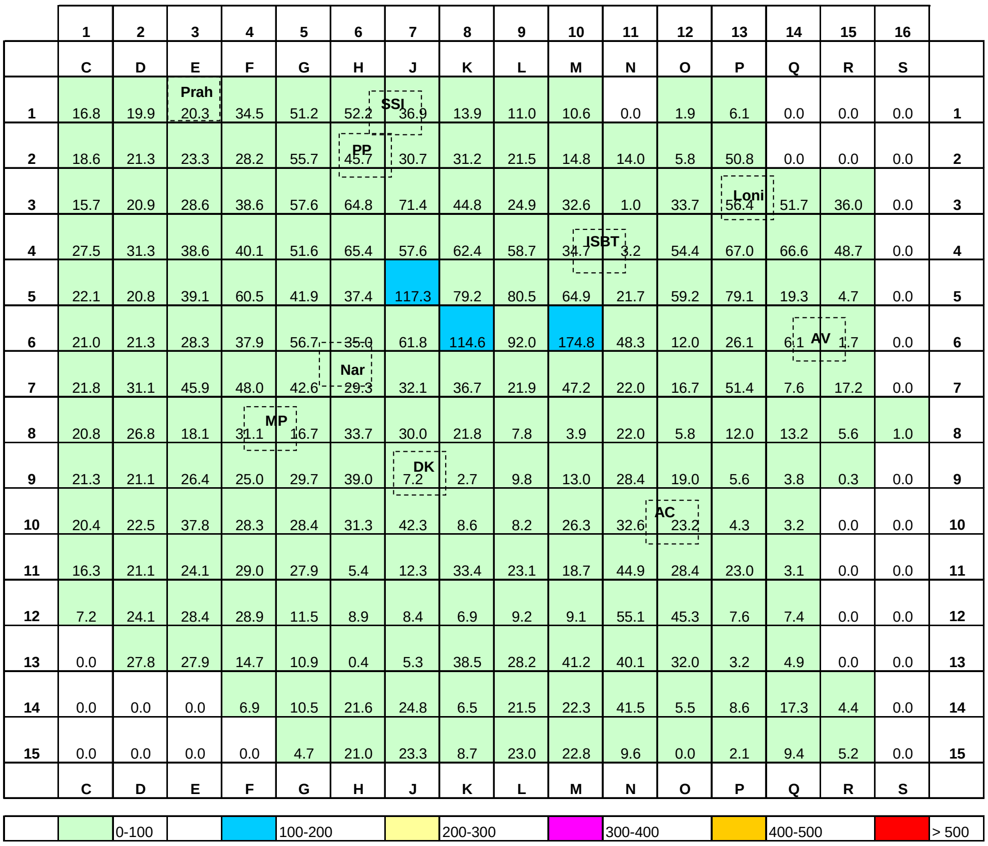
Fig.6.32: Grid wise SO_2 Emissions Rate (kg/d): Area Sources Control Scenario 2017



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1	28.2	49.1	Prah 49.1	55.0	99.6	80.8	SSI 68.0	34.1	28.9	29.9	0.0	13.1	11.5	0.0	0.0	0.0	1
2	36.9	49.3	49.2	66.4	101.6	PP 105.2	59.5	63.4	51.6	40.8	28.8	40.8	84.8	0.0	0.0	0.0	2
3	42.2	49.8	51.0	83.4	107.2	121.8	129.8	73.3	56.9	57.3	0.9	60.4	Loni 102.9	94.5	77.9	0.0	3
4	57.7	57.6	67.6	80.0	97.6	112.2	104.1	107.4	85.3	ISBT 79.5	3.2	81.9	116.9	119.9	75.3	0.0	4
5	46.1	44.9	66.3	91.6	71.4	78.9	171.9	120.1	118.5	113.2	34.8	81.6	117.4	72.9	33.7	0.0	5
6	44.8	45.7	53.9	67.5	78.8	74.4	91.9	129.5	130.5	242.2	74.9	26.0	80.5	AV 65.4	26.1	13.6	6
7	45.8	52.7	61.2	77.2	71.6	Nar 50.7	63.9	67.9	51.5	75.9	39.0	26.5	91.1	68.2	51.4	0.0	7
8	45.2	41.9	31.1	MP 51.6	30.3	60.7	64.1	44.8	29.3	25.6	42.6	5.2	40.2	70.8	62.8	0.0	8
9	45.4	46.2	47.7	52.4	62.4	67.6	DK 15.5	27.5	31.2	34.3	50.0	41.2	11.2	55.3	15.8	0.0	9
10	44.6	47.5	74.1	58.9	61.3	68.1	81.6	36.2	31.3	44.0	49.0	AC 40.4	11.8	12.7	0.0	0.0	10
11	36.0	45.6	53.4	61.3	61.3	45.8	54.2	60.4	60.7	58.1	75.1	55.5	27.4	4.9	0.0	0.0	11
12	15.9	53.0	62.1	61.1	17.3	45.7	46.6	48.6	49.9	50.6	96.1	71.3	10.5	11.9	0.0	0.0	12
13	0.0	60.7	61.3	30.0	12.9	16.3	38.0	62.2	56.1	77.7	73.8	70.4	3.5	6.5	0.0	0.0	13
14	0.0	0.0	0.0	15.3	13.1	28.3	37.7	16.9	28.0	30.2	48.0	7.7	11.5	20.2	5.7	0.0	14
15	0.0	0.0	0.0	0.0	5.8	27.7	29.4	12.4	27.8	29.0	12.6	0.0	2.8	12.4	6.9	0.0	15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

🟩	0-100	🟦	100-200	🟨	200-300	🟪	300-400	🟧	400-500	🟥	> 500

Fig. 6.33: Grid wise NOx Emissions Rate (kg/d): Area Sources Control Scenario 2012



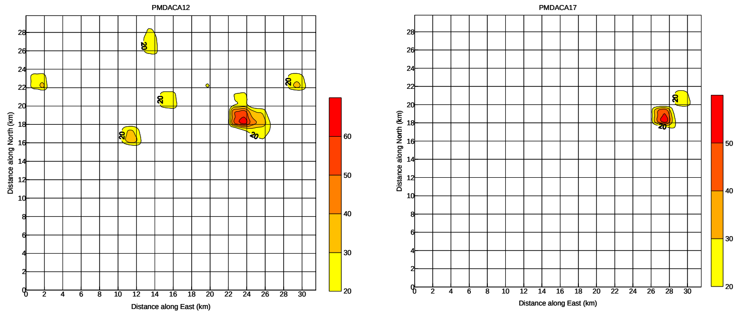
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1	16.8	19.9	Prah 20.3	34.5	51.2	52.2	SSI 36.9	13.9	11.0	10.6	0.0	1.9	6.1	0.0	0.0	0.0	1
2	18.6	21.3	23.3	28.2	55.7	PP 45.7	30.7	31.2	21.5	14.8	14.0	5.8	50.8	0.0	0.0	0.0	2
3	15.7	20.9	28.6	38.6	57.6	64.8	71.4	44.8	24.9	32.6	1.0	33.7	Loni 56.4	51.7	36.0	0.0	3
4	27.5	31.3	38.6	40.1	51.6	65.4	57.6	62.4	58.7	ISBT 34.7	3.2	54.4	67.0	66.6	48.7	0.0	4
5	22.1	20.8	39.1	60.5	41.9	37.4	117.3	79.2	80.5	64.9	21.7	59.2	79.1	19.3	4.7	0.0	5
6	21.0	21.3	28.3	37.9	56.7	35.0	61.8	114.6	92.0	174.8	48.3	12.0	26.1	6.1	AV 1.7	0.0	6
7	21.8	31.1	45.9	48.0	42.6	Nar 29.3	32.1	36.7	21.9	47.2	22.0	16.7	51.4	7.6	17.2	0.0	7
8	20.8	26.8	18.1	31.1	MP 16.7	33.7	30.0	21.8	7.8	3.9	22.0	5.8	12.0	13.2	5.6	1.0	8
9	21.3	21.1	26.4	25.0	29.7	39.0	DK 7.2	2.7	9.8	13.0	28.4	19.0	5.6	3.8	0.3	0.0	9
10	20.4	22.5	37.8	28.3	28.4	31.3	42.3	8.6	8.2	26.3	32.6	AC 23.2	4.3	3.2	0.0	0.0	10
11	16.3	21.1	24.1	29.0	27.9	5.4	12.3	33.4	23.1	18.7	44.9	28.4	23.0	3.1	0.0	0.0	11
12	7.2	24.1	28.4	28.9	11.5	8.9	8.4	6.9	9.2	9.1	55.1	45.3	7.6	7.4	0.0	0.0	12
13	0.0	27.8	27.9	14.7	10.9	0.4	5.3	38.5	28.2	41.2	40.1	32.0	3.2	4.9	0.0	0.0	13
14	0.0	0.0	0.0	6.9	10.5	21.6	24.8	6.5	21.5	22.3	41.5	5.5	8.6	17.3	4.4	0.0	14
15	0.0	0.0	0.0	0.0	4.7	21.0	23.3	8.7	23.0	22.8	9.6	0.0	2.1	9.4	5.2	0.0	15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

🟩 0-100	🟦 100-200	🟨 200-300	🟪 300-400	🟧 400-500	🟥 > 500

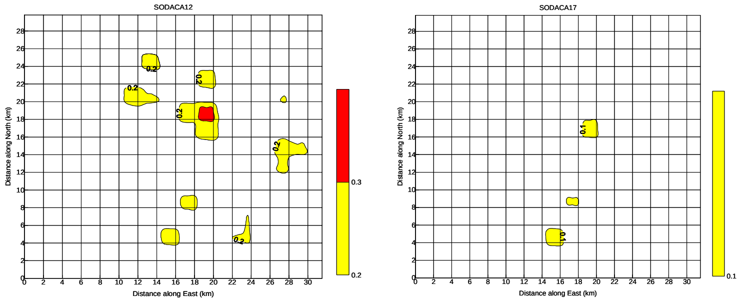
Fig. 6.34: Grid wise NOx Emissions Rate (kg/d): Area Sources Control Scenario 2017

6.4.1.3 Air Quality Modeling under Control Scenarios (2012 & 2017) – Area Sources

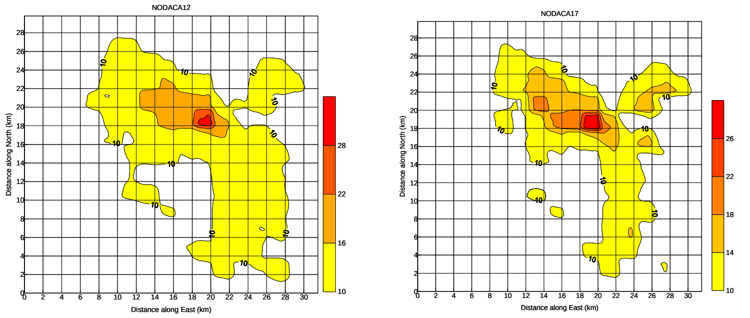
The impact of suggested pollution control measures on ambient air quality has been predicted adopting the similar approach as discussed earlier in this section. Scenarios for 2012 and 2017 have been generated. Using estimated grid wise emissions of PM, SO_2 and NOx, modeling exercises were carried out for critical winter season. Highest ten 24-hourly predicted GLC for PM, SO_2 and NOx in Delhi for 2012 and 2017 are given in **Annexure 6.2**. Maximum GLCs of PM, SO_2 and NOx in 2012 are observed to be 63.8, 0.33 & 29.8 µg/m^3 respectively occurring in Shashtri Nagar (Gita Colony), and Sultanpuri area. Predicted MGLC$_S$ of PM, SO_2 and NOx in 2017 are 53.8, 0.19 & 29.7 µg/m^3 respectively, occurring in Patparganj Industrial area, Ladho sarai and Sultanpuri area, respectively. Iso-concentration plots are drawn for PM, SO_2 and NOx separately for 2012 and 2017, are presented in **Fig. 6.35**.



Control PM-2012 Control PM-2017



Control SO_2-2012 Control SO_2-2017



Control NO_2-2012 Control NO_2-2017

Fig. 6.35: Iso- Concentration Plots for PM, SO_2 and NOx: 2012 & 2017 with Control Option Scenarios (Area Sources)

6.4.2 Point Sources

Methodology, Assumptions and Control Options

Industries use multiple fuel for combustion such as coal, furnace oil, LDO,HSD,NG etc. They also use wide varying control applications.

- **Cleaner fuel**

Natural Gas use in power plants and medium scale industries is considered as a better and cleaner fuel option as compared to coal and diesel. Possible requirement of cleaner fuel has been calculated using base of calorific value.

- **Air pollution control equipment**

To control PM and SO_2 emissions from medium scale industries, use of control equipment viz. Venturi scrubber and FGD have been considered as possible options. Efficiency of Venturi scrubber is considered at 60%. In the case of power plants, two stage ESPs (to increase efficiency from 99.5 to 99.9%) and FGDC (Flue Gas Desulphurization) system are considered for PM reduction.

- **Shifting of SSI units**

Small scale industries have been advised to shift. The location policy drives the problem associated with their air pollution.

6.4.2.1 Emission Load Projection for 2012 and 2017

Based on the above approach, grid wise emission load for 2012 and 2017 under control scenario have been estimated for PM, SO_2 and NOx. Emission Control Options studied for 2012 and 2017 scenario are given in **Table 6.21**. Source-wise estimated pollutant (PM, SO_2 and NOx) emission loads and percent reduction under control scenarios for 2012 and 2017 are presented in **Tables 6.22.**

Table 6.21: Emission Control Options Scenarios in 2012 and 2017 (industrial Sources)

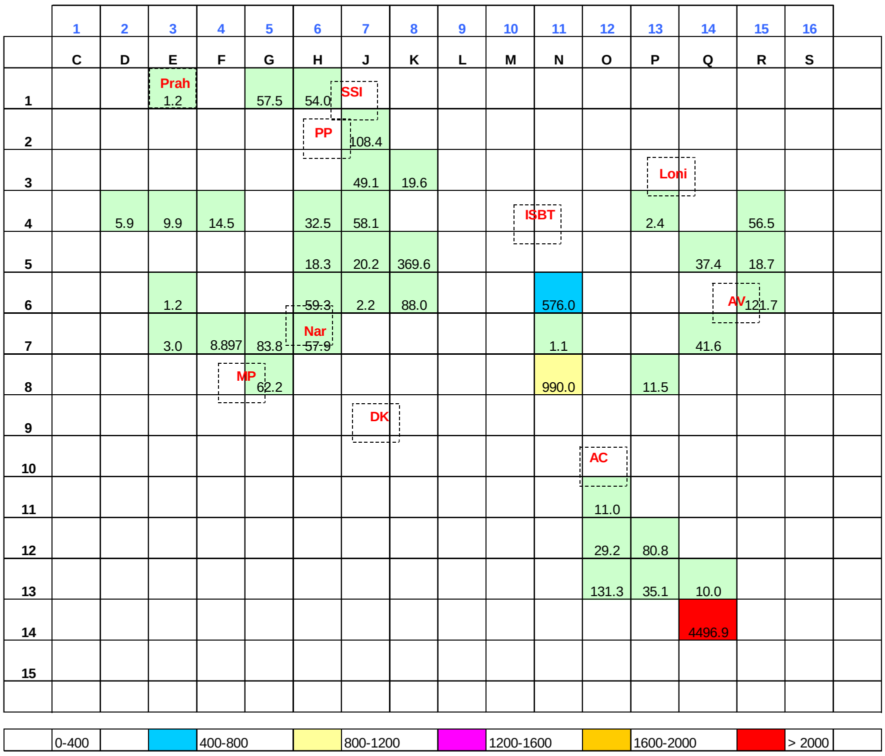
Control Option	Type of Industries	Scenario for 2012	Scenario for 2017
Use of cleaner fuels viz. NG	Large scale (power plants)	All power plants to be shifted to NG	All power plants to be operated on NG
	Medium scale	100% to be shifted to NG	100% to be operated on NG
	Small scale	--	--
Installation of control equipment viz. FGD, wet scrubber	Large scale (power plants)	Improvement in ESP efficiency, Installation of FGD	Upcoming power plants to be operated on NG
	Medium scale	Venturi scrubber to be installed in 100% industries	Venturi scrubber to be installed in 100% industries
	Small scale	Venturi scrubber to be installed in 50% industries	Venturi scrubber to be installed in 100% industries
Shifting of Industries	Large scale (power plants)	--	--
	Medium scale	--	--
	Small scale	50% industries to be shifted	100% industries to be shifted

Table 6.22: Emission Loads and % Reduction under Control Scenario – 2012 and 2017 (Industrial Sources)

Sources		Controlled Emissions (kg/day) 2012			Controlled Emissions (kg/day) 2017		
		PM10	SO_2	NOx	PM10	SO_2	NOx
Control Equipment	Large Scale	6049.1	2554.5	335462.4	6061.6	2752.5	427880.7
	Medium Scale	58.1	1809.3	185.9	58.1	1809.3	185.9
	Small Scale	1606.8	3135.4	24877.4	835.2	1771.8	24877.4
	Total	**7714.0**	**7499.1**	**360525.6**	**6954.9**	**6333.6**	**452944.0**
Fuel Change	Large Scale	5.4	85.4	39851.3	18.0	283.4	132269.6
	Medium Scale	0.7	0.1	24.0	0.7	0.1	24.0
	Small Scale	2088.0	4429.6	24877.4	2088.0	4429.6	24877.4
	Total	**2094.0**	**4515.0**	**64752.7**	**2094.0**	**4515.0**	**64752.7**
Shifting of Industries	Large Scale	30245.4	255446.2	335462.4	30245.4	255446.2	335462.4
	Medium Scale	145.2	4523.2	185.9	145.2	4523.2	185.9
	Small Scale	1286.0	2272.6	13707.8	-	-	-
	Total	**31677.0**	**262242.0**	**349356.0**	**30390.6**	**259969.4**	**335648.3**

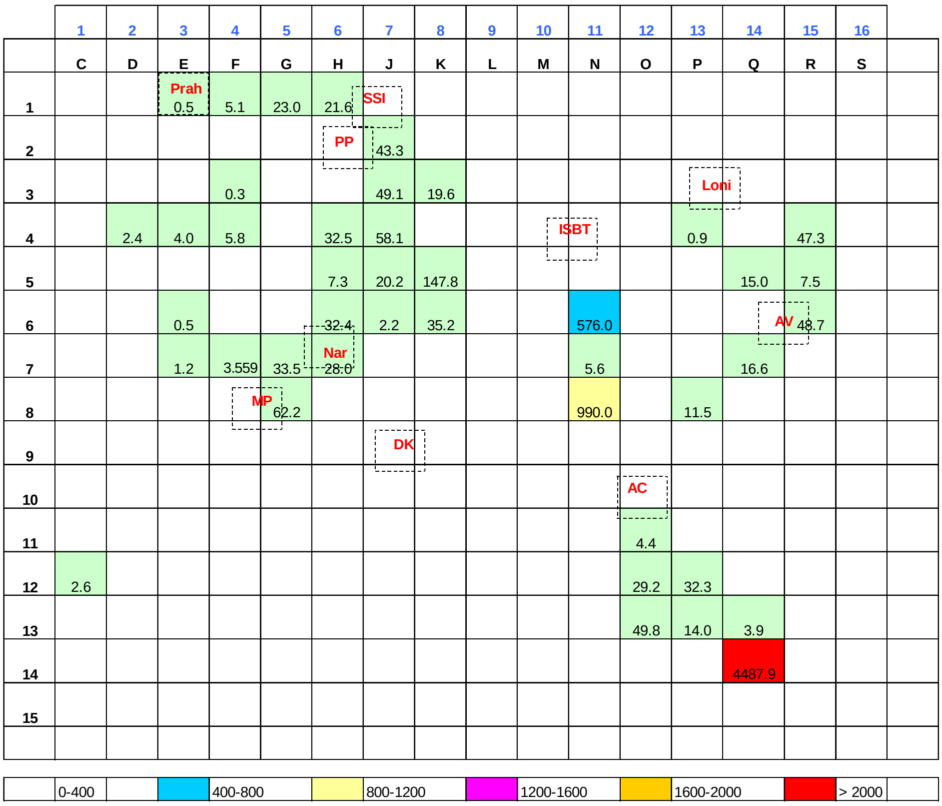
A perusal of above table indicates that in 2012, due to the usage of Control equipment, total PM and SO_2 emissions are reduced by 76.2% and 97.2%, while there is almost no reduction in NOx emissions. Total PM, SO_2 and NOx emissions can be reduced by 93.6%, 98.3% and 82.0% respectively by using cleaner fuel. By shifting small scale industries, 2.5%, 0.8% and 3.1% reductions can be achieved in PM, SO_2 and NOx emissions respectively in 2012.

In 2017, by using control equipments, emission loads of PM and SO_2 can be reduced by 78.6% and 97.6% respectively. Total PM, SO_2 and NOx emissions can be reduced by 93.5%, 98.2% and 65.3% respectively with cleaner fuel. By shifting small scale industries, 6.5%, 1.8% and 25.9% reductions can be achieved in PM, SO_2 and NOx emissions respectively in 2017. Grid wise emission loads for 2012 and 2017 under two scenarios, adoption of air pollution control equipment and use of cleaner fuels in industries are estimated for PM10, SO_2 and NOx, and these are given in **Figs. 6.36** through **6.47**.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S
1			1.2		57.5	54.0										
2							108.4									
3							49.1	19.6								
4		5.9	9.9	14.5		32.5	58.1						2.4		56.5	
5						18.3	20.2	369.6						37.4	18.7	
6			1.2			59.3	2.2	88.0			576.0				121.7	
7			3.0	8.897	83.8	57.9					1.1			41.6		
8					62.2						990.0		11.5			
9																
10																
11												11.0				
12												29.2	80.8			
13												131.3	35.1	10.0		
14														4496.9		
15																

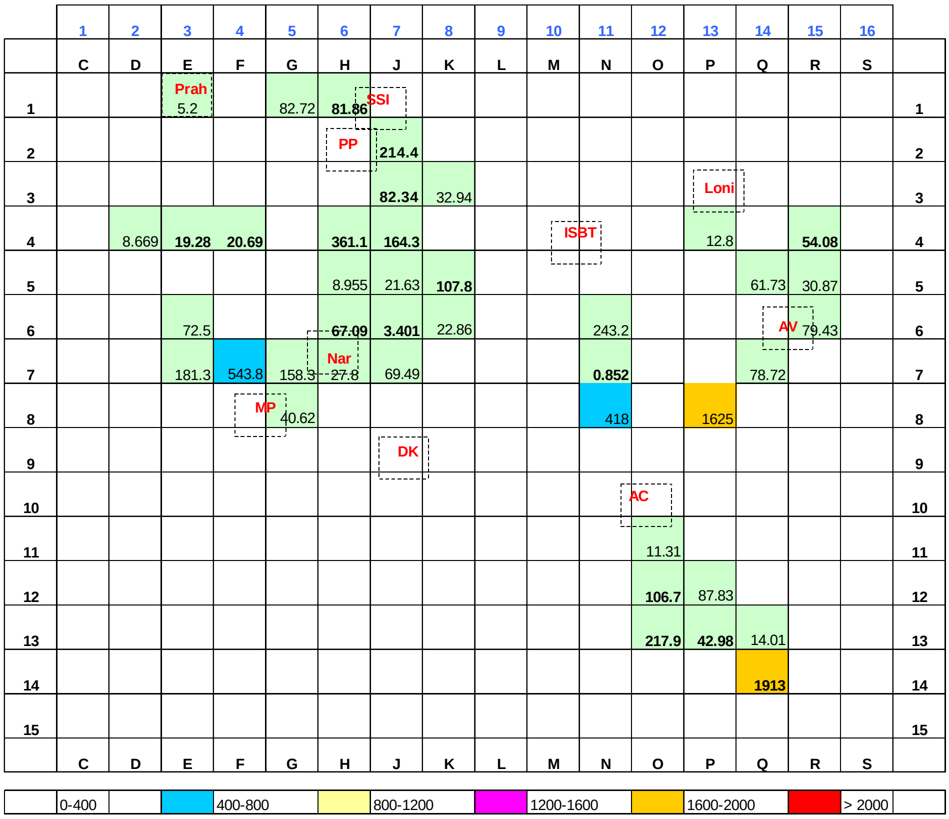
Fig. 6.36: Grid wise PM10 Emissions Load (kg/d): 2012 (Control Equipment Scenario)



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S
1			Prah 0.5	5.1	23.0	21.6	SSI									
2						PP	43.3									
3				0.3			49.1	19.6					Loni			
4		2.4	4.0	5.8		32.5	58.1			ISBT			0.9		47.3	
5						7.3	20.2	147.8						15.0	7.5	
6			0.5			32.4	2.2	35.2			576.0				AV 48.7	
7			1.2	3.559	33.5	Nar 28.0					5.6			16.6		
8				MP	62.2						990.0		11.5			
9							DK									
10												AC				
11												4.4				
12	2.6											29.2	32.3			
13												49.8	14.0	3.9		
14														4487.9		
15																

☐ 0-400	🟦 400-800	🟨 800-1200	🟪 1200-1600	🟧 1600-2000	🟥 > 2000

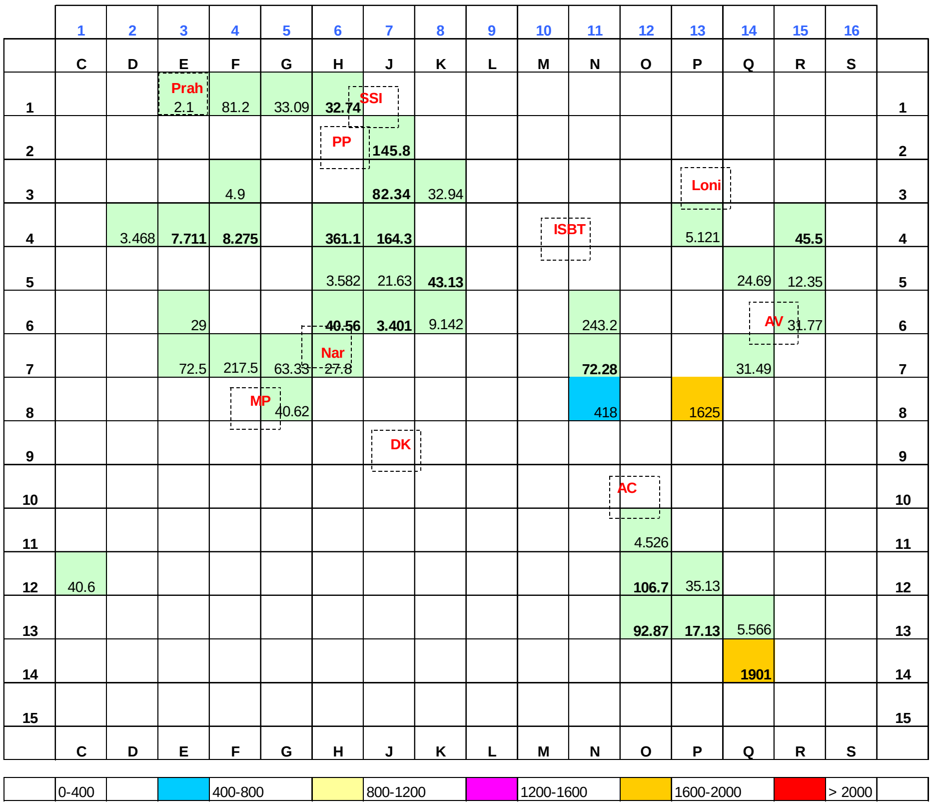
Fig. 6.37 : Grid wise PM10 Emissions Load (kg/d): 2017 (Control Equipment Scenario)



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1			Prah 5.2		82.72	**81.86**	SSI										1
2						PP	**214.4**										2
3							**82.34**	32.94					Loni				3
4		8.669	**19.28**	**20.69**		**361.1**	**164.3**			ISBT			12.8		**54.08**		4
5						8.955	21.63	**107.8**						61.73	30.87		5
6			72.5			**67.09**	**3.401**	22.86			243.2				AV 79.43		6
7			181.3	543.8	158.3	Nar 27.8	69.49				**0.852**			78.72			7
8				MP	40.62						418		1625				8
9							DK										9
10												AC					10
11												11.31					11
12												**106.7**	87.83				12
13												**217.9**	**42.98**	14.01			13
14														**1913**			14
15																	15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

☐ 0-400	🟦 400-800	🟨 800-1200	🟪 1200-1600	🟧 1600-2000	🟥 > 2000

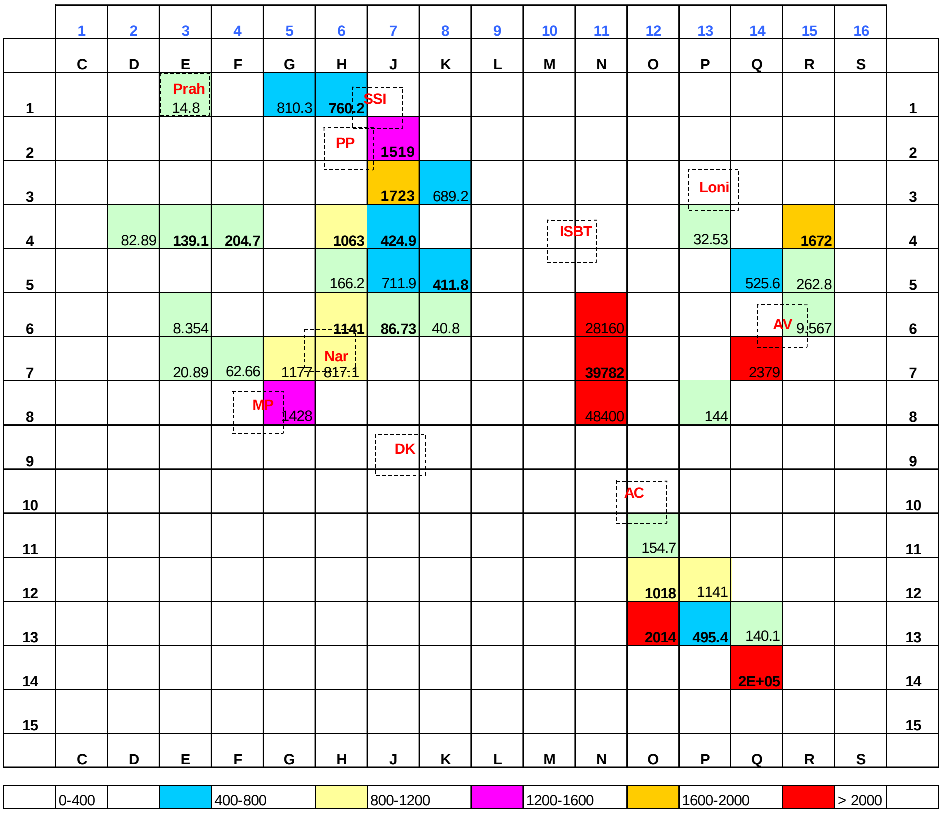
Fig. 6.38 : Grid wise SO_2 Emissions Load (kg/d): 2012 (Control Equipment Scenario)



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1			2.1	81.2	33.09	**32.74**											1
2							**145.8**										2
3				4.9			**82.34**	32.94									3
4		3.468	**7.711**	**8.275**		**361.1**	**164.3**						5.121		**45.5**		4
5						3.582	21.63	**43.13**						24.69	12.35		5
6			29			**40.56**	**3.401**	9.142			243.2				31.77		6
7			72.5	217.5	63.33	27.8					**72.28**			31.49			7
8					40.62						418		1625				8
9																	9
10																	10
11												4.526					11
12	40.6											**106.7**	35.13				12
13												**92.87**	**17.13**	5.566			13
14														**1901**			14
15																	15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

	0-400		🟦	400-800	🟨	800-1200	🟪	1200-1600	🟧	1600-2000	🟥	> 2000

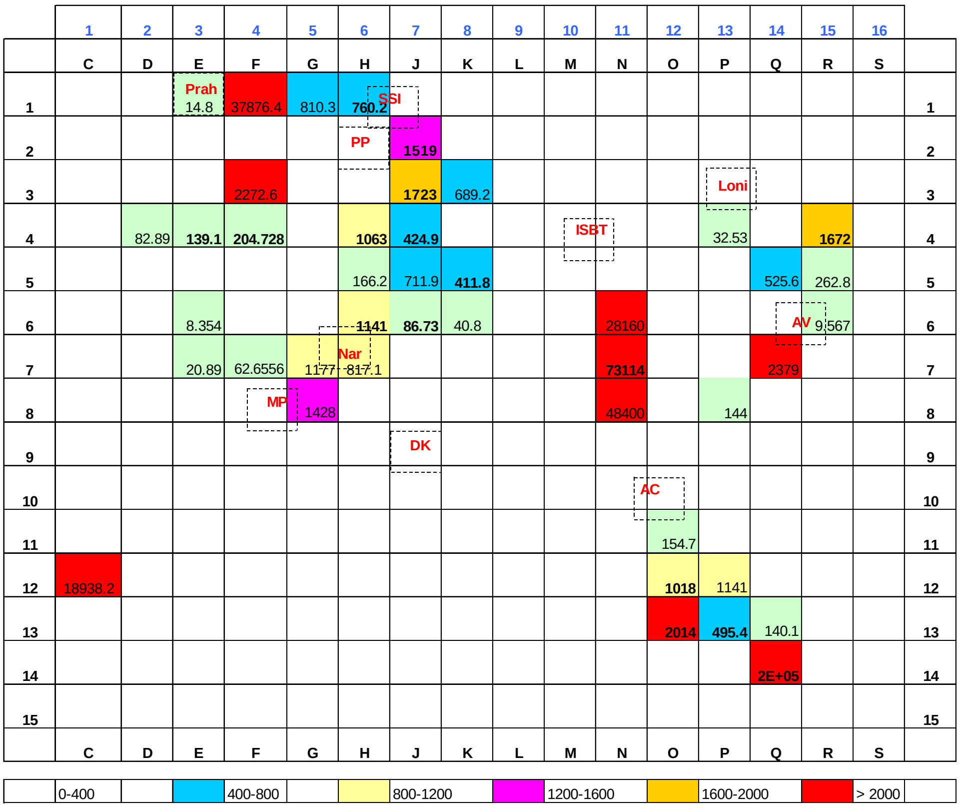
Fig. 6.39 : Grid wise SO_2 Emissions Load (kg/d): 2017 (Control Equipment Scenario)



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1			14.8		810.3	**760.2**											1
2							**1519**										2
3							**1723**	689.2									3
4		82.89	**139.1**	**204.7**		**1063**	**424.9**						32.53		**1672**		4
5						166.2	711.9	**411.8**						525.6	262.8		5
6			8.354			**1141**	**86.73**	40.8			28160				9.567		6
7			20.89	62.66	1177	817.1					**39782**			2379			7
8					1428						48400		144				8
9																	9
10																	10
11												154.7					11
12												**1018**	1141				12
13												**2014**	**495.4**	140.1			13
14														**2E+05**			14
15																	15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

	0-400		🟦	400-800	🟨	800-1200	🟪	1200-1600	🟧	1600-2000	🟥	> 2000

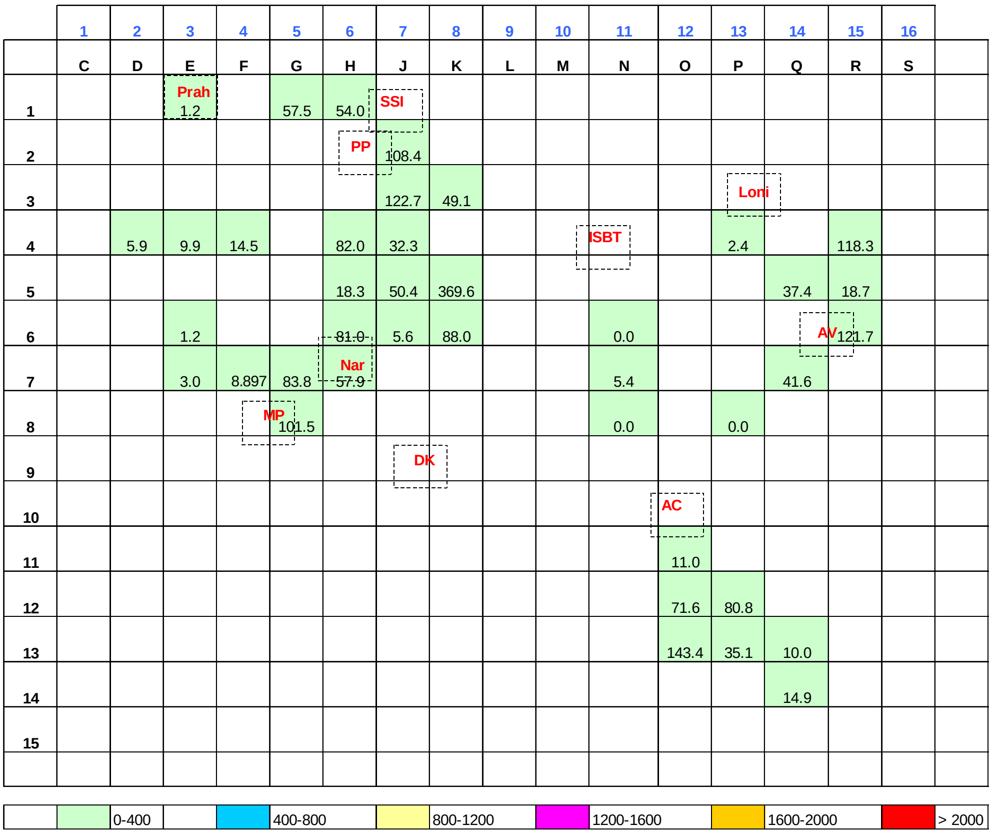
Fig. 6.40 : Grid wise NOx Emissions Load (kg/d): 2012 (Control Equipment Scenario)



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1			Prah 14.8	37876.4	810.3	760.2	SSI										1
2						PP	1519										2
3				2272.6			1723	689.2					Loni				3
4		82.89	139.1	204.728		1063	424.9			ISBT			32.53		1672		4
5						166.2	711.9	411.8						525.6	262.8		5
6			8.354			1141	86.73	40.8			28160			AV	9.567		6
7			20.89	62.6556	1177	Nar 817.1					73114			2379			7
8				MP	1428						48400		144				8
9							DK										9
10												AC					10
11												154.7					11
12	18938.2											1018	1141				12
13												2014	495.4	140.1			13
14														2E+05			14
15																	15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

	0-400		🟦	400-800		🟨	800-1200	🟪	1200-1600	🟧	1600-2000	🟥	> 2000	

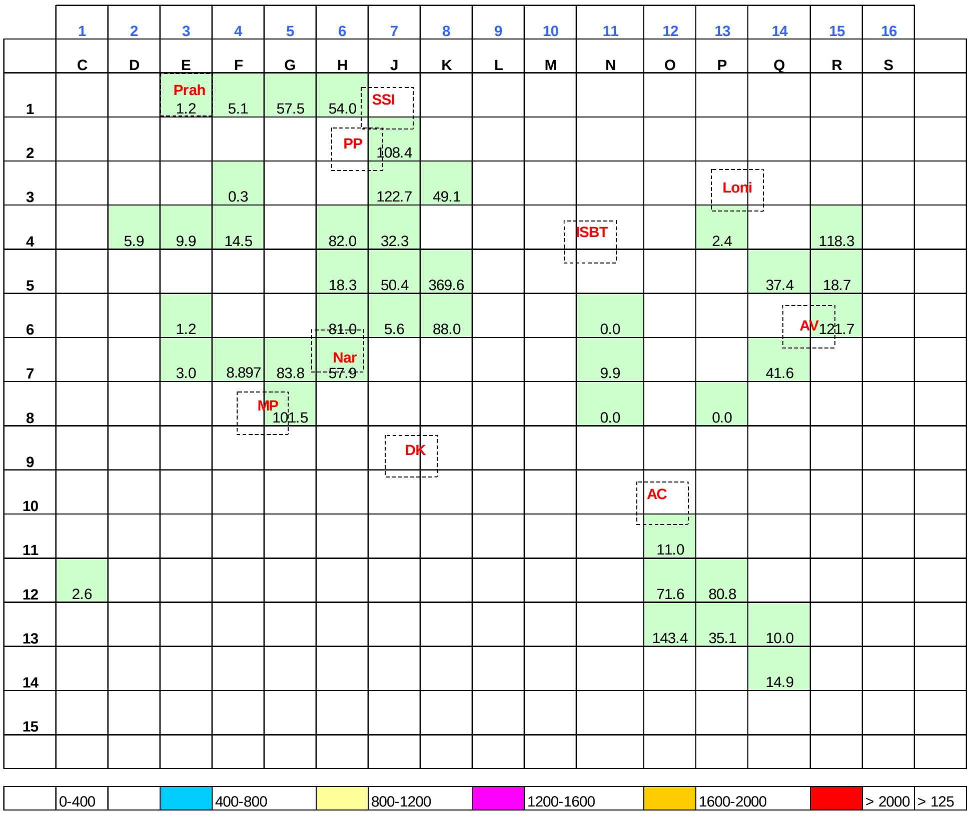
Fig. 6.41 : Grid wise NOx Emissions Load (kg/d): 2017 (Control Equipment Scenario)



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1			Prah 1.2		57.5	54.0	SSI										
2						PP	108.4										
3							122.7	49.1					Loni				
4		5.9	9.9	14.5		82.0	32.3				ISBT		2.4		118.3		
5						18.3	50.4	369.6						37.4	18.7		
6			1.2			81.0	5.6	88.0			0.0			AV	121.7		
7			3.0	8.897	83.8	Nar 57.9					5.4			41.6			
8				MP	101.5						0.0		0.0				
9							DK										
10												AC					
11												11.0					
12												71.6	80.8				
13												143.4	35.1	10.0			
14														14.9			
15																	

	🟩	0-400		🟦	400-800	🟨	800-1200	🟪	1200-1600	🟧	1600-2000	🟥	> 2000	

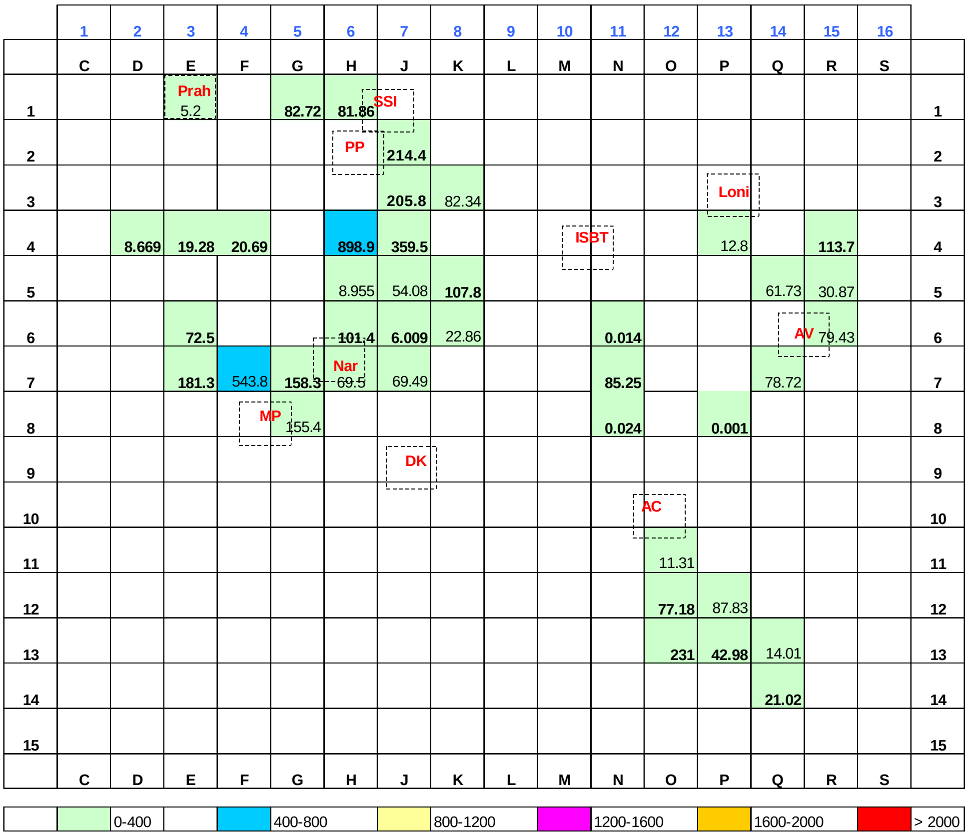
Fig. 6.42 : Grid wise PM10 Emissions Load (kg/d): 2012 (Industrial Fuel Change Scenario)



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1			1.2	5.1	57.5	54.0											
2							108.4										
3				0.3			122.7	49.1									
4		5.9	9.9	14.5		82.0	32.3						2.4		118.3		
5						18.3	50.4	369.6						37.4	18.7		
6			1.2			81.0	5.6	88.0			0.0				121.7		
7			3.0	8.897	83.8	57.9					9.9			41.6			
8					101.5						0.0		0.0				
9																	
10																	
11												11.0					
12	2.6											71.6	80.8				
13												143.4	35.1	10.0			
14														14.9			
15																	

	0-400		🟦	400-800	🟨	800-1200	🟪	1200-1600	🟧	1600-2000	🟥	> 2000	> 125

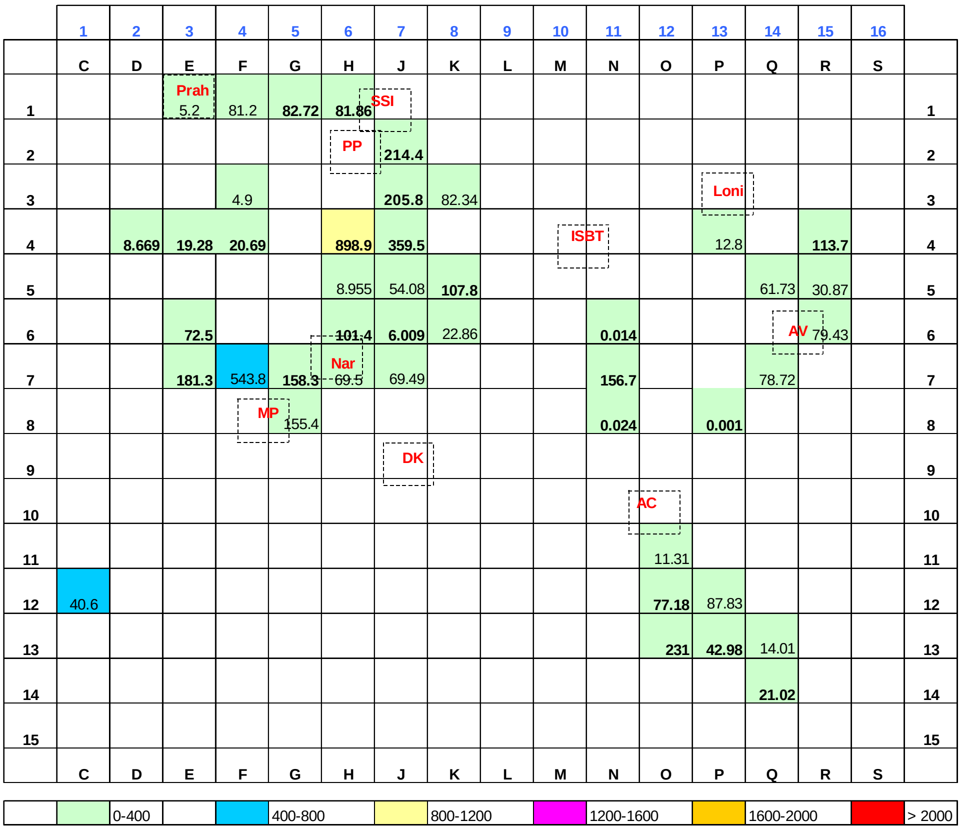
Fig. 6.43 : Grid wise PM10 Emissions Load (kg/d): 2017 (Industrial Fuel Change Scenario)



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1			5.2		82.72	81.86											1
2							214.4										2
3							205.8	82.34									3
4		8.669	19.28	20.69		898.9	359.5						12.8		113.7		4
5						8.955	54.08	107.8						61.73	30.87		5
6			72.5			101.4	6.009	22.86			0.014				79.43		6
7			181.3	543.8	158.3	69.5	69.49				85.25			78.72			7
8					155.4						0.024		0.001				8
9																	9
10																	10
11												11.31					11
12												77.18	87.83				12
13												231	42.98	14.01			13
14														21.02			14
15																	15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

	🟩	0-400		🟦	400-800	🟨	800-1200	🟪	1200-1600	🟧	1600-2000	🟥	> 2000

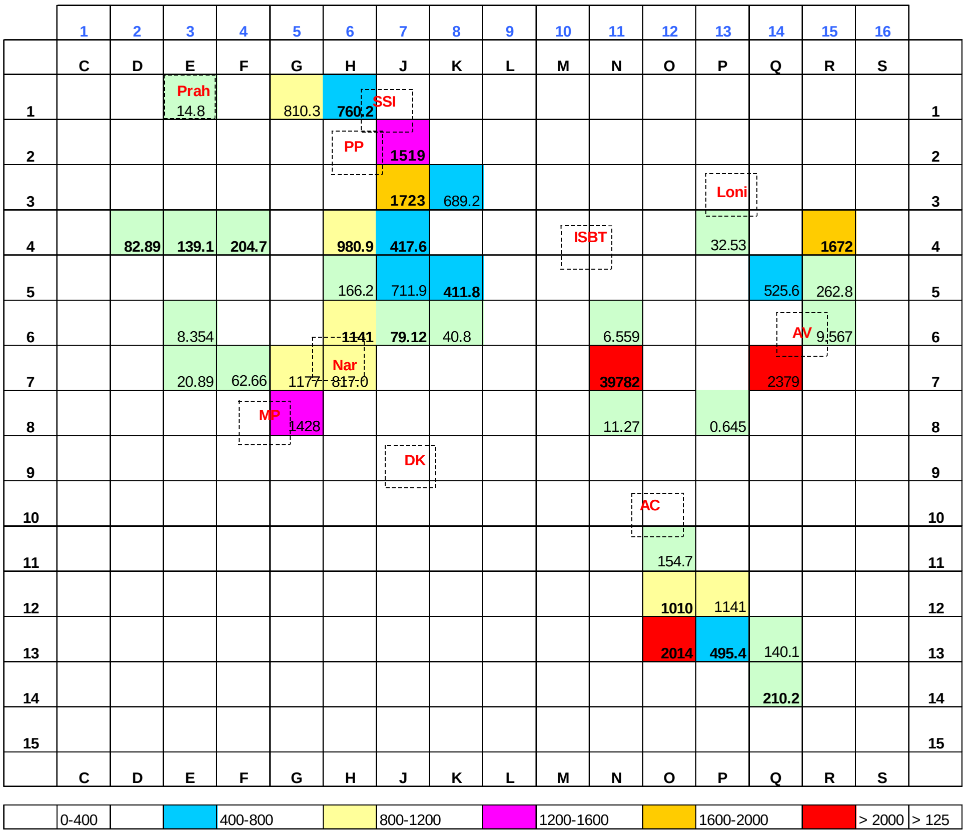
Fig. 6.44 : Grid wise SO_2 Emissions Load (kg/d): 2012 (Industrial Fuel Change Scenario)



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1			Prah 5.2	81.2	82.72	81.86	SSI										1
2						PP	214.4										2
3				4.9			205.8	82.34					Loni				3
4		8.669	19.28	20.69		898.9	359.5			ISBT			12.8		113.7		4
5						8.955	54.08	107.8						61.73	30.87		5
6			72.5			101.4	6.009	22.86			0.014			AV	79.43		6
7			181.3	543.8	158.3	Nar 69.5	69.49				156.7			78.72			7
8				MP	155.4						0.024		0.001				8
9							DK										9
10												AC					10
11												11.31					11
12	40.6											77.18	87.83				12
13												231	42.98	14.01			13
14														21.02			14
15																	15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

🟩 0-400 | 🟦 400-800 | 🟨 800-1200 | 🟪 1200-1600 | 🟧 1600-2000 | 🟥 > 2000

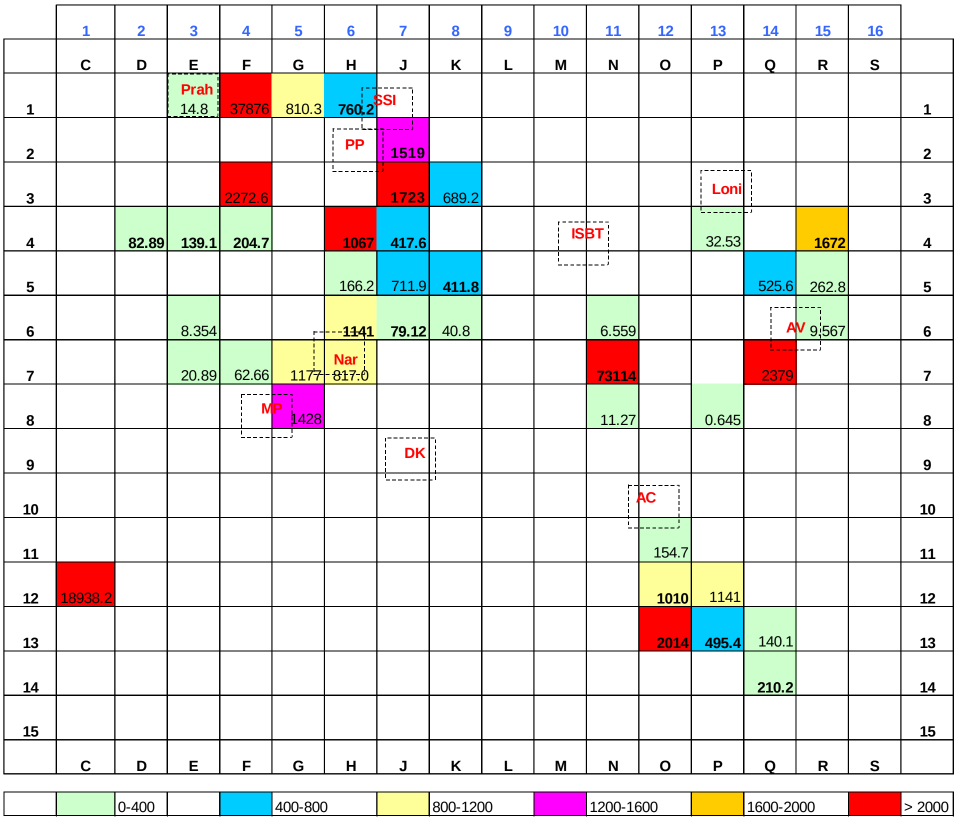
Fig. 6.45 : Grid wise SO_2 Emissions Load (kg/d): 2017 (Industrial Fuel Change Scenario)



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1			Prah 14.8		810.3	760.2	SSI										1
2						PP	1519										2
3							1723	689.2					Loni				3
4		82.89	139.1	204.7		980.9	417.6			ISBT			32.53		1672		4
5						166.2	711.9	411.8						525.6	262.8		5
6			8.354			1141	79.12	40.8			6.559			AV	9.567		6
7			20.89	62.66	1177	Nar 817.0					39782			2379			7
8				MP	1428						11.27		0.645				8
9							DK										9
10												AC					10
11												154.7					11
12												1010	1141				12
13												2014	495.4	140.1			13
14														210.2			14
15																	15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

🟩 0-400 | 🟦 400-800 | 🟨 800-1200 | 🟪 1200-1600 | 🟧 1600-2000 | 🟥 > 2000 | > 125

Fig. 6.46 : Grid wise NOx Emissions Load (kg/d): 2012 (Industrial Fuel Change Scenario)



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	
1			Prah 14.8	37876	810.3	**760.2**	SSI										1
2						PP	**1519**										2
3				2272.6			**1723**	689.2					Loni				3
4		**82.89**	**139.1**	**204.7**		**1067**	**417.6**			ISBT			32.53		**1672**		4
5						166.2	711.9	**411.8**						525.6	262.8		5
6			8.354			**1141**	**79.12**	40.8			6.559			AV	9.567		6
7			20.89	62.66	1177	Nar 817.0					**73114**			2379			7
8				MP	1428						11.27		0.645				8
9							DK										9
10												AC					10
11												154.7					11
12	18938.2											**1010**	1141				12
13												**2014**	**495.4**	140.1			13
14														**210.2**			14
15																	15
	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	

	🟩	0-400		🟦	400-800	🟨	800-1200	🟪	1200-1600	🟧	1600-2000	🟥	> 2000

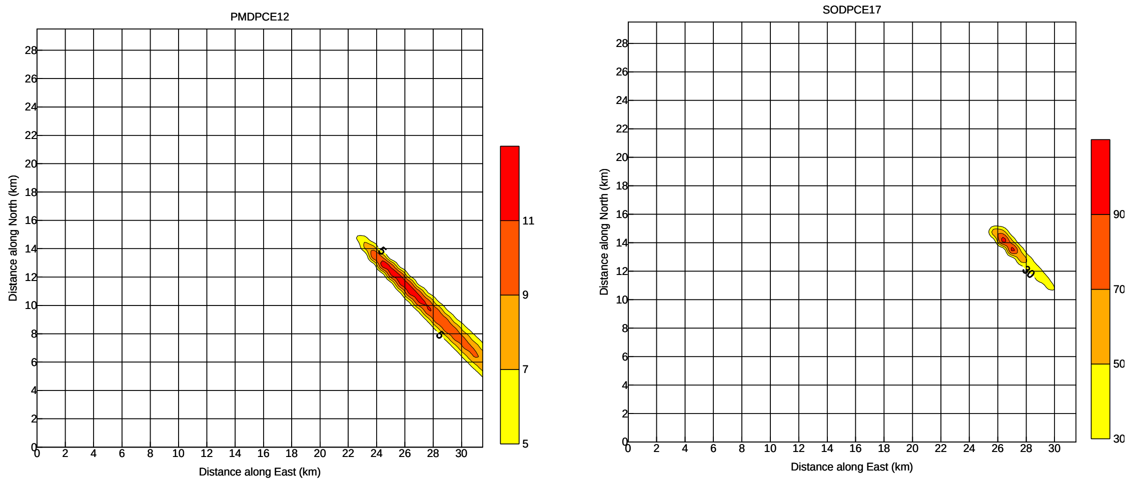
Fig. 6.47 : Grid wise NOx Emissions Load (kg/d): 2017 (Industrial Fuel Change Scenario)

6.4.2.2 Air Quality Modeling under Control Scenarios – Point Sources

The impact of suggested pollution control measures on ambient air quality has been predicted adopting the same modeling approach as discussed in earlier sections. Using estimated grid wise emissions of PM, SO_2 and NOx, modeling exercises were carried out for critical winter season. Highest ten 24-hourly predicted GLCs for PM, SO_2 and NOx in Delhi for 2012 and 2017 are given **Annexure 6.2**.

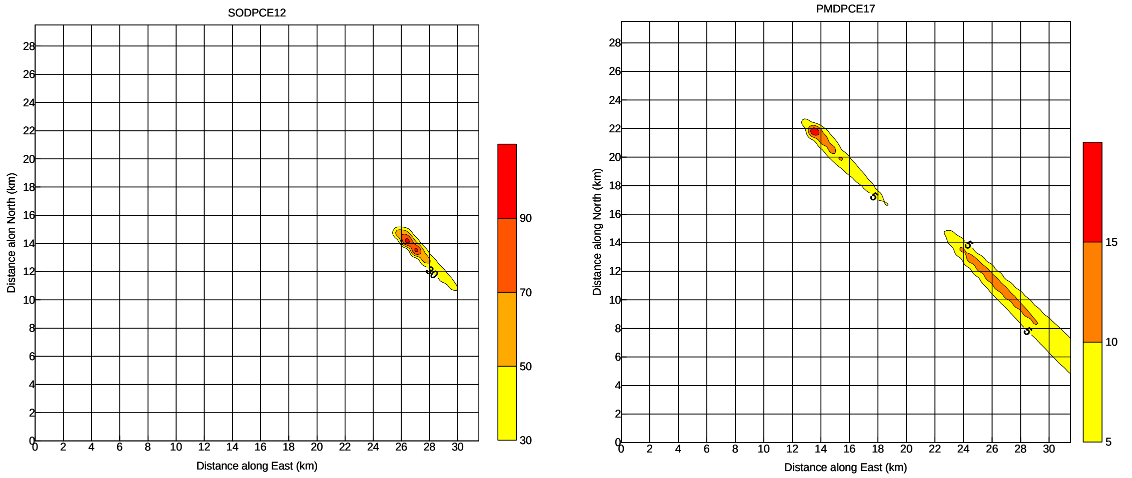
Modeling results indicate that maximum GLCs of PM, SO_2 and NOx in 2012 occur in Patparganj and Paharganj area. Predicted PM, SO_2 and NOx values are highest in Lawrence Road and Patparganj Industrial area, respectively.

There are locations of very high concentrations, however, these are point values. The average grid emissions are much lower. Predicted concentrations at 10 observed sites range between 40-120% of the observed values. Iso-concentration plots are drawn for PM, SO_2 and NOx separately for 2012 and 2017 for the two scenarios, adoption of control equipment and use of cleaner fuels in industries, as presented respectively in **Fig. 6.48** and **Fig. 6.49**.



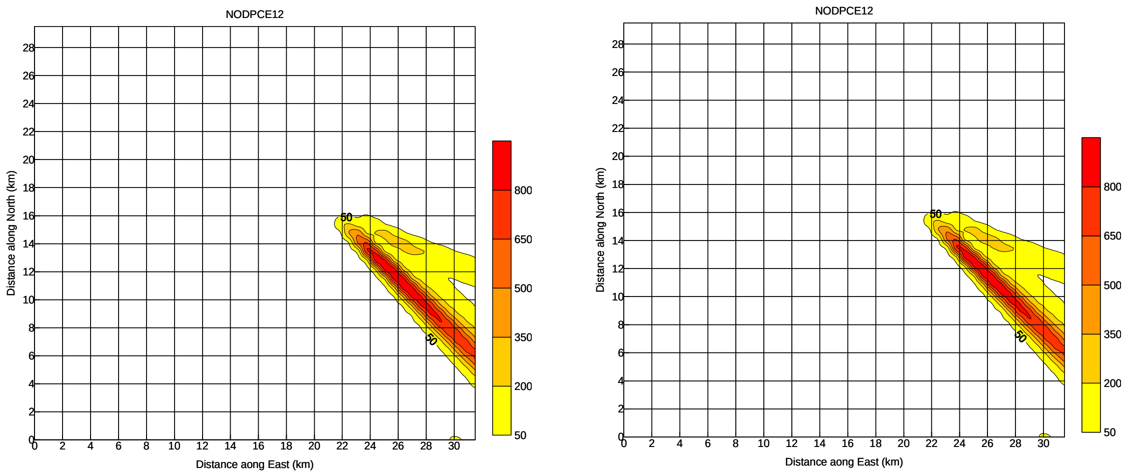
CES – PM 2012

CES – PM 2017



CES – SO_2 2012

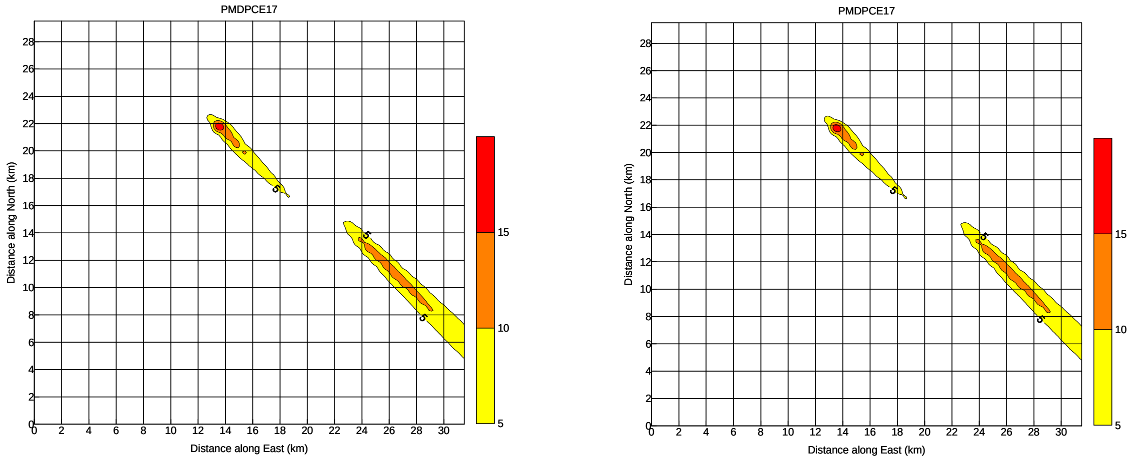
CES – SO_2 2017



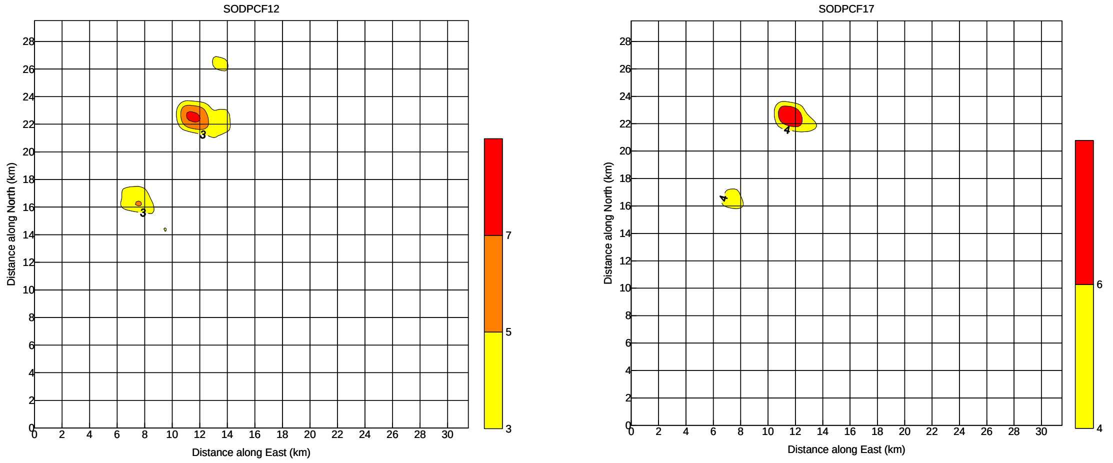
CES – NO_2 2012

CES – NO_2 2017

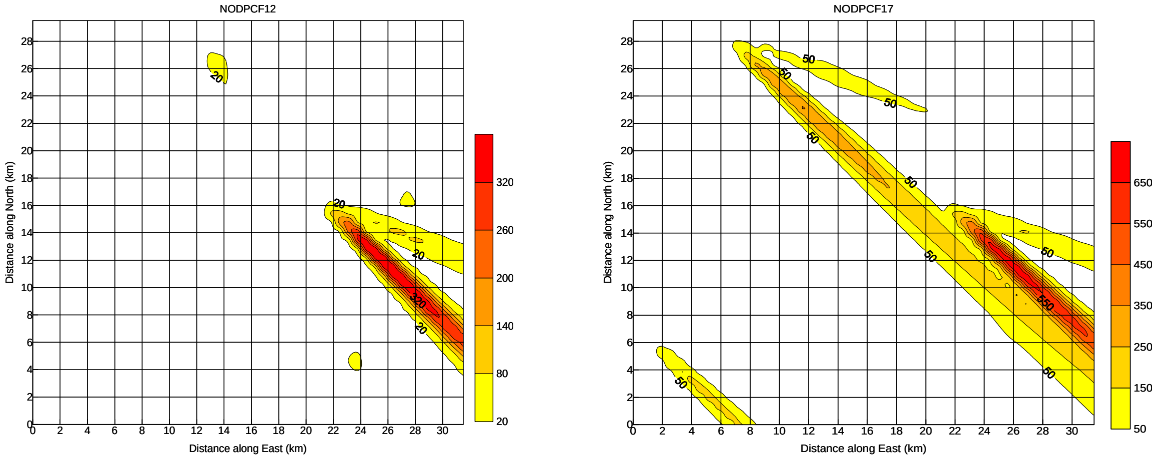
Fig. 6.48 : Iso-concentration Plots of Predicted PM, SO_2 & NOx in Delhi: 2012 & 2017 (Industrial Control Equipment Scenario)



FCS – PM 2012 FCS – PM 2017



FCS – SO_2 2012 FCS – SO_2 2017



FCS – NO_2 2012 FCS – NO_2 2017

Fig. 6.49 : Iso-concentration Plots of Predicted PM, SO_2 & NOx in Delhi: 2012 & 2017 (Industrial Fuel Change Scenario)

6.4.3 Vehicular Sources and Road dust Re-suspension

Vehicular sources mainly comprise of all on road vehicles not the registered numbers. Vehicles control options are numerous starting with fuel shift, technology change, public transport etc. Through re-suspended dust is not directly emitted by vehicles, however, to a greater extant the dust is re-suspended due to vehicle movement. Resuspension of dust can also be due to wind and construction practices.

6.4.3.1 Vehicular Pollution Control Measures : Current Scenario

Several steps were taken up from 1996 onwards to minimize the air pollution in Delhi due to automobiles. These steps are summarized in **Table 6.23.** These measures have resulted in significant improvement in ambient air quality of Delhi. Analysis of air quality data collected at 4 residential, 2 industrial and one traffic intersection sites indicated an overall decrease in pollution. The concentrations of CO and SO_2 decreased, while the concentrations of SPM, PM_{10} and NOx have shown mixed trend. Sulphur level reduction from 0.5% to 0.05% and now 0.035% has led to continuous decline in SO_2 levels.

Table 6.23 : Vehicular Pollution Control Measures Taken in Delhi: 1996-2001

Measures taken	1996	1998	2000	2001	2005
Emission Norms of Vehicles	Emission norms made stringent as compared to 1991	Emission norms for catalytic converter fitted vehicles made stringent. Hot- start replaced by cold – start test which gives less emissions	Euro – I equivalent norms for all types of vehicles except passenger vehicles which are Euro - II equivalent	CNG/ LPG norms finalized	No Change
Fuel Quality Improvement	Fuel quality specifications notified under EPA for the first time. Lead Content = 0.15 g/l Diesel sulfur = 0.5% Gasoline Benzene = 5%	Diesel sulfur reduced to 0.25% Gasoline Benzene reduced to 3% Gasoline Lead phased out	Diesel sulfur reduced to 0.05% in selected outlets. Gasoline Benzene reduced to 1% Gasoline sulfur with 0.05% maximum sulfur in all outlets. Low smoke 2 -T oil introduced	Diesel with 0.05% sulfur throughout retail outlets in NCT	Diesel with 0.035% sulphur for NCT
Other Measures	Govt. vehicles to run on CNG/ Catalytic Converter	15 years old commercial vehicles banned. Pre - mix 2 - T oil in retail outlets	Buses more than 8 years phased out. Replacement of pre-1990 autos/taxis to CNG initiated. Fuel testing laboratory established	All autos/ taxis & buses to run on CNG. 1600 buses, 11,000 taxis and 25,000 autos on CNG	All auto, taxies and buses continues to run on CNG

The levels of lead in PM were also found to be low, indicating the positive impact of supply of unleaded petrol in Delhi. Following the reduction of benzene content (1% from 3 to 1%) of petrol in 2001, benzene levels in ambient air have dropped considerably. In August 1998, the highest concentration of benzene was recorded as 42 µg/m^3. The annual average level of benzene dropped from 6 to 14 µg/m^3 during 2003 at different locations in Delhi. Concentration of polycyclic hydrocarbons (PAHs), highly toxic and carcinogenic compounds also began to decline with annual average concentration of 36.9 µg/m^3 in 1997 to 20.3 µg/m^3 in 2000 (CPCB, 2004).

6.4.3.2 Various Control Options Considered in the Present Study

Analysis of ambient air quality data indicates that the present air quality levels with respect to different pollutants are high. Particulate matter and oxides of nitrogen are particularly very high in Delhi and of which fine particulate and NOx can be attributed mainly to the vehicular activities in Delhi. Therefore, in order to control further emissions from different categories of vehicles, the control options can be classified broadly into categories as: technology based and management based control options. Various control options were discussed amongst the participating institutions (NEERI-Nagpur & Mumbai, ARAI, TERI, IITK, IITB, IITM) carrying out source apportionment study in different cities as well as CPCB experts. A list of possible technology based and management based options, applicable to different cities was prepared as given in **Table 6.24** and **Table 6.25** respectively. Based on the city specific situations, these control options are evaluated with respect to overall reduction in PM and NOx emission loads from vehicular sources by 2012 and 2017, as compared to Business-as-usual Scenario (BAU).

Table 6.24: Technology based Vehicular Control Options, Expected Reductions and Achievable Targets

Sr. No.	Control Option	Expected Reductions	2012 Scenario	2017 Scenario	Remarks
1.	**Implementation of Stringent Emission Norms**				
a.	Implementation of BS – IV norms	Difference between BS-III and BS-IV (as currently BS-III is in use): Gasoline – NOx: 47% Diesel – PM: 45%, NOx: 50%	BS-IV from 2012	BS-IV from 2012	Technically feasible, involves huge investments
b.	Implementation of BS – V norms	Difference between BS-IV and BS-V: Gasoline – NOx: 25% Diesel – PM: 90%, NOx: 28%	BS-V from 2012	BS-V from 2012	Technically feasible, involves huge investments
c.	Implementation of BS – VI norms	Difference between BS-V and BS-VI: Diesel – NOx: 55%	BS-VI from 2012	BS-VI from 2012	Technically feasible, involves huge investments

Table 6.24 (Contd..): Technology based Vehicular Control Options, Expected Reductions and Achievable Targets

Sr. No.	Control Option	Expected Reductions	2012 Scenario	2017 Scenario	Remarks
2.	**Introduction of Electric/Hybrid Vehicles**				
a.	Electric Vehicles	NOx and PM: 100% (Zero emissions)	Share of Electric vehicles in total city fleet - 2Ws: 1%, 3Ws and Taxi: 5%, Public buses: 5%	Share of Electric vehicles in total city fleet - 2Ws: 2%, 3Ws and Taxi: 10%, Public buses: 10%	Technically feasible, Infrastructure and power requirement to be assessed
b.	Hybrid vehicles	NOx: 50%	Share of Hybrid vehicles in total city fleet (Gasoline powered 4Ws - only) – 1%	Share of Hybrid vehicles in total city fleet (Gasoline powered 4Ws only) – 2%	
3.	**Change to Clean Fuel**				
a.	CNG/LPG to commercial (all 3 and 4-wheelers)	Public Transport (Buses) – PM: 75% NOx: 12.5% (as compared to BS-II and BS-III vehicles)	25% conversion	100% conversion	Technically feasible, Supply of CNG/LPG and required infrastructure to be assessed
4.	**Blending in Fuel**				
a.	Ethanol blending (E10 – 10% blend)	NOx: 5%	Share of Ethanol blended fuel – 10%	Share of Ethanol blended fuel – 10%	Technically feasible, Availability of Ethanol to be assessed
b.	Bio-diesel (B5/B10: 5 – 10% blend)	PM: 10% NOx: + 2.5% (increase)	Share of Bio-diesel fuel – 5%	Share of Bio-diesel fuel – 10%	Estimation, as no current data available on B5/B10
c.	Hydrogen – CNG blend (H10/H20: 10 – 20% blend)	NOx: 10%		Share of Hydrogen blended fuel - 10% (for vehicles on CNG)	Techno-economic feasibility to be established
5.	**Retro fitment of Diesel Vehicles**				
a.	Retrofitment of Diesel Oxidation Catalyst (DOC) in 4-wheeler public transport (BS – II)	PM: 22.5 % (as compared to BS – II vehicles)	50% conversion	100% conversion	Technically feasible but compliance to be ensured
b.	Retrofitment of Diesel Particulate Filter in 4-wheeler public transport (BS – III city buses)	PM: 70 % (as compared to BS – II and BS – III vehicles)	50% conversion	100% conversion	Technically feasible but compliance to be ensured

Table 6.25 : Management based Vehicular Control Options

Sr. No.	**Control Option**	**Expected Reductions**	**Target by 2012**	**Target by 2017**	**Remarks**
1.	Inspection/ maintenance	BS – II & BS – III public transport vehicles – PM: 12.5% 2 and 3-Ws (gasoline) – NOx: 10% 3Ws (diesel) – NOx: 5%, PM: 12.5% 4Ws (gasoline) – NOx: 7.5% 4Ws (diesel) – NOx: 7.5%, PM: 7.5%	New I&M regulation introduced and compliance by 50% anticipated	Strict enforcement to achive 100% compliance	Strict compliance mechanisms to be worked out
2.	Banning of 10 year old commercial vehicles	100% reduction of off-road vehicles	Old vehicles (15 years +)	Old vehicles (15 years +)	Regulatory provision required
3.	Banning of 15 year old private vehicle	100% reduction of off-road vehicles	Old vehicles (10 years +)	Old vehicles (10 years +)	Regulatory provision required
4.	Improvement of public transport: as per existing plan for the city (VKT of cars, 2-wheelers and buses)	Incorporated city specific proposals on public transport with respect to Metro/mono rail, BRT, large buses contingent etc. leading to percentage shift in VKT and off road personal transport vehicles for calculating reduction in PM & NOx emissions;	10% shift in VKT	20% shift in VKT	
5.	Synchronization of traffic signals	20% reduction in pollution load for the roads on which it is implemented	Effective synchronization on all major roads (or about 10% of the major roads)	Effective synchronization on all major & minor roads, excluding feeder roads (or about 20% of the major roads)	
6.	Fiscal incentives/disincentives like increased parking fee, proper fuel pricing policy, incentives for car pool, etc				Quantification may be difficult
7.	Scattered business timings				Quantification may be difficult
8.	Banning odd/even vehicles on particular roads	Zero emissions from the vehicles off the roads			

6.4.3.3 Evaluation of Vehicular Control Options

Approach and Assumptions

From vehicular pollution point of view, various technology based control options have been evaluated with respect to two main pollutants viz. PM and NOx. It has been estimated that under BAU Scenario, by 2012, PM and NOx emissions will increase by 29.2% and 32.4% respectively and by 2017, these will increase by 58.4% and 64.8% respectively. For evaluation of various vehicular pollution control options, the approach adopted and assumptions made are briefly discussed.

Technology based Control Options

- **Implementation of Stringent Emission Norms:** To evaluate the impact of implementation of stringent emission norms. It is considered that different emission norms (BS-IV, V and VI) are implemented by 2012. Currently BS-III norms are applicable to all 4 Wheelers, LCVs, Trucks and Buses, whereas BS-II are applicable to 2 & 3 Wheelers and next stage emission norms are considered to be implemented by 2010 and 2012.

- **Introduction of Electric/Hybrid Vehicles:** Electric vehicles are expected to be zero emission vehicles, hence implementation even in CNG vehicles, 3 Wheelers and Buses is also considered. Hybrid vehicles are applicable only for 4 Wheelers – Petrol vehicles (passenger cars).

- **Use of Clean Fuels (CNG/LPG) in Commercial Vehicles:** 3 Wheelers, Taxis and Buses, mainly plying within the city limits are already operating on CNG (retrofitted or new), hence no further conversion is envisaged and these vehicles will continue to ply.

- **Blending in Fuel:** 10% blending of ethanol in gasoline, 10% blending of bio-diesel in diesel and 10% blending of H_2 in CNG will be applicable to all the vehicles using respective fuel were indicated.

- **Retro-fitment in Diesel Vehicles:** Retro-fitment of diesel oxidation catalyst (DOC with reduction in PM by 22.5%) is applicable to BS-II diesel vehicles, whereas diesel particulate Filter (DPF with reduction in PM by 70%) is applicable to all LCVs, Trucks and Diesel-Buses, to both BS-II and BS-III vehicles. Hence, implementation of DPF is considered to yield more reductions in PM.

Management based Control Options

- **Improved I & M:** Applicable to all types of vehicles
- **Banning of 10 years old commercial vehicles:** All commercial vehicles (3W-CNG, LCVs, Trucks, Buses-D & CNG) more than 10 years of age are phased out and replaced with new vehicles conforming to the current emission norms
- **Banning of 15 years old private vehicles:** All private vehicles (2W-2S, 2W-4S, All 4Ws) more than 15 years of age are phased out and replaced with new vehicles conforming to present emission norms
- **Improvement in Public Transport:** With implementation of public transport facilities like metro rail, high capacity buses, 10% shift in VKT of private vehicles (2W and 4W-P) by 2012 and 20% shift in VKT by 2017 are considered.
- Other management options like synchronization of traffic signals, providing fiscal incentives/ disincentives like increased parking fee, proper fuel pricing policy, incentives for car pool, etc., scattered business timings etc have been analyzed qualitatively, since quantitative estimates in terms of emission reduction could not be directly computed.

All the calculations have been carried out on actual average fleet observed on different types of roads (arterial, main and feeder roads). Percentage reduction in emission level is estimated with respect to the corresponding year BAU (2012 or 2017) emission load and also with respect to present (2007) emission load. Evaluation of technology based and management based options is summarized in **Tables 6.26** and **6.27** respectively.

Table 6.26 : Evaluation of Technology based Options: Vehicular Sources

Sr. No.	Control Option/ Scenario	% Reduction with respect to Corresponding Year BAU Level		Overall Impact with respect to 2007 Baseline Status	
		PM	**NOx**	**PM**	**NOx**
	2007 Baseline Status	**--**	**--**	**--**	**--**
	2012 BAU Scenario	--	--	29.2	32.4
	2017 BAU Scenario	--	--	58.4	64.8
1.	**Implementation of Stringent Emission Norms**				
a.	Implementation of BS-IV in 2012				
	2017 Scenario	-8.6	-4.5	44.7	57.3
b.	Implementation of BS-V in 2012				
	2017 Scenario	-11.5	-6.0	40.3	55.0
c.	Implementation of BS-VI in 2012				
	2017 Scenario	-11.5	-6.9	40.3	53.4
2.	**Introduction of Hybrid Electric Vehicles (HEVs)**				
a.	**Electric Vehicles**				
	2012 Scenario	-0.5	-0.9	28.6	31.2
	2017 Scenario	-0.8	-1.7	57.1	61.9
b.	**Hybrid Vehicles**				
	2012 Scenario	0.01	-0.1	29.2	32.2
	2017 Scenario	0.06	-0.2	58.4	64.4
3.	**Fuel Blending: Ethanol (E10), Bio-Diesel (B10) and Hydrogen (H10)**				
	2012 Scenario	-7.9	-1.5	18.9	30.4
	2017 Scenario	-7.8	-1.6	46.0	62.1
4.	**Retro-fitment of DPF**				
	2012 Scenario	-19.5	0.0	4.1	32.4
	2017 Scenario	-39.9	0.0	-4.7	64.8

Table 6.27 : Evaluation of Management based Options: Vehicular Sources

Sr. No.	Control Option/ Scenario	% Reduction with respect to Corresponding Year BAU Level		Overall Impact with respect to 2007 Baseline Status	
		PM	NOx	PM	NOx
1.	**Improved I & M Practices**				
	2012 Scenario	-3.0	-3.3	25.4	28.1
	2017 Scenario	-5.9	-6.6	49.1	53.9
2.	**Ban on 10 Years Old Commercial Vehicles**				
	2012 Scenario	-18.7	-9.6	5.1	19.7
	2017 Scenario	-17.6	-8.1	30.5	51.5
3.	**Ban on 15 Years Old Private Vehicles**				
	2012 Scenario	-0.2	-1.8	28.9	30.0
	2017 Scenario	-1.0	-3.9	56.8	58.3
4.	**Improvement in Public Transport - Shift in VKT**				
	2012 Scenario	-1.6	-3.9	27.2	27.3
	2017 Scenario	-3.5	-8.0	52.8	51.5

Evaluation of Technology based Control Options

- **Implementation of Stringent Emission Norms (BS-IV, BS-V and BS-VI):** It has been estimated that implementation of BS-IV, BS-V and BS-VI by 2012 will yield a reduction in PM emissions of about 8.6%, 11.5% and 11.5%. This effect could be observed in 2017. Implementation of BS-V to BS-VI does not envisage reduction in PM emissions. The corresponding reductions in NOx by 2017 will be 4.5%, 6.0% and 6.9% respectively due to implementation of BS-IV, BS-V and BS-VI by 2012.

- **Introduction of Hybrid Electric Vehicles (HEVs):** With the assumption that the fleet composition in 2012 will contain 1% 2 Wheelers, 5% each 3 Wheelers, taxis and buses and 1% 4 Wheelers (Petrol) as hybrid electric vehicles that are non-polluting vehicles, the PM and NOx reductions achieved would be less than 1% each as compared to the BAU Scenario in 2012. Further, if the composition of HEVs is doubled by 2017, the reductions in PM and NOx would remain less than 2% for both the pollutants.

- **Use of Clean Fuels (CNG/LPG) in Commercial Vehicles:** 3 Wheelers, Taxis and Buses, mainly plying in Delhi are already operating on CNG (retrofitted or new, as a pollution control measure), hence no further conversion is envisaged for these categories of vehicles and these vehicles will continue to ply in Delhi.

- **Blending in Fuel:** 10% blending of ethanol in gasoline, 10% blending of bio-diesel in diesel and 10% blending of H_2 in CNG, if made applicable to all the vehicles using respective fuel, it is estimated to reduce PM emissions by 8% and NOx emissions by 1.5%.

- **Retro-fitment in Diesel Vehicles:** The reduction expected out of retro-fitment of diesel particulate filter is more (70%) when compared to oxidation catalyst (22.5%), DPF is considered more suitable for all the light commercial vehicles (LCVs), Trucks and Diesel-Buses. With retro-fitment of DPF, reduction in PM emissions achievable by 2012 is 19.5% and about 40% by 2017. Since DPF is a device to control PM emissions, reduction in NOx emissions is not envisaged.

Evaluation of Management based Control Options

- **Improved I & M:** The anticipated reduction in PM emissions is estimated to be 3.0% and 5.9% by 2012 and 2017 respectively. The corresponding reduction in NOx emissions is estimated to be 3.3% and 6.6% by 2012 and 2017 respectively.
- **Banning of 10 years old commercial vehicles:** If all commercial vehicles (3W-CNG, LCVs, Trucks, Buses-D & CNG) more than 10 years of age are phased out and replaced with new vehicles conforming to present emission norms, the anticipated reduction in PM emissions would be 18.7% by 2012 and 17.6% by 2017. The corresponding reduction in NOx emissions would be 9.6% (by 2012) and 8.1% (by 2017) as compared to the corresponding year BAU emission levels.
- **Banning of 15 years old private vehicles:** If all the private vehicles (2W-2S, 2W-4S, all 4Ws) more than 15 years of age are phased out and replaced with new vehicles conforming to present emission norms, the anticipated reduction in PM emissions would be only 0.2% by 2012 and 1.0% by 2017. The corresponding reduction in NOx emissions would be 1.8% (by 2012) and 3.9% (by 2017). This is due to the fact that in the calculation for the baseline emissions (2007 fleet), the vehicles (2W-2S & 4W-P) in the age group of 11-15 years are considered to be 5% and there is no 4 Stroke 2W vehicle that would be replaced.
- **Improvement in Public Transport:** With implementation of public transport facilities like metro rail, high capacity buses, 10% shift in VKT of private vehicles (2W and 4W-P) by 2012 and 20% shift in VKT by 2017 are considered. This will result in reduction in PM emissions by 1.6% by 2012 and 3.5% by 2017, whereas the corresponding reduction in NOx emissions would be 3.9% (by 2012) and 8.0% by 2017.
- ‘Other management options’ like synchronization of traffic signals, providing fiscal incentives/ disincentives like increased parking fee, proper fuel pricing policy, incentives for car pool, etc., have been analyzed qualitatively, since quantitative estimate in terms of emission reduction could not be direct.

- Synchronization of traffic signals will reduce idling emissions and will certainly have a positive impact towards air quality improvement. The reduction in idling stoppage time and number and frequency of speed changes will considerably reduce the pollution and improve environment. Besides, this will save substantial quantity of fuel being burnt unnecessarily while waiting for the signals to turn green
- Fiscal incentives/disincentives like increased parking fee, proper fuel pricing policy, incentives for car pool, etc. may be implemented to encourage car pool, less vehicle usage/ voluntary non-usage of vehicle in a week. For example, in order to encourage car-pooling/ adoption of public transport, the office going people in their own cars (single occupancy) should be levied additional eco-road-tax by the employer and such revenue generated could be used for public transport. At the same time, car pooling persons may be given some incentives also.
- Scattered business timings, particularly extending late evening hours may be considered when proper security and safety aspects are taken care of.
- Banning odd/even vehicles on particular roads is not considered a practical approach for implementation in Delhi. These options necessitate creating awareness to all users within the city as well as from outside so that people are not inconvenienced. It may encourage some people to buy multiple vehicles. However, if it is backed with high level of awareness and infrastructure upgradation for detection and levying charges to vehicles allowed on non compliance days, it can yield good benefits

6.4.3.4 Suggested Measures for Control of Vehicular Pollution

Analysis of various technology and management based options indicate that implementation of any one or all of the above strategies would not be able to achieve even the baseline status of 2007, by 2012 or 2017. However, the increase could be reduced to some extent. Significant reductions are not observed because several vehicular pollution control measures (introduction of BS-II for 2 Wheelers and BS-III for all other vehicles, introduction of CNG, less sulfur content in diesel, ban on more than 8 years old buses etc.) have already been implemented in Delhi during the last decade. To get further incremental reductions, the efforts required would be much more, whereas the expected benefits would not be commensurate with the efforts towards technology based pollution control systems.

Therefore, it warrants more emphasis on reducing pollution from in-use vehicles and road dust management. Accordingly, some of the suggested measures for control of vehicular pollution and road dust in Delhi are given below.

- **Control of Emissions from In-use Vehicles through Improved I&M Practices**

Vehicular emission norms/standards are applicable only for the new vehicles before they come on road, while PUC checks are the only means of emission testing for new or in-use vehicles. Once a vehicle comes on road and starts plying, it becomes an old vehicle, and it is assumed that such vehicles are conforming to the norms applicable to the new vehicles. Emissions from in-use vehicles also depend on the condition of individual vehicle. A new but poorly maintained vehicle can emit more emissions than an old but properly maintained vehicle. Therefore, all the vehicle owners should ensure that their vehicle is properly maintained. For the vehicle owner, besides smooth operation of vehicle, mileage of the vehicle could be an important parameter for getting proper and regular servicing of vehicle.

Over the years, the PUC system in Delhi has been changed from manual to computerized one to ensure proper emission certification of the vehicles. Considering the present scenario (when number of control measures are adopted in Delhi to curb air pollution and still the situation prevails), it is felt that more attention needs to be paid to the in-use vehicles.

In this regard, it is proposed that each vehicle manufacturing company should have its own service centers in sufficient number to cater to the need of their vehicles in the city. The automobiles manufacturing company owned service centers (AMCOSC) should be fully equipped for complete inspection and maintenance of vehicles ensuring vehicles conforming to emission norms and fuel economy after servicing. If a particular vehicle is unable to meet the emission norms/fuel economy even after servicing and best efforts at AMCOSC, the vehicle needs to be phased out. This is applicable to all types (models & make) and categories of vehicles. Systematic inspection and maintenance (I & M) in AMOCSC for Trucks and LCVs should be taken on priority as these two categories are estimated to contribute maximum pollution. Interstate commercial vehicles entering in to Delhi also need to follow the same.

- **Retro-fitment of DPF in Commercial Diesel Vehicles**

Diesel vehicles, mainly trucks and LCVs are found to be the major contributors of particulate matter, therefore retro-fitment of diesel particulate filter (DPF) is suggested (ensuring PM reduction efficiency of about 70% or so for BS-II and BS-III vehicles) in all the commercial vehicles (LCVs, Trucks, Buses operated on diesel) including inter-state vehicles as well.

The interstate vehicles particularly trucks (all types), diesel buses and LCVs should also meet the emission norms applicable for Delhi city. It would, therefore, need investigation and harmomization of vehicular emission reduction options to all the adjoining areas of Delhi such as UP, Haryana and other states. Recommended action points are given below:

- Implementation of Proposed Emission Norms (BS-III for 2 Wheelers and BS-IV for 4 Wheelers and heavy duty vehicles) as scheduled (April 1, 2010).
- Fuel quality improvements, as proposed by Auto Fuel Policy (2002) to meet the emission norms (BS-IV and BS-V) should be implemented as scheduled
- Strengthen and encourage more usage of public transport
- Check adulteration of fuels
- Any roadside activities like hawking, parking, etc preventing the smooth flows of the traffic should be regulated.
- Inspection and maintenance of vehicle through company owned facilities
- Public transport related policy and measures.

6.4.3.5 Suggested Measures for Control of Road Dust Re-suspension

- It has been observed that all along the roads, huge amount of dust, garbage, tree leaves and other refuse material lie or are dumped. The natural wind or traffic eddies around area the road cause, immense of re-suspended road dust. This is observed at many places along the arterial of main roads, feeder roads and even street roads throughout Delhi. This needs to be tackled in a very effective manner, as road dust re-suspension contributes significantly to near road particulate matter.
- All the unpaved roads should be paved on priority. This will reduce road dust re-suspension substantially. All the road construction should be carried out using better technology. There is a need to develop road construction codes which are strictly enforced.
- The roads are found to have potholes and many roads are in poor condition, which not only again aggravate wear and tear of vehicles and also result in more road dust re-suspension. Proper and periodic maintenance of roads is a must to avoid road dust re-suspension and maintaining the health of vehicles.
- Wall to wall paving (with proper provision for water percolation) is required for all the roads so that the materials (dust, garbage, leaves, refuse material etc.) do not get on to the road.
- Sweeping and collection of roadside material (dust, garbage, leaves, refuse material etc.) from all the roads should be done regularly. The collected materials should be disposed off properly
- Large scale burning of leaves and refuse near the roadside is prevalent. Its more so during winter seasons. Biomass burning and related dust emission is apparent is most part of Delhi. Such activities should be discouraged by creating awareness in combination with effective collection by municipal corporation.

6.4.3.6 Anticipated Benefits of Suggested Control Measures: Air Quality Modeling

Many control measures will yield variable results in terms of reduced air pollution. The impact of suggested vehicular pollution measures on ambient air quality has been predicted adopting the modeling approach as discussed earlier. Separate scenarios for 2012 and 2017 have been generated keeping in view the multiple feasible options. The percentage emission reductions considered in predicting the ambient air quality in terms of PM and NOx for 2012 and 2017 are summarized in **Table 6.28**, whereas the same for Road Dust are summarized in **Table 6.29**.

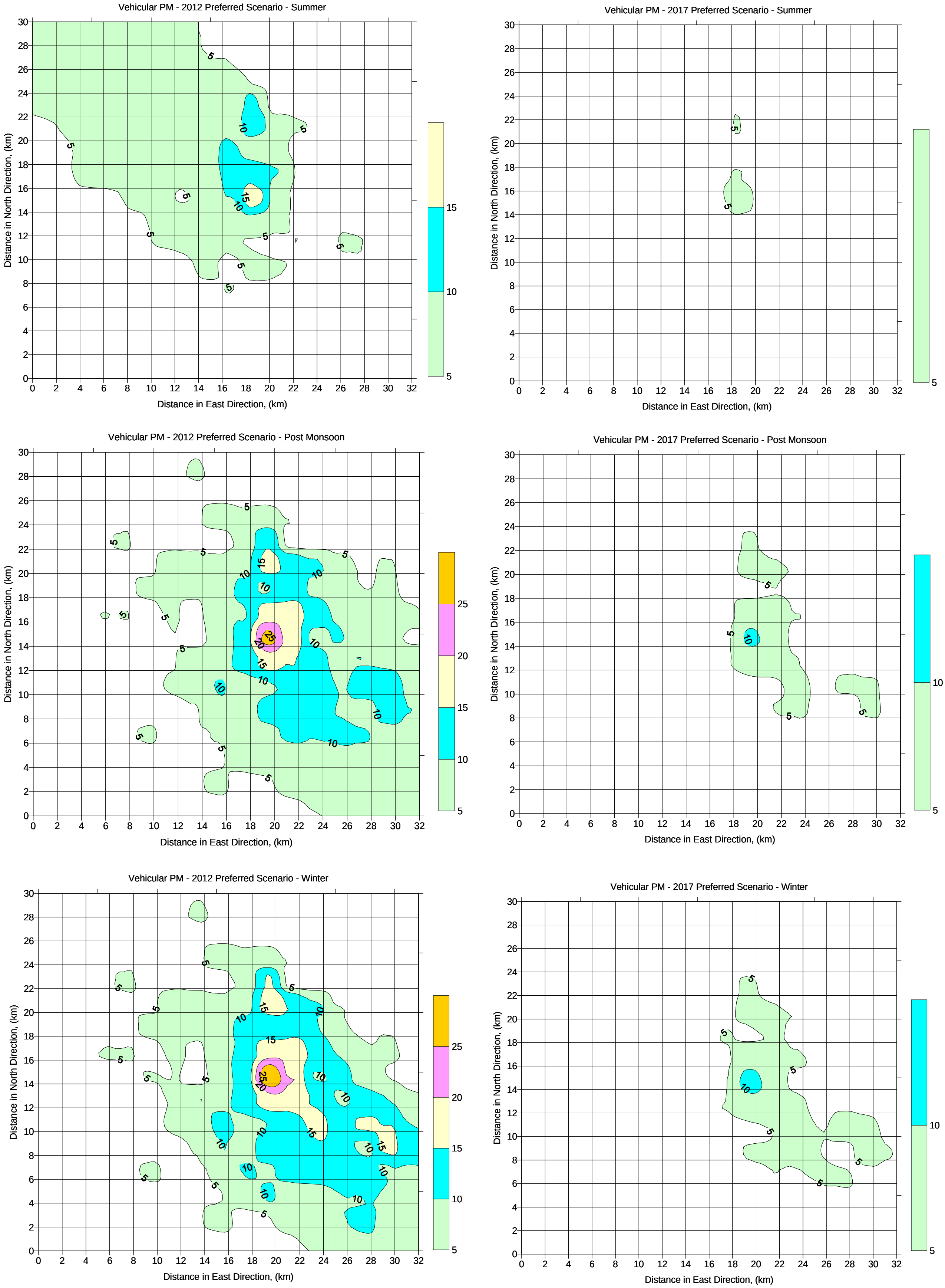
Table 6.28 : Expected % Reduction in PM and NOx Emissions by 2012 and 2017

Sr. No.	**Control/Management Option**	**2012 Scenario**		**2017 Scenario**	
		PM	**NOx**	**PM**	**NOx**
1.	Implementation of next stage emission norms for new vehicles (BS-III for 2 and 3 Wheelers and BS-IV for 4 Wheelers, LCVs, Trucks & Buses)	1.0	0.5	8.6	4.5
2.	Retro-fitment of DPF in all commercial diesel vehicles (Trucks and LCVs) including inter-state vehicles	19.5	0	40.0	0
3.	Improved I&M in AMCOSC	20.0	20.0	20.0	20.0
4.	Improvement in public transport	1.5	4.0	3.5	8.0
5.	Others (electric/ hybrid vehicles, Synchronization of traffic signals etc.)	5.0	5.0	10.0	10.0
	Total	47.0	29.5	82.1	42.5

Table 6.29 : Expected % Reductions in Road Dust Re-suspension by 2012 and 2017

Sr. No.	**Management Plan**	2012 Scenario	2017 Scenario
1.	Collection and proper disposal of road side dumped material (dust, garbage, leaves, refuse material etc.) and continue road cleaning regularly	20	20
2.	Repair/maintenance of all types of roads (arterial, main and feeder roads) for pot holes etc.	10	10
3.	Removal of encroachment of roads	10	10
4.	Conversion of unpaved road to paved roads (may be very less)	5	5
5.	Wall to wall paving of roads (with proper provision for water percolation)		
	- Arterial and main roads (about 825 km)	15	15
	- Feeder roads (about 2000 km on priority)	15	15
	- Remaining roads	-	15
	Total	75	90

The iso-concentration plots drawn under control scenario for vehicles in 2012 and 2017 for PM, NOx and Road Dust are shown in **Figs. 6.50** through **6.52** respectively for summer, post monsoon and winter seasons.



Vehicular PM - 2012 Preferred Scenario - Summer

Vehicular PM - 2017 Preferred Scenario - Summer

Vehicular PM - 2012 Preferred Scenario - Post Monsoon

Vehicular PM - 2017 Preferred Scenario - Post Monsoon

Vehicular PM - 2012 Preferred Scenario - Winter

Vehicular PM - 2017 Preferred Scenario - Winter

Fig. 6.50 : Predicted Iso-Concentration Plots in Different Seasons: Vehicular PM - 2012 & 2017 (Control Scenario)

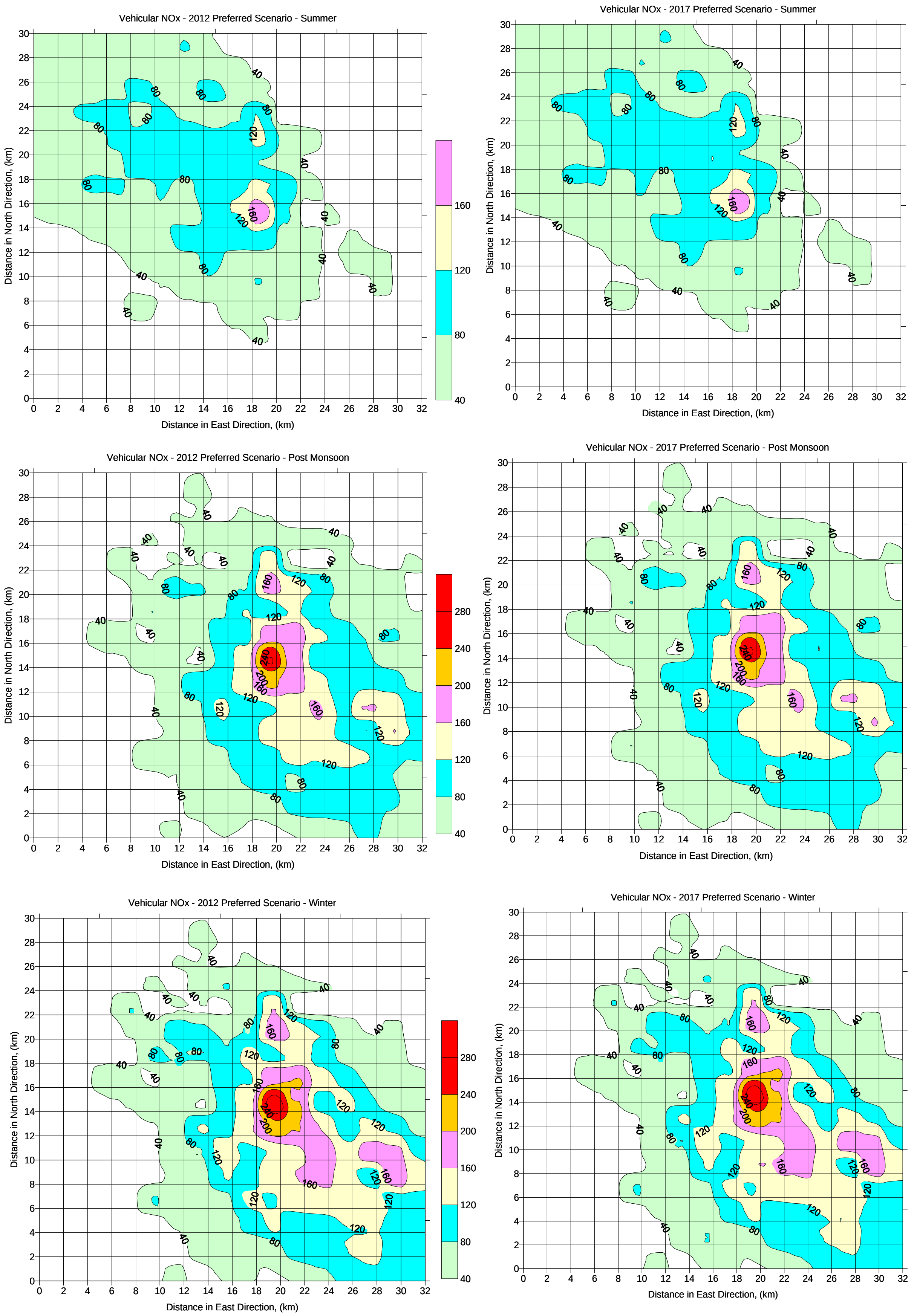
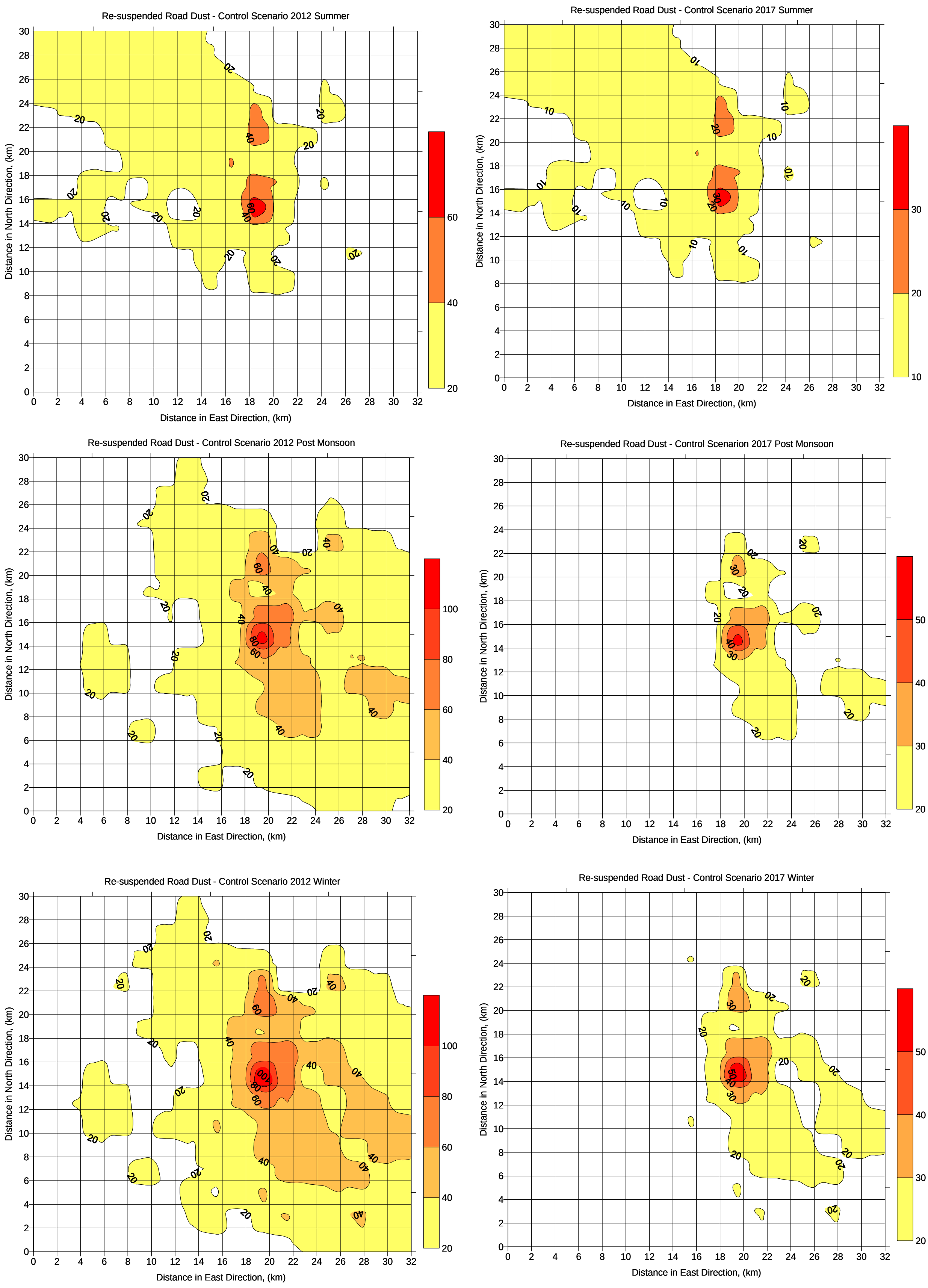


Fig. 6.51 : Predicted Iso-Concentration Plots in Different Seasons: Vehicular NOx – 2012 & 2017 (Control Scenario)



Re-suspended Road Dust - Control Scenario 2012 Summer

Re-suspended Road Dust - Control Scenario 2017 Summer

Re-suspended Road Dust - Control Scenario 2012 Post Monsoon

Re-suspended Road Dust - Control Scenarion 2017 Post Monsoon

Re-suspended Road Dust - Control Scenario 2012 Winter

Re-suspended Road Dust - Control Scenario 2017 Winter

Fig. 6.52 : Predicted Iso-Concentration Plots in Different Seasons: Road Dust Re-suspension - 2012 & 2017 (Control Scenario)

Summary of Iso-Concentration Plots – Control Scenario

The range and interval of iso-concentration plots drawn for the baseline status as well as for future scenarios (2012 & 2017 BAUS & Control) are summarized in **Table 6.30**.

Table 6.30 : Comparison of Range and interval of Iso-concentration Plots: Baseline, BAU and Control Scenarios for Different Vehicular Pollutants and Road Dust Re-suspension

Scenario	Iso-concentration Plots – Range & Interval (µg/m^3)			CPCB Standard*
	Summer	Post Monsoon	Winter	
PM				**200**
2007 BL	5-15, 5	5-35, 5	5-35, 5	
2012 BAU	10-30, 10	10-50, 10	10-50, 10	
2017 BAU	10-40, 10	10-50, 10	10-50, 10	
2012 Control	5-15, 5	5-25, 5	5-25, 5	
2017 Control	5-7.5, 5	5-10, 5	5-10, 5	
NOx				**80**
2007 BL	40-200, 40	40-280, 40	40-320, 40	
2012 BAU	80-240, 80	80-400, 80	80-400, 80	
2017 BAU	80-320, 80	80-400, 80	80-480, 80	
2012 Control	40-160, 40	40-280, 40	40-280, 40	
2017 Control	40-160, 40	40-280, 40	40-280, 40	
Road Dust (PM10)				**200**
2007 BL	40-200, 40	40-280, 40	40-320, 40	
2012 BAU	40-220, 60	40-400, 60	40-400, 60	
2017 BAU	40-280, 60	40-440, 60	40-520, 80	
2012 Control	20-60, 20	20-100, 20	20-100, 20	
2017 Control	10-30, 10	20-50, 10	20-50, 10	

BL – Baseline, BAU – Business-as-usual; * For Mixed use area category (24 hrly Average)

Perusal of iso-concentration plots indicate that area coverage for PM and NOx reduces substantially by 2012 and continues till 2017 as compared to the respective year BAU scenarios. With the suggested management plans, Road dust re-suspension is expected to get reduced to a large extent by 2012 and 2017.

6.5 Conclusions

6.5.1 Area Sources

- Total population of Delhi in 2007 is about 165 lakhs, which is expected to increase by 15% in 2012 and by 33% in 2017.
- An increase of about 4.9% in PM, 25.9% in SO_2 and 25.3% in NOx emissions is expected by 2012. The corresponding increase in emission in 2017 could be about 6.7% in the case of PM, 46.1% for SO_2 and 44.4% for NOx. Air quality modeling under BAU scenarios for 2012 and 2017 has been carried out for PM, SO_2 and NOx in summer, post monsoon and winter seasons and iso-concentration plots are drawn.
- To minimize the emissions from area sources, different control options for various source activities viz. domestic, hotels/ restaurants, bakery, crematoria, medical waste incinerators, construction activities etc. have been identified and analyzed for their efficacy.
- Analysis of various control options indicates that if all control options are applied to area sources, reductions achievable in total PM and SO_2 emissions will be about 73.2% and 80.2%, while NOx emissions can be reduced by 14.8% in 2012. In 2017, the total reductions of PM by 82.1%, SO_2 by 99.1% and NOx by 60.4% can be achieved.

6.5.2 Industrial Sources

- At present, total emission loads from all the industrial sources are estimated to be 324.8 TPD PM, 264.4 TPD SO_2 and 360.5 TPD NOx. Under BAU Scenario, further increase in PM and SO_2 emissions is not anticipated, whereas NOx emissions can increase by about 25% in 2017.
- Use of Natural Gas as fuel in power plants as well as medium scale industries is considered as a better and cleaner option as compared to coal/diesel.
- To control PM and SO_2 emissions from medium scale industries, use of control equipment viz. Venturi scrubber and FGD have been considered as possible options. Efficiency of Venturi scrubber is considered as 60%. In the case of coal based power plants, two stage ESPs (to increase efficiency from 99.5 to 99.9%) and FGDC (Flue Gas Desulphurization) system have been considered.

- Adoption of pollution control equipment in industries can reduce total PM and SO_2 emissions by about 76.2% and 97.2% by 2012. Reduction in NOx is not anticipated as most of the control equipment are meant for control of PM and SO_2 emissions.

- Use of cleaner fuels as suggested (by 2012) can reduce total PM, SO_2 and NO_2 emissions by about 93.6%, 98.3% and 82.0% respectively. Only marginal reductions of 2.5% in PM, 0.8% in SO_2 and 3.1% in NOx can be achieved by shifting of SSI units by 2012.

- In 2017, emission loads of PM and SO_2 can be reduced by 78.6% and 97.6% respectively through the use of control equipments. Substantial reductions in total PM, SO_2 and NO_2 emissions can be achieved through the use of cleaner fuel in industrial sector. Shifting SSI units is estimated to yield marginal reduction in emissions.

6.5.3 Vehicular Sources (including Road Dust Re-suspension)

- Growth in vehicular population witnessed during 2002 to 2007 has been considered as the reference and has been used after normalization to project growth for the next 5 and 10 years, as discussed earlier. The total vehicle population by 2012 and 2017 is estimated to be about 75 lakhs and 98 lakhs respectively.

- Considering the Business-As-Usual-Scenario (BAUS), increase in emission load of different pollutants by 2012 is estimated as PM - 29.1%, CO - 27.2%, HC - 28.4%, NOx - 32.0%, SO_2 - 46.5%, and road dust (average of PM10 & PM2.5) – 33.2%. By 2017, the increase in emission load is estimated as PM - 58.3%, CO - 54.4%, HC - 56.7%, NOx - 64.0%, SO_2 - 92.9%, and road dust (average of PM10 & PM2.5) – 65.3%.

- In order to control emissions from different categories of vehicles, the control options have been classified broadly into two categories as: technology based and management based control options. All these strategies were discussed among the participation institutions (NEERI-Nagpur & Mumbai, ARAI, TERI, IITK, IITB, IITM) and experts from CPCB, associated with the execution of source apportionment studies in India.

- ***Analysis of various technology and management based options indicated that implementation of any one of the above strategies would not be able to achieve significant reduction. However, the increase could be reduced by proactively combining technology options with management options. Introduction of BS-II for 2 Wheelers and BS-III for all other vehicles, introduction of CNG for 3 Wheelers, taxis and buses, less sulfur content in diesel, ban on more than 8 years old buses***

etc. have already been implemented in Delhi during the last decade. To get further incremental reductions, the efforts required would be much more. Therefore, it warrants more emphasis on reducing pollution from in-use vehicles use of mass rapid transit system, and through road dust management.

- The control scenario for vehicular emissions includes implementation of next stage emission norms for new vehicles, retro-fitment of diesel particulate filter in in-use commercial diesel vehicles, mandatory inspection and maintenance in automobile manufacture company owned service centers, improvement in public transport system, synchronization of traffic signals, introduction of hybrid vehicles with improvement in fuel quality, and no adulteration. All these options are expected to yield in reduction of PM emissions to the tune of 47% by 2012 and 82% by 2017 as compared to emissions estimated under BAU Scenario in respective years from vehicular sources. Reduction in NOx emissions is expected to be about 30% by 2012 and 42.5% by 2017, as compared to respective years BAU scenario emission levels.

- Road dust re-suspension is estimated to be one of the major contributor of particulate/ dust emissions. The management plans for checking road dust generation include collection and proper disposal of road side accumulated/dumped materials (like dust, garbage, leaves, refuse material etc.), proper and regular maintenance of roads, wall to wall paving of roads, conversion of unpaved to paved roads and removal of encroachments. All these options together are expected to reduce road dust re-suspension to the extent of 75% by 2012 and about 90% by 2017.

- In summary, it is important to note that though overall PM loads apparently come from area, industrial and road dust, their potential towards human health damage is much less. The fine particle emissions from vehicular sector (more than 90% below 1 micron) lend high toxicity to overall PM concentration exposure to human habitation. High particle number density of vehicular sources as well as gensets and other fuel combustion can cause very grievous health damage. The control sector especially to reduce risk of exposure.

Based on the above analysis, preferred scenarios considering all the options relevant for area, industrial and vehicular sources (including road dust) have been selected and presented in Chapter 7. Implementation of these options will provide the goal of better air quality in Delhi.

References

- CPCB, 2001, Transport Fuel Quality for Year 2005. PROBES/78/2000-01 (New Delhi: Central Pollution Control Board, MoEF, Government of India)
- CPCB (2003). Parivesh, Highlights 2002, Central Pollution Control Board, New Delhi.
- CPCB (2004). Parivesh, Highlights 2003, Central Pollution Control Board, New Delhi.
- CRRI, 2002, ‘Urban Road Traffic and Pollution (URTRAP) Study’, Technical Report (New Delhi: Central Road Research Institute)
- GOI, 2002, Report of the Expert Committee – Auto Fuel Policy, New Delhi. Government of India, August 2002

Chapter 7

Prioritization of Management/Control Options

7.0 Introduction

Air pollution management issues are linked with the prioritization of options which will bring the higher benefits with limited effort and time. The technical analysis of alternative scenarios, carried out in earlier chapter 6, had kept in view the efficiency of each control and management options. Prioritization however, needs to consider time targets stipulated for achievement for air quality goals, contribution of different sources in terms of emissions and their relevance, hotspots areas, administrative constraints involved, availability of financial resources, co-ordination required among the identified implementing agencies and acceptability to public and major stakeholders.

Prioritization also includes identification of immediate, short term and long term solutions to the identified problems. Low cost solutions with higher efficiency and relatively less time requirement for execution are generally preferred but long-term solutions with high effectiveness need to be considered even if they involve high cost and long gestation periods.

New growth strategies in urban air quality management paradigm will mainly revolve around:

(i) Increased substitution of cleaner fuels – for coal in industries, power plants and household cooking
(ii) Improved energy efficiency and diversification of energy options into non-coal resources
(iii) Reduction in emissions from industrial boilers and furnaces
(iv) Minimizing vehicular pollution through engine technology, retrofitment and fuel quality
(v) Providing effective urban transportation system and its management
(vi) Development of environment master plans to shift polluting industries from urban areas
(vii) Increase in pollution control investments
(viii) Ensure the compatibility of all the developmental policies and future growth scenarios and related air quality management options.
(ix) Bringing in Polluters Pays Principle with a view to finance air quality improvement programmes
(x) Providing the right institutional mechanism for implementation

Preferred scenario delineation involves critical examination of the constraints such as technical, fiscal and administrative, towards air quality improvement of Delhi city. In addition to addressing resource availability constraints, a detailed analysis of each alternative scenario to asses the feasibility of achieving the desired air quality goals for Delhi City is needed. The preferred air pollution management path that needs to be pursued must combine all the best features and elements of different alternative scenarios relating to industrial, area and vehicular sources, based on cost, time, ease of implementation and effectiveness of the selected options.

Major elements of the preferred scenario include:

(i) Technological interventions covering type of technology, fuel mix and emission control technologies

(ii) Industrial Typology and Zoning

(iii) Environmental Management Plan through public processes, and

(iv) Management Strategies and Action Plans

In this chapter an attempt has been made to analyse the benefits of various control options discussed in Chapter 6. Later, all possible control options have been prioritize using framework for air pollution reduction. All these options have later described with regard to their effectiveness, technology issue, barriers to implementation, and administrative / regulatory aspects along with possible stake holders. A prioritized list is presented at the end delineating the additional steps need for sustainable air quality of Delhi.

7.1 Control Options : Future Scenarios

Analysis of ambient air quality data indicates that the present air quality levels with respect to different pollutants, particulate matter (PM) and oxides of nitrogen are particularly very high in Delhi. Increase in PM can be attributed to the re-suspension of road dust, construction activities and fuel combustion in slums besides emissions from power plants in Delhi. Increase in NO_2 can be attributed to the use of generator sets, industries besides vehicular activities in Delhi. Based on the city specific situations, select control options are evaluated under the preferred scenario with respect to reduction in PM and NOx emission loads from different sources by 2012 and 2017, as compared to BAU Scenarios.

To evaluate the impact of select control options for the improvement in air quality, three scenarios have been considered for area sources. Focus of the first scenario is PM emissions reduction. Second scenario is formulated to facilitate mainly for NOx emissions reduction. Third scenario targets the reduction of both PM and NOx emissions. Under the three scenarios, (incorporating different combinations of control

options), there would be reduction in emissions of other pollutants (e.g. SO_2) also. On the other hand for industries all scenarios have been considered together as it mostly pertains to fuel quality change. Vehicular source scenario also consider the combined scenario of PM and NOx control.

7.1.1 Area Sources

Preferred control options from area sources have been evaluated with respect to two main pollutants viz. PM and NOx. These control options are on the basis of three distinct scenario as the characteristics of these sources are very diverse.

Scenario 1

Construction activities and combustion of fuels in domestic cooking are the major contributors to the PM emissions. These two sources are considered for controlling PM emissions.

- **Better Construction Practices**

Better construction and operating practices viz. proper loading/unloading of materials including water spraying is considered. These practices need to be upgraded with norms which prevent activities resulting in high PM emissions. Reduction of PM emissions through this control option is expected to be 50% by 2012 and 100% by the year 2017.

- **Use of Clean Fuels (LPG) in Domestic Sector**

LPG is considered to be cleaner fuel as compared to coal, wood and kerosene for domestic cooking. Substitution of LPG in the place of all solid fuels and kerosene in domestic cooking (including slums) is considered as the option leading to 50% and 100% reduction by 2012 and 2017 respectively.

Scenario 2

Diesel generator sets are the major contributors to the NOx emissions. This source category is mainly considered for reducing NOx emissions.

- **Adequate power supply**

Considering future power generation scenario and availability of adequate power, no use of generator sets beyond 2012 is envisaged leading to negligible emissions from generator sets.

Scenario 3

Third scenario considers both PM and NOx emissions reduction options as preferred combination of options. This option has been considered for industries and vehicular emission sources.

7.1.2 Industrial Sources

Select control options have been evaluated with respect to two main pollutants viz. PM and NOx. These control options are combination for PM and NOx together as in this source category the options are not different for PM and NOx.

Coal based Power plants are the major sources of PM and SO_2 emissions and NG based Power plants are the major sources of NOx emissions. Besides, medium scale industries also contribute to PM and SO_2 emissions and limited NOX. These two sources are considered for controlling PM and SO_2 emissions.

NG is considered to be the cleaner fuel as compared to coal and liquid fuels used in industries. Use of NG in all power plants and medium scale industries by 2012 is envisaged. Though many small scale industries may continue to operate on other liquid fuel, their contributions shall not be significant mainly due to their shifting from the non-conforming zones.

7.1.3 Vehicular Sources

From vehicular pollution point of view, various technology based control options have been evaluated with respect to the two main pollutants viz. PM and NOx. There are some options which are primarily addressing PM emissions (such as DPF), however, the overall preferred options analysis for vehicular sector will not be limited to only this options. All options together in vehicular sector considered are for the purpose of reducing PM and NOx. For evaluation of various vehicular pollution control options, the approach adopted and assumptions made have already been discussed chapter 6.

Table 7.1 presents the select main control options and expected emission load mass reductions of all pollutants for the year 2012 and 2017 compared to the base year 2007.

Table 7.1 : Select Major Control Options and Expected Reductions (kg/day) in Emissions by 2012 and 2017

Sr.No	Control/Management Option	2012 scenario		2017 scenario	
		PM	**NOx**	**PM**	**NOx**
A. Industrial Sources					
A1	Power Plants (Fuel shift: Coal to NG) All Plants by 2012	5.4	39851.3	17.95	132269.6
A2	Medium Scale industries (Fuel shift)	0.65	23.99	0.65	23.99
	Total Industrial Sources (A)	6.05	39875.26	18.6	132293.6
B. Area Sources					
B1	All Construction related emissions control adopted in 100 % of the activities by 2012 and 2017	4777.3	--	3645.0	--
B2	Domestic (including slums) emissions control options adopted in 50% of the activities by 2012 and 2017 (fuel shift SF to LPG)	12790.7	1296.9	14615.1	661.1
B3	DG Sets replaced due to power availability by 2012	613.7	8678.4	706.5	9990.0
	Total Area Sources (B)	**18181.7**	**9975.3**	**18966.6**	**10651.1**
C. Vehicular Sources					
C1.	Implementation of next stage emission norms for new vehicles (BS-III for 2 and 3 Wheelers and BS-IV for 4 Wheelers, LCVs, Trucks & Buses) by April 2010	126	556	1327	6214
C2.	Retro-fitment of DPF in all commercial diesel vehicles (Trucks and LCVs) including inter-state vehicles by January 2010	2454	0	6170	0
C3.	Improved I&M in AMCOSC	2517	22225	3085	27619
C4.	Improvement in public transport	189	4445	540	11048
C5.	Others (electric/ hybrid vehicles, Synchronization of traffic signals etc.)	629	5556	1543	13810
	Total Vehicular Sources (C)	**5916**	**32782**	**12664**	**58691**
D. Road Dust					
D1.	Implementation of Road Dust Management/Option 2010 (Arterial & Main Roads)	76684	0		
D2.	Implementation of Road Dust Management/Option 2015 (Feeder Roads)		0	114873	
	Total Road Dust (D)	**76684**	**0**	**114873**	**0**

Though the I&M will provide a small percentage reduction in Vehicles PM_{10} emission, its impact on toxic fine particles will be very high as vehicles PM are in mainly in finer sizes.

Percentage reductions in emissions of PM, SO_2 and NOx have been estimated for different control options with respect to the corresponding year BAUs (2012 and 2017) emission loads. The impact of suggested pollution control measures on ambient air quality has been predicted adopting the same modeling approach as discussed earlier in this chapter. Three scenarios have been generated separately for industrial, area, vehicular (including road dust) sources and cumulative (industrial, area, vehicular) impacts in 2012 and 2017.

Improvement in ambient air quality in terms of PM, SO_2 and NOx concentrations for 2012 and 2017 with respect to the corresponding year BAUs (2012 or 2017) due to control measures used for area, industrial sources and vehicular sources under different scenarios is summarized in **Table 7.2 through Table 7.4**. The concentrations mentioned in the table are on the basis of highest 10 concentrations in different grids in the city.

Table 7.2: Improvement in Ambient Air quality in terms of PM and NOx (µg/m^3) under 2012 and 2017 Scenarios: Area Sources

Year	Pollutant	BAU	Scenario 1	Scenario 2	Scenario 3
2012	PM10	146.4	67.5	146.4	67.4
	NOx	65.4	41.5	42.1	37.1
2017	PM10	146	56.2	139.7	56.0
	NOx	75.6	48.1	45.3	43.6

Table 7.3: Improvement in Ambient Air quality in terms of PM and NOx (µg/m^3) under 2012 and 2017 Scenarios: Industrial Sources

Year	Pollutant	BAU	All Scenarios
2012	PM10	115	111.3
	NOx	1153	691
2017	PM10	115	110
	NOx	1505	688

Table 7.4: Improvement in Ambient Air quality in terms of PM, SO_2 and NOx (µg/m^3) under 2012 and 2017 Scenarios: Line Sources

Year	Pollutant	BAU	All Scenarios
2012	PM10	58	31
	NOx	461	325
	Road Dust	476	119
2017	PM10	71	13
	NOx	568	327
	Road Dust	590	59

Predicted PM and NOx concentrations at ten AQM sites using preferred scenario No. 3 for 2012 and 2017 is given in **Table 7.5**.

Table 7.5 : Predicted PM and NOx Concentrations (µg/m^3) at ten AQM sites in Delhi : 2012 and 2017 (Winter)

PM

AQM Location	2012					2017				
	Point	Area	Line	Road Dust	Total	Point	Area	Line	Road Dust	Total
Ashram Chowk	0.60	9.50	15.40	54.00	**79.50**	0.60	14.40	6.40	27.00	**48.40**
Dhaula Kuan	0.30	5.80	9.40	34.00	**49.50**	0.30	4.70	3.90	17.00	**25.90**
Mayapuri	0.03	7.00	3.40	19.00	**29.43**	0.03	5.50	1.40	9.00	**15.93**
ISBT	0.30	33.10	16.00	64.00	**113.40**	0.30	34.50	6.60	32.00	**73.40**
Loni Road	0.00	3.50	2.80	27.00	**33.30**	0.00	3.50	1.20	14.00	**18.70**
Anand vihar	0.50	8.30	4.70	27.00	**40.50**	0.50	27.90	2.00	14.00	**44.40**
Naraina	0.50	28.70	5.80	20.00	**55.00**	0.50	10.40	2.40	10.00	**23.30**
SSI-GTK	0.00	12.20	3.30	22.00	**37.50**	0.00	2.20	1.40	11.00	**14.60**
Pitampura	0.10	3.70	4.10	24.00	**31.90**	0.10	4.10	1.70	12.00	**17.90**
Prahladpur	0.01	1.10	0.90	9.00	**11.01**	0.10	1.20	0.40	5.00	**6.70**

NOx

AQM Location	2012				
	Point	Area	Line	Road Dust	Total
Ashram Chowk	4.50	10.00	182.00	196.50	**4.50**
Dhaula Kuan	4.40	9.60	118.00	132.00	**4.40**
Mayapuri	0.20	6.90	46.00	53.50	**0.20**
ISBT	4.50	12.50	164.00	181.00	**4.50**
Loni Road	0.05	8.80	30.00	39.20	**0.05**
Anand vihar	0.90	9.60	57.00	67.60	**0.90**
Naraina	6.40	10.70	73.00	90.00	**6.40**
SSI-GTK	0.01	27.00	33.00	60.41	**0.01**
Pitampura	1.90	9.50	41.00	52.70	**1.90**
Prahladpur	0.10	2.70	12.00	14.30	**0.10**

Highest ten predicted GLCs for PM and NOx under cumulative sources for preferred scenarios (1, 2 and 3 of area sources as also all scenarios for industries and vehicular) are given in **Tables 7.6** and **7.7** for 2012 and 2017 respectively. The iso-concentration plots drawn for PM and NOx cumulative sources under preferred scenarios in 2012 and 2017 are shown in **Figs. 7.1 and 7.2** respectively. The highest concentrations exceeding the limits occur in limited grids and where the source is very high.

Table 7.6: Highest Ten Predicted Pollutant Concentrations –Preferred scenario: 2012

PM (PS 2012)

Rank	Scenario 1			Scenario 2			Scenario 3		
	GLC (µg/m^3)	Occurrence (m)		GLC (µg/m^3)	Occurrence (m)		GLC (µg/m^3)	Occurrence (m)	
		E	N		E	N		E	N
1	159	20.0	14.0	192	24.0	18.0	158	20.0	14.0
2	158	20.0	14.5	188	23.5	18.0	158	20.0	14.5
3	155	20.0	15.0	186	24.0	18.5	155	20.0	15.0
4	151	19.5	14.5	186	26.0	16.0	150	19.5	14.5
5	151	19.5	14.0	184	23.0	18.0	150	19.5	14.0
6	149	20.0	15.5	183	26.0	16.5	149	20.0	15.5
7	149	19.5	15.0	182	23.5	18.5	148	19.5	15.0
8	144	19.5	15.5	181	25.5	16.5	144	19.5	15.5
9	142	19.0	14.5	180	26.0	17.0	142	19.0	14.5
10	142	19.0	15.0	180	25.5	16.0	141	19.0	15.0

NOx (PS 2012)

Rank	Scenario 1			Scenario 2			Scenario 3		
	GLC (µg/m^3)	Occurrence (m)		GLC (µg/m^3)	Occurrence (m)		GLC (µg/m^3)	Occurrence (m)	
		E	N		E	N		E	N
1	607	26.5	11	606.3	26.5	11.0	604.7	26.5	11.0
2	606	24	13.5	604.5	24.0	13.5	602.8	24.0	13.5
3	604	27	10.5	602.6	27.0	10.5	601.0	27.0	10.5
14	596	27.5	10	594.6	27.5	10.0	593.1	27.5	10.0
5	594	24.5	13	593.3	24.5	13.0	591.4	24.5	13.0
6	588	25	12.5	587.4	25.0	12.5	585.4	25.0	12.5
7	576	25.5	12	575.6	25.5	12.0	573.6	25.5	12.0
8	572	26	11.5	571.0	26.0	11.5	569.2	26.0	11.5
9	551	28.5	9	549.6	28.5	9.0	548.1	28.5	9.0
10	547	23.5	14	546.6	23.5	14.0	544.9	23.5	14.0

Table 7.7: Highest Ten Predicted Pollutant Concentrations –Preferred scenario: 2017

PM (PS 2017)

Rank	Scenario 1			Scenario 2			Scenario 3		
	GLC ($\mu g/m^3$)	Occurrence (m)		GLC ($\mu g/m^3$)	Occurrence (m)		GLC ($\mu g/m^3$)	Occurrence (m)	
		E	N		E	N		E	N
1	80	20.0	14.0	155	28.0	18.0	80	20.0	14.0
2	80	20.0	14.5	153	28.0	18.5	79	20.0	14.5
3	79	20.0	15.0	150	27.5	18.5	78	20.0	15.0
4	76	19.5	14.5	148	27.5	18.0	76	19.5	14.5
5	76	19.5	14.0	147	28.0	19.0	76	19.5	14.0
6	76	20.0	15.5	147	27.5	19.0	76	20.0	15.5
7	76	19.5	15.0	146	27.0	19.0	75	19.5	15.0
8	75	20.0	22.0	142	27.0	18.5	75	20.0	22.0
9	74	19.5	15.5	140	27.0	19.5	73	19.5	15.5
10	72	20.0	22.5	140	26.5	19.5	72	20.0	22.5

NOx (PS 2017)

Rank	Scenario 1			Scenario 2			Scenario 3		
	GLC ($\mu g/m^3$)	Occurrence (m)		GLC ($\mu g/m^3$)	Occurrence (m)		GLC ($\mu g/m^3$)	Occurrence (m)	
		E	N		E	N		E	N
1	954.0	26.5	11.0	951.8	26.5	11.0	951.3	26.5	11.0
2	949.3	24.5	13.0	947.1	24.5	13.0	946.6	24.5	13.0
3	948.3	25.0	12.5	946.1	25.0	12.5	945.6	25.0	12.5
4	945.7	24.0	13.5	943.2	24.0	13.5	942.7	24.0	13.5
5	941.9	27.0	10.5	939.7	27.0	10.5	939.2	27.0	10.5
6	935.1	25.5	12.0	932.9	25.5	12.0	932.4	25.5	12.0
7	925.5	26.0	11.5	923.3	26.0	11.5	922.8	26.0	11.5
8	925.0	27.5	10.0	922.8	27.5	10.0	922.3	27.5	10.0
9	861.6	28.5	9.0	859.5	28.5	9.0	859.1	28.5	9.0
10	855.1	23.5	14.0	853.2	23.5	14.0	852.6	23.5	14.0

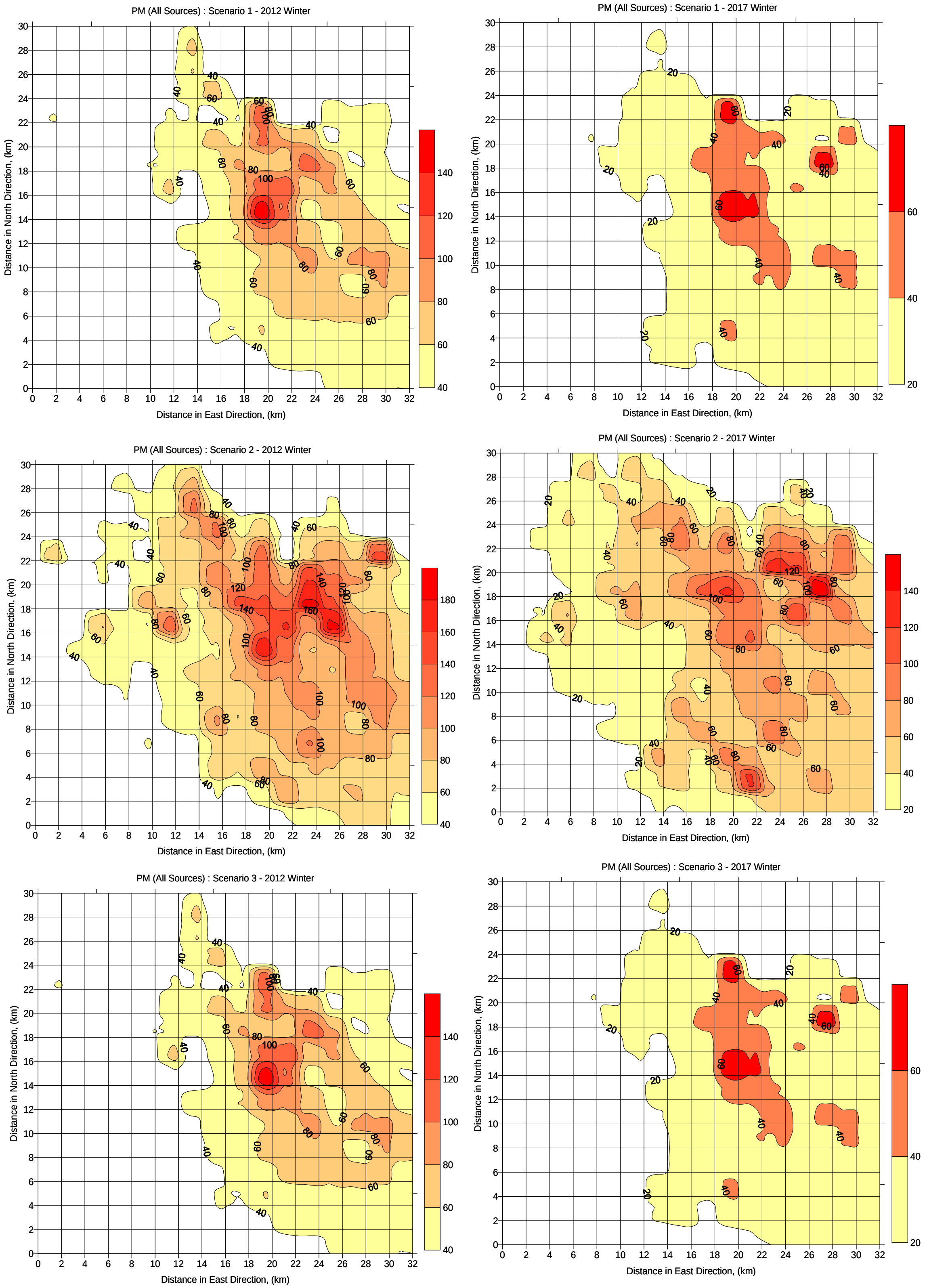


Fig. 7.1: Predicted Iso-Concentration Plots: PM (All Sources), Preferred Scenarios (1, 2 & 3) – 2012 & 2017

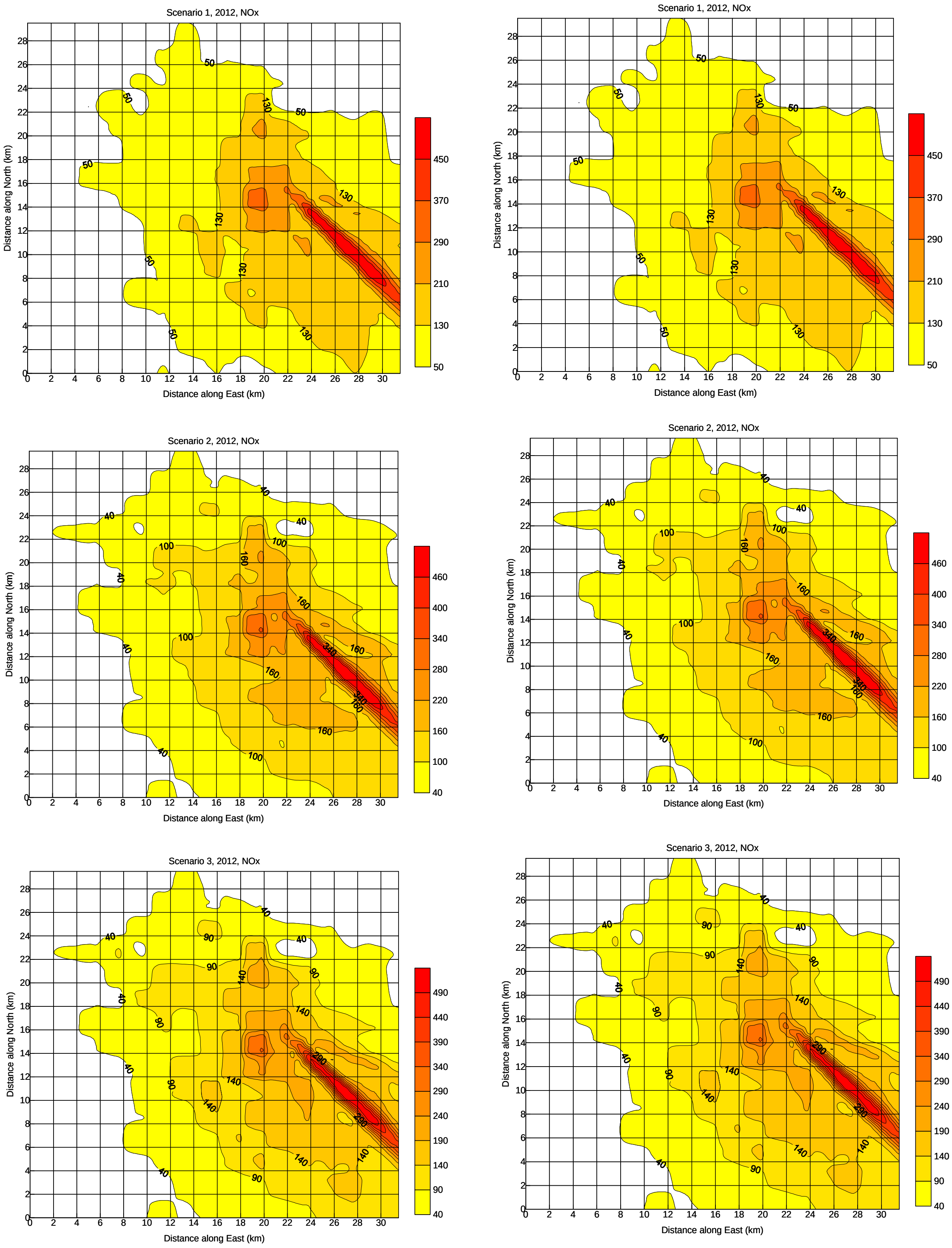


Fig.7.2: Predicted Iso-concentration Plots: NOx (All Sources), Preferred Scenarios (1, 2 & 3) – 2012 & 2017

The results presented above clearly indicates that control measures combined together as given in **Table 7.1** for all sources can lead to substantial improvement in the air quality of Delhi. The iso-concentration plots also indicate that area coverage for PM and NOx reduces substantially by 2012 and continues till 2017 as compared to the respective year BAU scenarios. With the suggested management plans, road dust re-suspension which is one of the major contributing factor will lead to large decline and bring the PM values lower after the implementation of suggested measures by the year 2012 and 2017.

7.2 Prioritized List of Management/Control Options

Management options leading to reduction of pollutants have been prioritized using a framework based on various considerations such as technical, administrative and economic/fiscal issues. These issues are intricately linked with each other and without which a major initiative for large area air quality improvement may not be possible to undertake. **Tables 7.8** through **7.10** present the framework for the selection of measures for each sector viz, vehicular (line), industrial (point) and area sources. Prioritized list of Management and Control options have been discussed based on all possible combination leading to optimized reduction in air pollution from all sources in the city of Delhi.

Table 7.8: Framework for Selecting Measures to Address Urban Air Pollution: Vehicles

Action Category	**(a) Technical**	**(b) Administrative / Regulatory**	**(c) Economic / fiscal**
(1) Strategy: Reducing Emissions per Unit of Fuel			
Fuel Quality Improvement	Sulphur Reduction	Delineating tighter diesel fuel standards	Phasing out fuel subsidies, uniform pricing all over the state followed by country,
Installation of after treatment devices	Fitment of Diesel Oxidation Catalyst, catalytic converter in older vehicles	Tighter diesel fuel standards particularly for Sulphur to bring down its level up to 50 ppm. Emission test frequency to be more for those without the after treatment devices	Differential taxation to those with and without after treatment device
Tackle fuel adulteration	Markers for detection	Better specification of fuel quality for detection as well as booking the offenders. Monitoring fuel quality in a specified laboratory, making companies accountable	Oil companies to finance the setting up of a laboratory, Fines and cancellation of license

Table 7.8 (Contd..) : Framework for Selecting Measures to Address Urban Air Pollution: Vehicles

Action Category	**(a) Technical**	**(b) Administrative / Regulatory**	**(c) Economic / fiscal**
(1) Strategy: Reducing Emissions per Unit of Fuel			
Use of alternative fuels	CNG and LPG use	Promote its use in private sector as well as organized sector through administrative orders	Differential taxation for older vehicles changing to CNG/ LPG, Incentive for new owners to buy CNG/LPG vehicles
Renewal of vehicle fleet	Phase out vehicles above a certain age	Scrappage of older vehicles	Older vehicles to remain on road if it passes the fitness test as well as emission test, however higher tax to be paid as the vehicle gets older
Improve traffic flow	Synchronized signal corridors	Coordination with other institutions to check indiscriminate parking, and enforce one way system at peak hours	Congestion pricing Higher parking fees
Reduce dust re-suspension	Road paving / cleaning	Coordination with all institutions working in the area of road and pavement maintenance, digging for utilities etc. One agency to monitor the working practices.	Steep fines to agencies leaving the debris-dust on the roads after the completion of jobs.
(2) Strategy: Reducing Fuel Consumption per unit Distance			
Change to better technology engines	4 stroke engines for two –three wheelers, Bharat stage III engines with DOC for older diesel vehicles, All new diesel vehicles to be Bharat stage III and above.	Standards for fuel economy need to be specified Useful age of the vehicles to be specified by the manufacturer	Tax break for older vehicles changing to new engine with DOC or DPF
Improve vehicle I&M	I&M programs that are difficult to cheat; computerized data capture and control of tests	Strict enforcement with socially acceptable failure rates	Better infrastructure, manpower augmentation, Strict fines for not displaying pass sticker
Better road maintenance	Investment in better road maintenance technology to avoid frequent relaying	Standards for road construction specified in terms of guaranteed life of the road	Financial incentives for contractors using better technology for road construction

Table 7.8 (Contd..) : Framework for Selecting Measures to Address Urban Air Pollution: Vehicles

Action Category	(a) Technical	(b) Administrative / Regulatory	(c) Economic / fiscal
(3) Strategy: Reduce Vehicle Distance Traveled			
Increase private vehicle occupancy		Encourage car pooling	Congestion pricing
Promote better and more public transport	Dedicated bus lanes; user friendly MRTS	Reform of public transport – competition, privatization, funding mechanism	Subsidize public transport by taxing private vehicle users
Demand management		Limit parking Limit the use of vehicles in congested areas	High one time tax on purchase of a new vehicle High parking fees Road user charges Higher taxes per vehicle km traveled
Encourage non motorized transport	Pedestrian friendly walkways / subways	Protection of pedestrian facilities	Financial incentives for pedestrian friendly design

Table 7.9: Framework for Selecting Measures to Address Urban Air Pollution: Industries

Action Category	(a) Technical	(b) Administrative / Regulatory	(c) Economic / fiscal
Fuel change and control technology	For power plants the fuel change leads to technology change as well. However, newer technologies are more efficient and long term cost effective. Other industries may experience lower level of technology issues.	DPCC can make the rule stringent and link with Delhi Clean Air Action Plan. Evaluation of control technology for NOx, PM and SO_2	High cost initially. However, in longer run more cost effective
Industrial Policy	Specifying technology needs policy review Area specific location policy	Detail feasibility study for technology as well as land use based policy issues.	Financial incentive to burn cleaner fuel or use of cleaner technology

Table 7.10: Framework for Selecting Measures to Address Urban Air Pollution: Area Sources

Action Category	(a) Technical	(b) Administrative / Regulatory	(c) Economic / fiscal
Fuel change - Domestic	No major technical issue	Adequate administrative measures in place	No major cost involved facilitation for awareness needed
Fuel change - Bakeries/ Crematoria	Need for technical evaluation	Standards to be specified to drive technical changes	Medium cost
Fuel change – Railways/ airport/ship	No major technical issue	Administrative directions needed	Medium cost
Re-suspended dust	Pavement to be wall to wall Better sweeping system Better road paving technology issue	Regulatory push required for better road paving technologies	Minor cost Fines for poor road surfaces
Construction	Improved construction practices, no technology issue	Regulatory push and surveillance needed for better compliance	Minor costs of regulation and surveillance

Based on the framework of each sector delineated above, each of the possible actions has been discussed in respect to their effectiveness, barriers to implementation and administrative issues. These options have also been considered for their co-benefits with regard to other pollutants adding values to the action planned. Delhi city specific measures at national as well as local levels have also been finalized after interactions in various meetings and workshops. These agencies indicated here are likely to have direct and indirect role in implementation. **Tables 7.11, 7.12 and 7.13** present the considerations in prioritizing various measures for vehicular, industrial and area sources, respectively.

Table 7.11 : Considerations in Prioritizing Technical Measures for Addressing Urban Air Pollution - Vehicles

Actions	Technical Issue	Effectiveness for Emission reduction	Barriers to implementation	Administrative /regulatory	Qualifiers	Local/ National Stakeholders
Strategy : Vehicles: Emission Reduction per unit Fuel Used						
S reduction in diesel	Technically feasible and being implemented	Moderate. Reported elsewhere 2000-300 ppm reduction in S leads to 2.5 – 13 % reduction in PM [#]	High cost. Being planned by Refineries as per the Auto Fuel Policy. The cost is in the range of 15000/35000 crores based on the levels of S	Improvement in emission standards as well as legislation for stringent fuel standards for S, Phasing out the subsidies on diesel. Bringing diesel cost at par in a state/centre	The S reduction will not only reduce the PM but also lead to correspondingly lower SO_2 emission leading to lower ambient SO_2 and sulphate. It will also allow exhaust after treatment devices.	Oil companies, Ministry of Petroleum, vehicle manufacturer
Reduce fuel adulteration	Better quality fuel by adopting stricter fuel supply and dispensing system (e.g. Pure for Sure etc.) Chemical marker system	Reduced adulteration will lead to reduced PM (difficult to quantify). Effectiveness is moderate as marker system has not been seen as a primary means to reduce PM	Present system of Anti Adulteration cell function needs major improvement in terms of higher manpower and spread. Success of marker system shall be highly dependent upon the joint working relation with Oil companies and AAC.	The current fuel specifications are too broad and therefore checking of conventional parameters such as density etc. does not reflect the adulteration. Finer fuel specifications are needed for implementation. Oil companies themselves can be proactive in proposing these values, which can be checked easily in any laboratory. They can suggest their own norms.	One of biggest advantage of non-adulteration shall be longer engine life besides the emission reduction for PM as well as CO and HC. The catalytic converter shall be active for its lifetime.	Anti-Adulteration cell, Oil Companies, Vehicle owners

Source (Air pollution from motor vehicles, Faiz Asif, Weaver C.S. and Walsh M.P., The World Bank, Washington, D.C., 1996)

Table 7.11 (Contd..) : Considerations in Prioritizing Technical Measures for Addressing Urban Air Pollution - Vehicles

Actions	Technical Issue	Effectiveness for Emission reduction	Barriers to implementation	Administrative /regulatory	Qualifiers	Local/ National Stakeholders
Strategy : Vehicles: Emission Reduction per unit Fuel Used						
Alternative fuels	• Technical infrastructure in Mumbai for dispensing CNG/LPG is fairly good and is improving	High, more than 90 % reduction in PM can be achieved compared to diesel [#]	Can be applicable mainly for vehicles, which are supposed to ply within the city. Applicable to only local public transport, taxies etc.	Incentive by the government authorities to private vehicle owners to shift to CNG/LPG.	Will lead to substantial reduction in CO and HC emission, however, NOx values may go up	Gas, Oil Companies marketing LPG
	• Biofuels can be used up to 5-10% without any major technical issue.	Similar to diesel but low SO_2 and low PM	Can be easily implemented	Regulatory system allows	Low SO_2 emission	Ministry of Petroleum
Phase out of grossly polluting vehicles	No major technical problem	High, Estimate suggest 25% of these vehicle may contribute 75% of total emission $	Poor Inspection system both for emission as well as vehicle. New legislation may require changes in Motor Vehicles Act	New legislation needed for improved Inspection certification system, better testing facility.	Better compliance will lead to reduction of other pollutants as well. It will also lead to less pressure on complying vehicles	Transport Commissioner office, Ministry of Road Transport and Highway

Source (Air pollution from motor vehicles, Faiz Asif, Weaver C.S. and Walsh M.P., The World Bank, Washington, D.C., 1996)

$ Source (Impact of Better Traffic Management, South Asia Urban Air Quality Management, Briefing Note No. 5, ESMAP, The World Bank, 2002)

Table 7.11 (Contd..) : Considerations in Prioritizing Technical Measures for Addressing Urban Air Pollution - Vehicles

Actions	Technical Issue	Effectiveness for Emission reduction	Barriers to implementation	Administrative /regulatory	Qualifiers	Local/ National Stakeholders
Strategy : Vehicles: Emission Reduction per unit Fuel Used						
Congestion reduction	Improvement of roads, new roads, scientifically planned traffic management, mass transit systems, parking on roads	High emission due to fuel burning at idle or slow moving traffic	Road quality improvement is a matter of technology and quality of work carried out. Concretization of road may be the solution. New road planning and Traffic management are being taken as integral part of the road and flyovers construction.	Better planning and training in traffic management. Mass Rapid Transit System (Metro and High Capacity Bus system) Road construction norms to be evolved and implemented	It will reduce traffic junction hotspot of all the pollutants It will also reduce continuous source of dust	Delhi Government, MCD, NCR Board, Transport police, other utilities.
Strategy : Vehicles: Emission Reduction per unit distance travelled						
Standards for new and In-use vehicles	No technical issue with new vehicles. For inuse old vehicles, technical feasibility needs to be established	Marginal improvement from newer vehicles except when implementation is for Euro V & VI In-use vehicles emission reduction can be substantial	The process of in-use vehicles standards may take time as they need to be revised at central level. Inadequate infrastructure and manpower at local; levels could other major barriers.	After the legislation is in place, provision of strict penalty leading to cancellation of vehicle registration.	As the old vehicle population is substantial, the standards will bring in the much needed control on emissions of all types	MoRTH, Transport Office Govt.of Delhi
Introduction of new technology vehicles	New technology based vehicles emit less per unit distance travelled Electric vehicles	High compared to grossly polluting, moderate with respect to inuse vehicles	Emphasis to allow only a type of technology to be permitted may meet with resistance from manufacturer as well as buyer. (e.g. rule to allow only 4 stroke vehicle to be registered)	This needs to be backed with proper legislation. Else charge higher registration fee or subject them to carry out more frequent I&C test. Electric vehicles for grossly polluting high VKT vehicles are a good option. It needs regulatory push	It will lead to better compliance from on-road emission test and overall improvement in emission of all the pollutants. Electric vehicles provide localized benefits of no air pollution	MoRTH, Transport Office Govt. of Delhi, MNRE

Table 7.11 (Contd..) : Considerations in Prioritizing Technical Measures for Addressing Urban Air Pollution - Vehicles

Actions	Technical Issue	Effectiveness for Emission reduction	Barriers to implementation	Administrative /regulatory	Qualifiers	Local/ National Stakeholders
Strategy : Vehicles: Emission Reduction per unit distance travelled						
Retrofitment of new engine/ Emission control device	Experience of other countries suggests that it can be feasible. However, in Indian scenario, a pilot retrofit programme to evaluate the efficacy needs to be undertaken. A small pilot project is on in Pune with USEPA, USTDA and NEERI	Engine replacement could lead to major reduction of PM. Emission control devices available (DPF, DOC) can remove PM upto 90%	Availability of new engines for retrofit. Vehicle manufacturers need to come forward. For Emission control devices, there are innumerable agencies.	Presently no legislation. Need to frame one including a mechanism by which the system can be evaluated by an appropriate agency.	Short time frame, high levels of compliance expected for all the in-use older vehicles.	MoRTH, Transport Office Govt. of Delhi, vehicle manufacturer, vehicle fleet owners
Higher usage of Public Transport	Dedicated bus lane, better buses, low cost of travel, faster travel etc.	Effectiveness is high as less and less road space will be occupied by private vehicles, faster movement of public transport in comfort shall lead to low emissions	Feasibility to be established for bus lane. Finances for better buses. Measures to reduce the cost of travel by way of cross subsidizing.	Local level planning in coordination with all the authorities involved in transport infrastructure related to metro, roads and flyovers. Dedicated funds for public transport	Future growth of the city will entirely depend upon the levels of public transport availability. Cheaper and faster mode of public transport will lead to higher per capita efficiency.	MCD, NCR Board, Metro Rail and public transport companies DTC etc.
Decrease Private vehicles on Road	No major technical issue	Less private vehicles on road, high road space utilization by public transport	Awareness matched with better public transport. Need for multiple barriers for buying personalized vehicles	Higher parking charges, high registration fees, higher car user charges	Private vehicles owners should must own their own garages, less parking on the roads, less congestion	MCD, Govt of Delhi, RTO

Table 7.11 (Contd..) : Considerations in Prioritizing Technical Measures for Addressing Urban Air Pollution - Vehicles

Actions	Technical Issue	Effectiveness for Emission reduction	Barriers to implementation	Administrative /regulatory	Qualifiers	Local/ National Stakeholders
Strategy : Vehicles: Emission Reduction per unit distance travelled						
Training and Awareness programme car owners, public transport operators, drivers and mechanics	On use of alternative fuel, Inspection and certification, adulteration of fuels, use of public transport, less usage of private vehicles	May lead to 5-10% reduction of emission.	Resources for awareness and training, bringing the different groups together	Support from local and national institutions with finances as well as manpower.	Savings by way of improved vehicle maintenance and operation	MCD, Govt of Delhi, Central Govt, Transport Department, Other institutions involved in awareness campaign

Table 7.12: Considerations in Prioritizing Technical Measures for Addressing Urban Air Pollution - Industries

Actions	Technical Issue	Effectiveness for Emission reduction	Barriers to implementation	Administrative /regulatory	Qualifiers	Local/ National Stakeholders
Strategy : Industries: Emission Reduction per unit Fuel Used						
Combustion Processes	Change in combustion technology will be needed for shifting from coal/oil to natural gas	Moderate	Finances to change the process technology	No regulatory issue	It will lead to lower emission of CO and HC	DPCC, CPCB, Power companies and Industries
Alternate Fuel	Large no of industries are using NG and LPG	The higher percentage of use of cleaner fuel has already resulted in better air quality in the city		More allocation of NG/LPG to the industrial sector by Govt. of India	Better air quality in terms of SO_2, CO and HC will be achieved.	Govt of India and DPCC

Table 7.12 (Contd..) : Considerations in Prioritizing Technical Measures for Addressing Urban Air Pollution - Industries

Actions	**Technical Issue**	**Effectiveness for Emission reduction**	**Barriers to implementation**	**Administrative /regulatory**	**Qualifiers**	**Local/ National Stakeholders**
Strategy : Industries: Emission Reduction by Industrial Policy and Standards						
Promoting Cleaner Industries	Use of cleaner production processes	Large scale shift shall result in major PM /NOx reduction	Finances to carry out these changes	MoEF can provide incentives to carry out the necessary change	It will lead to sustainable existence of industries within the city. It will also lead to other pollutants reduction	MoEF, CPCB, CII
Location Specific emission Reduction	Control technologies change to cleaner	Medium	Finances for advance control technologies	State as well as central government can provide the necessary incentive on use of advance technology by the power plant and other industries	Lower NOx and other emissions	Govt of Delhi, DPCC, CPCB and GoI
Fugitive Emission control	Industrial process improvement better operation and maintenance	For localized region, effective. Particularly for industries with fine particles raw material or products. High efficiencies can be achieved for quarries.	Monitored data is scarce and therefore how and where to undertake the action will be limited	DPCC and CPCB can work on the standards for fugitive emission and develop compliance system	Local area air quality improvement could be highly effective.	DPCC, CPCB, Industries

Table 7.13 : Considerations in Prioritizing Technical Measures for Addressing Urban Air Pollution – Area Source

Actions	**Technical Issue**	**Effectiveness for Emission reduction**	**Barriers to implementation**	**Administrative /regulatory**	**Qualifiers**	**Local/ National Stakeholders**
Strategy : Area Sources: Mixed sources and varied strategies						
Improve fuel used for domestic purposes	LPG/PNG major domestic fuel, however kerosene is still a major source in low income group/ better stoves or change in fuel to LPG	Likely to improve indoor air quality	Lack of finance to low income group, particularly in slums	Administrative mechanism to be evolved to provide low cost clean fuel to slum dwellers	It would alleviate large section of population with high indoor pollution of other sources leading to lower disease burden and better quality of life	Central and State Govt., MoPNG
Bakeries /crematoria	Electric/LPG source based bakeries needing changes in design Many crematoria have electric system, but need to convert all the other into electric system	Local grid based PM can be reduced.	Awareness to bakeries that the quality can still be maintained with electric or LPG ovens. Similarly, despite electric crematoria being available, people prefer using wood based pyres	Strict monitoring of emissions from bakeries and crematoria	Reduction in PM as well as odour will take place and is likely to improve the local air quality	MCD, DPCC
Biomass/trash burning, landfill waste burning	Better control on collection and disposal at the respective sites. Landfill waste burning needs proper technology driven site management	Local area can have substantial reduction in PM. Very high effectiveness to adjoining grids	Awareness and local control. Apathy to take urgent action. No burning day vow to be taken by BMC	DPCC needs to address this issues	High level improvement in local area ambient air quality not only for PM but other pollutants	MCD, DPCC

Table 7.13 (Contd..) : Considerations in Prioritizing Technical Measures for Addressing Urban Air Pollution – Area Source

Actions	Technical Issue	Effectiveness for Emission reduction	Barriers to implementation	Administrative /regulatory	Qualifiers	Local/ National Stakeholders
Strategy : Area Sources: Mixed sources and varied strategies						
Resuspension	Vehicle movement related resuspension can be reduced by having better paved roads, regular sweeping and spray of water.	Highly effective for kerb-side air quality	Awareness and will to implement	Norms for road construction to be framed and implemented	Roadside as well population within the distance of about 200-300 m from the road will have low exposure of PM leading to better sense of well being	MCD, DPCC
Illegal SSI	Level of problem not well known. Need to understand what are the levels of operation and their contribution in each of the grids in the city	Local area improvement can be moderately good	Knowledge of the problem	Need for strict rules of such units and identification by DPCC/DIC and MCD	It will lead to large scale reduction of fire accidents as well as minimization of wastewater problem	MCD, DPCC, DIC
Construction	Construction activities which involve demolition, digging, construction, vehicle movement etc.	Large scale improvement in local area is expected.	Emphasis on better construction practices and management plan for air emission and its control by the implementing agencies	Fine system to be employed by the local authorities for violating the best construction practices for air pollution control.	Spillage on road and further re-suspension of dust can be minimized	MCD, DPCC, Builders Association

The set of action plan components in each categories have been short-listed on the basis of analysis carried out in earlier in the report. The major recommended actions are listed in **Table 7.14** which are based on multiple factors and more specifically city specific issues. The options presented in Table 7.12 are based on four major factors:

- Effectiveness
- Ease of implementation
- Cost of implementation
- Time frame

These criteria have been used to prioritize the options besides consultations with many stakeholders. These criteria are based on some objective information and few based on understanding of the sources and their effectiveness.

The development needs of Delhi is not limited to its boundary alone but all of these options will need to be integrated to all the urban centers and growth centers around Delhi (NCR). The benefits accrued due to these options based on technology and management of air polluting sources will be limited if they are not only aligned with nearby urban centers (which will include area, point and vehicular sources) but also with the neighbouring states and finally country.

Table 7.14: Prioritized List of Management / Control Options

Source Category	Control/Management Option	Implementation and regulatory agencies
Industrial		
I.1	Power Plants (Fuel shift - coal to NG)	Power companies, Govt of Delhi, GOI
I.2	Medium Scale industries (Fuel shift)	Industries, DPCC
I.3	Technology up-gradation, fugitive emission control	Industries, DPCC
1.4	Illegal industries shifting	Govt of Delhi, DPCC
Area		
A.1	All construction demolition related emissions control	MCD, DPCC
A.2	Road Construction/repair Practices	MCD, PWD
A.3	All domestic (including slums) emission control through clean fuel	MCD, Govt of Delhi, GOI
A.4	DG Sets replacement by making power available	Power companies, Gas company, Govt of Delhi and GOI
A.5	Biomass and Refuse burning	MCD, DPCC
A.6	Public Awareness on local area air pollution problems	DPCC, MCD

Table 7.14: Prioritized List of Management / Control Options

Source Category	Control/Management Option	Implementation and regulatory agencies
Vehicular		
V.1	Augmentation of city public transport system	Govt of Delhi, GOI
V.2	Traffic restrain, and congestion related taxes – Financial aid to public transport	SIAM, MORTH,CPCB
V.3	Development of fuel economy based emission norms for all category of vehicles	Vehicle manufacturer, CPCB
V.4	Fuel Quality Improvement	Oil companies, GOI
V.5	Emission Norms for New Vehicles	GOI, CPCB, SIAM, MORTH
V.6	Inspection and Maintenance (I&M) System for all category of vehicles in Automobile Manufacture Company Owned Service Centers (AMCOSC)	DPCC, CPCB
V.7	Performance evaluation of Catalytic Converter and periodic performance evaluation	DPCC, CPCB
V.8	Conversion of private vehicles to clean fuel	Govt of Delhi, Gas companies
V.9	Retro-fitment of DPF in LCVs, Trucks and Diesel-Buses	DPCC, SIAM
V.10	Phase out of older grossly polluting vehicles	MORTH, DPCC, CPCB
V.11	Stringent system for checking for adulteration in fuels	Oil Companies, Anti Adulteration Cell
Road Dust		
RD.1	Collection and proper disposal of road side dumped material (dust, garbage, leaves, refuse material etc.) and continue road cleaning regularly	MCD
RD.2	Repair/maintenance of all types of roads (arterial, main and feeder roads) for pot holes etc.	MCD
RD.3	Removal of encroachment of roads	MCD
RD.4	Conversion of unpaved road to paved roads	MCD
RD.5	Wall to wall paving of roads (with proper provision for water percolation)	MCD

7.3 Anticipated Benefits

Most of the options discussed above have direct benefit in terms of reduced air pollutants, but they also have indirect benefits with regard to other pollutants besides NOx and PM. Some of these area reduction in SO_2, VOCs, CO, HC as also GHG and finally they lead to overall improvement in the health of population, better ecology of the urban regions, better quality of life of citizen of the city.

Though few of these could be quantified in terms of loads as also concentrations, however, many others are intangibles and hold high values in our life, such as better visibility and sense of breathing clean air. Some of these associated benefits are listed in **Table 7.15, 7.16 and 7.17.**

Table 7.15 : Benefits associated with prioritized control /management options –Vehicular

Action Components	Direct benefits	Co-benefits
S reduction in diesel	Moderate reported elsewhere 2000-300 ppm reduction in S leads to 2.5 – 13 % reduction in PM	The S reduction will not only reduce the PM but also lead to correspondingly lower SO_2 emission leading to lower ambient SO_2 and sulphate. It will also allow exhaust after treatment devices.
Reduce fuel adulteration	Reduced adulteration will lead to reduced PM (difficult to quantify). Effectiveness is moderate as marker system has not been seen as a primary means to reduce PM	One of biggest advantage of non-adulteration shall be longer engine life besides the emission reduction for PM as well as CO and HC. The catalytic converter shall be active for its lifetime
Alternative fuels • CNG/LPG • Biofuels	• High, more than 90 % reduction in PM can be achieved compared to diesel • Similar to diesel but low SO_2 and low PM	• Will lead to substantial reduction in CO and HC emission, however, NOx values may go up • Low SO_2 emission
Phase out of grossly polluting vehicles	High estimate suggest 25% of these vehicle may contribute 75% of total emission	Better compliance will lead to reduction of other pollutants as well. It will also lead to less pressure on complying vehicles
Congestion reduction	High emission due to fuel burning at idle or slow moving traffic	It will reduce traffic junction hotspot of all the pollutants. It will also reduce continuous source of dust
Standards for new and In-use vehicles	• Marginal improvement from newer vehicles except when implementation is for Euro V & VI • In-use vehicles emission reduction can be substantial	As the old vehicle population is substantial, the standards will bring in the much needed control on emissions of all types
Introduction of new technology vehicles	High compared to grossly polluting, moderate with respect to in-use vehicles	It will lead to better compliance from on-road emission test and overall improvement in emission of all the pollutants. Electric vehicles provide localized benefits of no air pollution
Retrofitment of new engine/ Emission control device	Engine replacement could lead to major reduction of PM. Emission control devices available (DPF, DOC) can remove PM upto 90%	Short time frame, high levels of compliance expected for all the in-use older vehicles.
Higher usage of Public Transport	Effectiveness is high as less and less road space will be occupied by private vehicles, faster movement of public transport in comfort shall lead to low emissions	Future growth of the city will entirely depend upon the levels of public transport availability. Cheaper and faster mode of public transport will lead to higher per capita efficiency
Decrease Private vehicles on Road	Less private vehicles on road, high road space utilization	Private vehicles owners must own their own garages, less parking on the roads, less congestion
Training and Awareness programme car owners, public transport operators, drivers and mechanics	May lead to 5-10% reduction of emission	Savings by way of improved vehicle maintenance and operation

Table 7.16 : Benefits associated with prioritized control / management options –Industrial

Action Components	Direct benefits	Co-benefits
Combustion Processes	Moderate	It will lead to lower emission of CO and HC
Alternate Fuel	The higher percentage of use of cleaner fuel has already resulted in better air quality in the city	Better air quality in terms of SO_2, CO and HC will be achieved.
Promoting Cleaner Industries	Large scale shift shall result in major PM reduction	It will lead to sustainable existence of industries within the city. Also lead to other pollutants reduction
Location Specific emission Reduction	Medium	High level emission shall have lower PM and other gaseous pollutants
Fugitive Emission control	For localized region, effective. Particularly for industries with fine particles raw material or products. High efficiencies can be achieved for SSI.	Local area air quality improvement could be highly effective.

Table 7.17 : Benefits associated with prioritized control / management options –Area Source

Action Components	Direct benefits	Co-benefits
Improve fuel used for domestic purposes	Likely to improve indoor air quality	It would alleviate large section of population with high indoor pollution of other sources leading to lower disease burden and better quality of life
Bakeries /crematoria	Local grid based PM can be reduced	Reduction in PM as well as odour will take place and is likely to improve the local air quality
Biomass/trash burning, landfill waste burning	Local area can have substantial reduction in PM. Very high effectiveness to adjoining grids	High level improvement in local area ambient air quality not only for PM but other pollutants
Resuspension	Highly effective for kerb-side air quality	Roadside as well population within the distance of about 200-300 m from the road will have low exposure of PM leading to better sense of well being
Illegal SSI	Local area improvement can be moderately good	It will lead to large scale reduction of fire accidents as well as minimization of wastewater problem
Construction	Large scale improvement in local area is expected.	Spillage on road and further re-suspension of dust can be minimized

7.4 Additional Measures for Sustainable Delhi Air Quality Plans

The air quality sustainability goal of Delhi aims at addressing mainly two pollutants such as PM_{10} and NOx. Though, there are other related air pollutants such as finer particles which may have very high toxic components, hydrocarbons of varied origin (VOCs), Ozone and others, however, PM and NOx dominate the current goals of sustainable ar quality. The sustainability goal of Delhi is linked with overall environmental quality, of which Clean Urban Air Goal is one of the most important areas.

The city boasts of many cleaner areas and regions of better visibility and air quality, however, large tracts of Delhi region has been witnessing severe air pollution problems. Many steps have been undertaken in the past to address air pollution issue. Of those initiatives, majority of measures were taken for vehicle sector. Actions pertaining to other sectors, which are more distributed and widespread, have been limited.

The analyses of situation and the development taking place in Delhi need multiple pronged approach to arrive at better and sustainable air quality. The apparent problems of PM and NOx control for the overall city (which also includes other areas within NCR for control option implementation) can be addressed by prioritizing the following sectors in following ways:

7.4.1 : Industrial

The contributions of industries medium and large (particularly power plants) for PM and NOx are very high [11854.7 TPD PM and 131591.8 TPD NOx]. Though the tall chimneys associated with these industries provide high dilution and dispersion, however, in stable atmospheric conditions (inversion combined with high wind related calm conditions) in some part of the year, these can add substantial quantities of pollutants in urban air. The options of fuel shift which mainly involves opting for gas based operation of power plants will only yield PM reduction. However, NOx levels would continue to get added with increased capacity. These additional loads shall create situation of frequent and longer duration of violation of ambient air quality norms in select regions of Delhi city.

Industrial NOx control options will need to be looked at as priority options, in addition to measures suggested above. Possible NOx control technologies include selective catalytic reduction (SCR), non catalytic reduction (NSCR), lean burn technologies etc. Many of these are proven technologies and can be adopted. For older coal based power plant as well, retrofitting of NOx control technologies can be attempted. As can be seen from the model results presented in **Table 7.7 and Figure 7.2** that in 2017 scenario of control measures, reduction in PM will be substantial, however, NOx values will be much higher than the standards. Though these values are for worst condition of season and meteorology with highest 10 concentrations within the city, still they reflect overall trend of NOx situation in the city.

7.4.2 Vehicular

The concepts of control scenario for vehicles provide umpteen options. Many technologies mentioned earlier have yielded large scale benefits for the city air quality besides impring the quality of life. However, all these technology measures and improved fuel quality alone do not lead to sustainable air quality solution. These options are able to reduce the PM and NOx levels to a limited extent. As our vehicles population is rapidly rising, all these benefits get nullified in a limited period. The personalized mode of transport has taken over the public transport which is leading to high congestion.

The vehicular pollution in coming years will not be driven by technology of the engine and types of the fuel but by the congestion related air emission. It means fuel burnt per unit distance will continue to increase.

The problem of PM from vehicles will remain to be addressed only for fine fraction; however, as the technology of engine improve along with fuel quality, this issue will also get addressed to a great extent. The biggest challenge remaining for this sector will be NOx emissions despite improvement in engine out emission.

One of the most workable solutions emerging for high growth Delhi is to develop mass rapid transport system comprising of road as well as railway options. Benefits of MRTS operations have been clearly felt elsewhere in the emerging cities of many countries. Delhi also has started experiencing its benefits not only in terms of better mobility but also in urban air quality improvement of the region. An example of MRTS and its benefits are given in the box for the stretch of Central Secretariat to Badarpur Border.

This solution however, will make an impact on NOx and PM only when its coverage is far and wide across Delhi as well as to its nearby growth centers. This option in combination with traffic restraints system, congestion charges, parking restrictions etc will bring the sustainability of the air quality on a better platform.

Delhi Metro Rail Projects

Delhi with phenomenal growth in population has also seen corresponding high rise in vehicles. Delhi vehicle population has been rising at the rate of about 6.21 per annum. The number of motor vehicles in Delhi is now more than that of Mumbai, Calcutta, Chennai put together. The extreme congestion on Delhi roads has been leading to slowing of average speeds, increase in road accidents, fuel wastage and air pollution.

It is normally believed that with city growth when the number of vehicular trips on road system goes up to 20,000 persons per hour in a given direction, a pragmatic approach should be to discourage private modes and encourage public transport such as rail based Mass Rapid Transit System (MRTS). Though these are capital intensive and have long gestation period, its usefulness is very high where the users population is high. Ideally, Delhi with a population of about 16.2 million should have had an MRTS network of at least 300 kms by now, however, its still 65.10 kms.

Government of India and the Government of National Capital Territory of Delhi, in equal partnership have set up a company named Delhi Metro Rail Corporation Ltd. under the Companies Act,1956, which has already commissioned a 65.10 kms route in Phase-I and is proceeding ahead with another 121 kms in Phase –II.

Delhi city is an ideal city for MRTS or BRTS as it has much wider roads with about 23 % of area under roads. Old city area may have some difficulty, otherwise as a future planning measures, MRTS/BRTS should be planned for much larger regions with high connectivity within the city as well outskirts of the city. (source: DMRC). Central secretariat to Badarpur Boarder Corridor: An example of benefits associated with MRTS in terms of time and fuel saved is given below.

	2011	2012	2013	2014	2015	2016	2019	2021
Total Road Pass km	4086402	4164562	4286658	4412335	5035603	5148818	5503965	6421721
Daily Vehicle km Saving (Road)	546913	557373	573714	590535	673951	689103	736635	859465
Daily Vehicle Demand (Metro)	11557	11778	12123	12478	14241	14561	15566	18161
Average Travel Time Saving /Trip (Metro)	36	36	36	36	37	37	37	37
Daily Travel Time Saving Min (Metro)	12964392	13212359	13465068	13722611	15819091	16014604	16615760	18714119
Travel Time Savings in min by Road Pass	928728	1014098	1082489	1193813	1430569	1481248	1596895	1900367
Daily Fuel Saved in Liter (Metro)	43633	44468	45771	47113	53768	54977	58769	68569
Annual Fuel Saved in Tonne (Metro)	15926	16231	16707	17196	19625	20067	21451	25028
Daily Fuel Savings due to decongestion (Liter)	54071	64965	72189	84697	105101	109702	118884	143120
Annual Fuel Savings due to decongestion (Tonne)	19736	23712	26349	30914	38362	40041	43393	52239
Annual No of all accidents savings	104	105	106	107	114	115	117	120

.

7.4.3 Area Sources

Area sources such as DG sets, use of biomass and kerosene for domestic cooking, refuse burning, crematoria, bakeries etc create local air quality problems. Some of these sources are located in a particular area and therefore any control as discussed earlier shall bring the immediate improvement in local area quality. However, there are many options which need wide ranging policy and management intervention. Some of these are:

DG sets Air Quality Management : Emissions reductions at the household levels can not be easily controlled. Its elimination by way of electricity supply is the only workable solution. The implementation of additional power supply for Delhi shall provide wide ranging improvement in overall Delhi air quality.

Bakeries and Crematoria: These sources impact a limited region or locality. Local issue of air pollution can be substantially improved through their control by shift in fuel types. Benefits accrued would be in terms of local area hot spot air quality improvements.

Dust sources: The air quality monitoring and analysis clearly indicates the following: Delhi particulate problems can be ascribed to four different sources, viz; 1- wind blown natural dust (sometime getting transported a longer distance), 2- road dust resuspension (dust lying on the roads due to inadequate sweeping gets resuspended due to vehicles movement), 3- construction dust (due to poor quality of road construction and repair, large scale construction/ demolition and movement of construction material), and the last 4- particles generated from all combustion sources including vehicles.

The dust components which can be controlled through measures suggested above in prioritized list are mainly from combustion sources, construction of roads/buildings, and road side dust. A large amount of dust emission due to wind blown dust as also the dust storm related contributions can not be controlled.

The controllable options need implementation of better code of construction for road and buildings as also for repair and demolition etc. These codes will need to be framed and integrated into the contractual system of all agencies including private agencies engaged in construction and demolition. This will bring about large scale improvement in whole of Delhi.

7.5 Major Recommendations

Based on the framework of each sector delineated above, major recommendations for industrial, vehicular and area source are given below :

7.5.1 Recommended Action for Vehicular Sector

Major recommendations of the study as derived from the various study components and also consultation exercise are discussed here. It is, however, important to understand that all actions as listed in **Table 7.11** will need to be implemented in concerted efforts, without which a sustainable long term solution can not be realized.

7.5.1.1 Fuel Issues

Sulphur Levels in Fuel

It is well known that the introduction of low S diesel leads to bringing down the PM emission from all the diesel vehicles. Despite the introduction of low S level in the metro cities at <350 ppm, it has been seen that the diesel being used by most of the operators of the HDDV and LDDV are of higher S level. The operators opine that this is happening due to the fact that outside city limit the cost of the diesel is much lower. And, therefore, even if the owner wants to fill a cleaner diesel, drivers have tendency to fill from outside. The same will also be true for vehicles coming from outside the city and not registered within the city, which will still carry diesel with higher S content. Therefore, the S reduction plan only for cities does not necessarily get translated into cleaner vehicles.

To cater to this problem, following suggestions emerge:

- Price structure of the diesel in the whole of the state (and ideally for whole country) should be rationalized so that there are no incentives for buying diesel from outside the city or state.
- Alternately, the nearby cities and states should also be brought under the regime of same fuel quality, for which oil companies can be urged to maintain the same S levels in and around the city.
- In the interim period, a measure which can dissuade truck operators from buying high S fuel should be stricter, reliable and reproducible inspection for smoke levels.

7.5.1.2 Fuel Adulteration

Fuel adulteration is one of the major issues, the most of the lubricants presently being sold in the market are of low grade and that leads to high levels of emission. This is also true for vehicles being run on CNG as low-grade lubricants used in these vehicles also lead to high PM emission.

Following suggestions emerge:

- Oil companies can ensure better movement of their produce to ensure that the adulteration does not take place. This is valid for both petrol as well as diesel. Some of the schemes suggested are use of colour codes on the tanker transporting the fuel, regular testing of the fuel before it is filled in the bunks and after. This task can be undertaken effectively by the Oil Companies.

- The petrol pumps operators can be educated and trained to check the adulteration before they let the fuel get into the bunks. This will help monitor and fix responsibilities of the petrol pump operator.
- The procedure for such tests should be set up with the common understanding with the oil companies and operators. The protocol should be set up in a way that public and user can check its effectiveness, whenever desired.
- The oil companies should show pro-activeness in promoting the better lubricants.
- Ministry of petroleum should develop better specification for the lubricants to be used and its testing.
- Oil companies should also put their own manpower and machineries in checking effectively their products being sold from their outlets. (e.g. BPCL's Pure for Sure; HPCL's Club HP and IOC's Q & Q etc., which are being carried out in, limited way.)
- Ministry of petroleum has constituted anti adulteration cell for preventing the malpractices of fuel adulteration. Fuel quality standards are required to be strengthened and range of values for specified parameters required to be narrowed. Use of MARKER elements in fuel may ease the process of preventing adulteration and should be implemented on priority basis.
- Economic measures such as removing the disparity in petrol, diesel and kerosene prices will be required to remove incentives for such large scale malpractices.

7.5.1.3 Fuel Alternatives

Most of the operators of HDDV and LDDV operate within the city as well as outside. There is an apparent resistance to not change the fuel use pattern for many reasons such as:

- Unavailability of CNG in areas outside the city limit
- Unavailability of kits for such conversion to the older vehicles
- Retrofitment of older engines with the CNG kits is likely to be not efficient in terms of PM emission.
- Maintenance cost of such retrofitted vehicles is much higher.
- Unavailability of trained manpower for CNG operated vehicles outside the city limit
- 5-10% use of Bio fuels without any major technical issue would lead to low SO_2 and PM emissions.

In view of the above factors, of which the availability of CNG outside the city limit could be the major factor for HDDV and LDDV's not changing to CNG. The bus operators and other contract carriages will have slightly higher vehicles km trip.

Based on the various pros and cons discussed above following suggestions emerge:

- Vehicles should be subjected to strict, reliable and reproducible inspection for smoke levels.
- These vehicles should be brought under the operation by which the smoke levels are below 45 HSU by the use of DOC or DPF, whichever achieves the desirable result.

7.5.1.4 Engine Technology

The higher emission at present from the HDDV and LDDV can be attributed to the fact that a large number of them are with older technology engine. In future as planned, Bharat III standards would require a better engine technology from the manufacturer. The Bharat III norms are already in place for all metros; however, this is applicable only for new vehicles. The improvement in engine technology does not affect the old fleet.

Change of Engine

For effective reduction in the emission from diesel vehicles, it is felt that in-use vehicles may be allowed to replace their engines by Bharat III compliant engines duly approved by the test agencies. As this concept would need effective implementation format and agreement between the manufacturer and the buyer, it is desirable that a pilot study is undertaken to evaluate the effectiveness of such option. The other major aspect is that the rule and protocol for such changes should be applicable to the whole state and the attempt should also be made to take this matter at national level. For two and three wheeler sector, it is necessary that the entire new vehicles fleets are 4 stroke vehicles with catalytic converter to meet the future norms. Most of the old three wheelers have started converting to CNG/LPG. Here, the engine is not changed but a kit is installed. In this sector, there is no apparent need to consider engine change.

Suggestion emerging in this area:

- Undertake a pilot study with the major manufacturer of HDDV/LDDV engines to evaluate the effectiveness of engine replacement with better emission compliant engines. The study should also ensure the details of the mechanism of certification and testing of such engines from reputed test agencies in India, so that the local RTO can allow only the certified engines for replacement.

- Manufacturers and the state can take this further with the national authority (MoRTH) to issue guidelines for nationwide implementation
- Bharat III compliant engines therefore should be sold throughout India, rather than only in Metro.

7.5.1.5 Fitment of Emission Control Technology

The new vehicles meeting the requirement of Bharat III have been designed to meet the norms specified for the manufacturer. In cases, where the engine is new and is under warranty, the manufacturer can be held responsible and necessary action can be taken. However, the moment warranty period is over, the responsibility of meeting the emission norms falls on the owner of the vehicle. The reasons of higher emission could be many as discussed earlier such as fuel quality, overloading, bad roads, poor maintenance etc. Manufacturers have started giving emission warranty for all new passenger cars, 2-3 wheelers etc. since July 2001. Under this, commercial vehicles get emission warranty of 80,000 kms or 1 year whichever is earlier compared to private cars and two wheelers with 80,000kms and 3 years whichever is earlier. This emission warranty, however, is only for idling emission tests. Our idling norms are too lenient and therefore can be easily met. Such warranty should be extended for the BS III norms to a new certification system.

The emission control devices such as catalytic converter for any of the vehicles are never monitored for its efficiency or its defects. As also mentioned in Auto-Fuel Policy document, that the utility and serviceability of the emission reduction technologies fitted to a vehicle in India is neither judged nor monitored. For example, a conversion kit or catalytic converter may not necessarily give stipulated service, if defective (even when new), there is no mechanism to identify those. In such a situation, the onus of proving the emission worthiness of the vehicles is always with the owner.

To address the issues pertaining to this, following suggestions have emerged:

- Evaluation of all the vehicles emission control system bought between 1995-2000 (catalytic converter were first introduced in the year 1995) through a proper inspection schedule.
- Evaluate the need for emission control device replacement for all the vehicles bought between 1995-2000
- There are large numbers of diesel private vehicles, which were not required to fit catalytic converter in the year 1995. Almost all of them will need fitment of emission control devices, as they together could be large enough in numbers for contribution of PM in the atmosphere.

- All the grossly polluting vehicles (identification through inspection mechanism) should be identified and appropriate fitment of the emission control devices should be made. This could be particularly required for all the vehicles plying only within the city, such as school buses, water tankers, garbage trucks etc.
- As retrofitment of emission control devices also needs a certain levels of fitness of the vehicle, it would be desirable to follow the norm after developing the same through the inspection and certification procedures.
- There is a need to undertake a pilot study to test the need and efficacy of emission control device retrofitment on older vehicles, before it is implemented for all the vehicles needing such fitment.
- Vehicle manufacturer should be asked to get the emission warranty for the complete period of the operation of the vehicle which should be based on Bharat norms. Therefore, there is a need to delineate the useful vehicles life along with the emission warranty for a longer period. The same may also be included in the MoRTH guidelines to be developed asking manufacturer to be proactive even when vehicles have been sold.

7.5.1.6 Phasing out of the Vehicles

Vehicles operating-standards and consequent maintenance decides the vehicles fitness as well as emission. The deterioration in the vehicle emission could be due to varied reasons, such as overloading, fuel quality, poor maintenance etc. However, there can be some estimates regarding the useful life of a vehicle, which could be defined by the manufacturer. Based on the deterioration of engine components, a general consensus could be reached on the basis of vehicles age. The phase out of older vehicles should be based on the rationale, which can have many combinations; however, it should invariably be linked with inspection and certification procedure.

Suggested measures are:

- The private vehicles older than 15 years may go through the inspection and certification every year
- The vehicles should be able to meet the current norms at that time of certification
- Vehicles between 8 and 15 years should go through inspection and certification every two years
- Other vehicles can go through the inspection every three years
- The vehicle owners can voluntarily phase out their vehicles after 15 years even if it meets the requirement of retrofitment. There should be an incentive for an owner to phase out his vehicle after 15 years. This could be given in the form of low registration cost or direct subsidy.

- Another important matter relating to the phase out mentioned often is that there are no designated places for scrapped vehicles. As an ever-growing city, the phase out of the vehicle will always take place, even if there is no scheme.

7.5.1.7 Inspection and Maintenance/ Certification

Most of the vehicles emission problem can be associated with poor maintenance of the vehicles. Also the poor inspection set-up does not help much in terms of identifying the polluting vehicles disabling taking appropriate steps.

The present certification method for different types of vehicles for fitness is also not adequate enough to weed out the emission in-efficient as well as highly deteriorated engine power. These vehicles are frequently found to be stranded on the roads or are not able to climb the flyovers gradient. The inspection certification procedure therefore needs dual approach leading to one goal, viz. low emission and fitness of vehicles on road/roadworthiness.

The suggestions emerging are:

- Design and testing of inspection and certification procedure for all types of vehicles. The first test design should have the basis of engine and overall vehicles fitness (roadworthiness). This could be undertaken for some types of vehicles first: Privately owned diesel cars of more than 10 years of age and commercial vehicles more than 8 years old.
- The inspection and certification system development and its implementation should include all the stakeholders.
- The Vahan-nagari as described above should be equipped with state-of-the-art testing set-up for all the types of emission as well as fitness testing. These test centers should have the facility to test all types of vehicles and the test results will reflect the reliability and reproducibility. It should produce is a certificate that will be robust enough to stand all the scrutiny from all the quarters.
- The design of the facility, its component, manpower details, types of equipment and calibration system, testing and communication system details should be worked out. Institutional arrangement for the same needs to be developed.

7.5.1.8 Roads and Pavement

Roads and traffic control related issues have some wider and local effect. As discussed earlier, the major points of concern with regard to the high vehicle density and associated higher emission loads, it would be necessary to address many of these problem areas from traffic point of view.

The suggestions pertaining to this sector is detailed below:

- City roads are better due to their concretized condition and therefore give less resuspended dust. In view of the above, it is suggested that the outskirt roads also need better paving.
- Need for better construction practices and codes for roads and pavement construction.
- Pavement improvement is the other major issues, should be taken up on priority. Dug-up pavements have shown that fine particles keep getting resuspended in the atmosphere as the pavements are either not maintained or after the digging, those are not brought back to their original conditions.
- Encroachment of roads space by slums are one of the major reasons for slow down of traffic and leading to higher per unit emission due to congestion.
- Parking on roads should be regulated along with a rule to allow purchase of vehicles only if parking place is available.

7.5.1.9 Transportation Planning and New Roads

The current density of vehicles on roads has resulted in exhaustion of space at many places as discussed earlier. Most of the places, there is a need to study the traffic movement and possible need of an additional corridor to take care of the existing vehicle movement. Many additional flyovers and public transport projects have been planned in the city.

7.5.1.10 Traffic Management

A good traffic management can effectively reduce fuel consumption, emission, congestion and increase productivity of the city. A slow moving traffic requiring frequent acceleration, deceleration and long idling at various stops could contribute significantly even if the efficient engines are on roads, on better roads, better pavements and better maintained engines by well-behaved motorists. Levels of pollutants near the junctions with higher idling times, may reach an alarming proportion. Many of the traffic junctions in Mumbai have shown consistently high levels of pollutants (Particulate Matter as well as gaseous).The traffic management has potential to reduce PM and NOx emissions. Some of the suggestions are:

- Besides better road, there is a need for better pavements to prevent pedestrian from using road space that otherwise lead to congestion and accidents. Most of the problem sites are near the railway station and link to the main road.

- Better awareness, training and inspection of the road users in terms of abiding by the traffic rules, development of respect for traffic rules. (Need for training and awareness workshops)
- Augmentation of capability of the personnel involved, better resource availability in terms of manpower and infrastructure
- Need of better legislation, regulation and procedure with a view to effective implementation of the existing rules and regulations
- Good support from transport as well as other authorities in terms of imparting the recent knowledge as well as practices
- Coordination with all the other concerned authorities in the city.

7.5.1.11 Policy Level Instruments

There are various issues related to the policy matters which can have overall significant impact on the pollution reduction in the city. Some of these cannot be directly correlated emission reduction however; its impact can be seen in terms of improved ambient air quality.

Delhi has been known to be city with moderate public transport usage; the policy initiative should actually lead to promotion of better public transport.

Box: 7.1

For example, for one km of travel, a car consumes nearly five times more energy than a 52-seater bus with an average load factor of 82 percent. The corresponding consumption factor for two-wheeler is 2.6. The comparative fuel costs of a car and two-wheeler are 11.8 and 6.8 times respectively for the same distance. Besides, the major issue is that a car occupies 38 times more road space compared to a bus for a kilometer of a travel. Two wheelers space requirement is even higher at 54 times that of a bus*.

Further, the emission from a two-wheeler equivalent to a bus could add 27 percent higher, whereas the cars would cause 17 percent more pollution. The age of the bus can be of no major concern, when we compare the benefits that it could give in terms of fuel savings, emission and safety.

---

* Report on the Expert Committee on Auto Fuel Policy, Chapter 15, Government of India, 2002.
Every stakeholders consulted during the process, have agreed the major focus of any future transport initiative should be based on low cost public transport. Some of these initiatives are discussed hereunder:

7.5.1.12 Prioritization of Public Transport on Roads

Public transport and its importance in the city need to be maintained for one most important reason. Once more and more people get used to personalized transport, it would be very difficult to bring them back into the fold of public transport users. The fact that personal vehicles are occupying more and more space on the road; it is felt necessary that disincentive mechanism should be developed for personal vehicle owners. There are many methods of carrying out this task, however, financial and space constraints can achieve the balance

As the road space widely available in Delhi, the efficiency of the public transport can be maintained, if priority is given to the public transport vehicles. The objectives of such policy will be priority to the buses. Some of the suggestions are:

- Improvement in Public transport by Delhi Transport Nigam Limited which helps in not only ferrying people but also reduces green house gases.
- If one wishes to see higher bus utilization, it also has to see correspondingly higher service levels. This could be achieved by way of providing better frequency to reduce congestion during peak period, better bus quality in terms of sitting as well as standing space.
- The cost of the bus fare has been increasing at a steady pace. This is also seen almost every time when there is an increase in the diesel cost. What it leads to is that the bus fare for two-four persons becomes almost equivalent to either the taxi fare or attractive enough to own a private two or four wheeler. In such a situation, it is likely that increasing bus fare is becoming the main responsible agent for higher private vehicles purchase. The other reason, such as better roads with flyovers (faster travel) makes it attractive for private vehicle ownership. Public transport fare pricing, therefore, should not only be dependent upon the actual cost, but on some other sources of income.
- Bus fare reduction can be achieved from various means, but not alone from improving its own efficiency (as is normally believed). The public transport should be cross-supported directly from the personalized vehicles either being purchased newly or older one running on the road. Funds generated from measures such as higher car user charges, higher parking charges, high registration fees, higher taxes on private mode of transport etc. should be directly transferred to them to achieve the low cost, better comfort, better frequency and faster travel.
- Diesel or any fuel used for public transport should be sold at lower price to keep the bus fare lower.
- Certain areas of business district or identified regions of high congestion, free bus services can be provided. The cost can be recovered from parking, congestion and high fuel costs charged to personal vehicles.

7.5.1.13 Incentive/ Subsidy for Better Compliance towards I&M

Although the inspection and maintenance issue has been discussed earlier, the proactive approach of getting more and more people adopting the practice requires an incentive scheme. Such incentives could be given in-terms of specialized advice on how the vehicle maintenance should be carried out, as well as provide small grant for carrying out minor repairs when found polluting first time. However, if they are found to be flouting the emission norms, they can be asked to scrap the vehicle. This can be integrated into the improved in-use vehicle emission test standards.

7.5.1.14 Drivers & Mechanics Training Programme

Awareness campaign for various transport related issues such as use of alternate fuel, adulteration of fuels, benefits of various measures being adopted by the oil companies, government and others could be undertaken. This should mainly address the drivers and mechanics first and later include people/ groups as well government authorities engaged in the activities related to the transport sector.

7.5.2 Recommendations for Industrial Sector

- Major reduction industrial emission can be achieved by the fuel shift to cleaner fuel, though the overall emission scenario shows declining trend from this sector.
- The only power plant within the city, if it shifts to Natural Gas, major reduction in emission shall be achievable.
- With fuel change, it will be imperative to study the feasibility of adopting the new technology.
- The other industries also need to get larger share of the natural gas for combustion processes to shift from FO and LSHS.
- Diffused emissions from industries need a better assessment to delineate the control needs and level of control.
- The data for small scale and unauthorized industries is scanty and at this stage to suggest the levels of contribution from these are difficult. The source apportionment study and the data indicate large part of the PM from other sources, which also need further investigations. These investigations of sources should be undertaken by DPCB/ CPCB.

7.5.3 Recommendations for Area Sector

- In domestic sources, though the reach of LPG and PNG is increasing, the use of kerosene and retrieved material from garbage are also burnt at large scale in slums and low-income areas. The use of trash of various kinds for cooking need better control as they contribute largely to local ambient air quality deterioration.
- Emission due to burning of garbage has been one of the major sources of area air pollution. There is a need to constantly monitor and provide urgent technical solution for these sites to avoid deliberate burning.

- Hotel and restaurants normally use LPG; however, roadside eateries use wood and kerosene. Many of these are illegal and locally may be responsible for air pollution problems. Use of good stove and proper location for such eateries can reduce the problem to some extent.
- Largest wood burning in an authorized sector is by the bakeries. Though many of these have started changing to alternate fuel such as LPG, however, still large scale bakeries operations are based on wood. Therefore, there is a need to increase awareness and also fix some guidelines regarding the use of fuel by bakeries.
- Resuspended dust is one of the major contributors of PM, which could be due to construction/demolition of roads and buildings, vehicle movements as also from natural wind induced sources. The road side dust reduction can be achieved by better pavement and good quality of roads combined with better sweeping
- The electrical cremation system is readily available and also carries out awareness programmes to educate people about emissions reduction from crematoria. Crematoria need better control mechanism before the emission is let out through the chimney.
- In case of Illegal SSI one needs to understand the levels of operation and their contribution in each of the grid in the city. Such units needs to be identified by DPCC / DIC and MCD and strict rules should be implemented. It would needs to large scale reduction of fire accidents as well as minimization of wastewater problem
- Construction activities, involve demolition, digging, construction, vehicle movement etc, emphasis should be on better construction practices and management plan for air emission and its control by the implementing agencies.

7.6 Summary

The prioritization of various options in all three categories have addressed mostly all the major reduction in the overall pollutants load reduction combined with ambient air quality improvement. However, many of these measures still may not lead to resolving very small area high concentration locations, which could be due to short term but high emission or high activity for a limited period in a limited area. Such hot spots in the city of Delhi could exist when a local road is dug up and/or being repaired, construction and demolition of buildings, biomass and refuse burning, short term emissions from industries etc. All of such activities can be controlled and regulated through local efforts and constant vigil on the part of citizen, pollution control agency and respective responsible implementing agency.

The benefits computed in the process described above will not only yield PM and NOx related pollution reduction but also co benefit of other pollutants (SO_2, VOCs, HC, CO etc) reductions as well. One of the other major co-benefits of these options (adoption of mass transport, use of cleaner fuel, efficient combustion etc) will provide large scale green house gas reduction. As a city of Delhi, it will provide the impetus of overall mitigation of GHG.

The benefits of air quality improvement plan suggested and delineated above again will not yield desired results if the adjoining urban centers and states do not adopt measures suggested for Delhi as the objectives of clean air can not be kept limited to the political boundary of Delhi.

Chapter 8

Highlights and Recommendations

8.1 Need for the Study

In the present urban setting, the ever growing activities are related to motor vehicle, variable degree of biomass and refuse combustion, construction activities and population rise and congestion. Some other activities of the past within the city have still continued which are industries of different types (legal and illegal), use of DG sets, poor road and pavement maintenance etc. These anthropogenic sources gives rise to gaseous pollutants and smaller fractions of particulate matter comprising of inorganic and volatile organic compounds. Epidemiological studies conducted in many countries have demonstrated that there is an association between increase in morbidity and mortality due to increase in particulate matter (PM) specially the finer fraction. The effects caused by PM on humans as a result of short term exposure are lung inflammatory reactions, respiratory symptoms, adverse effects on the cardiovascular system, increase in medication usage, increase in hospital admissions, increase in mortality etc. The long term exposure can lead to increase in lower respiratory symptoms, reduction in lung function in children and adults, increase in chronic obstructive pulmonary disease, reduction in life expectancy due to cardiopulmonary mortality lung cancer. The smaller particles (PM2.5) penetrate deep into the lung and can reach the alveolar region. These fine particles are important from health viewpoint because of their high number and large surface area which may absorb/adsorb toxic compounds such as heavy metals and PAHs.

Air pollution is one of the major environmental problems faced by Delhi today. The tremendous increase in the number of vehicles has contributed significantly to the increase in combustion of petroleum products. The vehicular pollution in Delhi has grown from 64% to 72% in the last decade (1990 – 2000) whereas petrol and diesel consumption have grown by 400% and 300% respectively in the last two decades. Taking cognizance of the public concern for improvement in air quality, the Government of India had constituted a Committee of Experts under the chairmanship of Dr. R.A. Mashelkar, Director General, Council of Scientific and Industrial Research (CSIR) and entrusted it with the task of formulating an Auto Fuel Policy for the country together with a road map for its implementation. The committee submitted its report to the Government of India in August 2002.

The committee identified knowledge gaps in many areas of air pollution, particularly related to source contributions form various sources. This knowledge gap can be bridged by a detailed study for source apportionment in urban areas which will state the extent of contribution from all sources. With this in view, oil companies in India, in association with premier research institutions, have embarked upon a detailed study for source apportionment of ambient air pollutants. NEERI in collaboration with IOCL, R&D Center, Faridabad and other oil companies (BPCL, HPCL, and RIL) initiated a study in Delhi in 2004 for achieving this objective.

Later, Central Pollution Control Board (CPCB) took up the coordination of this study for six cities based on common methodology framework. A common methodology was followed for conducting source apportionment studies in all six cities. This common methodology is the guiding document for conducting this study. NEERI was retained for carrying out the studies in May 2006 for Delhi and Mumbai.

8.2 Objectives

Primarily the project aims at identifying the urban air pollution sources and quantifying them. Quantification of these sources would help in ranking them and formulating appropriate control strategies and management options. Although total control of air polluting sources would be certainly an ideal goal, but will not be practically feasible and therefore emission reduction based on exposure reduction by technology options and management techniques have been opted. A comprehensive air quality management would need three basic requirements viz. assessment of ambient air quality levels, preparation of emission inventory and conducting source apportionment analysis. The study started with following objectives:

1. To measure baseline air pollutants and air toxic levels in different parts of Delhi, including "hot spots" near kerbside locations
2. To inventorise various air pollutants for projection analysis
3. To conduct source apportionment studies for Particulate Matter
4. To delineate an Urban Air Quality Management Plan for exposure reduction

8.3 Approach to the Study

Approach to the study was designed to comply with the multi-objective tasks as presented in **Figure 8.1**. The ultimate objective is urban air quality management that primarily requires knowledge of ambient air quality status, sources and emission loads and later using these information to devise air pollution control options and implementation plan. These objectives were achieved through monitoring of air pollutants at 10 locations as shown in **Figure 8.2** using various Instruments.

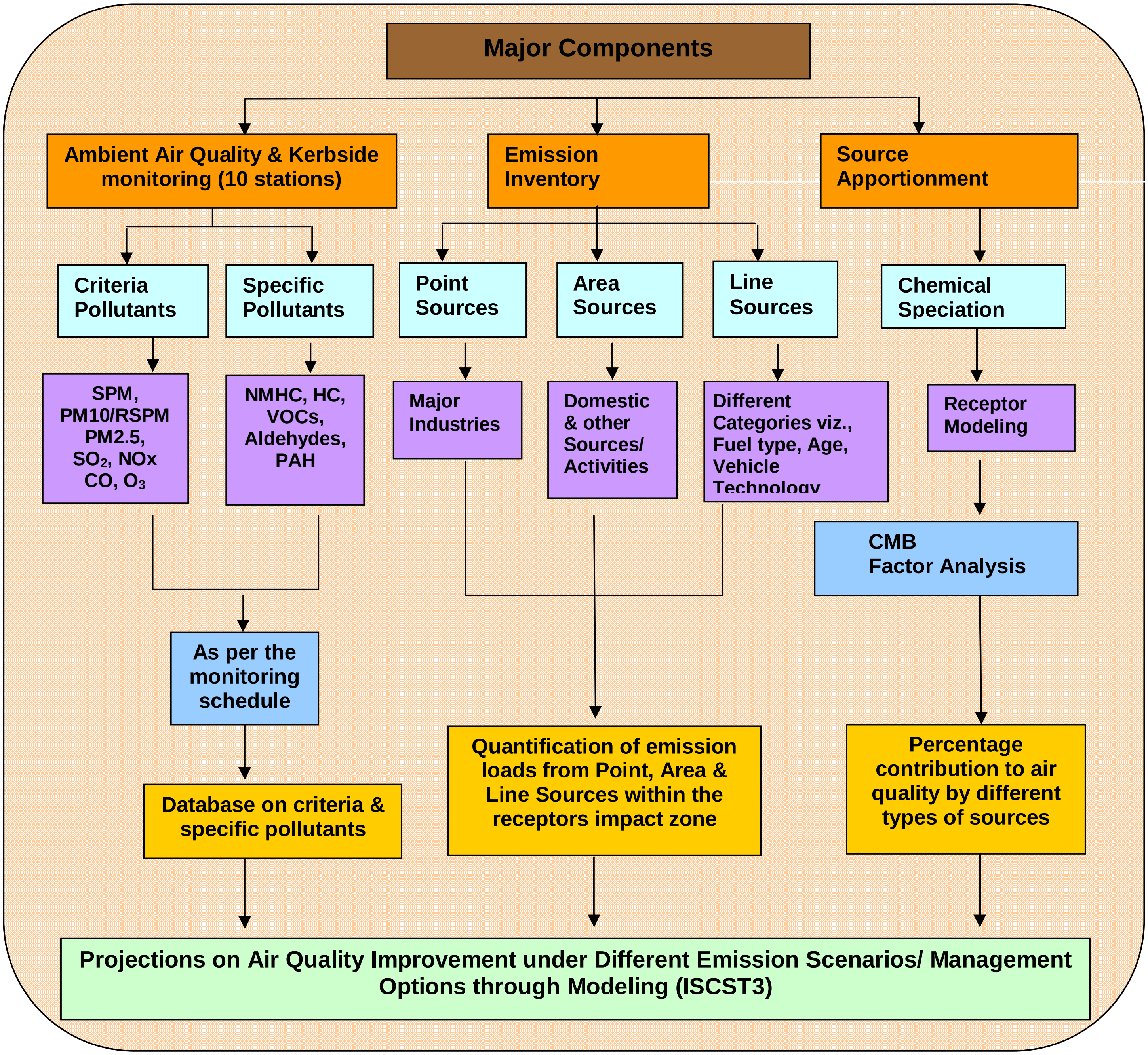


Fig 8.1: Air Quality Monitoring & Emission Source Apportionment Studies

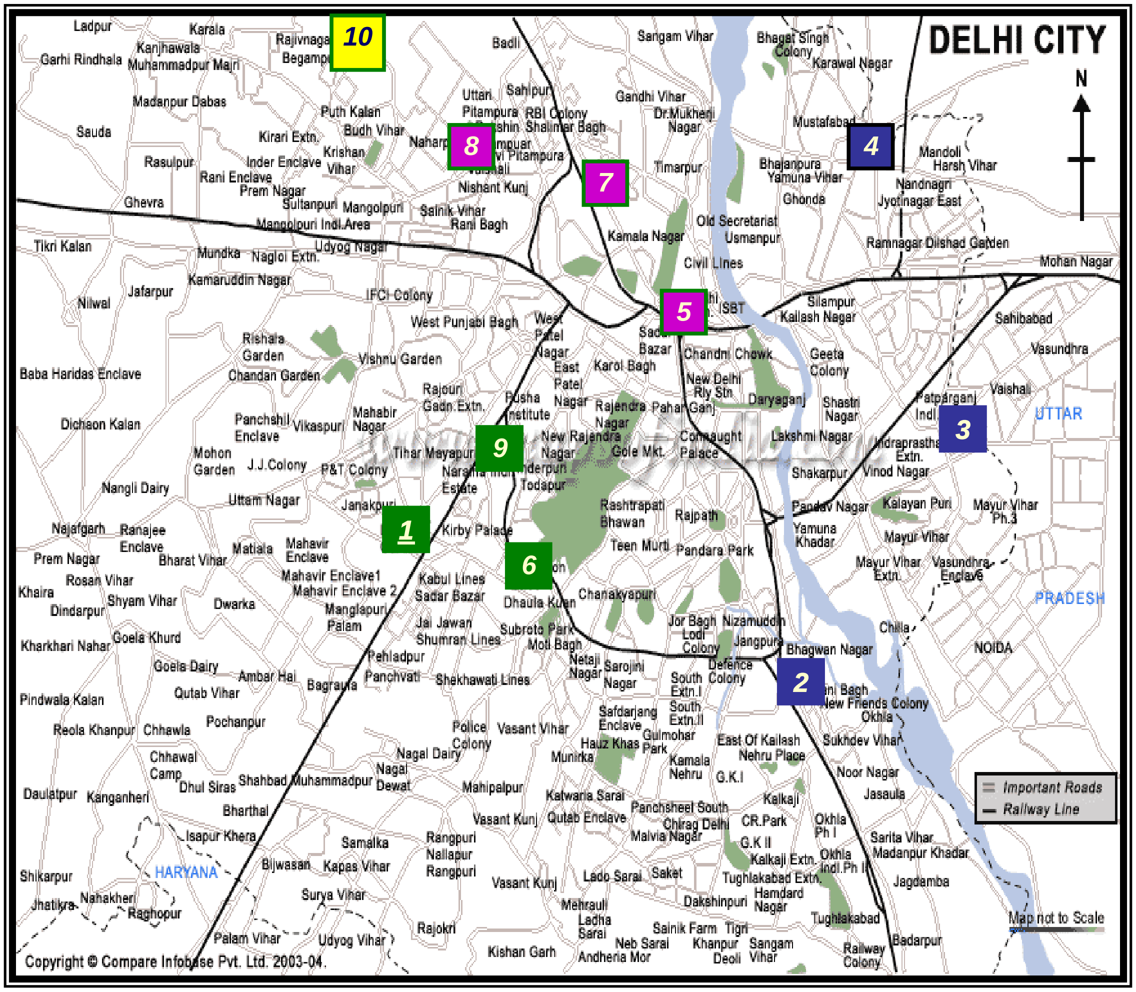


Figure 8.2: Locations of Ambient Air Quality Monitoring Stations

Different gadgets were used for different pollutants. Identification of sources of emissions and carrying out emission inventory through primary and secondary data collection were carried out using well laid out plan as the protocol. The information about emissions was used to predict the ambient air quality levels using source dispersion models that facilitate forecasting long term air quality under different meteorological conditions and emission scenarios. In order to exercise the source control measures, it is necessary to know the contribution from each type of source. This was carried out by receptor modeling for source apportionment. The methodology is divided into four parts namely ambient air quality monitoring, sources emission inventory, source apportionment analysis and finally delineating an urban air quality management plan based on the data collected during the study.

8.4 Ambient Air Quality Status in Delhi

Ambient air quality monitoring includes both criteria pollutants monitoring as well as specific pollutants that are source specific. Some of the air pollutants attributed to vehicular emissions are not listed in National Air Quality Standards of India yet. However, these were included in the study and air quality standards from USEPA, WHO etc. were used to facilitate comparison. Some of the critical air pollutants that were covered in the study are SPM, PM10 and PM2.5, SO_2, NOx, CO, Benzene, 1-3 Butadiene, Aldehydes, Alkanes, NMHC, THC, Ozone, PAHs,. Ambient air quality status in Delhi with respect to average concentration of major pollutants is presented in **Figure 8.3.**

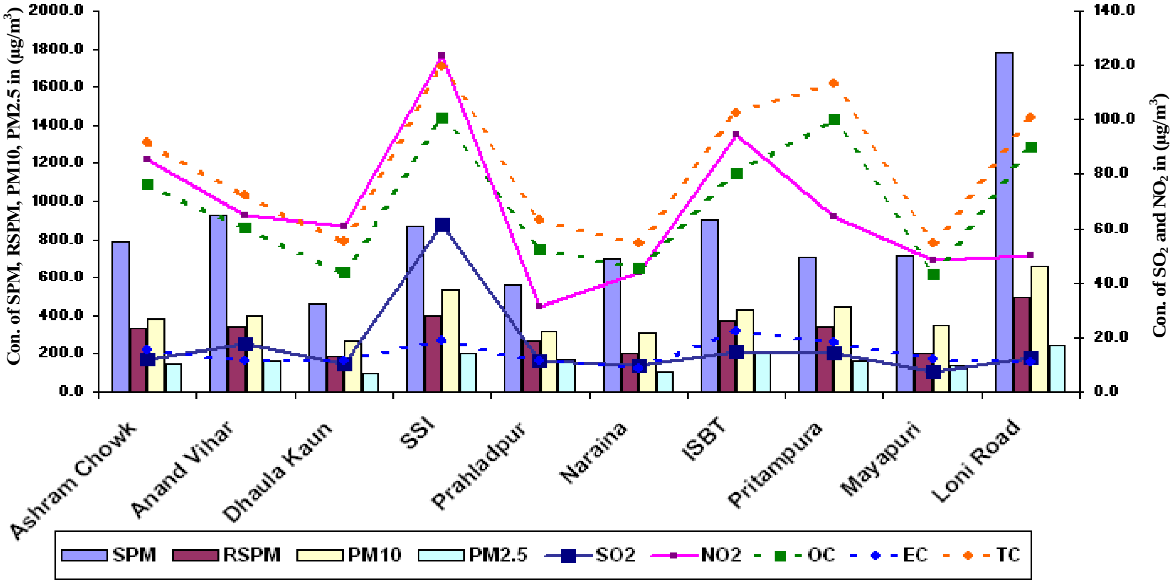


Figure 8.3 : Average Concentration of Particulate and Gaseous Pollutants at Ten Sites

The background site Prahladpur shows the levels of coarse fine particulate matter exceeding the CPCB standards for PM. Later in the analysis, it appears that from activity ont of view, Prahaladpur can still be considered a reference site. Similarly at all remaining sites as well, same trend for particulate pollution has been noticed. SPM concentration were highest at Loni road, followed by Anand Vihar, ISBT, SSI. On the other hand, RSPM concentration were higher at Loni, SSI and ISBT compared to other sites. Being a Kerb site (Loni Road) and industrial and SSI shows high concentration of PM_{10}. At ISBT and Pitampura, PM10 is ranging between 200-400 μg/m^3. Dhaula Kuan shows lowest PM_{10} concentrations. At all sites $PM_{2.5}$ concentrations are exceeding the USEPA standard 35 μg/m^3. Whereas the criteria pollutant NO_2 exceeded the CPCB standard value at Kerb site, such as ISBT and Ashram Chowk. It is clear that vehicular movement is more at these sites. Being an industrial site (SSI) NOx concentration is high. Whereas, at remaining all seven locations the levels of NO_2 & SO_2 are within the limit as per the CPCB norms.

Molecular Marker Analysis

The PM samples of all sites were analysed for molecular markers. These markers are signature molecules which indicate the sources bases on their presence as also on their abundances. Their presence and absence indicates the impacts of sources close to the site or away. Representative samples from all 10 sites were analysed at Desert Research Institute, Nevada. **Figure 8.4** presents concentration of molecular marker at 10 sites.

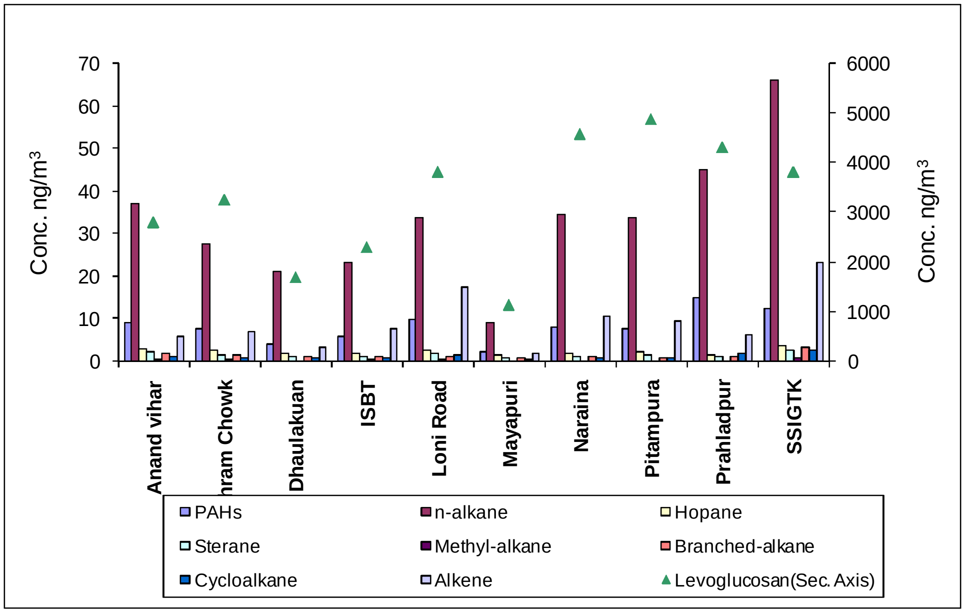


Figure 8.4 Molecular Markers Concentrations at all Sites in Delhi

It is evident that variation is random in most of the places. However, the presence of hopanes and steranes at all the sites in much higher quantities compared to Prahaladpur indicates that vehicles effect is prevalent at all sites of Delhi. Even residential location such as Pitampura shows much higher values of these vehicular markers compared to Naraina and ISBT. The marker for biomass burning "Levoglucosan" is found to be highest at residential site of Pitampura followed by Naraina, Prahaldpur and SSI-GTK. It clearly indicates that biomass burning is prevalent all across Delhi and adjoining areas. The lowest biomass burning is seen at Mayapuri. N-Alkane and Alkene values were highest at SSI-GTK which could be attributed to industrial processes present in the industrial area.

8.5 Emission Inventory

Emission inventory of different sources of air pollution has been prepared at two scales, one for the ten Study Zones of 2 km x 2 km around the air quality monitoring sites and then this emission inventory is used to estimate/extrapolate total emissions for the whole of the city. The very purpose of 2 km x 2 km study zones is to accurately identify and quantify emissions from different sources to be used to predict air quality in the study zones and compare the predicted air quality levels with the measured air quality levels. Emission inventory has been prepared in terms of five major pollutants, viz. PM_{10}, SO_2, NOx, CO and HC. Source categories and types of sources of air pollution in Delhi are presented in **Table 8.1**

Table 8.1: Source Categories and Types of Sources of Air Pollution

Source Category	Types of Sources
Area Sources	Domestic cooking Bakeries Crematoria Hotels & Restaurants Open eat outs Open burning (refuse/biomass/tyre etc. burning) Paved & unpaved roads Construction/Demolition/Alteration activities for buildings, roads, flyovers Waste Incinerators DG Sets
Point Sources	Large scale industries and Power plants Medium scale industries Small scale industries (36 industrial estates)
Line Sources	2 Wheelers (Scooters, Motor Cycles, Mopeds) 3 Wheelers (CNG) 4 Wheelers (Gasoline, Diesel, CNG) LCVs (Light Commercial Vehicles) Trucks (Trucks, min-trucks, multi-axle trucks) Buses (Diesel, CNG)

Total emissions from point, area and line sources in Delhi are presented in **Table 8.2.** Estimated emission loads from all the sources are **PM**: 147.2 TPD, **SO_2**: 267.7 TPD, **NOx** : 460.1 TPD, **CO** : 374.1 TPD and **HC** : 131.4 TPD.

Table 8.2: Summary of Emission Loads from All the Sources in Delhi

	Pollutant Emission Rate (kg/day)				
Source	**PM10**	**SO_2**	**NOx**	**CO**	**HC**
Industrial	32479	264399	360526	23771	4765
Area	27730	2608	15332	132552	59968
Vehicular	9750	720	84200	217800	66700
Road Dust	77275	-	-	-	-
Total	147234	267727	460058	374123	131433

Percentage emission contribution has been estimated for major source categories (area, industrial, vehicular and road dust) in terms of different pollutants and presented in **Fig. 8.5**.

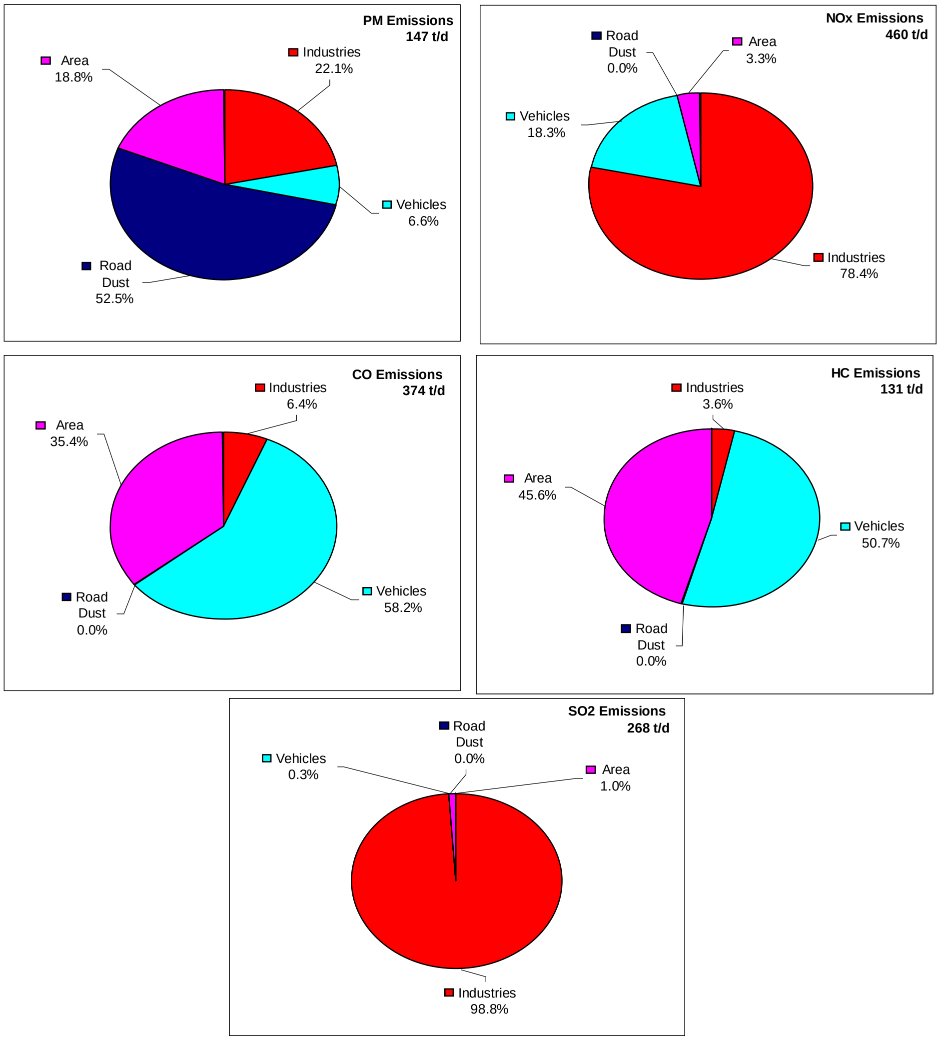


Fig. 8.5: %Contribution of Different Source Categories to Total Emission Loads: Delhi

It can be observed that PM10 is dominated by re-suspension of road dust to the extent of 52%. NOx is contributed by the industries (79%), mainly power plants, whereas vehicles contribute about 18%. CO and HC are primarily contributed by vehicular sources to the tune of 59% and 50% respectively. Area sources, mainly fuel combustion/open burning also contribute significantly to CO (35%) and HC (46%) emissions. SO_2 to the extent of about 99% is contributed by the industries, mainly power plants and some SSI units.

8.6 Receptor Modeling

The modeling methodology used to derive the contribution of sources to a particular receptor is called receptor modeling. If the marker chemical species of pollution sources are known, statistical methodology called factor analysis can be used on the chemical species data collected at the receptor end.

If the composition of chemical species at the source is known, besides the chemical species composition at the receptor, mass balance can be worked out between source and receptor chemical species and the methodology is called chemical mass balance (CMB) method.

In this study, receptor data includes chemical species concentration of particulate matter collected at 10 AAQ Monitoring stations within Delhi. Pollution sources in the 2km x 2km grids around the 10 monitoring stations were considered. Particulate matter collected from these sources were chemically analysed for various species (ions, metals, carbons, molecular markers) and signature of sources were identified. The chemical species data generated for PM10 / PM2.5 of pollution sources is called source signature profile. The source signature profile data generated by IIT Bombay and ARAI, Pune under this project was provided to NEERI. Based on the receptor modeling studies carried out for Delhi, major sources contributing PM 10 emissions are presented in **Table 8.3.**

Table 8.3: Major source contributions to PM10 at different sites during three seasons

Site	Summer	Post monsoon	Winter
Prahladpur	Construction, industrial DG sets, kerosene generators, agricultural waste, **soil dust**, auto exhaust	Coal based power plant, unpaved road dust, solid waste burning, **soil dust**, industrial DG sets	**Soil dust**, solid waste burning, unpaved road dust, construction
Pitampura	Industrial DG sets, wood combustion, chullah, construction	Construction, tandoor combustion, solid waste burning, auto exhaust	Solid waste burning, paved road dust, industrial DG sets, solid waste burning, auto exhaust
SSI-GTK	**Construction**, paved road dust, auto exhaust, **solid waste burning**, wood combustion, soil dust	**Construction**, **solid waste burning**, kerosene generators	Soil dust, **construction**, **solid waste burning**, auto exhaust, paved road dust
Naraina	Paved road dust, kerosene generator, tandoor combustion, wood combustion, chullah, solid waste burning, auto exhaust	Construction, tandoor combustion, kerosene generators, soil dust, auto exhaust, paved road dust	Construction, solid waste burning, soil dust
Mayapuri	Industrial DG sets, paved road dust, kerosene generators, soil dust, fuel combustion, **auto exhaust**	Construction, coal based power plant, tandoor combustion, **auto exhaust,** solid waste burning, paved road dust	Soil dust, tandoor combustion, solid waste burning, construction, **auto exhaust**
Loni Road	**Soil dust**, coal based power plant, tandoor combustion, **construction**	**Construction**, **soil dust**, solid waste burning	**Construction**, **soil dust,** tandoor combustion, unpaved road dust, solid waste burning
ISBT	Soil dust, construction, **fuel combustion, auto exhaust**	Paved road dust, industrial DG sets, kerosene generator, **fuel combustion, auto exhaust**, solid waste burning	Construction, solid waste burning, **fuel combustion**, tandoor combustion, soil dust, **auto exhaust**
Ashram Chowk	Fuel combustion, industrial DG sets, **construction**, kerosene generators, **auto exhaust**, paved road dust, fuel combustion	Soil dust, **construction**, solid waste burning, **auto exhaust**	**Construction**, **auto exhaust**, soil dust, tandoor combustion, solid waste burning, coal based power plant
Anand Vihar	Solid waste burning, soil dust, kerosene generator, auto exhaust	Construction, solid waste burning, paved road dust, auto exhaust	
Dhaula kuan	--	Fuel combustion, industrial DG sets, chullah, tandoor combustion, auto exhaust, construction, paved road dust, wood combustion	Soil dust, fuel combustion, tandoor combustion, construction, auto exhaust, wood combustion, kerosene generator

Note: **Bold font** indicates the similar sources contributing in three seasons and underline indicates the similar sources contributing in two seasons

8.7 Dispersion Modeling: Existing Scenario

Air quality dispersion modeling exercise has been undertaken with a view to delineate the important sources and their impact on ambient air quality in general, and specifically at measurement locations. Dispersion modeling tool has been also used for the whole city air quality scenario generation for different emission loads. The existing scenario model runs are to establish the dispersion pattern of pollutants due to local meteorology and emissions from all possible sources. Model runs also provide an idea about missing sources or additional sources which may have not been accounted earlier.

Scenarios covering different seasons, locations and sources have been generated to assess the impacts of contributions and variations. The comparison of concentrations for the existing scenario has been carried out by considering the highest ten concentrations. Air quality modeling was carried out for three seasons viz., summer, post monsoon and winter. The USEPA developed/validated ISCST-3 air quality model was used to predict spatial distribution of PM10 and NO_2 concentrations in ambient air (USEPA, 1995) Salient features of the dispersion modeling studies conducted for Delhi city are presented in **Table 8.4**

Table 8.4: Salient Features of Modeling Exercise

Parameter	**10 Study Zones (2 km x 2 km)**	**Delhi City**
Sources considered	Area, Industrial, Vehicular, Road dust and all sources together	Area, Industrial, Vehicular, Road dust and all sources together
Pollutants modeled	PM, NOx & RD-PM10	PM, SO_2, Nox & RD-PM10
Emission rate	Hourly variations	Hourly variations
Sources grids	0.5 km x 0.5 km	2 km x 2 km
Surface Met data	Site specific	IMD
Upper air Met data	CPCB document on mixing height	CPCB document on mixing height
Seasons	Summer, Post Monsoon, Winter	Summer, Post Monsoon, Winter
Model used	ISCST3	ISCST3
Receptors grids	50 m x 50 m	500 m x 500 m
Model Output		
GLC prediction at	1600 receptor locations	3840 receptor locations
Ranked GLCs	First 10 highest values	First 10 highest values
Iso-concentration plots	--	For each pollutant in each season using Surfer 32 graphical software

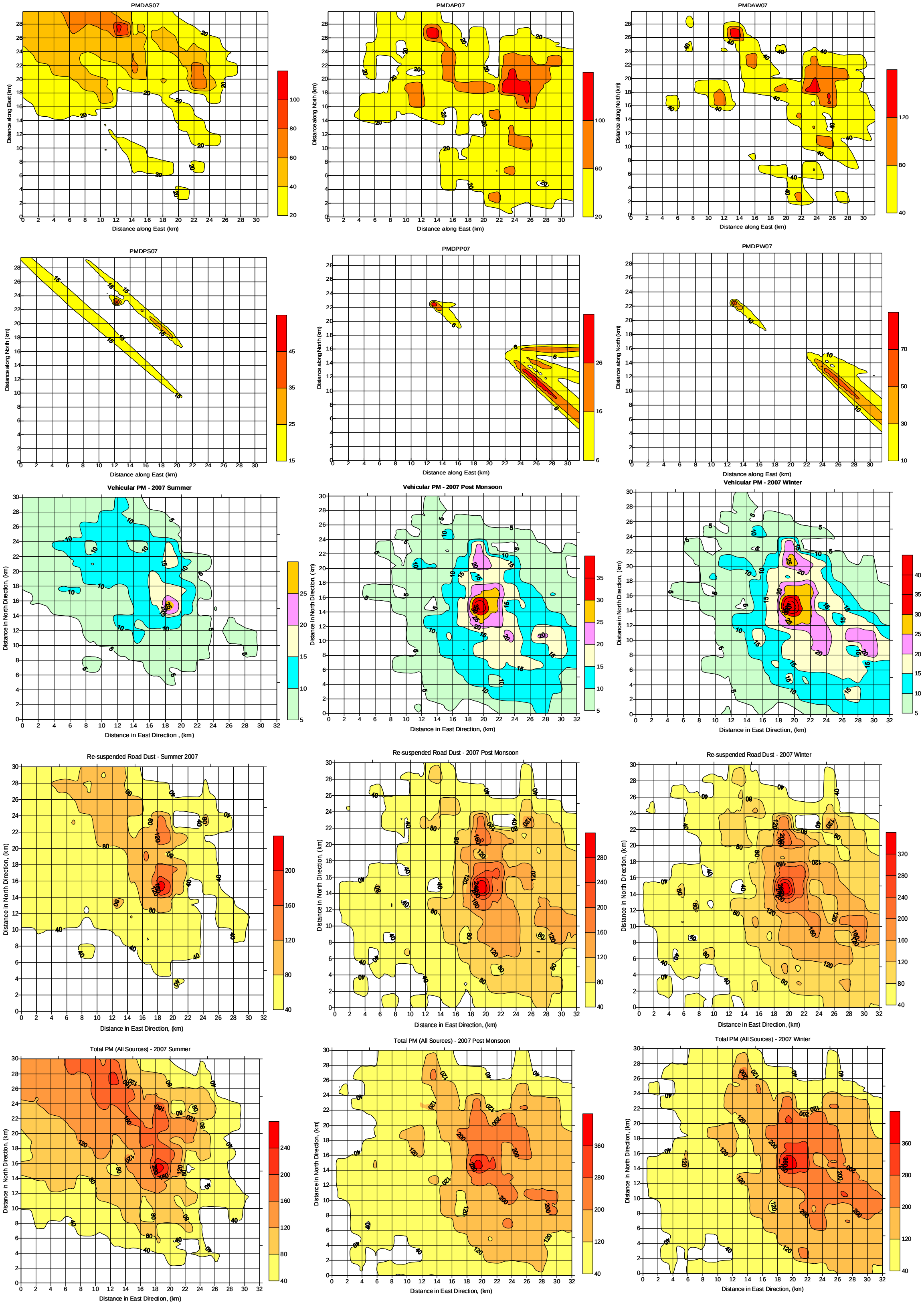
o Maximum GLCs of PM (total of all sources) during summer, post-monsoon and winter are observed to be 260, 387 and 438 µg/m^3 respectively, occurring in Connaught Place-India Gate-ITO area. Very high PM concentration levels are due to the fact that contribution of road dust is also included in the total PM.

o Maximum GLCs of NOx during summer, post-monsoon and winter are predicted to be 735, 732 and 1297 µg/m^3 respectively, occurring in Chandni Chowk-Chawri Bazar area (during summer) and in Mayur Vihar-Patparganj area (during post monsoon and winter). The predicted maximum concentration levels of NOx are found to be about 9 to 15 times higher than the CPCB standard (80 µg/m^3) for mixed area category.

o Maximum GLCs of SO_2 during summer, post-monsoon and winter are predicted to be 361, 295 and 514 µg/m^3 respectively, occurring in Laxmi Nagar – Preet Vihar area (during summer), Mayur Vihar area (during post monsoon) and Mayur Vihar-Patparganj area (during winter). The predicted maximum concentration levels of SO_2 are found to be considerably high, about 4 to 7 times the 24 hourly average CPCB standard of 80 µg/m^3 (for mixed area category).

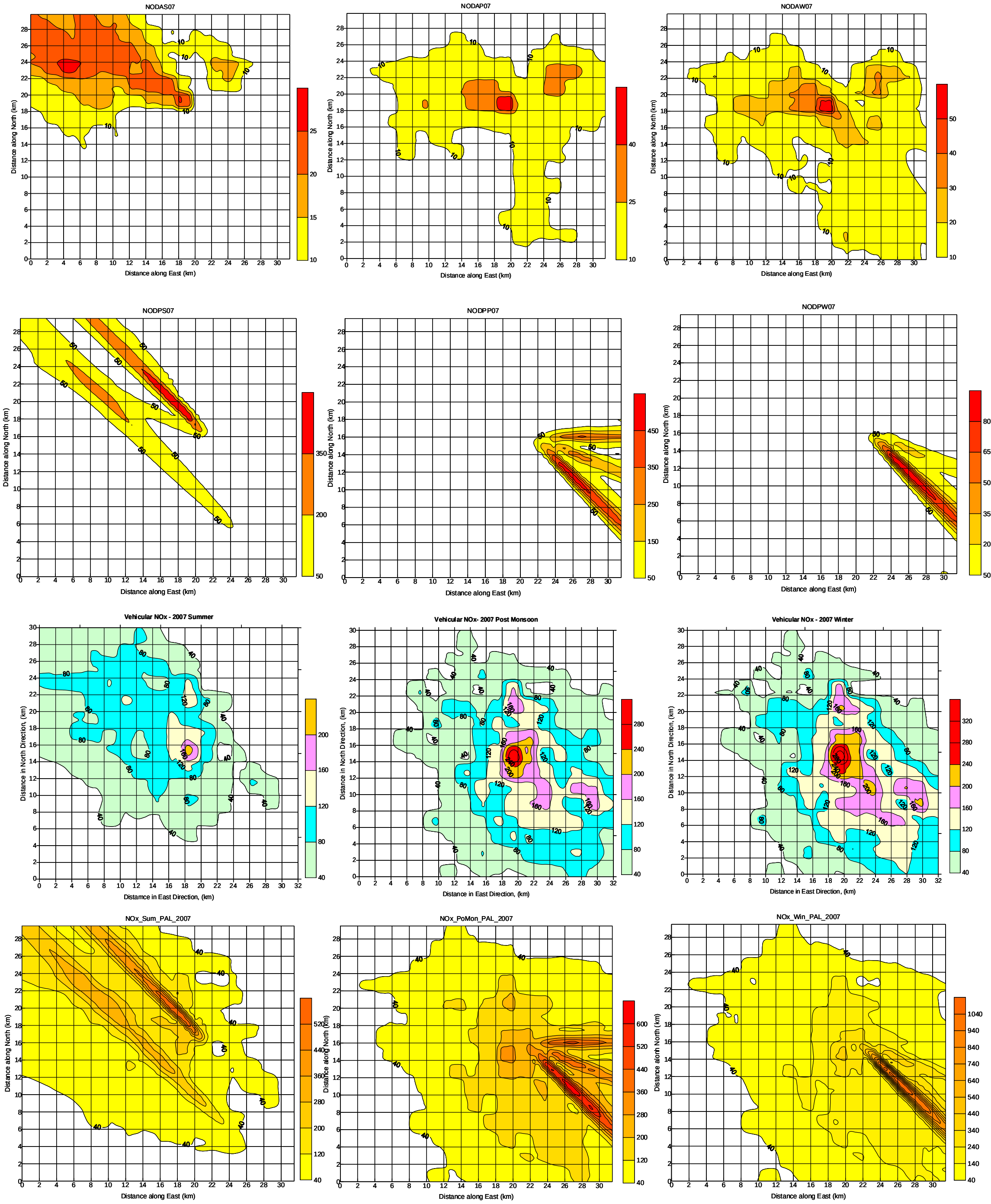
o Iso-concentration plots drawn for total PM (as PM10), NOx and SO_2 for summer, post-monsoon and winter seasons indicate that concentration of PM is well distributed through out the Delhi, with higher levels confining to the area between ISBT and Ashram Chowk following mainly the ring road area. A good spread of high levels of NOx (40 µg/m^3) was observed in all the three seasons, but highest levels are following the trend of dispersion from point sources, mainly power plants. Similarly, spread of SO_2 is confined to a few grids and it also follows the dispersion pattern of power plants. Higher levels of SO_2 are predicted in Mayur Vihar area during post monsoon and winter, whereas in summer, its spread is more and observed along the Chandni Chwok-Chawri Bazar-Ashok Vihar-SSI-GTK-Pitampura area.

Figures 8.6 and 8.7 show Iso-concentration plots for PM and NOx from Area, point, Line, Road Dust Re-suspension and their Cumulative Impact during three seasons for 2007.



Plots Sequence: 1st Row – Area Sources; 2nd Row – Point Sources, 3rd Row – Line Sources, 4th Row – Road dust re-suspension, 5th Row – Cumulative Impact

Fig. 8.6 : Iso-concentration Plots for PM from Area, point, Line, Road Dust Re-suspension and their Cumulative Impact during Summer, Post Monsoon and Winter (Existing Scenario-2007)



Plots Sequence: 1st Row – Area Sources; 2nd Row – Point Sources,
3rd Row – Line Sources, 4th Row –Cumulative Impact

Fig. 8.7 : Iso-concentration Plots for NOx from Area, point, Line, Road Dust Re-suspension and their Cumulative Impact during Summer, Post Monsoon and Winter (Existing Scenario -2007)

8.8 Future Projections under BAU Scenarios for 2012 and 2017

8.8.1 Prominent Sources of Air Pollution

Delhi has multiple sources such as vehicles, industries (both large and small scale), and diverse area sources, such as DG sets, domestic burning, biomass-refuse burning etc. The city has its own share of emissions which are not very area specific. These are construction activities, road paving, repairing, demolition etc. Business as usual scenarios have been generated for each source category based on major trends, which are likely to continue in the time frame of 5 & 10 years, viz. 2012 & 2017. Prominent sources under each category are given below.

8.8.1.1 Area Sources

- Due to power shortage, diesel generator sets are used in large numbers in Delhi, which may be contributing towards local area air quality plan and implemented.
- Delhi, due to its high population density and a high percentage of people living in the slums, the extent of usage of cooking fuel in the form of biomass including coal and kerosene is considerably high leading to high level of emissions. However, a change in this pattern is now being observed as there is rapid increase in the use of LPG as cooking fuel.
- Urban infrastructural development and related construction activities are contributing to particulate pollution in Delhi

8.8.1.2 Industrial Sources

- Coal based Power plants are the major source of PM and SO_2 emissions
- NG based Power plants are the major source of NO_2 emissions

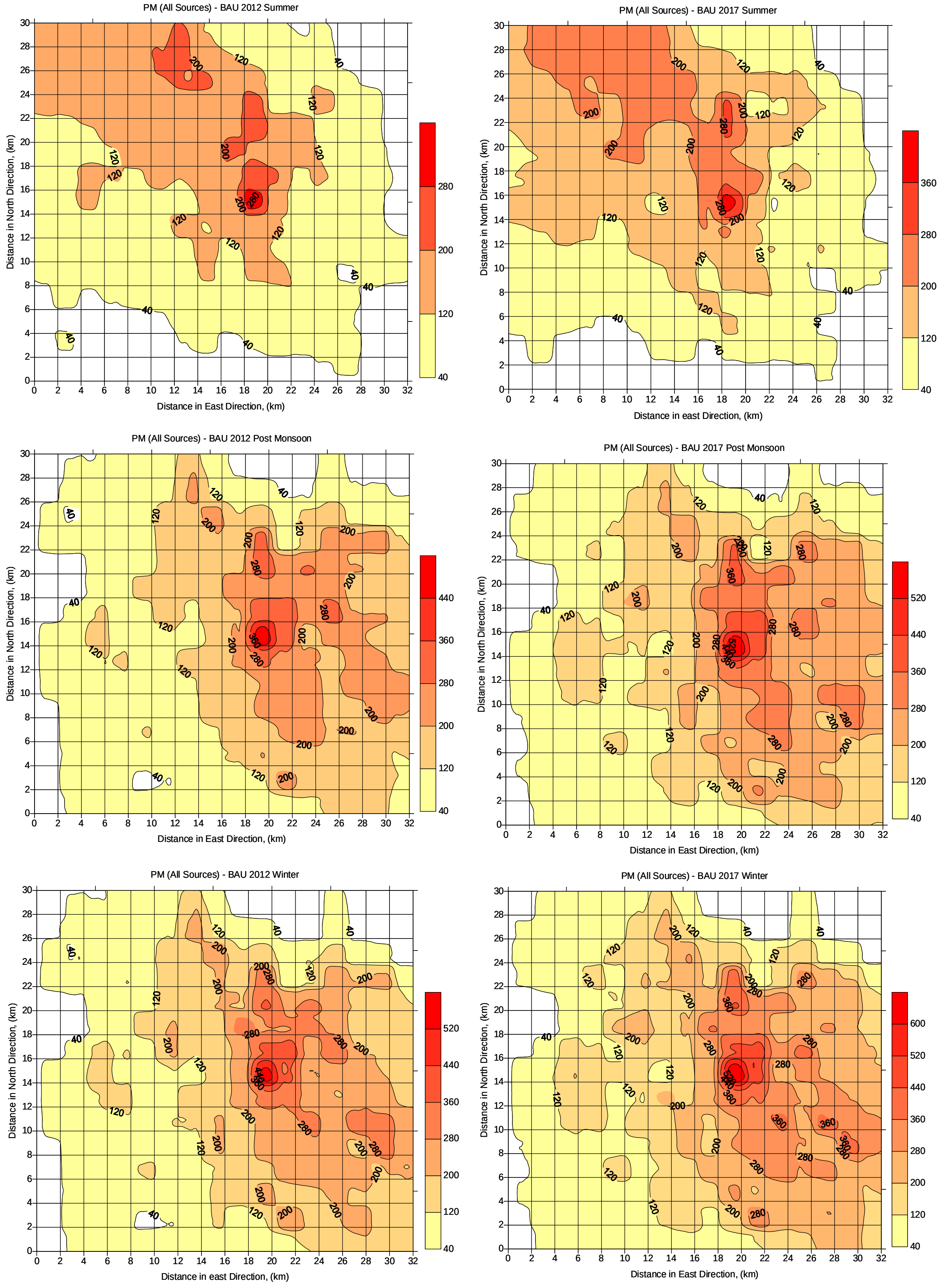
8.8.1.3 Vehicular Sources

- PM emissions due to Re-suspension of road dust
- Trucks and LCVs are the two major sources of vehicular pollution.

Projections of pollutants (PM, SO_2 and NOx) emission loads under BAU scenario in 2012 and 2017 were made and Pollutant and season-wise predicted maximum GLCs and their occurrence in 2012 and 2017 are discussed below.

It has been observed that concentration of PM is well distributed through out Delhi with higher levels confining to the area between ISBT and Ashram Chowk. In general, a good spread of high levels of NOx (40 µg/m^3) can be seen in all the three seasons, but highest levels are following the trend of dispersion from the point sources, mainly power plants. Similarly, spread of SO_2 is limited to confined grids and follows mainly the dispersion pattern from point sources. Higher levels of SO_2 is predicted in Mayur Vihar area during post monsoon and winter, whereas in summer its spread is more and observed along the Chandini Chowk-Chawri Bazaar- Ashok Vihar-SSI-GTK-Pitampura.

Figures 8.8 and 8.9 show the predicted concentration of PM and NOx for BAU 2012 and 2017 for different seasons due to all Sources.



PM (All Sources) - BAU 2012 Summer

PM (All Sources) - BAU 2017 Summer

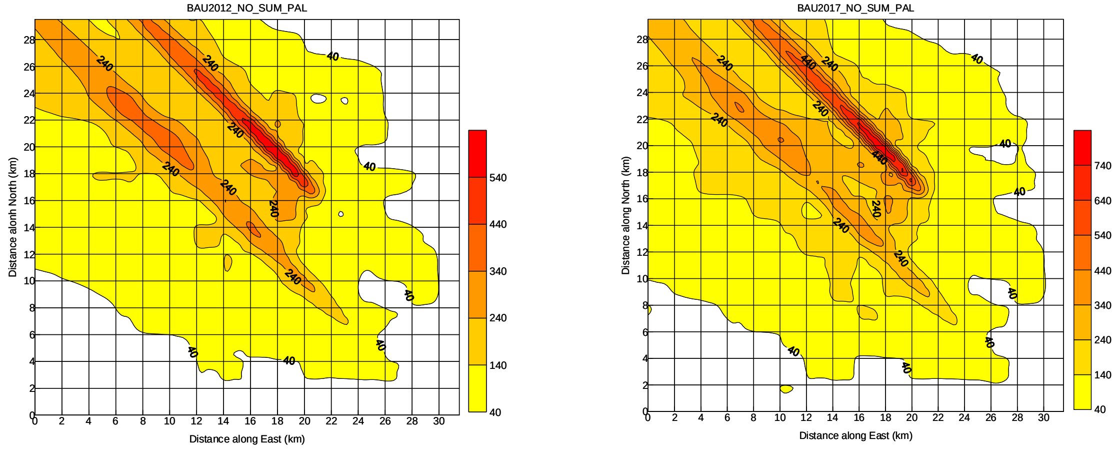
PM (All Sources) - BAU 2012 Post Monsoon

PM (All Sources) - BAU 2017 Post Monsoon

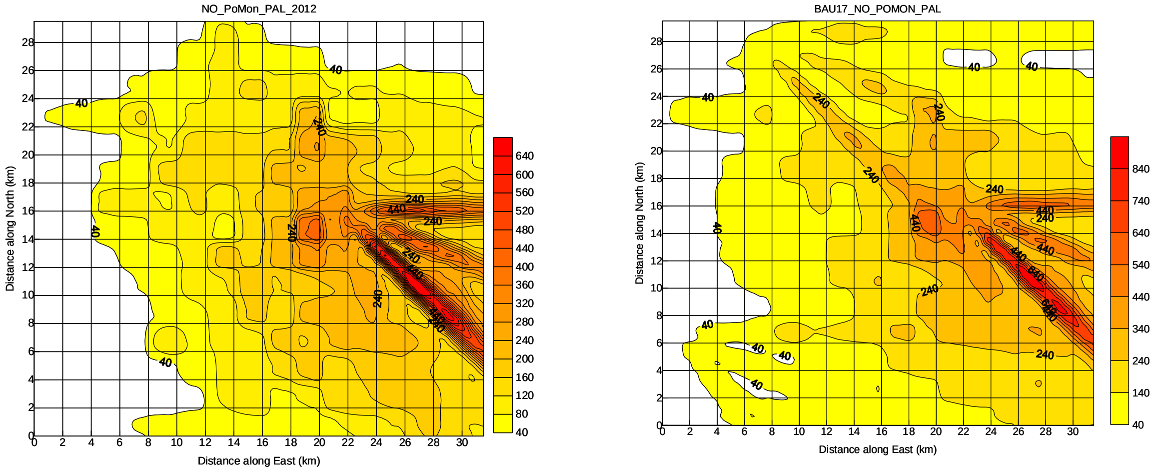
PM (All Sources) - BAU 2012 Winter

PM (All Sources) - BAU 2017 Winter

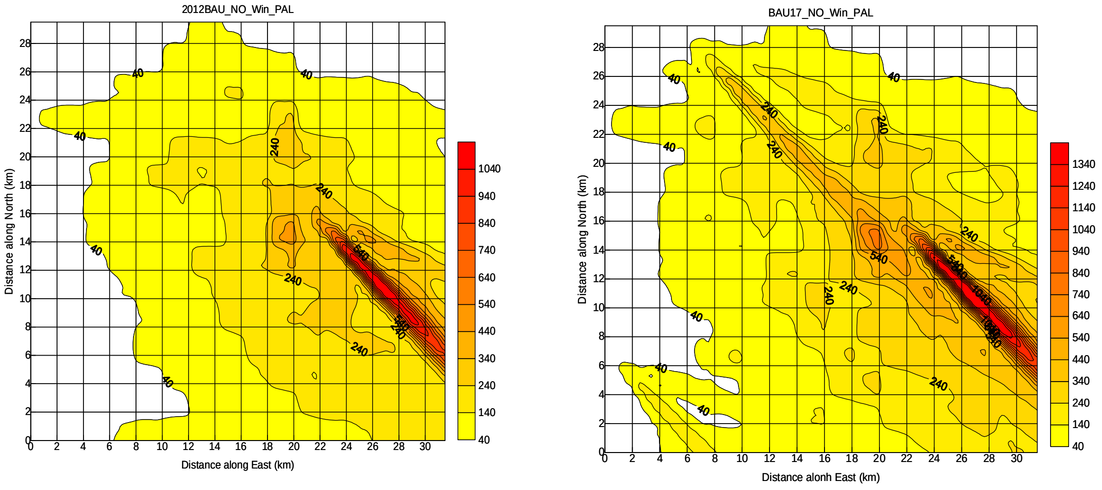
Figure. 8.8 : Predicted Iso-concentration Plots for PM during Different Seasons: 2012 & 2017 BAU Scenarios – Cumulative Impact of All Sources



Summer 2012 **Summer 2017**



Post Monsoon 2012 **Post Monsoon 2017**



Winter 2012 **Winter 2017**

Figure. 8.9: Predicted Iso-concentration Plots for NOx during Different Seasons: 2012 and 2017 BAU Scenarios – Cumulative Impact of All Sources

8.9 Evaluation of Control options for 2012 and 2017

Emission Control Options studied for 2012 and 2017 Scenarios are given in **Table 8.5** and **Table 8.6** for point and area sources respectively. Evaluation of technology based and management based options for vehicular sources is summarized in **Table 8.7** and **Table 8.8**

Table 8.5: Emission Control Options Scenarios in 2012 and 2017- Point Sources

Control Option	Type of Industries	Scenario for 2012	Scenario for 2017
Use of cleaner fuels viz. NG	Large scale (power plants)	All power plants to be shifted to NG	All power plants to be operated on NG
	Medium scale	100% to be shifted to NG	100% to be operated on NG
	Small scale	--	--
Installation of control equipment viz. FGD, wet scrubber	Large scale (power plants)	Improvement in ESP efficiency Installation of FGD	Upcoming power plants to be operated on NG
	Medium scale	Venturi scrubber to be installed in 100% industries	Venturi scrubber to be installed in 100% industries
	Small scale	Venturi scrubber to be installed in 50% industries.	Venturi scrubber to be installed in 100% industries
Shifting on Industries	Large scale (power plants)	--	--
	Medium scale	--	--
	Small scale	50% industries to be shifted	100% industries to be shifted

Table 8.6: Area Source Control Options BAU Emission Scenario in 2012 and 2017

Source Category	Control Options	Scenario for 2012	Scenario for 2017
Domestic	Use of cleaner fuels viz. LPG/ NG	50% solid fuel, kerosene for domestic use to be shifted to LPG/NG	100% solid fuel, kerosene for domestic use to be shifted to LPG/NG
Hotels, Restaurants Bakeries	Use of cleaner fuels viz. LPG/ NG	100% to be shifted to LPG/NG	100% to be shifted to LPG/NG
Crematoria	Use of cleaner fuels viz. electricity	50% to be operated on electricity	100% to be operated on electricity
Incinerators	Installation of control equipment viz. wet scrubber	100% to be installed	100% to be installed
Generator sets	Adequate supply of grid power	Use of generator sets till adequate grid power available	No use of generator sets
Open burning	Strict compliance with ban on open burning	100% compliance	100% compliance
Locomotives	Use of cleaner fuels viz. electricity	100% to be operated on electricity	100% to be operated on electricity
Construction	Better construction practices viz. proper loading and unloading of materials, water spraying etc.	50% reduction from construction activities under BAU 2012	100% reduction from construction activities under BAU 2017

Table 8.7: Evaluation of Technology based Options: Vehicular Sources

Sr.	Control Option/ Scenario	% Reduction with respect to Corresponding Year BAU Level	
		PM	NOx
1. Implementation of Stringent Emission Norms			
a.	Implementation of BS-IV in 2012		
	2017 Scenario	-8.6	-4.5
b.	Implementation of BS-V in 2012		
	2017 Scenario	-11.5	-6.0
c.	Implementation of BS-VI in 2012		
	2017 Scenario	-11.5	-6.9
d.	Implementation of BS-IV in 2007		
	2012 Scenario	-12.1	-6.8
	2017 Scenario	-18.5	-10.0
e.	Implementation of BS-V in 2007		
	2012 Scenario	-18.0	-12.0
	2017 Scenario	-27.7	-17.8
f.	Implementation of BS-VI in 2007		
	2012 Scenario	-19.0	-15.9
	2017 Scenario	-29.1	-23.6
2. Introduction of Hybrid Electric Vehicles (HEVs)			
a.	**Electric Vehicles**		
	2012 Scenario	-0.5	-0.9
	2017 Scenario	-0.8	-1.7
b.	**Hybrid Vehicles**		
	2012 Scenario	0.01	-0.1
	2017 Scenario	0.06	-0.2
3.	**Fuel Blending: Ethanol (E10), Bio-Diesel (B10) and Hydrogen (H10)**		
	2012 Scenario	-7.9	-1.5
	2017 Scenario	-7.8	-1.6
4.	**Retro-fitment of DPF**		
	2012 Scenario	-19.5	0.0
	2017 Scenario	-39.9	0.0
5. Improved I & M Practices			
	2012 Scenario	-3.0	-3.3
	2017 Scenario	-5.9	-6.6
6. Ban on 10 Years Old Commercial Vehicles			
	2012 Scenario	-18.7	-9.6
	2017 Scenario	-17.6	-8.1
7. Ban on 15 Years Old Private Vehicles			
	2012 Scenario	-0.2	-1.8
	2017 Scenario	-1.0	-3.9
8. Improvement in Public Transport - Shift in VKT			
	2012 Scenario	-1.6	-3.9
	2017 Scenario	-3.5	-8.0

Table 8.8: Evaluation of Management based Options: Vehicular Sources

Sr. No.	**Control Option/ Scenario**	**% Reduction with respect to Corresponding Year BAU Level**	
		PM	**NOx**
1. Improved I & M Practices			
	2012 Scenario	-3.0	-3.3
	2017 Scenario	-5.9	-6.6
2. Ban on 10 Years Old Commercial Vehicles			
	2012 Scenario	-18.7	-9.6
	2017 Scenario	-17.6	-8.1
3. Ban on 15 Years Old Private Vehicles			
	2012 Scenario	-0.2	-1.8
	2017 Scenario	-1.0	-3.9
4. Improvement in Public Transport - Shift in VKT			
	2012 Scenario	-1.6	-3.9
	2017 Scenario	-3.5	-8.0

Analysis of various technology and management based options for vehicular sources indicats that implementation of any of the above strategies would not be able to achieve even to the baseline status of 2007, by 2012 or 2017. However, the increase could be reduced to some extent. Significant reductions are not observed because several vehicular pollution control measures like introduction of BS-II for 2 Wheelers and BS-III for all other vehicles, introduction of CNG for 3 Wheelers, taxis and buses, less sulfur content in diesel, ban on more than 8 years old buses etc. have already been implemented in Delhi during the last decade. To get further incremental reductions, the efforts required would be much more, whereas the expected benefits would not be commensurate with the efforts towards technology based pollution control systems. Therefore, it warrants more emphasis on reducing pollution from in-use vehicles and through road dust management and most of all carefully drafted management options such as more public transport meeting the economic and environment criteria.

The control scenario for vehicular emissions includes implementation of next stage emission norms for new vehicles, retro-fitment of diesel particulate filter in in-use commercial diesel vehicles, mandatory inspection and maintenance in automobile manufacture company owned service centers, improvement in public transport system, synchronization of traffic signals, introduction of hybrid vehicles with improvement in fuel quality (no adulteration) is expected to yield about 47% reduction by 2012 and 82% reduction in PM emissions by 2017 as compared to emissions estimated under BAU Scenario in respective years from vehicular sources. Reduction in NOx emissions is expected to the tune of 30% by 2012 and 42.5% by 2017, as compared to respective years BAU scenario emission levels.

8.10 Preferred Scenario

Preferred scenario delineation involves critical examination of the constraints (both economic and ecological) imposed by the air environment assimilative capacity of Delhi city in addition to resource availability constraints and detailed analysis of each alternative scenario to asses the feasibility of achieving the desired air quality goals to finally arrive at the preferred air pollution control/ management path that needs to be pursued since the same combines all the best features and elements of different alternative scenarios (covering point, area and line sources) which are economically and environmentally feasible . Major elements of the preferred scenario include

i. Technological interventions covering type of technology, fuel mix and emission control technologies
ii. Industrial Typology and Zoning
iii. Environmental Management Plan
iv. Management Strategies/ Action Plans

8.10.1 Dispersion Modeling for Select Control Options for Preferred Scenarios

Analysis of ambient air quality data indicates that the present air quality levels with respect to different pollutants, particulate matter (PM) and oxides of nitrogen are particularly very high in Delhi. Increase in PM can be attributed to the resuspension road dust, construction activities and fuel combustion in slums besides emissions from power plants in Delhi. Increase in NO_2 can be attributed to the use of generator sets besides vehicular activities in Delhi. Based on the city specific situations, select control options are evaluated under the preferred scenario with respect to reduction in PM and NOx emission loads from different sources by 2012 and 2017, as compared to BAU Scenarios.

To evaluate the impact of select control options for the improvement in air quality, three scenarios have been considered. Focus of the first scenario is PM emissions reduction. Second scenario is formulated to facilitate mainly NOx emissions reduction. Third scenario targets the reduction of both PM and NOx emissions. Under the three scenarios, (incorporating different combinations of control options), there would be reduction in emissions of other pollutants (e.g. SO_2) also. Improvement in Ambient Air quality in terms of PM, SO_2 and NO_2 ($\mu g/m^3$) under 2012 and 2017 Scenarios for Area and Industrial Sources are given in **Tables 8.9** to **8.11** respectively.

Table 8.9 : Improvement in Ambient Air quality in terms of PM and NOx (µg/m^3) under 2012 and 2017 Scenarios: Area Sources

Year	Pollutant	BAU	Scenario 1	Scenario 2	Scenario 3
2012	**PM10**	146.4	67.5	146.4	67.4
	NOx	65.4	41.5	42.1	37.1
2017	**PM10**	146	56.2	139.7	56.0
	NOx	75.6	48.1	45.3	43.6

Table 8.10 : Improvement in Ambient Air quality in terms of PM and NOx (µg/m^3) under 2012 and 2017 Scenarios: Industrial Sources

Year	Pollutant	BAU	All Scenarios
2012	**PM10**	115	111.3
	NOx	1153	691
2017	**PM10**	115	110
	NOx	1505	688

Table 8.11 : Improvement in Ambient Air quality in terms of PM, and NOx (µg/m^3) under 2012 and 2017 Scenarios: Line Sources

Year	Pollutant	BAU	All Scenarios
2012	**PM10**	58	31
	NOx	461	325
	Road Dust	476	119
2017	**PM10**	71	13
	NOx	568	327
	Road Dust	590	59

8.11 Anticipated Benefits of Preferred Scenario

Percentage reductions in emissions of PM, SO_2 and NOx have been estimated for different control options with respect to the corresponding year BAUs (2012 and 2017) emission loads as given in **Table 8.12**. Area coverage for PM and NOx reduces substantially by 2012 and continues till 2017 as compared to the respective year BAU scenarios. With the suggested management plans, road dust re-suspension is expected to be reduced to a large extent by 2012 and 2017.

Table 8.12 Select Control Options and Expected Reductions (kg/day) in Emissions by 2012 & 2017

Sr. No.	Control/Management Option	2012 Scenario			2017 Scenario		
		PM	SO_2	NOx	PM	SO_2	NOx
A.	**Industrial Sources**						
A1	**Power Plants (Fuel shift: Coal to NG) All Plants by 2012**	5.4	85.39	39851.27	17.95	283.43	132269.6
A2	**Medium Scale industries (Fuel shift)**	0.65	0.05	23.99	0.65	0.05	23.99
A3	**Any other**						
	Total Industrial Sources (A)	6.05	85.44	39875.26	18.6	283.48	132293.6
B.	**Area Sources**						
B1	All Construction related emissions control adopted in 100 % of the activities by 2012 and 2017	4777.3	--	--	3645.0	--	--
B2	Domestic (including slums) emissions control options adopted in 50% of the activities by 2012 and 2017 (fuel shift SF to LPG)	12790.7	1190.0	1296.9	14615.1	1372.4	661.1
B3	DG Sets replaced due to power availability by 2012	613.7	572.4	8678.4	706.5	658.9	9990.0
	Total Area Sources (B)	**18181.7**	**1762.4**	**9975.3**	**18966.6**	**2031.3**	**10651.1**
C.	**Vehicular Sources**						
C1.	Implementation of next stage emission norms for new vehicles (BS-III for 2 and 3 Wheelers and BS-IV for 4 Wheelers, LCVs, Trucks & Buses) by April 2010	126	0	556	1327	0	6214
C2.	Retro-fitment of DPF in all commercial diesel vehicles (Trucks and LCVs) including inter-state vehicles by January 2010	2454	0	0	6170	0	0
C3.	Improved I&M in AMCOSC	2517	0	22225	3085	0	27619
C4.	Improvement in public transport	189	0	4445	540	0	11048
C5.	Others (electric/ hybrid vehicles, Synchronization of traffic signals etc.)	629	0	5556	1543	0	13810
	Total Vehicular Sources (C)	**5916**	**0**	**32782**	**12664**	**0**	**58691**
D	**Road Dust**						
D1.	Implementation of Road Dust Management/Option 2010 (Arterial & Main Roads)	76684	0	0			
D2.	Implementation of Road Dust Management/Option 2015 (Feeder Roads)				114873		
	Total Road Dust (D)	**76684**	**0**	**0**	**114873**	**0**	**0**

Though the I&M will provide a small percentage reduction in Vehicles PM_{10} emission, its impact on toxic fine particles will be very high as vehicles PM are in mainly in finer sizes.

8.12 Action Plan –Prioritized list of Management/Control options

Prioritized list of Management/Control option are presented in **Table 8.13**

Table 8.13 : Prioritized List of Management / Control Options

Source Category	Control/Management Option	Implementation and regulatory agencies
Industrial		
I.1	Power Plants (Fuel shift - coal to NG)	Power companies, Govt of Delhi, GOI
I.2	Medium Scale industries (Fuel shift)	Industries, DPCC
I.3	Technology up-gradation, fugitive emission control	Industries, DPCC
1.4	Illegal industries shifting	Govt of Delhi, DPCC
Area		
A.1	All construction demolition related emissions control	MCD, DPCC
A.2	Road Construction/repair Practices	MCD, PWD
A.3	All domestic (including slums) emission control through clean fuel	MCD, Govt of Delhi, GOI
A.4	DG Sets replacement by making power available	Power companies, Gas company, Govt of Delhi and GOI
A.5	Biomass and Refuse burning	MCD, DPCC
A.6	Public Awareness on local area air pollution problems	DPCC, MCD
Vehicular		
V.1	Augmentation of city public transport system	Govt of Delhi, GOI
V.2	Traffic restrain, and congestion related taxes – Financial aid to public transport	SIAM, MORTH,CPCB
V.3	Development of fuel economy based emission norms for all category of vehicles	Vehicle manufacturer, CPCB
V.4	Fuel Quality Improvement	Oil companies, GOI
V.5	Emission Norms for New Vehicles	GOI, CPCB, SIAM, MORTH
V.6	Inspection and Maintenance (I&M) System for all category of vehicles in Automobile Manufacture Company Owned Service Centers (AMCOSC)	DPCC, CPCB
V.7	Performance evaluation of Catalytic Converter and periodic performance evaluation	DPCC, CPCB
V.8	Conversion of private vehicles to clean fuel	Govt of Delhi, Gas companies
V.9	Retro-fitment of DPF in LCVs, Trucks and Diesel-Buses	DPCC, SIAM
V.10	Phase out of older grossly polluting vehicles	MORTH, DPCC, CPCB
V.11	Stringent system for checking for adulteration in fuels	Oil Companies, Anti Adulteration Cell

Table 8.13 (Contd...) : Prioritized List of Management / Control Options

Source Category	Control/Management Option	Implementation and regulatory agencies
Road Dust		
RD.1	Collection and proper disposal of road side dumped material (dust, garbage, leaves, refuse material etc.) and continue road cleaning regularly	MCD
RD.2	Repair/maintenance of all types of roads (arterial, main and feeder roads) for pot holes etc.	MCD
RD.3	Removal of encroachment of roads	MCD
RD.4	Conversion of unpaved road to paved roads	MCD
RD.5	Wall to wall paving of roads (with proper provision for water percolation)	MCD

8.13 Recommendations

The prioritization of various options in all three categories have addressed mostly all the major reduction in the overall pollutants load reduction combined with ambient air quality improvement. However, many of these measures still may not lead to resolving very small area high concentration points which could be due to short term but high emission or high activity for a limited period and limited area. Such hot spots in the city of Delhi could exist when a local road is dug up and/or being repaired, construction and demolition of buildings, biomass and refuse burning, industries short term emissions etc. All of such activities can be controlled and regulated through local efforts and constant vigil on the part of citizen, pollution control agency and respective responsible implementing agency.

The development needs of Delhi are not limited to its boundary alone but all of these options will need to be integrated to all the urban centers and growth centers around Delhi (NCR). The benefits accrued due to these options based on technology and management of air polluting sources will be limited if they are not only aligned with nearby urban centers (which will include area, point and vehicular sources) but also with the neighboring states and finally country.

The benefits computed in the process described above will not only yield PM and NOx related pollution reduction but also co benefit of other pollutants (SO_2, VOCs, HC, CO etc) reductions as well. One of the other major co-benefits of these options (adoption of mass transport, use of cleaner fuel, efficient combustion etc) will provide large scale green house gas reduction. As a city of Delhi, it will provide the impetus of overall mitigation of GHG. The benefits of air quality improvement plan suggested and delineated above again will not yield desired results if the adjoining urban centers and states do not adopt measures suggested for Delhi as the objectives of clean air can not be kept limited to the political boundary of Delhi.

Bibliography

Documents/Reports:

1. Annual Survey of Industries2002-2003, Coal India report, 2002-2003
2. Auto Fuel Policy Report, 2002
3. California Environmental Protection Agency Air Resources Board Vapor Recovery Test ProcedureTP-201.2H
4. Beard, M. E. and Margeson, J. H., 1974. An Evaluation of Arsenite Procedure for Determination of Nitrogen Dioxide in Ambient Air, *US EPA Report No. 650/4-74-048*, November, PB 239 737.
5. California Environmental Protection Agency , Air Resources Board ; SOP MLD 064 Standard Operating Procedure for the analysis of Anions and cations in PM 2.5 Speciation samples by Ion chromatography
6. CPCB stipulated regulatory standards and CPCB regulatory standards, USEPA standards
7. CPCB, 2001, Transport Fuel Quality for Year 2005. PROBES/78/2000-01 (New Delhi: Central Pollution Control Board, MoEF, Government of India)
8. Compendium Method TO-17 Determination of Volatile Organic Compounds in Ambient Air Using Active Sampling Onto Sorbent Tubes
9. CRRI, 2002, 'Urban Road Traffic and Pollution (URTRAP) Study', Technical Report (New Delhi: Central Road Research Institute)
10. Eicher Map of Delhi City
11. Emission factor for estimation of road dust re-suspension. http://www.usepa.gov/ttn/chief/AP42/ch13/final/c13s0201.pdf
12. Emission Factors for Non Vehicular Sources (Point and Area) Central Pollution Control Board (CPCB), USEPA –1992, USEPA 2000, EPA (2000), AP- 42 (2000), The Energy Research institute (TERI).
13. Emission Factors for Vehicular Sources, Automotive Research Association of India (ARAI), Pune Emission Factor Report, January 2008
14. GOI, 2002, Report of the Expert Committee – Auto Fuel Policy, New Delhi. Government of India, August 2002
15. Industrial units in Delhi, Economic Survey of Delhi, 2001-2002
16. Master Plan of Delhi (MPD) - 2021
17. *Methods of Air Sampling and Analysis*, 2nd ed., APHA, Washington. Katz, M.1997.

18. Power generation in Delhi, Socio-Economic Profile, 2007-08
19. PM2.5 Speciation Trends Network -- Measurement Uncertainties and Method Detection LimitsPrepared for: U.S. Environmental Protection Agency Office of Air Quality Planning and standards Research Triangle Park, NC 27711EPA Contract No. 68-D-03-038 Prepared by RTI
20. Statistical Handbook, 2008
21. U.S. Department of Labor Occupational Safety & Health Administration Method No.56
22. User's Guide for Industrial Source Complex (ISC 3) Dispersion Models, 1995a. User's Instructions, vol. 1. EPA-454/B-95-003a, USEPA. Research Triangle Park, North Carolina
23. User's Guide for Industrial Source Complex (ISC 3) Dispersion Models, 1995b. Description of Model Algorithms, vol. 2. EPA-454/B-95-003a, USEPA; Research Triangle Park, North Carolina

Data Collection:

1. Bakeries, Municipal Corporation of Delhi (MCD), Directorate of small scale Industries, Bakery association
2. Central Pollution Control Board (CPCB), Delhi Pollution Control Committee (DPCC), Office of Commissioner of Industries, Govt. of NCT, Delhi, District Industrial Centre (DIC), Delhi White Paper, 2003
3. Commercial generators set (capacity, number and fuel consumption), Generator set manufacturers/suppliers (Honda Seil, Birla Yamaha)
4. Crematoria (location, number of dead bodies burnt etc.), Health department of Municipal Corporation of Delhi (MCD), New Delhi Municipal Corporation (NDMC), Delhi Cantonment Board (DCB), Department of Economics and Statistics
5. Diesel locomotives (Number, trips, consumption of diesel), Northern Railways
6. Fuel supply data (LPG, NG, Kerosene etc.), Petroleum Planning and Analysis Cell (PPAC), Indian Oil Corporation Limited (IOCL), Food and Consumers Department, Indraprastha gas Limited (IGL)
7. Hotels, restaurants, eating houses, dhabas, Municipal Corporation of Delhi (MCD), New Delhi Municipal Corporation (NDMC), Office of Commissioner of Excise, Entertainment & Luxury Taxes, Association of Hotels/Restaurants, Department of Economics and statistics

8. Households and fuel consumption, Office of Registrar General
9. Location and number of slum households, Slum and JJ Wing of Municipal Corporation of Delhi (MCD)
10. Number and location of co-operative societies, Registrar of co-operative societies
11. Number of registered Industries, Department of industries, Delhi
12. National Council of Applied Economic Research (NCAER) Industrial Census Report of New Delhi, 2002 - 2003
13. Number of registered Industries, Department of industries, Delhi
14. PNG Consumption, Indraprastha gas Limited (IGL)
15. Population distribution & registered deaths, Office of Registrar General
16. Rajghat Thermal Power Plant, Pragati Power Co. Ltd, Indraprastha Power House, Gas Turbine Power Station, Badarpur Power Plant
17. Road and building construction activities, Public Works Department (PWD), Municipal Corporation of Delhi (MCD)
18. Solid waste and Hospital waste incinerators (number, capacity, type and consumption of fuel etc), open burning of waste, Municipal Corporation of Delhi (MCD), Delhi Pollution Control Committee (DPCC)
19. Total fuel supply to Delhi (Year wise), , Indian Oil Corporation Limited (IOCL), Delhi
20. WHO: 1976, Selected Methods for Measuring Ambient Air. WHO Offset Publication No. 24, WHO, Geneva.

Websites:

1. www.comind.nic.in
2. Http://Epa.Gov
3. www.delhistat.com
4. http://www.cpcb.nic.in/DRAFTREPORT-on-efdiv.pdf, 2008

Research Paper:

1. Andrade, F., Orsini, C., Maenhaut, W., 1993. Receptor modeling for inhalable atmospheric particles in Sao Paolo, Brazil. Nuclear Instrumentation. Methods in Phys Res. B75, 308-311.

2. Aneja, V.P., Agarwal, A., Roelle, P.A., Philips, S.B., Tong, Q., Watkins, N., Yablonsky, R., 2001, Measurement and analysis of criteria pollutants in New Delhi, India. Environ. Model. Soft. 27 (1), 35-42.
3. Balachandran, S., Raj Meena, B., Khillare, P.S., 2000. Particle size distribution and its elemental composition in the ambient air of Delhi. Environ. Int. 28, 49-54.
4. Chelani, A.B. and Devotta, S., 2005. Impact of change in fuel quality on PM10 in Delhi. Bull. Environ. Contam. Toxicol. 75(3), 600-607.
5. Chelani, A.B. and Devotta, S., 2007. Air quality assessment in Delhi: Before and after CNG as fuel. Environ. Monit. Assess. 125, 257-263.
6. Chelani, A.B., Gajghate, D.G., Devotta, S., 2008. Source apportionment of PM10 in Mumbai, India using CMB model. Bull. Environ. Contam. Toxicol. 81,190–195.
7. Chelani, A.B., Gajghate, D.G., Tamhane, S.M., Hasan, M.Z., 2001. Statistical modeling of air pollutants in ambient air of Delhi. Water, Air Soil Pollut. 132, 315-331.
8. Chow, J.C., Watson, J.G., Fujita, E.M. and Lowson, D.R., 1994. Temporal and spatial variations of PM2.5 and PM10 aerosol in the Southern California air quality. Atmos. Environ. 28, 2061-2080.
9. Chow, J.C., Watson, J.G., Lowenthal, D.H., 1996. Sources and Chemistry of PM10 Aerosol in Santa Barbara County, CA. Atmos. Environ. 30, 1489-1499.
10. Chow, J.C., Watson, J.G., Lowenthal, D.H., Solomon, P.A., Magliano, S.D., Ziman, S.D., Richards, L.W., 1992. PM10 source apportionment in California's San Joaquin Valley. Atmos. Environ. 26A, 3335-3354.
11. Gadi, R., Singh, N., Sarkar, A.K., Parashar, D.C., 2000. Mass size distribution and chemical composition of aerosols at New Delhi. In: Siddappa, K., Sadasivan, S., Sastri, V.N., Eappen, K.P., Somashekar, R.K., Rao, M., ed., Pollution in urban environ. 30-32.
12. Goyal, P. and Sidhartha, 2003. Present scenario of air quality in Delhi: a case study of CNG implementation. Atmos. Environ. 37, 5423-5431.
13. Gurjar B.R., Aardennea J.A., Lelievelda J., Mohanb M., 2004. Emission estimates and trends (1990–2000) for mega city Delhi and implications. Atmospheric. Environment 38, 5663–5681.
14. Kandlikar M., 2007. Air pollution at a hotspot location in Delhi: Detecting trends, seasonal cycles and oscillations. Atmospheric. Environment 41, 5934-5947.

15. Khillare, P.S., Balachandran, S., Raj Meena, B., 2004. Spatial and temporal variation of heavy metals in atmospheric aerosol of Delhi. Environ. Monit. Assess. 90, 1–21.
16. Laakso, L., Koponen, I.K., Monkkonen, P., Kulmala, M., Kerminen, V-M., Wehner, B., Wiedensohler, A., Wu, Z., Hu, M., 2006. Aerosol particles in the developing world- A comparison between New Delhi in India and Beijing in China. Water, Air & Soil Pollut. 173, 5-20.
17. Manoli, E., Voutsa, D. and Samara, C., 2002. Chemical Characterization and source identification/ apportionment of fine and coarse air particles in Thessaloniki, Greece. Atmos. Environ. 36, 949-961.
18. Pinto, J.P., Stevens, R.K., Willis, R.D., Kellogg, R., Mamane, Y., Novak, J., Santroch, J., Benes, I., Lenicek, J., Bures, V., 1998. Czech air quality monitoring and receptor modeling study. Environ. Sci. Technol. 32, 843-854.
19. Reddy, M. S., Venkataraman, C., February 2002, Inventory of aerosol and sulphur dioxide emissions from India I—Fossil fuel combustion. Atmospheric Environment, 36 (4), 677-697.
20. Rogge, W.F., Hildemann, L.M., Mazurek, M.A., Caw, G.R., Simoneit, B.R.T., 1993. Sources of Fine Organic Aerosol 2. Noncatalyst and Catalyst-Equipped Automobiles and Heavy-Duty Diesel Trucks. Environ. Sci. Tech. 27, 636-651.
21. Sharma, D.N., Sawant, A.A., Uma, R., Cocker, D.R., 2003. Preliminary chemical characterization of particle-phase organic compounds in New Delhi, India. Atmos. Environ. 37, 4317-4323.
22. Sharma, V.K., Patil, R.S., 1991. Insitu measurements of atmospheric aerosols in an industrial region of Bombay. J Aerosol Sci. 22(4), 501-507.
23. Sharma, V.K., Patil, R.S., 1994. Chemical mass balance model for source apportionment of aerosols in Bombay. Environ. Monit. Assess. 29(1), 75-88.
24. Srivastava, A. and Jain, V.K., 2007. Seasonal trends in coarse and fine particle sources in Delhi by the chemical mass balance receptor model. J. Hazard. Material. 144 (1-2), 283-291.
25. Srivastava, A. and Jain, V.K., 2007. Size distribution and source identification of total suspended particulate matter and associated heavy metals in the urban atmosphere of Delhi. Chemos. 68, 579-589.

26. Srivastava, A. and Jain, V.K., 2008. Source apportionment of suspended particulate matters in a clean area of Delhi: a note. Transport. Res. D 13(1), 59-63.

27. Stedman, J. R., etal (2001), An Empirical Model for Predicting Urban Roadside NO_2 Concentrations in UK. Atmospheric Environment, 35, 1451-1463.

28. Thurston, G.D., Spengler, J.D., 1985. A quantitative assessment of source contributions to inhalable particulate matter pollution in metropolitan Boston. Atmos. Environ. 19, 9-25.

29. Yadav, S., Rajamani, V., 2006. Air quality and trace metal chemistry of different size fractions of aerosols in N-NW India - Implications for source diversity. Atmos. Environ. 40, 698-712.

Annexure 2.1

Correlation Matrix of Fine Particulate Matter at Different Sites

A) Prahladpur

Summer

	PM2.5	OC	EC	TC
PM2.5	1	0.77	0.99	0.88
OC		1	0.83	0.98
EC			1	0.92
TC				1

The attempt of $PM_{2.5}$ correlation shows good correlation between $PM_{2.5}$, EC and OC giving an indication of domestic fuel such as coal and kerosene burning in the study area.

B) Pitampura

Summer

	PM2.5	OC	EC	TC
PM2.5	1	0.86	0.97	0.56
OC		1	0.96	0.87
EC			1	0.75
TC				1

Winter

	PM2.5	OC	EC	TC
PM2.5	1	0.56	-0.36	0.46
OC		1	0.57	0.99
EC			1	0.66
TC				1

OC and EC correlate well with $PM_{2.5}$ in summer and winter indicating sources of $PM_{2.5}$ are combustion sources including vehicular and multiple area sources.

C) Naraina

Summer

	PM2.5	OC	EC	TC
PM2.5	1	0.91	0.32	0.79
OC		1	-0.11	0.47
EC			1	0.83
TC				1

In case of Naraina OC gets well correlated with the $PM_{2.5}$ indicating that the fine combustion particles get contributed from the domestic & industrial combustion of coal and other sources of fuel.

D) SSI- GTK

Post Monsoon

	PM2.5	OC	EC	TC
PM2.5	1	0.84	-0.28	0.94
OC		1	-0.76	0.97
EC			1	-0.59
TC				1

Winter

	PM2.5	OC	EC	TC
PM2.5	1	0.15	0.76	0.61
OC		1.00	-0.53	0.88
EC			1	-0.06
TC				1

In SSI, during post monsoon the significant correlation of OC with fine particles exist which indicates that industrial combustions source are predominant. Whereas, the remarkable correlation of EC and fine particle shows the high temperature combustion activity in around the monitoring site.

F) Dhaula Kuan

Post Monsoon

	PM2.5	OC	EC	TC
PM2.5	1	0.96	0.6	0.8
OC		1	0.40	0.63
EC			1	0.96
TC				1

In Dhaula Kuan during post monsoon the significant correlation of OC with fine particles is indicating that vehicular sources are predominant.

G) Mayapuri

Post Monsoon

	PM2.5	OC	EC	TC
PM2.5	1	-0.95	-0.03	-0.80
OC		1	0.3	0.94
EC			1	0.63
TC				1

Winter

PM2.5	OC	EC	TC
1	-0.15	0.86	0.10
	1	-0.63	0.97
		1	-0.41
			1

The correlation of EC and PM$_{2.5}$ in winter season is an indication of some contribution of vehicles and other combustion in and around the locations. Post monsoon PM$_{2.5}$ does not correlate with OC, EC and TC indicating that biomass combustion and vehicles do not dominate in winter.

H) Anand Vihar

Summer

	PM2.5	OC	EC	TC
PM2.5	1.0	0.6	-0.4	0.5
OC		1.0	0.6	0.99
EC			1.0	0.7
TC				1.0

Post Monsoon

PM2.5	OC	EC	TC
1	0.70	0.5	0.69
	1	0.9	0.99
		1	0.99
			1

Winter

	PM2.5	OC	EC	TC
PM2.5	1	0.90	-0.47	0.98
OC		1	-0.8	0.8
EC			1	-0.27
TC				1

In winter, PM$_{2.5}$ correlate well with OC and EC. OC and EC correlate well in Summer indicating sources of PM$_{2.5}$ are combustion sources including vehicular and area sources. In post monsoon and winter OC gets well correlated to PM$_{2.5}$ is and clear indication of low temperature combustion activity in around the sampling location. Whereas the significant correlation of EC & PM2.5 in post monsoon are pointed dominantly towards the vehicular emissions exhaust and other combustion activities.

I) ISBT

	Summer				Post Monsoon			
	PM2.5	**OC**	**EC**	**TC**	**PM2.5**	**OC**	**EC**	**TC**
PM2.5	1	-0.12	-0.16	-0.14	1	0.78	-0.64	0.72
OC		1	0.99	0.99		1.00	-0.02	0.996
EC			1	0.99			1.00	0.07
TC				1				1.00

Winter

	PM2.5	**OC**	**EC**	**TC**
PM2.5	1	0.59	0.51	0.54
OC		1	0.99	0.99
EC			1	0.99
TC				1

In winter, $PM_{2.5}$ correlate well with OC and EC. OC and EC correlate well in post monsoon and winter indicating sources of $PM_{2.5}$ are combustion sources including vehicular and other area sources.

Annexure 2.2

Observed Concentrations of Ambient Air

Table 1: Observed Concentrations of Ambient Air Quality at Prahladpur (Summer)

Sr. No.	Date	SPM (µg/m^3)	RSPM (µg/m^3)	PM$_{10}$ (µg/m^3)	PM$_{2.5}$ (µg/m^3)	SO$_2$ (µg/m^3)	NO$_X$ (µg/m^3)	CO (mg/m^3)	O3 (mg/m^3)	HCHO (µg/m^3)	CH$_4$ (ppm)	NMHC (ppm)	THC (ppm)	OC (ug/m^3)	EC (ug/m^3)	TC (ug/m^3)	OC /EC
1	28/29-04-07	829.7	359.7	479.5		10.0	24.3				43.1	1.6	44.7				
2	29/30-04-07	967.0	328.0	409.5		6.3	26.2				34.0	12.2	46.2	34.0	12.2	46.2	2.78
3	30/1-04-07	660.7	348.7	240.0		6.2	26.8				23.6	8.9	32.4	23.6	8.873	32.4	2.66
4	1/2-05-07	564.3	271.7	289.0		6.5	26.2				70.3	3.3	73.6	15.0	3.3	18.3	4.60
5	2/3-05-07	594.7	368.0	274.0		4.7	43.0				28.1	6.0	34.1	28.1	6.0	34.1	4.70
6	3/4-05-07	581.3	293.0	271.0		13.5	31.2	0.90	21.5	11	31.1	7.5	38.6	31.1	7.5	38.6	4.11
7	4/5-05-07	414.0	326.3	248.0		6.0	38.0	0.73	16.9		26.4	16.0	42.4				
8	21/22-05-07	862.0	305.0	215.0		6	17.3	0.72	2.7								
9	22/23-05-07	803.3	206.3	266.0		21.0	33.2	0.71	14.5								
10	23/24-05-07	693.3	183.3	239.5		17.3	22.1	0.61	11.4								
11	24/25-05-07	889.0	309.0	445.5	233	6.50	31.9	0.70	25.2								
12	25/26-05-07	524.0	170.3	260.5	87	6.6	24.0	0.60	22.0								
13	26/27-05-07	349.0	111.0	166.5	110	15.0	20.5										
14	27/28-05-07	599.0	208.7	319.5		6.8	17.8										
15	14-15/06/07	421.3	91.7	138.7		14.8	35.3				66.2	7.0	73.3	24.2	8.3	32.5	2.91
16	15-16/06/07	320.0	64.3	118.0		6.4	34.6				81.1	5.8	87.0	16.5	10.4	26.9	1.59
17	16-17/06/07	251.0	54.7	108.0		6.6	21.5				60.1	4.5	64.5	25.0	9.2	34.2	2.73
18	17-18/06/07	268.0	70.0	121.8		6.1	24.0				42.0	4.8	46.8	23.3	9.9	33.2	2.36
19	18-19/06/07	312.0	106.0	142.8		6.0	18.0				111.6	7.2	118.7	30.6	7.1	37.6	4.32
20	19-20/06/07	468.0	181.7	372.2		6.3	18.7							28.9	6.0	34.9	4.82
21	20-21/06/07	355.3	144.0	196.5		6.4	15.0										

Table 2: Observed Concentrations of Ambient Air Quality at Prahladpur (Post Monsoon)

Sr. No.	Date	SPM (µg/m^3)	RSPM (µg/m^3)	PM$_{10}$ (µg/m^3)	PM$_{2.5}$ (µg/m^3)	SO$_2$ (µg/m^3)	NO$_X$ (µg/m^3)	CO (mg/m^3)	O3 (mg/m^3)	HCHO (µg/m^3)	CH$_4$ (ppm)	NMHC (ppm)	THC (ppm)	OC (ug/m^3)	EC (ug/m^3)	TC (ug/m^3)	OC /EC
1	17/09/07	307.0	122.0	159.2		6.0	13.8				1.9	0.7	2.6	47.6	6.0	51.1	7.9
2	18/09/07	426.9	206.4	344.0		22.1	30.0	1.9	21.6		2.3	0.9	3.2	56.3	9.5	65.7	5.9
3	19/09/07	364.0	164.7	207.6		24.0	18.4	2.1	27.4					31.8	5.0	34.1	6.4
4	20/09/07	440.0	177.0	352.0		27.5	19.3							56.6	7.5	60.6	7.5
5	21/09/07	364.0	146.0	163.8		12.8	24.5			10				35.9	10.0	39.2	3.6
6	22/09/07	284.0	138.4	156.0		18.9	28.0							30.6	4.3	34.9	7.1
7	23/09/07	351.6	142.5	213.9		5.9	27.7							19.4	2.7	22.1	7.3
8	24/10/07	657.0	383.0	440.0		6.0	39.0							111.9	9.3	121.2	12.0
9	25/10/07	777.0	460.0	199.0		9.1	46.0	1.5	27.8		2.0	1.0	3.0				
10	26/10/07	665.0	352.5	561.0		16.0	54.0	1.2	22.6		2.0	1.2	3.2				
11	27/10/07	600.0	300.0	411.0		15.0	52.0	1.5	19.8		2.0	1.1	3.1				
12	28/10/07	600.0	394.0	376.0		18.3	44.0										
13	29/10/07	648.5	466.3	571.0		11.7	40.5										
14	30/10/07	620.0	470.5	508.0		10.9	36.0							122.0	10.8	132.8	11.3
15	26/11/07	888.0	508.0			30.0	51.0	1.2	19.5		2.3	1.0	3.2		39.4		
16	03/12/07	560.0	216.7			32.0	42.0	1.8	18.4		2.1	0.9	3.0	43.2	33.6	72.1	1.3
17	04/12/07	653.0	232.4			27.0	39.0							180.0	32.9	212.9	5.5
18	05/12/07	860.0	370.4			18.0	35.0										
19	06/12/07	753.8	363.6			17.0	38.0							78.4	19.9	98.3	3.9
20	07/12/07	702.0	453.0			14.0	34.0							178.8	25.7	204.5	6.9
21	08/12/07	541.0	324.0			9.0	32.0							129.6	19.6	149.2	6.6

Table 3: Observed Concentrations of Ambient Air Quality at Prahladpur (Winter)

Sr. No.	Date	SPM (µg/m^3)	RSPM (µg/m^3)	PM_{10} (µg/m^3)	$PM_{2.5}$ (µg/m^3)	SO_2 (µg/m^3)	NO_X (µg/m^3)	CO (mg/m^3)	O3 (mg/m^3)	HCHO (µg/m^3)	CH_4 (ppm)	NMHC (ppm)	THC (ppm)	OC (ug/m^3)	EC (ug/m^3)	TC (ug/m^3)	OC /EC
1	26/12/07	513.8	268.6	356.0		6.0	53.0							61.8	8.8	70.7	7.0
2	27/12/07	518.5	228.5	337.5		10.0	22.0							42.6	9.5	52.1	4.5
3	28/12/07	497.8	302.1	348.5		6.0	27.0							56.0	9.7	65.7	5.8
4	29/12/07	500.3	230.5	384.0		6.0	14.0							60.3	13.6	73.9	4.4
5	30/12/07	492.5	278.0	355.0		20.0	25.0							51.3	10.6	62.0	4.8
6	31/12/2007	543.4	252.7	447.0		5.0	47.0	0.7			2.7	0.6	3.3				
7	1/1/2008	613.0	317.6	513.0		5.0	41.0	0.6			2.2	0.4	2.7				
8	24/01/08	480.0	211.4	249.0		15.0	37.0			24.9				47.2	9.7	56.9	4.9
9	25/01/08	400.0	282.7	264.5		14.0	30.0							48.3	9.4	57.7	5.1
10	26/01/08	422.0	270.0	253.0		9.0	28.0	1.3	26.9		2.5	0.5	3.0	30.0	14.3	44.3	2.1
11	27/01/08	500.0	259.0	322.5		10.0	43.0	1.7	50.8		2.7	0.6	3.4	46.8	12.0	58.8	3.9
12	28/01/08	592.0	433.0	515.5		8.4	25.5	0.9	47.7		2.5	0.4	2.8	60.0	14.8	74.8	4.1
13	29/01/08	500.0	309.0	366.0		12.0	52.0							54.6	14.0	68.5	3.9
14	30/1/2008	540.4	359.7	362.5		10.0	45.0							58.1	17.7	75.7	3.3
15	20/2/2008	833.0	459.2	500.8		10.0	25.0							56.8	10.1	66.8	5.6
16	21/2/2008	779.3	253.9	389.3		6.9	30.3							55.7	10.0	65.7	5.6
17	22/2/2008	564.1	194.1	261.8		5.5	29.5							33.8	14.3	48.2	2.4
18	23/2/2008	777.2	276.0	470.0		5.0	19.6										
19	24/2/2008	584.7	234.0	334.8		5.7	24.9										
20	25/2/2008	533.0	200.8	280.2		6.2	32.0	0.5			2.6	0.7	3.3				
21	26/2/2008	542.1	204.4	345.0		6.5	45.0	0.7			2.5	0.6	3.1				

Table 4: Observed Concentrations of Ambient Air Quality at Pitampura (Summer)

Sr. No.	Date	SPM (µg/m^3)	RSPM (µg/m^3)	PM$_{10}$ (µg/m^3)	PM$_{2.5}$ (µg/m^3)	SO$_2$ (µg/m^3)	NO$_X$ (µg/m^3)	CO (mg/m^3)	O3 (mg/m^3)	HCHO (µg/m^3)	CH$_4$ (ppm)	NMHC (ppm)	THC (ppm)	OC (ug/m^3)	EC (ug/m^3)	TC (ug/m^3)	OC /EC
1	14-15/06/07	345.0	128.0	131.5		11.3	18.7							7.1	4.4	11.5	1.61
2	15-16/06/07	321.7	127.7	124.5		10.2	20.2										
3	16-17/06/07	317.7	80.3	105.5		8.7	29.8			12.0				15.4	7.3	22.7	2.11
4	17-18/06/07	305.0	68.5	143.5		8.7	34.3							16.6	5.0	21.6	3.33
5	18-19/06/07	325.0	100.0	151.5		9.0	32							16.6	9.6	26.3	1.73
6	19-20/06/07	358.0	124.0	145.0		9.1	26.2							21.2	12.3	33.4	1.72
7	20-21/06/07	337.7	112.3	184.0		9.2	39.7							10.1	4.3	14.4	2.34
8	21-22/06/07	314.3	89.3	105.5		8.8	43.7							11.5	3.5	15.0	1.15
9	22-23/06/07	312.7	59.3	93.5		6.0	36.2							9.9	7.0	16.9	1.41
10	23-24/06/07	298.0	70.3	74.0		8	19.0							9.9	6.0	16.0	1.64
11	24-25/06/07	303.3	60.7	75.0		8.1	21.8							9.4	5.2	14.6	1.82
12	25-26/06/07	264.0	53.3	56.0		6.5	23.2										
13	26-27/06/07	308.3	47.7	31.5		6.2	33.7							19.0	11.0	29.9	1.73
14	27-28/06/07	277.3	34.0	25.5		6.3	24.0	0.7	11.7					10.7	5.5	16.1	1.94
15	28-29/06/07	257.0	71.5	62.7		5.0	34.8	0.8	15.2					19.6	10.5	30.1	1.86
16	29-30/06/07	240.3	80.0	95.5		10.5	33.3	0.9	16.0					20.5	12.8	33.3	1.61
17	30-01/0707	252.7	60.3	63.5	30	10.3	27.8	0.7	10.5					15.0	5.2	20.1	2.91
18	01-02/07/07	279.0	51.3	64.5	30	5.8	27.0	0.5	13.1					12.7	3.8	16.5	3.37
19	02-03/07/07	173.7	47.3	44.0	30	6.0	34.8	0.6	9.7					12.6	4.3	16.9	2.94
20	03-04/07/07	184.0	35.7	58.8		3.0	29.2	0.8	6.9					11.3	4.0	15.3	2.85

Table 5: Observed Concentrations of Ambient Air Quality at Pitampura (Post Monsoon)

Sr. No.	Date	SPM (µg/m^3)	RSPM (µg/m^3)	PM$_{10}$ (µg/m^3)	PM$_{2.5}$ (µg/m^3)	SO$_2$ (µg/m^3)	NO$_X$ (µg/m^3)	CO (mg/m^3)	O3 (mg/m^3)	HCHO (µg/m^3)	CH$_4$ (ppm)	NMHC (ppm)	THC (ppm)	OC (ug/m^3)	EC (ug/m^3)	TC (ug/m^3)	OC /EC
1	19/11/07	1063.1	441.7	625.0		14.0	98.0							164.9	31.4	196.3	5.2
2	20/11/07	789.6	361.0	517.0		11.0	99.0							113.6	15.0	128.6	7.6
3	21/11/07	1252.5	625.7	947.0		14.1	116.7							176.8	23.6	200.4	7.5
4	22/11/07	1427.0	661.0	890.0		23.0	69.0										
5	23/11/07	1021.2	528.0	697.0		13.1	84.5							149.2	32.3	181.5	4.6
6	24/11/07	1139.6	703.4	973.0		20.1	69.5							246.4	16.1	262.5	15.3
7	25/11/07	1288.6	661.3	1119.0		20.0	120.3							251.8	21.1	273.0	11.9
8	26/11/07	1148.6	674.0	694.0		15.2	87.0							177.8	24.5	202.3	7.3
9	27/11/07	1034.9	607.7	308.0		9.9	79.1							195.1	16.5	211.6	11.8
10	28/11/07	1075.4	516.7	417.0		20.0	110.7			9.0				282.9	16.1	299.0	17.6
11	29/11/07	690.2	402.0			34.4	106.2										
12	30/11/07	915.9	554.0			31.1	109.0										
13	1/12/2007	739.5	395.3			21.2	90.4										
14	2/12/2007	703.1	335.7			28.2	59.3	1.13			2.9	0.6	3.5				
15	3/12/2007	640.0	226.3			14.6	69.4	1.77	25.7		2.8	0.7	3.5				
16	4/12/2007	742.3	342.7			28.9	82.9	1.61	26.8		3.3	0.3	3.6				
17	5/12/2007	1046.4	517.7			17.0	71.4	2.02	20.3		3.7	1.1	4.9	202.5	25.0	227.5	8.1
18	6/12/2007	1039.8	540.0			21.0	107.2	2.12	14.3		3.1	0.3	3.4	147.0	17.2	164.2	8.5
19	7/12/2007	1032.3	551.7			16.0	97.9	1.46	12.8		3.3	0.8	4.1	192.4	23.0	215.3	8.4
20	8/12/2007	1006.3	490.0			14.2	74.0	1.71	9.7		2.8	0.8	3.6	246.0	23.0	269.0	10.7

Table 6: Observed Concentrations of Ambient Air Quality at Pitampura (Winter)

Sr. No.	Date	SPM (µg/m^3)	RSPM (µg/m^3)	PM_{10} (µg/m^3)	$PM_{2.5}$ (µg/m^3)	SO_2 (µg/m^3)	NO_X (µg/m^3)	CO (mg/m^3)	O3 (mg/m^3)	HCHO (µg/m^3)	CH_4 (ppm)	NMHC (ppm)	THC (ppm)	OC (ug/m^3)	EC (ug/m^3)	TC (ug/m^3)	OC /EC
1	12/19/07	1133.0	648.0	901.3		9.0	61.6										
2	12/20/07	818.0	450.2	473.4		14.7	80.7							70.1	16.4	86.5	4.3
3	12/21/07	751.0	375.2	292.2		10.4	68.4							44.1	11.0	55.1	4.0
4	12/22/07	691.0	360.6	284.5		10.6	88.2							40.2	8.6	48.8	4.7
5	12/23/07	772.6	436.4	570.0		3.2	72.5							120.3	15.9	136.2	7.6
6	12/24/07	795.9	483.9	562.0		14.4	66.6							96.4	26.6	123.1	3.6
7	12/25/07	758.8	451.8	530.5		19.4	76.5							63.4	17.8	81.2	3.6
8	12/26/07	699.1	369.1	415.8		11.4	66.2							69.4	10.0	79.4	6.9
9	12/27/07	653.7	350.3	336.8		17.1	76.5							52.8	8.3	61.0	6.4
10	12/28/07	743.0	411.7	489.5		14.0	57.1							66.5	12.7	79.2	5.2
11	12/29/07	714.7	403.4	436.6		13.9	70.8										
12	12/30/07	722.9	388.3	453.7		14.0	57.0							66.0	15.3	81.3	4.3
13	12/31/07	737.7	354.2	499.8	297	15.2	86.0										
14	1/1/08	888.4	403.0	425.5		20.0	81.0	1.1	53.2		3.1	0.7	3.8				
15	1/2/08	890.7	451.6	649.4	304	22.0	93.0	1.57			3.5	0.7	4.2	80.7	14.6	95.4	5.5
16	1/3/08	865.0	391.8	668.4		19.0	90.0	1.44	56.9		3.3	0.8	4.1	142.0	37.1	85.4	3.8
17	1/4/08	1066.4	580.6	730.8		21.1	62.2	0.78			3.2	0.7	3.9	150.0	61.1	133.6	2.5
18	1/5/08	1081.1	559.5	534.6		12.1	71.9	0.87			2.9	0.7	3.6	120.0	49.3	139.1	2.4
19	1/6/08	939.0	516.4	756.1		24.0	94.0	0.99	17.9		3.4	0.6	4.1	138.0	54.6	151.5	2.5
20	1/7/08	1060.6	530.9	529.5		11.1	62.1	1.38	20.0		3.2	0.8	4.0	142.0	69.1	182.6	2.1

Table 7: Observed Concentrations of Ambient Air Quality at Naraina (Summer)

Sr. No.	Date	SPM (µg/m^3)	RSPM (µg/m^3)	PM$_{10}$ (µg/m^3)	PM$_{2.5}$ (µg/m^3)	SO$_2$ (µg/m^3)	NO$_X$ (µg/m^3)	CO (mg/m^3)	O3 (mg/m^3)	HCHO (µg/m^3)	CH$_4$ (ppm)	NMHC (ppm)	THC (ppm)	OC (ug/m^3)	EC (ug/m^3)	TC (ug/m^3)	OC /EC
1	28-29/04/07	696.0	207.0	320.0		18.5	46.2	1.49	41.1					36.3	14.2	50.5	2.55
2	29-30/04/07	782.0	209.3	312.0		12.0	43.3	1.84	57.0					24.7	17.6	42.3	1.40
3	30-1/05/07	857.3	149.7	226.5	50	5.3	33.7	1.42	41.5					47.9	6.8	54.7	7.05
4	1-2/05/07	841.3	130.7	193.0	53	16.2	23.3	1.71	40.5					37.5	6.1	43.6	6.18
5	2-3/05/07	423.3	129.7	197.0		8.3	62.3	1.06	56.2								
6	3-4/05/07	754.7	180.0	260.5		12.3	50.7	1.42	46.4	9							
7	4-5/05/07	655.7	136.7	172.0		10.0	34.5	1.32						38.6	11.4	50.0	3.39
8	5-6/05/07	444.3	121.0	148.0		4.7	49.3							30.9	10.6	41.5	2.91
9	6-7/05/07	452.0	109.7	124.0		7.0	47.8							27.2	11.7	38.9	2.33
10	7-8/05/07	525.0	116.2	169.0		9.0	60.0							23.0	11.8	34.8	1.95
11	8-9/05/07	972.3	171.3	231.5		11.0	44.0							26.7	10.4	37.1	2.57
12	9-10/05/07	786.7	149.0	226.5		10.2	44.2							29.1	12.9	42.0	2.26
13	10-11/05/07	594.7	119.3	229.5		5.0	30.2							27.8	7.4	35.2	3.77
14	11-12/05/07	409.3	102.0	177.5		9.2	24.3							30.1	9.8	39.9	3.08
15	12-13/05/07	537.3	103.7	208.0		4.2	24.2							29.7	9.3	39.0	3.20
16	13-14/05/07	548.3	122.3	217.7		9.2	30.7										
17	14-15/05/07	710.0	137.7	186.8		22.7	52.8										
18	15-16/05/07	926.0	189.0	358.7		3.5	30.3										
19	16-17/05/07	385.0	141.3	163.3		15.7	45.2										
20	17-18/05/07	440.3	111.7	204.8		9.7	44.2										

Table 8: Observed Concentrations of Ambient Air Quality at Naraina (Post Monsoon)

Sr. No.	Date	SPM (µg/m^3)	RSPM (µg/m^3)	PM_{10} (µg/m^3)	$PM_{2.5}$ (µg/m^3)	SO_2 (µg/m^3)	NO_X (µg/m^3)	CO (mg/m^3)	O3 (mg/m^3)	HCHO (µg/m^3)	CH_4 (ppm)	NMHC (ppm)	THC (ppm)	OC (ug/m^3)	EC (ug/m^3)	TC (ug/m^3)	OC /EC
1	17/09/07	426.0	123.7	235.0		7.2	34.8	1.02	10.0		3.2	0.8	4.0	55.0	7.7	62.7	7.13
2	18/09/07	503.7	136.0	244.0		12.0	37.0	1.4	10		3.0	1.1	4.0	40.5	5.4	46.0	7.50
3	19/09/07	464.7	124.0	237.5	81	5.7	33.5	1.1	11		3.2	0.6	3.8	30.2	5.3	35.5	5.72
4	20/09/07	533.4	140.8	238.0	89	10.0	32.3	1.02	7.7	12	2.5	1.0	3.6	37.5	5.5	42.9	6.87
5	21/09/07	551.1	153.6	191.5	56	7.8	35.0	0.87	7.6		2.7	1.1	3.8	33.7	5.0	38.7	6.73
6	22/09/07	427.6	86.8	190.0		8.8	27.1	0.97	5.8		3.5	1.5	5.0	20.1	3.4	23.5	5.90
7	23/09/07	362.8	137.5	201.5		6.6	34.0	1.30	6.0		3.3	0.6	3.8	24.5	7.2	31.8	3.40
8	24/09/07	437.2	137.0	193.5		6.2	33.2							27.6	6.1	33.7	4.52
9	25/09/07	298.0	37.1	226.0		6.0	20.4										
10	26/09/07	325.0	56.6	235.0		4.1	13.0										
11	27/09/07	337.6	134.6	189.5		8.3	25.3										
12	28/09/07	268.0	40.7	172.5		6.2	33.8										
13	29/09/07	389.7	129.0	273.0		4.3	30.8							69.7	11.7	81.4	5.94
14	30/09/07	356.0	142.0	215.0		6.0	35.0							30.7	3.5	34.2	8.75
15	01/10/07	502.0	160.0	340.0		8.5	34.5										
16	02/10/07	523.5	199.3	433.3		3.2	21.0										
17	03/10/07	804.0	257.0	485.0		8.0	25.0							78.5	15.1	93.6	5.20
18	04/10/07	823.9	236.0	492.2		4.1	35.8							100.3	14.3	114.6	6.99
19	05/10/07	684.0	307.0	332.0		6.1	38							73.4	13.5	86.9	5.44
20	06/10/07	610.7	261.7	246.3		3.4	42.8							48.8	12.0	60.7	4.08

Table 9: Observed Concentrations of Ambient Air Quality at Naraina (Winter)

Sr. No.	Date	SPM (μg/m^3)	RSPM (μg/m^3)	PM$_{10}$ (μg/m^3)	PM$_{2.5}$ (μg/m^3)	SO$_2$ (μg/m^3)	NO$_X$ (μg/m^3)	CO (mg/m^3)	O3 (mg/m^3)	HCHO (μg/m^3)	CH$_4$ (ppm)	NMHC (ppm)	THC (ppm)	OC (ug/m^3)	EC (ug/m^3)	TC (ug/m^3)	OC /EC
1	02/11/08	709.8	171.3	321.5		7.7	51.0							63.1	7.2	70.3	8.77
2	02/12/08	863.1	243.9	317.0		4.5	36.0							47.9	6.8	54.8	7.01
3	13/02/08	728.4	342.0	294.0		6.6	47.2							61.4	7.5	68.9	8.21
4	14/02/08	1173.0	489.8	725.0		16.6	59.6								8.6		
5	15/02/08	809.0	259.4	369.0		7.0	67.0							67.8	7.7	75.5	8.76
6	16/02/08	796.3	241.8	352.5		8.9	70.5							63.6	7.2	70.8	8.89
7	17/02/08	824.5	298.3	441.0		13.5	51.5							53.2	6.7	59.9	7.97
8	18/02/08	1005.0	307.5	696.0		8.5	45.0										
9	19/02/08	1210.1	483.9	279.5		18.8	79.0							57.7	6.2	63.9	9.30
10	20/02/08	1463.0	489.8	385.0		15.1	79.6							68.0	7.6	75.6	8.95
11	21/02/08	756.8	364.0	424.5		14.3	74.4							69.1	7.0	76.1	9.87
12	22/02/08	995.3	249.1	407.0		5.9	41.0							45.8	7.6	53.3	6.06
13	23/02/08	1242.6	360.7	518.5		14.8	50.3										
14	24/02/08	906.0	176.7	369.5		7.0	51.0	1.5	9.9	7.8	2.9	1.1	4.0	41.1	9.4	50.5	4.38
15	25/02/08	815.9	146.5	310.8		8.3	37.6	1.7	9.9		3.2	1.1	4.3				
16	26/02/08	747.2	188.9	354.3	185.9	21.4	53.5	1.7	11		3.0	1.3	4.3				
17	27/02/08	928.6	276.9	482.5	209.4	11.9	59.8	1.2	9.5		3.5	1.4	5.0				
18	28/02/08	1197.2	356.1	584.7		16.8	75.1	1.9			3.6	1.6	5.3				
19	29/02/08	1266.5	353.4	605.0		16.0	70.1	2	7.6		3.0	0.9	3.9				
20	03/01/08	1369.2	396.9	680.8		19.5	97.3	1.6	29.4		3.6	1.5	5.1				

Table 10: Observed Concentrations of Ambient Air Quality at SSI-GTK (Summer)

Sr. No.	Date	SPM $(\mu g/m^3)$	RSPM $(\mu g/m^3)$	PM_{10} $(\mu g/m^3)$	$PM_{2.5}$ $(\mu g/m^3)$	SO_2 $(\mu g/m^3)$	NO_X $(\mu g/m^3)$	CO (mg/m^3)	O3 (mg/m^3)	HCHO $(\mu g/m^3)$	CH_4 (ppm)	NMHC (ppm)	THC (ppm)	OC (ug/m^3)	EC (ug/m^3)	TC (ug/m^3)	OC /EC
1	14-15/06/07	685.0	148.7	417.0		13.0	50.0							19.4	4.4	23.8	4.41
2	15-16/06/07	373.3	104.0	238.7		14.7	76.8							20.1	7.1	27.2	2.82
3	16-17/06/07	286.3	89.7	188.2	6.0	19.5	51.8							22.1	11.4	33.6	1.93
4	17-18/06/07	300.7	100.0	200.3		15.7	83.5							36.9	15.2	52.0	2.43
5	18-19/06/07	480.0	188.3	334.0		16.5	92.8							52.0	18.3	70.3	2.84
6	19-20/06/07	618.3	217.3	417.7		9.0	75.7							45.5	24.2	69.8	1.88
7	20-21/06/07	542.7	164.7	353.8		14.4	90.2							39.7	15.0	54.6	2.65
8	21-22/06/07	375.0	218.0	252.5		14.3	83.8	0.7	18.6					21.2	13.2	34.4	1.61
9	22-23/06/07	360.0	163.7	225.5		5.0	53.0	0.9	16.5					22.1	5.2	27.2	4.27
10	23-24/06/07	536.3	297.0	416.7		4.7	34.0	1.0	17.7					16.7	9.2	25.9	1.82
11	24-25/06/07	513.7	170.7	342.3	46.0	4.2	43.5	1.2	21.9					22.0	5.4	27.4	4.05
12	25-26/06/07	365.3	83.7	224.7	8.0	9.8	53.7	1.1	11.7					21.8	8.1	29.9	2.68
13	26-27/06/07	400.0	160.0	280.0	22.0	18.0	86.8	0.9	7.9					37.1	13.9	51.0	2.66
14	27-28/06/07	380.3	247.3	313.7		16.7	83.7	1.0	13.3					43.1	7.2	50.3	5.94
15	28-29/06/07	360.3	162.7	167.2		14.8	52.0							26.2	12.8	39.0	2.05
16	29-30/06/07	462.0	259.3	180.3		15.8	36.7							31.7	17.3	49.0	1.83
17	30-01/0707	494.3	238.3	131.8		5.8	53.3							26.5	8.5	35.0	3.12
18	01-02/07/07	460.3	216.3	131.2		10.3	53.0							17.9	6.5	24.3	2.76
19	02-03/07/07	306.0	209.7	94.5		7.3	49.3							15.5	6.1	21.6	2.56
20	03-04/07/07	169.3	88.0	104.7		8.3	46.8							13.3	8.1	21.4	1.65

Table 11: Observed Concentrations of Ambient Air Quality at SSI-GTK (Post Monsoon)

Sr. No.	**Date**	**SPM (µg/m^3)**	**RSPM (µg/m^3)**	**PM$_{10}$ (µg/m^3)**	**PM$_{2.5}$ (µg/m^3)**	**SO$_2$ (µg/m^3)**	**NO$_X$ (µg/m^3)**	**CO (mg/m^3)**	**O3 (mg/m^3)**	**HCHO (µg/m^3)**	**CH$_4$ (ppm)**	**NMHC (ppm)**	**THC (ppm)**	**OC (ug/m^3)**	**EC (ug/m^3)**	**TC (ug/m^3)**	**OC /EC**
1	19/20.11.07	1165.2	605.5	782.0		74.4	153.4	1.2	18.0		3.1	0.8	3.9	151.3	15.9	167.3	9.5
2	20/21.11.07	970.3	476.4	782.0		123.0	179.0	0.5	22.4		3.2	0.5	3.7				
3	21/22.11.07	1394.1	702.8	782.0		82.0	190.0	1.6	22.5		3.1	0.6	3.7				
4	22/23.11.07	1776.3	895.8	1425.0		137.0	216.0	1.7	26.8		3.0	0.8	3.8	294.7	25.2	319.9	11.7
5	23/24.11.07	1415.6	616.2	811.0		70.5	150.0	1.8	25.6		3.9	1.3	5.2				
6	24/25.11.07	1608.0	761.8	1181.0		75.0	152.2	1.6	24.9		2.9	0.7	3.5	302.5	23.9	326.5	12.6
7	25/26.11.07	1391.0	712.8	909.0		43.3	145.5	1.7	42.2		3.7	1.7	5.3				
8	26/27.11.07	1508.9	729.0	925.0		68.3	126.3										
9	27/28.11.07	1415.2	712.2	629.0		70.2	134.9							202.44	28.046	230.5	7.2
10	28/29.11.07	1547.4	637.4	1003.0		61.3	174.9			17.0				188.5	28.8	217.2	6.5
11	29/30.11.07	1168.5	497.1	619.0	303.0	33.9	81.4							117.6	12.3	129.8	9.6
12	30/01.11.07	1115.9	519.8	618.0	699.0	48.0	127.0										
13	01/02.12.07	1133.3	494.9	706.0	146.0	88.6	118.4							118.0	43.6	161.6	2.7
14	02/03.12.07	888.4	331.9	389.0		59.4	82.4							62.3	15.3	77.6	4.1
15	03/04.12.07	762.2	317.0	459.0		96.7	145.0							70.0	29.9	99.9	2.3
16	04/05.12.07	1265.8	442.0	623.0		144.2	141.2							111.7	43.2	154.8	2.6
17	05/06.12.07	1200.0	320.7	870.0		94.0	112.0							227.3	48.0	275.3	4.7
18	06/07.12.07	1147.9	522.0	798.0		57.4	172.8							164.3	54.4	218.7	3.0
19	07/08.12.07	1185.1	559.3	949.0		111.0	148.9							250.0	27.6	277.6	9.1
20	08/09.12.07	1207.2	571.0	1041.0		120.8	164.8							242.0	28.8	270.8	8.4

Table 12: Observed Concentrations of Ambient Air Quality at SSI-GTK (Winter)

Sr. No.	Date	SPM (μg/m^3)	RSPM (μg/m^3)	PM$_{10}$ (μg/m^3)	PM$_{2.5}$ (μg/m^3)	SO$_2$ (μg/m^3)	NO$_X$ (μg/m^3)	CO (mg/m^3)	O3 (mg/m^3)	HCHO (μg/m^3)	CH$_4$ (ppm)	NMHC (ppm)	THC (ppm)	OC (ug/m^3)	EC (ug/m^3)	TC (ug/m^3)	OC /EC
1	19/12/07	1196.1	490.0	502.0		52.1	115.4										
2	20/12/07	851.6	541.0	515.0		132.0	133.0							105.7	16.3	122.0	6.5
3	21/12/07	885.8	385.3	397.0		81.0	180.6							75.7	12.8	88.5	5.9
4	22/12/07	720.0	382.3	513.0		123.2	170.3							66.3	10.8	77.1	6.1
5	23/12/07	989.2	427.4	586.0		51.1	149.8							80.0	11.2	91.2	7.1
6	24/12/07	940.4	453.7	671.0		62.2	98.0							120.6	16.8	137.3	7.2
7	25/12/07	800.5	405.4	532.0		79.0	173.0							115.2	27.5	142.7	4.2
8	26/12/07	806.4	330.1	486.5		47.6	140.9	0.7	18.0		3.5	0.5	3.9	92.6	20.2	112.8	4.6
9	27/12/07	743.6	333.2	404.4		78.3	162.6	1.0	22.4		2.7	0.4	3.1	71.2	8.9	80.0	8.0
10	28/12/07	934.9	526.7	644.7	74.0	85.0	125.0	1.0	22.4		3.5	0.5	4.0	133.6	15.0	148.6	8.9
11	29/12/07	692.2	351.8	433.1	320.3	69.1	175.7	0.8	26.8		2.4	0.6	2.9	94.1	11.0	105.1	8.6
12	30/12/07	775.4	380.6	487.0	241.5	101.0	119.0	1.0	25.5		3.2	0.5	3.7	93.0	18.0	111.0	5.2
13	31/12/2007	819.0	436.0	515.0		130.3	212.3	1.5	25.3		3.1	0.5	3.6	119.7	15.0	134.7	8.0
14	1/1/2008	974.9	481.7	494.0		134.0	227.0	0.9	41.0	12.0	2.7	0.5	3.2	96.0	17.2	113.2	5.6
15	2/1/2008	808.4	393.1	601.7		102.2	199.3							88.0	10.0	98.0	8.8
16	3/1/2008	909.0	436.0	618.4		64.0	228.0										
17	4/1/2008	1062.0	469.7	726.1		111.0	171.0										
18	5/1/2008	1152.4	517.2	665.0		103.0	166.7										
19	6/1/2008	1154.0	529.0	604.0		74.0	143.0										
20	7/1/2008	1359.0	542.0	668.0		117.0	157.0										

Table 13: Observed Concentrations of Ambient Air Quality at Ashram Chowk (Summer)

Sr. No.	Date	SPM (μg/m^3)	RSPM (μg/m^3)	PM$_{10}$ (μg/m^3)	PM$_{2.5}$ (μg/m^3)	SO$_2$ (μg/m^3)	NO$_X$ (μg/m^3)	CO (mg/m^3)	O3 (mg/m^3)	HCHO (μg/m^3)	CH$_4$ (ppm)	NMHC (ppm)	THC (ppm)	OC (ug/m^3)	EC (ug/m^3)	TC (ug/m^3)	OC /EC
1	21/22-05-07	809.7	159.0	231.5		6.0	26.6	1.5						20.3	15.1	35.4	1.3
2	22/23-05-07	688.7	168.7	366.5		12.8	40.3	1.5	6.8					43.7	29.0	72.7	1.5
3	23/24-05-07	793.0	162.3	321.5	82.0	10.7	57.0	1.5	7.2					35.6	31.6	67.2	1.1
4	24/25-05-07	783.3	201.7	274.0	102.0	6.7	61.0	1.5	9.9					60.5	43.0	103.4	1.4
5	25/26-05-07	717.3	143.7	217.0	56.0	7.0	59.0	1.4	101.0	12.0				25.2	12.5	37.8	2.0
6	26/27-05-07	638.3	114.3	153.0		6.0	57.8	1.4	25.1					16.8	15.5	32.3	1.1
7	27/28-05-07	632.0	172.0	261.5		6.1	42.0	1.4	17.8								
8	28/29-05-07	705.7	223.7	205.0		3.2	49.8		11.9					19.7	14.9	34.6	1.3
9	29/30-05-07	577.0	143.7	190.5		3.0	54.3							26.0	14.1	40.1	1.8
10	30/31-05-07	802.0	246.3	319.0		8.7	47.2										
11	31/01-05-07	819.7	323.7	324.0		10.3	60.7							42.9	29.3	72.2	1.5
12	01/02-06-07	821.3	246.7	306.5		5.8	46.5							54.6	29.8	84.4	1.8
13	02/03-06-07	904.3	251.3	383.5		4.8	58.0							20.7	11.0	31.6	1.9
14	03/04-06-07	910.0	217.7	378.3		4.8	41.0							28.8	9.4	38.2	3.1
15	04/05-06-07	912.7	215.3	375.0		4.2	44.2										
16	05/06-06-07	985.0	257.7	372.5		4.3	44.2							26.6	13.6	40.2	1.9
17	06/07/-06-07	898.0	253.3	347.8		4.2	39.5							28.6	17.6	46.2	1.6
18	07/08-06-07	893.3	222.3	283.0		4.3	37.2							25.1	17.1	42.2	1.5
19	08/09-06-07	915.0	304.0	335.8		5.7	47.0							26.3	9.3	35.6	2.8

Table 14: Observed Concentrations of Ambient Air Quality at Ashram Chowk (Post Monsoon)

Sr. No.	**Date**	**SPM (µg/m^3)**	**RSPM (µg/m^3)**	**PM$_{10}$ (µg/m^3)**	**PM$_{2.5}$ (µg/m^3)**	**SO$_2$ (µg/m^3)**	**NO$_X$ (µg/m^3)**	**CO (mg/m^3)**	**O3 (mg/m^3)**	**HCHO (µg/m^3)**	**CH$_4$ (ppm)**	**NMHC (ppm)**	**THC (ppm)**	**OC (ug/m^3)**	**EC (ug/m^3)**	**TC (ug/m^3)**	**OC /EC**
1	11/12.10.07	914.5	553.7	406.0		8.7	101.2	1.9	11.7		2.2	1.3	3.4	100.7	6.1	106.8	16.5
2	12/13.10.07	812.6	300.6	341.5		12.5	98.8	1.7	12.5	15.0	2.4	1.5	3.9	85.7	6.4	92.1	13.3
3	13/14.10.07	1021.2	220.8	328.0		17.9	85.1	1.9	21.4		2.0	1.3	3.3				
4	14/15.10.07	872.9	362.5	315.0		14.2	77.0	1.5	19.0		2.2	1.3	3.5	125.3	6.6	132.0	18.8
5	15/16.10.07	706.0	294.7	341.0		24.8	82.4	1.9	22.1		2.8	1.3	4.1	74.5	10.3	84.7	7.2
6	16/17.10.07	692.0	127.1	138.0		16.0	67.0	1.5	20.2		2.6	1.3	4.0	33.4	8.0	41.4	4.2
7	17/18.10.07	678.2	302.0	221.0		10.9	81.7	1.5	10.9		2.1	0.9	3.0				
8	18/19.10.07	847.4	390.1	348.0		6.9	85.0							87.9	10.6	98.5	8.3
9	19/20.10.07	792.7	348.9	391.5		14.3	72.0							117.3	5.5	122.8	21.4
10	20/21.10.07	929.1	581.0	476.0		16.0	85.0							131.8	7.5	139.2	17.7
11	21/22.10.07	763.8	306.9	407.0		15.1	102.0							108.9	10.9	119.9	9.9
12	22/23.10.07	920.2	430.3	537.5		15.0	91.0							116.1	6.6	122.6	17.7
13	23/24.10.07	1041.4	469.9	798.0		23.0	145.0							135.0	6.7	141.7	20.1
14	24/25.10.07	931.0	399.7	486.0		13.0	152.0							118.5	7.3	125.8	16.3
15	25/26.10.07	1097.3	577.7	578.3	148.0	17.0	162.0							189.2	23.4	212.6	8.1
16	26/27.10.07	1027.5	512.7	525.8	226.1	20.0	144.0							153.6	22.4	176.0	6.9
17	27/28.10.07	944.5	519.4	519.8	171.3	15.0	172.0							121.9	20.0	141.9	6.1
18	28/29.10.07	926.0	460.8	550.0		8.0	167.0							154.5	18.4	173.0	8.4
19	29/30.10.07	940.4	487.9	717.7		8.1	142.0							173.0	29.0	202.0	6.0
20	30/31.10.07	935.1	548.5	640.0		12.6	170.9							162.8	32.4	195.2	5.0

Table 15: Observed Concentrations of Ambient Air Quality at Ashram Chowk (Winter)

Sr. No.	Date	SPM (µg/m^3)	RSPM (µg/m^3)	PM$_{10}$ (µg/m^3)	PM$_{2.5}$ (µg/m^3)	SO$_2$ (µg/m^3)	NO$_X$ (µg/m^3)	CO (mg/m^3)	O3 (mg/m^3)	HCHO (µg/m^3)	CH$_4$ (ppm)	NMHC (ppm)	THC (ppm)	OC (ug/m^3)	EC (ug/m^3)	TC (ug/m^3)	OC /EC
1	15/01/08	688.8	343.2	324.2		9.7	80.0	1.7			3.0	0.5	3.6	69.2	16.0	85.2	4.3
2	16/01/08	696.7	314.9	378.1		15.7	64.9	1.6	21.4		3.1	0.7	3.8	76.5	9.3	85.8	8.2
3	17/01/08	705.7	281.0	402.4	203.1	16.0	92.6	1.5	58.5		3.0	0.6	3.6	79.2	14.8	94.0	5.4
4	18/01/08	658.0	229.5	585.0	104.0	13.0	81.7	1.6			2.8	0.5	3.4				
5	19/01/08	662.9	374.5	325.1	190.5	12.5	105.4	1.6			3.1	0.6	3.7	73.4	14.4	87.8	5.1
6	20/01/08	661.2	339.0	261.9		15.6	74.0	1.5			3.1	0.6	3.7	42.9	8.8	51.7	4.9
7	21/01/08	678.2	352.0	365.4		17.0	119.0	1.9			3.5	0.4	4.0	76.0	12.1	88.0	6.3
8	22/01/08	742.3	321.3	408.7		20.0	76.7							110.2	9.5	119.6	11.6
9	23/01/08	613.2	321.2	324.6		15.2	64.4							78.9	11.2	90.2	7.0
10	24/01/08	587.9	235.1	282.6		13.8	52.0							72.5	13.2	85.7	5.5
11	25/01/08	535.3	305.0	318.7		14.8	60.0							77.0	9.3	86.3	8.3
12	26/01/08	591.6	351.0	281.5		17.0	70.9							62.2	18.8	80.9	3.3
13	27/01/08	707.2	431.0	393.0		15.4	105.4			11.0				82.0	12.0	94.0	6.8
14	28/01/08	852.5	494.0	515.2		16.1	89.8							121.8	14.0	135.8	8.7
15	29/01/08	860.9	493.0	514.3		17.8	136.1							67.7	12.0	79.7	5.6
16	30/1/2008	844.1	567.0	503.1		11.8	150.2							79.6	14.8	94.4	5.4
17	31/1/2008	838.3	517.4	450.9		15.1	129.0							58.4	15.6	74.0	3.7
18	1/2/2008	681.0	627.0	417.0		14.0	135.0							100.7	16.5	117.2	6.1
19	2/2/2008	524.5	278.0	384.6		16.0	90.0							60.1	16.0	76.2	3.7
20	3/2/2008	501.3	305.0	418.6		11.0	98.0							55.6	15.6	71.1	3.6

Table 16: Observed Concentrations of Ambient Air Quality at Dhaula Kuan (Summer)

Sr. No.	Date	SPM (µg/m^3)	RSPM (µg/m^3)	PM$_{10}$ (µg/m^3)	PM$_{2.5}$ (µg/m^3)	SO$_2$ (µg/m^3)	NO$_X$ (µg/m^3)	CO (mg/m^3)	O3 (mg/m^3)	HCHO (µg/m^3)	CH$_4$ (ppm)	NMHC (ppm)	THC (ppm)	OC (ug/m^3)	EC (ug/m^3)	TC (ug/m^3)	OC /EC
1	28-29/04/07	604.0	358.3			8.0	73.2										
2	29-30/04/07	623.0	173.7			10.7	54.0										
3	30-1/05/07	695.0	268.7			12.5	68.0										
4	1-2/05/07	764.3	166.3			6.3	64.0										
5	2-3/05/07	504.3	198.3			10.3	79.0										
6	3-4/05/07	529.7	188.7			10.0	86.8										
7	4-5/05/07	470.0	344.0			6.1	92.0			18.0							
8	5-6/05/07	410.3	154.3			6.7	67.8										
9	6-7/05/07	468.3	150.0			6.0	56.3										
10	7-8/05/07	431.7	174.3			6.0	88.8										
11	8-9/05/07	565.0	253.7			10.2	80.5										
12	9-10/05/07	543.7	211.7			9.3	51.2										
13	10-11/05/07	504.0	204.0			6.2	59.7	1.5	9.0								
14	11-12/05/07	446.3	155.7			9.7	60.8	1.5	8.9								
15	12-13/05/07	409.0	184.0			9.5	93.3	1.4	7.5								
16	13-14/05/07	449.7	115.7			12.3	60.3	1.3	8.6								
17	14-15/05/07	525.0	158.0			6.0	57.5	1.4	8.2								
18	15-16/05/07	489.7	213.3			6.0	40.8	1.3	8.3								
19	16-17/05/07	607.7	145.0			7.2	60.7	1.3	9.6								
20	17-18/05/07	531.3	123.0			8.5	72.7										

Table 17: Observed Concentrations of Ambient Air Quality at Dhaula Kuan (Post Monsoon)

Sr. No.	Date	SPM (µg/m^3)	RSPM (µg/m^3)	PM$_{10}$ (µg/m^3)	PM$_{2.5}$ (µg/m^3)	SO$_2$ (µg/m^3)	NO$_X$ (µg/m^3)	CO (mg/m^3)	O3 (mg/m^3)	HCHO (µg/m^3)	CH$_4$ (ppm)	NMHC (ppm)	THC (ppm)	OC (ug/m^3)	EC (ug/m^3)	TC (ug/m^3)	OC /EC
1	17/09/07	336.3	118.0	172.0		8.2	31.3							41.6	12.4	53.9	3.4
2	18/09/07	347.5	130.0	221.0		8.4	56.4							49.8	12.7	62.5	3.9
3	19/09/07	347.5	128.0	202.5		8.2	51.1							36.7	15.4	52.1	2.4
4	20/09/07	374.6	104.7	191.5		8.7	48.6							47.6	10.6	58.2	4.5
5	21/09/07	308.1	130.7	155.0		6.0	52.0			16.0				28.7	10.1	38.9	2.8
6	22/09/07	265.3	132.7	134.5		6.0	29.9							23.1	17.2	40.3	1.3
7	23/09/07	310.0	128.0	183.0		8.7	59.5							24.5	21.8	46.3	1.1
8	24/09/07	357.0	176.0	125.0		7.0	34.4	1.2	14.3		2.8	1.3	4.0	17.2	10.5	27.8	1.6
9	25/09/07	180.0	138.0	112.0		6.0	32.1	1.6	11.7		2.1	1.1	3.2	13.8	11.1	24.9	1.2
10	26/09/07	195.7	145.0	99.5	43.0	8.2	39.9	1.1	8.9		2.1	1.1	3.2	12.8	11.1	23.9	1.2
11	27/09/07	231.0	109.9	117.5	55.0	9.4	44.0	2.0	9.8		2.2	1.2	3.4	24.3	14.0	38.3	1.7
12	28/09/07	178.9	108.0	96.0	50.0	7.2	46.9	2.0	12.6		2.4	1.3	3.7	20.0	11.7	31.8	1.7
13	29/09/07	246.2	138.0	191.5		7.9	31.8	2.0	19.1		2.3	1.5	3.9	44.8	18.0	62.8	2.5
14	30/09/07	264.0	142.0	201.5		6.0	22.4	2.0			2.8	1.3	4.1	23.3	6.0	29.3	3.9
15	01/10/07	323.0	123.4	259.7		6.5	23.0							34.5	17.6	52.2	2.0
16	02/10/07	374.3	205.3	320.2		6.0	28.3							53.2	14.0	67.2	3.8
17	03/10/07	366.6	255.3	309.5		6.9	35.0							47.4	11.2	58.6	4.2
18	04/10/07	444.4	242.3	352.8		6.2	42.6							36.7	16.8	53.5	2.2
19	05/10/07	324.0	157.3	231.8		6.3	44.0							49.8	10.4	60.2	4.8
20	06/10/07	337.6	172.3	229.2		8.1	47.5							41.2	9.9	51.0	4.2

Table 18: Observed Concentrations of Ambient Air Quality at Dhaula Kuan (Winter)

Sr. No.	Date	SPM (µg/m^3)	RSPM (µg/m^3)	PM$_{10}$ (µg/m^3)	PM$_{2.5}$ (µg/m^3)	SO$_2$ (µg/m^3)	NO$_X$ (µg/m^3)	CO (mg/m^3)	O3 (mg/m^3)	HCHO (µg/m^3)	CH$_4$ (ppm)	NMHC (ppm)	THC (ppm)	OC (ug/m^3)	EC (ug/m^3)	TC (ug/m^3)	OC /EC
1	11/2/2008	384.4	155.2	272.5		5.7	62.1	1.0	49.8		2.7	0.6	3.3	36.4	5.6	42.0	6.5
2	12/2/2008	388.2	176.7	209.0		6.3	42.0	1.0	67.6		2.7	0.7	3.4	29.7	3.0825	32.8	9.6
3	13/2/2008	364.4	218.7	255.5	137	7.0	55.9	1.3			3.1	0.7	3.7	38.7	3.9429	42.7	9.8
4	14/2/2008	585.4	305.8	451.5		21.7	87.8	2.7			3.4	1.0	4.4	65.0	8.4985	73.5	7.6
5	15/2/2008	413.3	175.0	284.5	143	10.0	64.6	1.0			2.8	0.7	3.5	41.05	7.8298	48.9	5.2
6	16/2/2008	430.3	186.1	256.0		10.4	60.6	1.4			2.9	0.8	3.7	35.3	6.1156	41.4	5.8
7	17/2/2008	480.9	269.2	188.0		23.2	79.8	1.7			2.9	0.7	3.6				
8	18/2/2008	468.1	273.5	344.5		7.4	95.4										
9	19/2/2008	536.5	250.9	433.0		27.9	93.4										
10	20/2/2008	970.8	314.5	536.0		31.2	97.7										
11	21/2/2008	884.6	236.1	343.0		18.7	97.7										
12	22/2/2008	555.3	182.8	272.0		15.4	69.7										
13	23/2/2008	712.9	293.4	327.0		13.0	80.0										
14	24/2/2008	503.7	171.7	383.0		6.0	48.0			8.0				79.0	8.0	87.0	9.9
15	25/2/2008	572.5	98.1	366.2		7.0	53.0							71.5	6.7	78.3	10.6
16	26/2/2008	495.3	166.9	378.8		15.0	74.0							52.5	13.629	66.1	3.9
17	27/2/2008	515.9	156.7	370.3		12.0	56.0							68.3	10.821	79.2	6.3
18	28/2/2008	530.0	237.0	412.7		34.6	93.6							52.4	7.2	59.6	7.3
19	29/2/2008	757.8	316.9	422.0		19.3	96.2							74.7	7.76	82.5	9.6
20	1/3/2008	771.7	337.2	432.0		18.7	85.1							60.3	38.29	98.6	1.6

Table 19: Observed Concentrations of Ambient Air Quality at Mayapuri (Summer)

Sr. No.	Date	SPM (μg/m^3)	RSPM (μg/m^3)	PM$_{10}$ (μg/m^3)	PM$_{2.5}$ (μg/m^3)	SO$_2$ (μg/m^3)	NO$_X$ (μg/m^3)	CO (mg/m^3)	O3 (mg/m^3)	HCHO (μg/m^3)	CH$_4$ (ppm)	NMHC (ppm)	THC (ppm)	OC (ug/m^3)	EC (ug/m^3)	TC (ug/m^3)	OC /EC
1	28-29/04/07	816.3	199.3	507.8		6.0	75.5							35.1	21.9	57.0	1.6
2	29-30/04/07	922.3	195.00	512.0		6.3	64.2										
3	30-1/05/07	847.3	189.0	518.2		6.0	42.0							5.9	0.9	6.8	6.6
4	1-2/05/07	841.3	95.7	410.0		8.7	44.2							34.2	8.5	42.7	4.0
5	2-3/05/07	513.7	140.0	326.8		5.3	55.7										
6	3-4/05/07	806.7	147.3	477.0		3.8	44.8			15.0				4.0	1.2	5.2	3.3
7	4-5/05/07	489.7	135.0	312.3		10.0	72.5							47.0	26.5	73.5	1.8
8	5-6/05/07	536.3	144.0	340.2		6.0	39.8		19.2					24.2	19.6	43.7	1.2
9	6-7/05/07	553	161.7	357.3		6.2	52.3	1.2	23.1					24.9	15.5	40.3	1.6
10	7-8/05/07	446.67	122	350.0		6.0	62.5	0.9	31.3								
11	8-9/05/07	537.67	197.3	367.5	55.0	6.0	42.0	1.0	28.3					6.5	1.8	8.3	3.6
12	9-10/05/07	618.33	153.3	407.0		6.3	33.0	1.1	29.6					37.5	10.8	48.3	3.5
13	10-11/05/07	547.67	169.3	352.0	54.0	6.5	37.0	1.0	31.5					24.5	5.9	30.3	4.2
14	11-12/05/07	454.33	118.3	288.0		8.5	40.7	1.1	29.6					20.2	8.4	28.7	2.4
15	12-13/05/07	338	94.67	137.2		6.7	38.7	1.1						26.6	9.0	35.6	3.0
16	13-14/05/07	455.67	125	179.0		9.0	36.2							32.2	13.4	45.7	2.4
17	14-15/05/07	720.33	129.7	271.3		6.9	44.3							32.8	18.1	50.9	1.8
18	15-16/05/07	570	229.7	380.7		6.3	31.2							34.4	9.0	43.4	3.8
19	16-17/05/07	521.33	194.7	206.7		6.4	38.7							31.1	5.0	36.0	6.2
20	17-18/05/07	542	107	185.2		6.6	48.8							23.0	12.1	35.1	1.9

Table 20: Observed Concentrations of Ambient Air Quality at Mayapuri (Post Monsoon)

Sr. No.	Date	SPM (µg/m^3)	RSPM (µg/m^3)	PM$_{10}$ (µg/m^3)	PM$_{2.5}$ (µg/m^3)	SO$_2$ (µg/m^3)	NO$_X$ (µg/m^3)	CO (mg/m^3)	O3 (mg/m^3)	HCHO (µg/m^3)	CH$_4$ (ppm)	NMHC (ppm)	THC (ppm)	OC (ug/m^3)	EC (ug/m^3)	TC (ug/m^3)	OC /EC
1	17/09/07	363.7	106.4	205.0		6.1	35.8							38.6	6.8	45.4	5.6
2	18/09/07	367.7	85.0	211.5		6.2	36.3							36.1	7.1	43.2	5.1
3	19/09/07	374.1	94.2	214.5		4.5	30.1							31.8	5.2	37.1	6.1
4	20/09/07	334.0	102.0	191.0		4.2	38.2							36.6	8.2	44.8	4.5
5	21/09/07	303.0	73.1	186.0		4.1	27.0			14.0				29.4	6.8	36.2	4.3
6	22/09/07	333.1	69.0	251.0		5.7	30.1										
7	23/09/07	416.0	80.1	326.0		4.2	31.3							29.8	6.7	36.5	4.5
8	24/09/07	416.0	96.0	312.0		5.3	26.7							24.8	5.5	30.3	4.5
9	25/09/07	337.0	47.2	107.0		4.7	30.6							17.5	7.4	24.8	2.4
10	26/09/07	275.0	42.2	84.0		4.0	25.7							14.0	6.8	20.7	2.1
11	27/09/07	258.5	57.1	107.5		6.7	36.2							19.1	8.3	27.4	2.3
12	28/09/07	280.0	64.1	123.0		5.0	33.0							20.6	9.8	30.3	2.1
13	29/09/07	441.8	114.0	248.5		5.7	40.7							54.1	7.3	61.4	7.4
14	30/09/07	458.5	87.8	215.5		5.8	25.6	2.9	21.9		2.3	1.1	3.7	36.8	9.0	45.8	4.1
15	01/10/07	475.0	116.5	341.0		5.4	26.7	3.0	24.1		1.8	1.2	3.0	58.4	20.5	78.9	2.8
16	02/10/07	499.0	139.7	367.3	112.0	5.0	27.9	2.6	23.7		2.3	1.3	3.6	66.4	18.0	84.4	3.7
17	03/10/07	674.0	177.0	457.5	136.0	5.2	34.0	3.3	17.3		2.5	1.5	4.0	87.5	21.4	108.9	4.1
18	04/10/07	697.0	158.0	499.0	176.0	6.1	45.6	3.1	23.9		2.7	1.2	3.9		17.1		0.0
19	05/10/07	612.5	142.2	298.7		5.1	31.8	2.1	19.5		2.5	1.7	4.1	57.6	9.6	67.2	6.0
20	06/10/07	526.6	115.7	281.8		6.6	36.0	1.4	20.5		2.3	1.3	3.6	40.2	8.6	48.8	4.7

Table 21: Observed Concentrations of Ambient Air Quality at Mayapuri (Winter)

Sr. No.	**Date**	**SPM (µg/m^3)**	**RSPM (µg/m^3)**	**PM$_{10}$ (µg/m^3)**	**PM$_{2.5}$ (µg/m^3)**	**SO$_2$ (µg/m^3)**	**NO$_X$ (µg/m^3)**	**CO (mg/m^3)**	**O3 (mg/m^3)**	**HCHO (µg/m^3)**	**CH$_4$ (ppm)**	**NMHC (ppm)**	**THC (ppm)**	**OC (ug/m^3)**	**EC (ug/m^3)**	**TC (ug/m^3)**	**OC /EC**
1	11/2/2008	739.9	228.0	425.0		9.0	41.0							42.1	9.3	51.4	4.5
2	12/2/2008	656.0	283.4	292.5		5.0	38.3							36.8	6.0	42.8	6.2
3	13/2/2008	950.9	478.0	353.0		6.0	45.0							46.9	4.9	51.8	9.6
4	14/2/2008	1262.0	390.1	672.0		11.0	76.0							102.0	14.8	116.8	6.9
5	15/2/2008	838.1	401.7	452.0		10.0	90.4										
6	16/2/2008	833.2	315.4	233.0		9.0	71.1							42.4	6.9	49.3	6.2
7	17/2/2008	863.7	301.3	464.0		11.2	71.8							42.0	15.5	57.5	2.7
8	18/2/2008	1320.6	296.9	495.0		9.3	61.6	0.7			3.5	0.7	4.2	81.9	8.6	90.5	9.5
9	19/2/2008	1357.1	365.5	617.0		10.5	68.3	2.0	20.9		3.2	0.8	4.0				
10	20/2/2008	1355.6	432.6	688.0	326.8	11.9	87.1	2.0			2.7	0.9	3.6				
11	21/2/2008	1195.0	261.9	408.0	172.4	11.7	78.9	1.2			2.9	0.6	3.6	51.0	8.2	59.3	6.2
12	22/2/2008	934.5	259.1	305.0	128.9	12.1	58.9	0.9			2.7	0.5	3.3	39.7	6.9	46.6	5.8
13	23/2/2008	1329.8	388.3	468.0		13.3	65.1	1.7			3.2	0.9	4.1	74.9	11.5	86.5	6.5
14	24/2/2008	1131.8	364.7	346.0		7.0	38.0	1.2		6.0	3.1	0.6	3.7	40.5	11.0	51.5	3.7
15	25/2/2008	1149.4	333.7	422.0		7.1	65.3							38.9	8.4	47.2	4.6
16	26/2/2008	1246.6	278.8	335.0		8.9	69.2							37.7	18.3	56.0	2.1
17	27/2/2008	1320.3	393.3	381.0		12.5	61.4							84.0	20.4	104.3	4.1
18	28/2/2008	891.1	179.8	654.0		12.5	75.5							98.8	22.0	120.8	4.5
19	29/2/2008	1463.7	517.3	597.0		16.2	76.4							87.3	20.0	107.3	4.4
20	1/3/2008	1372.3	535.5	453.0		13.5	68.5							84.0	23.0	107.0	3.7

Table 22: Observed Concentrations of Ambient Air Quality at Anand Vihar (Summer)

Sr. No.	Date	SPM ($\mu g/m^3$)	RSPM ($\mu g/m^3$)	PM$_{10}$ ($\mu g/m^3$)	PM$_{2.5}$ ($\mu g/m^3$)	SO$_2$ ($\mu g/m^3$)	NO$_X$ ($\mu g/m^3$)	CO (mg/m^3)	O3 (mg/m^3)	HCHO ($\mu g/m^3$)	CH$_4$ (ppm)	NMHC (ppm)	THC (ppm)	OC (ug/m^3)	EC (ug/m^3)	TC (ug/m^3)	OC /EC
1	21/22-05-07	1019.0	250.0	262.0		6.0	18.0							19.9	3.9	23.8	5.1
2	22/23-05-07	1315.0	271.0	368.0		31.8	67.1							27.0	3.6	30.6	7.5
3	23/24-05-07	962.3	285.7	297.5	82.0	13.3	33.7							35.5	8.9	44.4	4.0
4	24/25-05-07	962.3	275.7	442.0	102.0	14.7	36.7							32.0	4.6	36.6	7.0
5	25/26-05-07	1139.3	511.3	209.0	56.0	20.7	40.2			5				29.8	7.5	37.3	4.0
6	26/27-05-07	974.0	361.7	163.0		24.2	48.7							25.8	8.9	34.7	2.9
7	27/28-05-07	974.0	373.3	308.5		33.8	67.0							53.2	5.8	59.0	9.1
8	28/29-05-07	1020.0	340.7	206.0		6.0	34.1	1.45	7.7					24.1	3.2	27.3	7.5
9	29/30-05-07	716.7	322.7	171.5		7.7	30.2	1.40	14.3					23.9	3.9	27.8	6.1
10	30/31-05-07	965.7	322.7	298.5		12.5	46.0	1.46	25.9					52.5	5.8	58.3	9.0
11	31/01-05-07	1004.7	207.7	296.5		10.5	58.2	1.58	22.61					49.3	7.3	56.6	6.8
12	01/02-06-07	1210.7	207.7	301.0		11.7	32.8	1.40	33.0					14.7	7.0	21.8	2.1
13	02/03-06-07	1446.3	241.0	172.5		20.6	33.6	1.49	18								
14	03/04-06-07	1695.0	581.7	382.0		9.8	29.8	1.41	28.5								
15	04/05-06-07	1695.0	673.0	417.8		6.3	22.1							29.2	5.1	34.3	5.7
16	05/06-06-07	1543.7	341.0	249.5		5.8	22.8							25.3	4.7	30.1	5.3
17	06/07-06-07	1922.5	322.3	306.8		6.0	25.3							24.0	3.8	27.8	6.3
18	07/08-06-07	1660.0	377.7	475.7		6.0	19.8							25.0	4.6	29.5	5.5
19	08/09-06-07	1272.3	370.3	333.7		17.0	32.3							27.4	8.3	35.7	3.3
20	09/10-06-07	1944.3	426.0	486.0		19.5	37.3							45.6	6.2	51.8	7.4

Table 23: Observed Concentrations of Ambient Air Quality at Anand Vihar (Post Monsoon)

Sr. No.	Date	SPM (µg/m^3)	RSPM (µg/m^3)	PM$_{10}$ (µg/m^3)	PM$_{2.5}$ (µg/m^3)	SO$_2$ (µg/m^3)	NO$_X$ (µg/m^3)	CO (mg/m^3)	O3 (mg/m^3)	HCHO (µg/m^3)	CH$_4$ (ppm)	NMHC (ppm)	THC (ppm)	OC (ug/m^3)	EC (ug/m^3)	TC (ug/m^3)	OC /EC
1	11/12.10.07	867.0	230.2	260.0		19.4	84.7							24.0	3.9	27.9	6.2
2	12/13.10.07	663.0	252.8	304.0		6.7	66.2			16.0				70.9	4.6	75.5	15.5
3	13/14.10.07	784.8	329.3	392.0		22.5	79.0							82.8	8.2	91.0	10.1
4	14/15.10.07	924.1	516.3	552.0		15.3	66.3							50.0	4.2	54.2	12.0
5	15/16.10.07	647.7	215.7	328.5		29.3	64.2							63.8	7.5	71.3	8.4
6	16/17.10.07	459.4	217.3	177.0		32.2	41.4							50.3	7.0	57.3	7.2
7	17/18.10.07	644.2	365.7	418.0		17.0	72.1							92.2	8.0	100.2	11.5
8	18/19.10.07	595.5	306.8	362.0		13.0	112.0	1.28	43.2		2.1	1.3	3.45	91.9	8.8	100.7	10.5
9	19/20.10.07	674.9	304.9	380.0		15.0	104.6	1.30	44.9		1.8	0.9	2.68	30.0	4.7	34.7	6.3
10	20/21.10.07	892.0	220.7	517.5	209	16.8	54.6	2.02	34.6		2.1	1.3	3.41	70.0	7.4	77.4	9.4
11	21/22.10.07	780.6	273.4	440.5	146	20.9	47.8	1.71	22.5		3.1	1.4	4.46	89.3	7.3	96.6	12.3
12	22/23.10.07	1059.0	448.0	734.0	268	49.0	101.0	1.75	26.6		2.7	1.3	4.01				
13	23/24.10.07	1032.4	547.0	644.0		28.4	77.8	2.32	35.8		2.2	0.9	3.09				
14	24/25.10.07	1009.3	328.3	512.5		11.4	92.5	1.83	42.3		3.4	1.2	4.64				
15	25/26.10.07	1059.5	429.0	655.0		39.3	119.0							175.9	18.9	194.8	9.3
16	26/27.10.07	1261.0	392.2	795.2		22.0	112.0							152.3	20.0	172.3	7.6
17	27/28.10.07	746.7	323.4	461.0		43.4	114.5							124.7	20.6	145.3	6.1
18	28/29.10.07	1020.7	347.6	617.0		6.8	125.0							64.3	12.4	76.7	5.2
19	29/30.10.07	1156.0	444.0	761.0		16.0	107.0							144.9	21.0	165.9	6.9
20	30/31.10.07	1285.0	405.0	842.3		39.0	66.0										

Table 24: Observed Concentrations of Ambient Air Quality at Anand Vihar (Winter)

Sr. No.	Date	SPM (μg/m^3)	RSPM (μg/m^3)	PM$_{10}$ (μg/m^3)	PM$_{2.5}$ (μg/m^3)	SO$_2$ (μg/m^3)	NO$_X$ (μg/m^3)	CO (mg/m^3)	O3 (mg/m^3)	HCHO (μg/m^3)	CH$_4$ (ppm)	NMHC (ppm)	THC (ppm)	OC (ug/m^3)	EC (ug/m^3)	TC (ug/m^3)	OC /EC
1	15/01/08	504.7	328.0	317.0		14.0	100.0							46.4	12.9	59.3	3.6
2	16/01/08	547.8	342.1	353.0		11.3	43.5							53.6	11.606	65.2	4.6
3	17/01/08	625.0	490.7	529.0		24.9	85.2							86.1	25.657	111.7	3.4
4	18/01/08	429.1	228.1	333.0		11.5	60.0							46.6	11.2	57.8	4.2
5	19/01/08	526.8	197.7	259.0		8.9	71.6							46.75	11.613	58.4	4.0
6	20/01/08	500.5	249.1	301.0		10.1	44.4							52.0	23.824	75.8	2.2
7	21/01/08	541.1	243.4	289.0		17.9	85.7							58.1	8.7	66.9	6.6
8	22/01/08	546.4	292.7	306.0		17.1	55.0	1.54			2.8	0.5	3.27	60.7	11.884	72.6	5.1
9	23/01/08	652.7	345.1	295.0		14.0	67.0	1.25			3.0	0.2	3.18	68.4	16.386	84.8	4.2
10	24/01/08	624.9	421.7	432.0	176	33.0	78.0	1.81			2.4	0.3	2.67	83.3	9.2987	92.6	9.0
11	25/01/08	541.0	279.0	198.0	194	27.0	64.1	1.23			2.7	0.3	3.02	75.2	9.5777	84.8	7.9
12	26/01/08	556.0	230.0	282.0	224	16.7	58.0	2.14			3.2	1.0	4.19	51.0	15.588	66.6	3.3
13	27/01/08	698.2	342.1	346.0		16.3	73.4	1.75		11	2.5	0.5	2.99	66.0	18.711	84.7	3.5
14	28/01/08	694.5	341.0	449.0		13.9	43.7	2.09			3.4	0.9	4.34	84.53	23.29	107.8	3.6
15	29/01/08	772.1	346.5	595.7		18.6	77.0							75.0	35.6	110.6	2.1
16	30/1/2008	604.6	286.7	405.7		8.2	87.0							59.3	17.75	77.0	3.3
17	31/1/2008	678.9	299.9	422.7		13.6	92.6							56.0	27.409	83.4	2.0
18	1/2/2008	987.8	503.7	678.0		14.0	102.0							80.0	24.9	104.9	3.2
19	2/2/2008	787.7	339.6	445.3		13.6	70.6							75.3	22.29	97.6	3.4
20	3/2/2008	735.4	332.4	362.3		14.7	74.8							63.0	27.04	90.0	2.3

Table 25: Observed Concentrations of Ambient Air Quality at ISBT (Summer)

Sr. No.	Date	SPM ($\mu g/m^3$)	RSPM ($\mu g/m^3$)	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	NO_X ($\mu g/m^3$)	CO (mg/m^3)	O3 (mg/m^3)	HCHO ($\mu g/m^3$)	CH_4 (ppm)	NMHC (ppm)	THC (ppm)	OC (ug/m^3)	EC (ug/m^3)	TC (ug/m^3)	OC /EC
1	14-15/06/07	573.0	165	149.0		6.0	52.2	52.17	18.7								
2	15-16/06/07	612.3	190	197.0		6.1	48.0	48.00	20.8					14.1	12.6	26.7	1.1
3	16-17/06/07	572.3	186.0	210.5	102	6.8	34.8	34.83	21.6	7				21.1	6	27.1	0.9
4	17-18/06/07	563.0	181.7	194.5	105	6.4	41.7	41.67	21.2					28.9	8.7	37.6	0.6
5	18-19/06/07	447.0	155.7	207.5	114	6.7	45	97.33	22.1					42.4	36.7	79.1	1.2
6	19-20/06/07	599.3	310.3			13.5	51.5	51.50	20.2					38.7	28.6	67.3	1.4
7	20-21/06/07	649.7	237.3			6.5	35.0	35.00	19.4					54.4	20.4	74.9	2.7
8	21-22/06/07	399.3	157.7	218.5		4.3	57.8							33.8	33.4	67.2	1.0
9	22-23/06/07	442.3	159.7	122.5		6.0	45.3							11.3	10.3	21.6	1.1
10	23-24/06/07	368.7	217.3	125.5		6.2	52.0										0.0
11	24-25/06/07	322.0	119.7	106.5		6.1	52.5							16.1	14.8	30.9	1.1
12	25-26/06/07	390.7	123.0	92.0		6.8	55.3							17.7	14.1	31.7	1.3
13	26-27/06/07	373.3	168.7	131.5		9.2	47.7							32.0	15.0	47.0	2.1
14	27-28/06/07	311.3	83.7	113.5		3.0	39.3							20.0	12.5	32.5	1.6
15	28-29/06/07	643.7	193.3	189.3		7.7	60.8							30.7	21.0	51.7	1.5
16	29-30/06/07	507.3	171.0	161.2		9.0	52.3							30.8	27.5	58.3	1.1
17	30-01/0707	390.0	137.7	130.3		9.7	57.1							23.3	22.6	45.8	1.0
18	01-02/07/07	314.3	121.0	113.3		4.0	44.2							22.4	16.6	39.0	1.4
19	02-03/07/07	389.3	126.7	110.5		5.7	48.5							23.8	20.8	44.6	1.1
20	03-04/07/07	333.0	113.7	105.5		4.8	34.7							26.0	21.6	47.6	1.2

Table 26: Observed Concentrations of Ambient Air Quality at ISBT (Post Monsoon)

Sr. No.	Date	SPM (μg/m^3)	RSPM (μg/m^3)	PM$_{10}$ (μg/m^3)	PM$_{2.5}$ (μg/m^3)	SO$_2$ (μg/m^3)	NO$_X$ (μg/m^3)	CO (mg/m^3)	O3 (mg/m^3)	HCHO (μg/m^3)	CH$_4$ (ppm)	NMHC (ppm)	THC (ppm)	OC (ug/m^3)	EC (ug/m^3)	TC (ug/m^3)	OC /EC
1	19/20.11.07	1562.4	546.2	857.0		7.0	137.4							235.4	44.8	280.2	5.3
2	20/21.11.07	1387.4	608.0	422.0		10.0	92.9							208.4	33.1	241.5	6.3
3	21/22.11.07	1248.0	534.0	871.0		8.5	129.9							129.2	19.6	148.8	6.6
4	22/23.11.07	1248.9	688.0	805.0		20.0	137.8							176.7	25.2	201.9	7.0
5	23/24.11.07	1343.1	679.5	958.0		14.5	144.6							139.1	16.0	155.1	8.7
6	24/25.11.07	1288.2	646.9	834.0		17.2	132.3							193.0	20.6	213.6	9.4
7	25/26.11.07	1432.8	651.8	789.0		17.8	165.1										
8	26/27.11.07	1258.7	594.1	655.0		19.5	111.3	2.1	11.3		2.7	0.7	3.4				
9	27/28.11.07	1348.0	546.2	669.0		12.5	109.7	2.2	14.1		2.7	0.5	3.2				
10	28/29.11.07	1569.0	608.2	798.0		21.9	182.8	1.2	15.1	18	2.7	0.4	3.1				
11	29/30.11.07	1256.3	647.3	505.0	103	25.0	86.2	1.2	43.3		2.8	0.6	3.4				
12	30/01.11.07	1476.6	553.4	438.0	199	25.5	158.3	1.7	37.6		3.0	0.4	3.5				
13	01/02.12.07	1353.5	515.8	303.0	146	30.6	130.0	1.8			3.3	0.4	3.8	118.8	19.0	137.8	6.2
14	02/03.12.07	947.8	395.0	240.0		31.0	100.8	2.3			3.3	0.7	4.0	80.3	9.0	89.3	8.9
15	03/04.12.07	670.1	223.3	294.0		11.0	69.3							67.3	11.0	78.3	6.1
16	04/05.12.07	906.7	310.1	518.0		19.2	96.6							83.3	20.0	103.3	4.2
17	05/06.12.07	1138.9	500.9	650.0		22.2	94.6										
18	06/07.12.07	1318.4	551.8	813.0		32.2	130.4							234.6	51.3	285.9	4.6
19	07/08.12.07	1259.9	574.2	1028.0		20.0	153.2							118.9	24.1	143.0	4.9
20	08/09.12.07	1263.6	534.0	1053.0		15.2	115.1							121.1	24.6	145.7	4.9

Table 27: Observed Concentrations of Ambient Air Quality at ISBT (Winter)

Sr. No.	Date	SPM (μg/m^3)	RSPM (μg/m^3)	PM$_{10}$ (μg/m^3)	PM$_{2.5}$ (μg/m^3)	SO$_2$ (μg/m^3)	NO$_X$ (μg/m^3)	CO (mg/m^3)	O3 (mg/m^3)	HCHO (μg/m^3)	CH$_4$ (ppm)	NMHC (ppm)	THC (ppm)	OC (ug/m^3)	EC (ug/m^3)	TC (ug/m^3)	OC /EC
1	19/12/07	1291.9	552.7	661.0		6.0	95.0	0.9	10.9		2.7	0.7	3.4				
2	20/12/07	851.9	329.9	346.4		11.7	85	0.9	12.9		3.0	0.8	3.7	82.8	16	98.8	5.2
3	21/12/07	843.7	214.6	278.9	128	16.6	135.7	1.3	15.8		2.8	0.5	3.3	40.6	16.933	57.6	2.4
4	22/12/07	680.9	222.6	269.5	122	10.5	149.0	0.6	15.1		2.9	0.4	3.3	38.9	13.084	52.0	3.0
5	23/12/07	954.9	351.0	510.0	160	8.3	129.3	1.9	11.4		3.5	0.7	4.1	37.28	28.677	66.0	1.3
6	24/12/07	940.6	361.0	448.0		14.2	60.4	0.7	11.4		2.8	0.5	3.2	77.5	25.989	103.5	3.0
7	25/12/07	878.7	378.9	394.0		19.6	100.1	0.9	12.0		3.2	0.4	3.6				
8	26/12/07	825.7	286.7	371.5		7.6	74.6							91.1	16.184	107.3	5.6
9	27/12/07	716.8	243.0	295.6		20.1	82.8							54.4	10.438	64.8	5.2
10	28/12/07	867.5	306.0	444.0		19.8	125.7							87.9	15.157	103.0	5.8
11	29/12/07	706.8	269.8	308.9		19.8	90.3							72.1	15.802	87.9	4.6
12	30/12/07	720.0	253.5	212.0		18.6	71.4							66.4	14.566	81.0	4.6
13	31/12/07	887.3	408.9	350.0		18.3	114.8							81.1	17.06	98.2	4.8
14	1/1/2008	1345.3	579.7	836.0		25.1	138.0			9				48.52	37.325	85.8	1.3
15	2/1/2008	1041.2	459.8	641.0		28.1	143.0										
16	3/1/2008	977.1	415.0	562.0		23.0	129.0							51.6	47.812	99.4	1.1
17	4/1/2008	1142.9	505.7	545.0		20.7	115.9							79.3	52.349	131.7	1.5
18	5/1/2008	1247.1	573.3	794.0		28.0	129.0										
19	6/1/2008	1382.2	695.5	838.0		22.0	122.8							67.3	20.18	87.4	3.3
20	7/1/2008	1368.7	599.3	638.0		21.2	148.2							87.3	26.18	113.4	3.3

Table 28: Observed Concentrations of Ambient Air Quality at Loni Road (Summer)

Sr. No.	Date	SPM (µg/m^3)	RSPM (µg/m^3)	PM$_{10}$ (µg/m^3)	PM$_{2.5}$ (µg/m^3)	SO$_2$ (µg/m^3)	NO$_X$ (µg/m^3)	CO (mg/m^3)	O3 (mg/m^3)	HCHO (µg/m^3)	CH$_4$ (ppm)	NMHC (ppm)	THC (ppm)	OC (ug/m^3)	EC (ug/m^3)	TC (ug/m^3)	OC /EC
1	21/22-05-07	788.7	279.3	203.0		6.0	34.0							17.5	4.1	21.5	4.3
2	22/23-05-07	2007.3	443.7	868.5		22.0	57.1							90.0	12.9	102.9	7.0
3	23/24-05-07	1235.3	234.3	400.5		5.8	34.9							54.3	8.7	63.0	6.2
4	24/25-05-07	1376.0	401.0	436.0		20.8	39.4										
5	25/26-05-07	2568.0	271.0	472.5		9.2	28.0			11.0				63.2	7.3	70.6	8.7
6	26/27-05-07	2431.7	233.7	457.5		18.0	57.0							64.9	14.0	78.9	4.6
7	27/28-05-07	1834.0	430.0	718.5		15.0	48.7							93.6	15.3	108.9	6.1
8	28/29-05-07	1238.3	453.0	317.0		4.5	25.5							35.1	5.0	40.1	7.0
9	29/30-05-07	893.0	251.7	217.5		4.5	33.5							27.8	7.5	35.4	3.7
10	30/31-05-07	1090.7	307.0	413.5		16.5	43.3							60.7	8.0	68.7	7.6
11	31/1-05-07	1059.3	287.7	327.5		9.0	39.7							45.1	8.0	53.2	5.6
12	1/2-06-07	541.3	226.7	202.5		9.7	24.3							39.0	7.9	46.9	4.9
13	2/3-06-07	1066.7	409.3	269.5		5.5	21.3										
14	3/4-06-07	2154.0	404.3	337.0		6.7	28.2	2.7	42.9								
15	4/5-06-07	1231.0	282.7	349.5		4.2	16.2	2.8	35.0					24.2	3.7	27.9	6.5
16	5/6-06-07	1145.3	241.0	130.7	47.0	7.5	18.0	2.4	33.9					16.4	3.6	20.0	4.5
17	6/7-06-07	1322.0	263.3	193.0	46.0	4.0	9.4	2.9	24.3					13.5	3.1	16.6	4.3
18	7/8-06-07	868.3	235.0	273.8	46.0	4.5	21.2	2.7	15.1					17.7	3.4	21.1	5.1
19	8/9-06-07	675.0	171.7	284.5		5.8	26.3	2.4	15.9					37.1	6.6	43.6	5.7
20	9/10-06-07	1250.0	272.0	632.0		15.0	51.2	2.2	9.4					37.0	8.7	45.7	4.2

Table 29: Observed Concentrations of Ambient Air Quality at Loni Road (Post Monsoon)

Sr. No.	Date	SPM (µg/m^3)	RSPM (µg/m^3)	PM$_{10}$ (µg/m^3)	PM$_{2.5}$ (µg/m^3)	SO$_2$ (µg/m^3)	NO$_X$ (µg/m^3)	CO (mg/m^3)	O3 (mg/m^3)	HCHO (µg/m^3)	CH$_4$ (ppm)	NMHC (ppm)	THC (ppm)	OC (ug/m^3)	EC (ug/m^3)	TC (ug/m^3)	OC /EC
1	11/12.10.07	1216.9	338.0	589.0		6.0	37.0							94.9	5.4	100.4	17.4
2	12/13.10.07	1058.0	327.0	483.0		6.1	49.0			19				90.4	4.9	95.3	18.4
3	13/14.10.07	3145.7	960.8	687.5		6.2	36.7							117.7	5.8	123.5	20.3
4	14/15.10.07	2615.7	868.8	1310.5		6.3	37.0							168.5	9.9	178.4	17.0
5	15/16.10.07	2487.3	759.5	732.5		6.8	37.0							107.5	5.3	112.7	20.5
6	16/17.10.07	3521.0	665.0	888.5		7.0	36.0							86.7	5.6	92.2	15.6
7	17/18.10.07	2378.8	902.0	648.5		6.8	39.0							116.9	5.9	122.8	19.8
8	18/19.10.07	1185.8	311.0	341.0		7.8	50.0							91.2	6.9	98.1	13.2
9	19/20.10.07	1906.4	566.0	546.5		8	44.0							103.5	5.6	109.1	18.6
10	20/21.10.07	3234.4	984.2	837.5		9.0	39.0							123.2	7.2	130.4	17.1
11	21/22.10.07	3240.9	526.0	1490.0		6.0	67.0							177.5	9.7	187.2	18.3
12	22/23.10.07	3243.0	728.0	1506.0		6.9	46.0							184.9	10.0	194.9	18.5
13	23/24.10.07	3502.0	693.6	1342.0		7.8	40.0							203.0	11.5	214.5	17.6
14	24/25.10.07	3726.9	671.5	1291.5		8.0	37.0	1.4	43.7		2.2	1.3	3.5	184.2	14.8	199.0	12.4
15	25/26.10.07	3206.6	953.0	1495.0		6	47.0	1.8	45.4		3.1	1.3	4.4	277.5	24.1	301.6	11.5
16	26/27.10.07	3877.0	1385.0	1290.5		6.5	58.0	1.8	39.8		2.5	1.5	4.0	222.3	22.5	244.8	9.9
17	27/28.10.07	2258.0	513.0	521.0	375	6.4	43.0	1.6	33.7		2.4	1.3	3.7				
18	28/29.10.07	2399.7	735.0	1275.0	347	6.8	40.0	1.9	41.3		2.4	1.1	3.5	226.5	21.5	248.1	10.5
19	29/30.10.07	3741.0	1365.0	2023.0		6.5	57.0	2.2	41.6		2.6	1.2	3.8	183.3	9.9	193.2	18.4
20	30/31.10.07	3357.6	892.9	1731.0		6.8	38.0	2.0	43.2		2.4	0.8	3.2				

Table 30: Observed Concentrations of Ambient Air Quality at Loni Road (Winter)

Sr. No.	Date	SPM (µg/m^3)	RSPM (µg/m^3)	PM$_{10}$ (µg/m^3)	PM$_{2.5}$ (µg/m^3)	SO$_2$ (µg/m^3)	NO$_X$ (µg/m^3)	CO (mg/m^3)	O3 (mg/m^3)	HCHO (µg/m^3)	CH$_4$ (ppm)	NMHC (ppm)	THC (ppm)	OC (ug/m^3)	EC (ug/m^3)	TC (ug/m^3)	OC /EC
1	15/01/08	736.0	278.0	345.0		18.0	73.0										
2	16/01/08	887.7	354.0	394.0		20.0	47.3							61.6	10.8	72.4	5.7
3	17/01/08	1238.1	604.0	365.0		28.0	60.7							164.3	19.1	183.5	8.6
4	18/01/08	852.0	240.0	290.5		32.0	90.7							42.6	12.2	54.8	3.5
5	19/01/08	654.3	176.0	277.0		14.0	66.0							50.7	7.7	58.4	6.6
6	20/01/08	668.7	175.0	243.0		21.0	60.7							41.2	7.2	48.4	5.7
7	21/01/08	675.0	294.0	307.0		33.0	90.7							54.1	15.6	69.7	3.5
8	22/01/08	1128.0	298.0	421.0		23.0	69.4							76.6	11.7	88.3	6.5
9	23/01/08	1903.0	595.0	440.5		33.0	85							111.2	15.6	126.8	7.1
10	24/01/08	1803.4	476.0	626.0		28.0	93.0							87.3	17.9	105.1	4.9
11	25/01/08	1132.0	289.9	379.5		19.0	71.2							69.3	21.6	90.9	3.2
12	26/01/08	864.7	251.1	332.5		21.0	74.8							42.3	14.2	56.4	3.0
13	27/01/08	989.7	291.4	360.0		23.0	77.1			8				57.9	14.4	72.3	4.0
14	28/01/08	1335.3	435.9	599.0		21.0	78.6	1.3	49.3		3.8	0.8	4.6	92.5	14.2	106.7	6.5
15	29/01/08	1689.4	467.0	653.0		13.0	74.0	1.9			3.6	0.7	4.3				
16	30/1/2008	1059.8	392.5	418.5	296	13.0	77.0	2.0			3.8	0.7	4.5				
17	31/1/2008	1014.6	326.7	452.7	276	14.0	69.0	1.6			3.1	0.5	3.6				
18	1/2/2008	1280.0	639.1	658.3	350	20.0	76.1	1.6			4.0	0.7	4.7				
19	2/2/2008	1116.4	597.8	895.0		22.0	77.2	2.2			3.7	0.8	4.5				
20	3/2/2008	1428.0	430.0	665.5		11.0	68.3	1.5			3.3	0.8	4.1				

Table 31 : Average Elemental Concentrations at Ten Different Sites During Three Seasons

	Ag	Al	Ba	Ca	Cd	Co	Cr	Cu	Fe	Ga	In	La	Mg	Mn	Mo	Na	Ni	P	Pb	Pd
ISBT																				
Summer	0.168	4.168	0.136	2.264	0.067	0.067	0.128	0.097	2.856	0.333	0.067	0.067	0.647	0.139	0.067	0.230	0.068	0.581	0.296	0.101
Post Monsoon	0.042	8.715	0.122	8.768	0.222	0.069	0.069	0.201	7.589	0.486	0.232	0.222	2.029	0.552	0.222	0.098	0.222	1.320	0.844	0.042
Winter	0.042	8.448	0.073	10.256	0.042			0.178	6.624	0.208	0.050	0.042	2.692	0.234	0.042	0.261	0.047	0.732	0.788	0.042
Pitampura																				
Summer	0.067	3.897	0.118	1.675	0.067	0.067	0.111	0.282	1.933	0.333	0.067	0.067	0.550	0.109	0.067	0.092	0.067	0.596	0.653	0.067
Post Monsoon	0.083	14.878	0.431	14.634	0.079	0.083	0.097	0.457	12.892	0.417	0.083	0.083	4.578	0.400	0.083	0.278	0.083	0.681	1.275	0.083
Winter	0.059	20.531	0.113	13.994	0.054	0.050	0.071	0.307	7.826	0.268	0.054	0.054	3.431	0.228	0.050	0.316	0.056	0.906	1.576	0.054
Naraiana																				
Summer	0.042	7.509	0.191	6.875	0.067	0.067	0.067	0.130	5.253	0.333	0.067	0.102	2.288	0.149	0.067	0.091	0.067	0.878	0.314	0.067
Post Monsoon	0.042	7.021	0.186	10.766	0.083	0.083	0.084	0.188	6.866	0.208	0.088	0.088	2.385	0.195	0.088	0.128	0.088	0.625	0.734	0.087
Winter	0.042	10.936	0.265	15.077	0.042	0.042	0.072	0.099	8.417	0.208	0.054	0.042	2.984	0.212	0.042	0.310	0.049	0.877	0.983	0.042
Prahladpur																				
Summer	0.080	5.713	0.097	6.171	0.083	0.070	0.085	0.488	5.966	0.398	0.080	0.080	2.509	0.283	0.070	0.082	0.070	0.756	6.591	0.070
Post Monsoon	0.096	7.294	0.102	2.394	0.088		0.127	0.920	5.299	0.224	0.045	0.045	1.523	0.214	0.045	0.286	0.060	0.451	8.734	0.060
Winter	0.053	6.585	0.077	3.996	0.051	0.051	0.051	0.059	4.176	0.278	0.051	0.051	1.759	0.185	0.056	0.161	0.053	0.673	3.737	0.051
Ashram Chowk																				
Summer	0.067	16.441	0.128	13.060	0.067	0.067	0.067	0.110	10.726	0.333	0.067	0.067	5.088	0.274	0.067	0.153	0.105	0.994	0.300	0.067
Post Monsoon	0.108	11.811	0.292	15.065	0.066	0.066	0.074	0.243	9.603	0.331	0.074	0.066	3.193	0.250	0.066	0.161	0.083	1.147	0.942	0.066
Winter	0.105	9.398	0.094	10.883	0.067	0.071	0.066	0.114	6.467	0.315	0.065	0.063	2.393	0.158	0.063	0.199	0.072	0.881	0.461	0.067
Anand Vihar																				
Summer	0.067	15.199	12.900	12.900	0.067	0.067	0.067	0.100	10.242	0.333	0.067	0.067	5.021	0.284	0.067	0.151	0.096	1.175	0.427	0.067
Post Monsoon	0.063	14.161	0.321	14.450	0.079	0.063	0.091	0.760	10.709	0.312	0.065	0.063	3.670	0.337	0.063	0.210	0.071	1.319	4.828	0.063
Winter	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Dhaula Kuan																				
Summer	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Post Monsoon	0.061	5.125	0.065	1.721	0.061	0.059	0.059	0.095	4.152	0.304	0.066	0.059	1.005	0.133	0.059	0.084	0.457	0.061	0.588	0.073
Winter	0.042	5.998	0.080	8.724	0.042	0.042	0.047	0.403	6.326	0.208	0.045	0.042	2.325	0.150	0.042	0.224	0.042	0.728	1.034	0.044
Loni Road																				
Summer	0.075	10.843	0.171	11.137	0.075	0.075	0.088	0.582	11.722	0.375	0.075	0.075	3.518	0.314	0.075	0.252	0.185	--	1.172	0.075
Post Monsoon	0.134	33.791	0.391	23.082	0.120	0.060	0.060	1.264	26.992	0.277	0.070	0.060	9.062	0.576	0.060	0.308	0.074	1.064	6.124	0.060
Winter	0.069	28.483	0.175	21.786	0.071	0.069	--	0.292	20.304	0.347	0.065	0.069	7.345	0.424	0.069	0.364	0.073	1.771	4.499	0.074
SSI –GTK																				
Summer	0.067	4.879	0.055	4.220	0.067	0.067	0.423	0.392	5.962	0.333	0.067	0.067	2.250	0.541	0.067	0.084	0.100	0.682	0.911	0.072
Post Monsoon	0.083	15.348	0.265	14.147	0.083	2.068	--	0.754	22.572	0.417	0.083	0.083	4.188	1.440	0.083	0.320	0.116	1.042	2.210	0.083
Winter	0.042	2.075	0.097	11.226	0.042	0.042	1.189	0.720	13.498	0.255	0.042	0.042	3.235	0.905	0.042	0.279	0.067	1.034	2.400	0.052
Mayapuri																				
Summer	0.075	2.947	0.205	5.166	0.075	0.075	0.075	--	0.235	5.285	0.333	0.075	0.075	1.226	0.067	0.062	0.067	0.643	0.403	0.067
Post Monsoon	0.063	6.171	0.082	2.952	0.056	0.056	0.262	--	6.410	0.312	0.063	0.063	1.247	0.181	0.063	0.078	0.063	0.417	0.061	0.061
Winter	0.042	7.858	0.084	9.994	0.042	0.042	0.102	0.042	6.484	0.208	0.045	0.042	2.484	0.140	0.042	0.176	0.042	0.594	0.683	0.042

-- Not detected

Table 31 (Contd..) : Average Elemental Concentrations at Ten Different Sites During Three Seasons

	Rb	Si	Sn	Sr	Ti	V	Se	Zn	Zr	As	Hg	Sb	Y
ISBT													
Summer	0.148	9.793	0.133	0.067	0.170	0.067	0.067	0.769	0.067	0.067	0.067	0.067	
Post Monsoon	0.729	13.549	0.124	0.222	0.384	0.222	0.222	1.312	0.222	0.222	0.222	0.222	
Winter	0.313	11.745	0.168	0.061	0.304	0.046	0.042	1.023	0.042	0.042	0.042	0.042	
Pitampura													
Summer	0.500	0.133		0.067	0.134	0.067	0.067	0.622	0.071	0.067	0.067	0.067	0.067
Post Monsoon	0.625	13.300	0.242	0.169	0.654	0.083	0.083	2.476	0.083	0.083	0.422	0.083	0.083
Winter	0.402	14.637	1.647	0.086	0.350	0.054	0.050	1.923	0.050	0.050	0.050	0.050	0.050
Naraiana													
Summer	0.535	9.656	0.135	0.072	0.324	0.067	0.067	0.436	0.067	0.067	0.067	0.067	0.067
Post Monsoon	0.625	8.545	0.165	0.086	0.315	0.088	0.088	0.915	0.079	0.088	0.088	0.088	0.088
Winter	0.297	21.615	0.182	0.087	0.407	0.049	0.042	0.959	0.042	0.042	0.042	0.042	0.042
Prahladpur													
Summer	0.577	3.188	0.486	0.083	0.211	0.071	0.070	3.802	0.070	0.091	0.118	0.125	0.070
Post Monsoon	0.451	24.491	0.353	0.063	0.299	0.060	0.060	5.496	0.060	0.064	0.072	0.060	0.060
Winter	0.382	7.839	0.350	0.053	0.224	0.052	0.051	1.237	0.051	0.075	0.093	0.093	0.051
Ashram Chowk													
Summer	0.502	10.697	0.133	0.086	0.497	0.069	0.067	0.067	0.067	0.067	0.067	0.067	0.228
Post Monsoon	0.497	21.377	0.149	0.145	0.441	0.067	0.066	0.989	0.066	0.066	0.066	0.066	0.066
Winter	0.473	13.461	2.137	0.077	0.346	0.063	0.063	0.751	0.063	0.063	0.063	0.063	0.063
Anand Vihar													
Summer	0.500	12.164	0.133	0.077	0.492	0.067	0.067	0.333	0.067	0.067	0.067	0.067	0.067
Post Monsoon	0.469	19.998	0.320	0.095	0.507	0.067	0.063	2.473	0.063	0.063	0.063	0.063	0.063
Winter	--	--	--	--	--	--	--	--	--	--	--	--	--
Dhaula Kuan													
Summer	--	--	--	--	--	--	--	--	--	--	--	--	--
Post Monsoon	0.457	15.910	0.122	0.061	0.239	0.057	0.059	0.522	0.062	0.068	0.065	0.059	0.059
Winter	0.313	6.261	0.211	0.057	0.299	0.043	0.042	0.669	0.042	0.042	0.042	0.042	0.042
Loni Road													
Summer	0.375	9.146	0.154	0.081	0.402	0.076	0.075	0.497	0.075	0.075	0.058	0.075	0.075
Post Monsoon	0.446	16.740	0.289	0.137	1.038	0.092	0.060	3.316	0.060	0.068	0.060	0.060	0.060
Winter	0.521	43.880	2.426	0.110	0.872	0.088	0.069	2.533	0.074	0.076	0.042	0.069	0.069
SSI -GTK													
Summer	0.313	5.973	0.133	0.067	0.182	0.067	0.067	0.917	0.067	0.067	0.067	0.067	0.067
Post Monsoon	0.625	12.533	0.274	0.135	0.609	0.083	0.083	3.457	0.083	0.083	--	0.083	0.083
Winter	0.382	8.563	0.352	0.089	0.343	0.042	0.042	3.683	0.042	0.042	0.042	0.042	0.042
Mayapuri													
Summer	0.500	2.257	0.141	0.075	0.167	0.067	0.069	0.329	0.067	0.067	0.067	0.067	0.112
Post Monsoon	0.417	11.520	0.115	0.056	0.290	0.063	0.063	0.844	0.058	0.063	0.063	0.063	0.063
Winter	0.313	6.079	0.174	0.063	0.273	0.042	0.042	0.398	0.042	0.042	0.042	0.042	0.042

-- Not detected

Table 32 : Average Ions Concentrations at Ten Different Sites During Three Seasons

	Fl^-	**Cl^-**	**NO_3^-**	**SO_4^-**	**Na^+**	**NH_3^+**	**K^+**	**Mg^+**	**Ca^+**
ISBT									
Summer	0.206	10.192	2.788	4.646	2.255	0.277	1.567	0.359	1.440
Post Monsoon	0.788	15.022	16.760	31.326	3.950	10.734	3.694	6.885	10.374
Winter	0.414	34.230	30.208	38.591	5.371	13.501	4.250	1.393	12.140
Pitampura									
Summer	0.550	5.352	2.004	9.274	8.538	3.850	3.131	0.940	7.112
Post Monsoon	1.048	68.916	44.965	43.372	5.675	25.512	8.208	3.444	15.325
Winter	0.654	47.461	44.620	46.094	8.788	20.539	5.935	1.940	14.566
Naraiana									
Summer	6.480	12.769	4.008	8.620	7.736	4.033	9.633	4.412	8.803
Post Monsoon	0.444	17.339	9.458	20.240	8.953	6.289	6.716	7.911	25.251
Winter	0.329	28.917	28.256	35.337	3.860	16.448	5.368	1.814	21.076
Prahladpur									
Summer	0.985	19.915	7.934	12.758	18.833	7.562	7.246	2.230	13.213
Post Monsoon	0.306	22.060	13.045	33.830	4.192	7.053	3.799	0.944	6.375
Winter	1.280	51.891	28.327	31.429	6.039	22.298	6.041	3.369	12.057
Ashram Chowk									
Summer	0.676	17.179	2.856	10.341	7.302	0.000	8.828	3.609	10.048
Post Monsoon	0.552	20.346	19.496	26.561	8.992	10.208	7.769	3.408	15.922
Winter	0.706	21.716	19.731	21.073	7.482	17.690	4.241	0.720	11.327
Anand Vihar									
Summer	0.621	9.399	3.285	7.342	4.373	0.501	2.132	0.582	4.302
Post Monsoon	0.431	31.651	16.905	27.775	12.797	10.233	12.007	5.148	20.453
Winter	--	--	--	--	--	--	--	--	--
Dhaula Kuan									
Summer	--	--	--	--	--	--	--	--	--
Post Monsoon	0.288	9.075	6.196	13.397	0.453	2.461	2.461	2.587	9.422
Winter	0.442	31.609	28.438	37.143	4.210	12.721	3.983	2.749	10.738
Loni Road									
Summer	1.597	24.097	4.980	25.783	21.499	1.003	3.023	1.400	17.142
Post Monsoon	0.549	34.469	21.215	41.365	8.522	1.274	9.489	9.862	42.203
Winter	1.526	38.951	29.295	49.659	9.922	15.332	7.476	3.644	23.019
SSI-GTK									
Summer	0.883	13.604	5.172	15.879	14.625	5.401	5.148	2.022	10.632
Post Monsoon	1.709	46.927	55.625	70.437	5.515	18.176	9.362	5.052	76.985
Winter	0.446	43.451	33.878	51.244	3.253	19.283	5.082	3.012	14.445
Mayapuri									
Summer	0.679	12.406	3.769	13.196	8.663	0.118	7.824	42.217	8.153
Post Monsoon	0.520	11.623	14.383	25.650	4.253	2.559	1.376	7.696	17.579
Winter	0.123	35.087	0.009	16.455	6.194	16.520	4.372	1.519	11.174

-- Not detected

Annexure 2.3 : Average Concentration of Molecular Marker at Ten Different Sites During Three Seasons

	Anand vihar			Ashram Chowk			Dhaulakuan			ISBT			Loni Road			Mayapuri			Naraina		
	Sum	Post Mon	Win	Sum	Post Mon	Win	Sum	Post Mon	Win	Sum	Post Mon	Win	Sum	Post Mon	Win	Sum	Post Mon	Win	Sum	Post Mon	Win
PAHs																					
Average	2.19	10.75	14.75	1.89	10.16	10.51		2.62	5.27	0.99	5.93	10.33	3.97	17.79	7.22	2.60	1.75	2.20	6.32	2.86	14.88
Minimum	0.01	0.07	0.06	0.01	0.08	0.06		0.03	0.06	0.02	0.04	0.05	0.02	0.15	0.06	0.01	0.01	0.03	0.03	0.01	0.06
Maximum	17.45	124.16	144.93	20.30	115.85	151.26		31.14	34.53	9.13	83.98	98.26	35.48	169.43	75.97	26.40	19.33	10.92	55.26	26.11	141.44
stdev	3.44	22.84	25.09	3.49	22.03	24.74		5.34	7.43	1.77	14.14	18.03	6.94	31.42	12.96	4.49	3.44	2.68	11.28	5.40	25.05
n-alkane																					
Average	10.22	45.62	55.21	6.82	42.59	33.61		9.51	32.29	4.96	26.22	38.64	19.10	56.46	25.84	10.25	8.64	8.48	35.03	19.15	49.03
Minimum	0.71	2.78	2.16	0.84	2.79	2.73		1.21	2.24	0.74	1.67	2.76	1.54	8.34	0.06	1.07	0.60	0.75	0.97	1.19	3.91
Maximum	25.10	88.52	113.92	15.87	94.51	58.95		21.65	54.82	9.63	44.73	74.42	40.51	114.97	54.61	28.26	17.56	17.46	79.81	41.00	77.82
stdev	7.91	28.11	33.67	4.70	27.47	16.85		6.43	16.07	2.66	12.92	21.11	12.94	31.50	15.20	7.93	5.94	4.73	26.57	13.41	24.25
Hopane																					
Average	0.82	2.90	4.93	1.65	3.56	2.01		1.07	2.69	1.16	1.73	2.45	2.06	4.62	1.14	1.65	1.60	1.41	1.40	1.01	2.66
Minimum	0.09	0.29	0.50	0.18	0.38	0.23		0.15	0.30	0.12	0.19	0.28	0.21	1.30	0.15	0.13	0.13	0.12	0.17	0.10	0.29
Maximum	2.85	11.39	19.61	5.88	14.03	8.60		3.99	11.13	4.16	7.25	9.79	8.09	16.52	4.87	6.15	5.76	5.47	5.43	4.00	10.52
stdev	0.81	2.94	4.94	1.56	3.68	2.19		1.06	2.84	1.08	1.87	2.55	2.09	4.37	1.25	1.58	1.54	1.37	1.44	1.06	2.74
Sterane																					
Average	0.54	2.03	4.40	0.80	1.95	1.15		0.55	1.62	0.54	0.95	1.44	1.21	3.19	0.84	0.77	0.72	0.72	1.04	0.65	1.65
Minimum	0.15	0.66	1.17	0.29	0.75	0.47		0.22	0.60	0.21	0.42	0.56	0.45	0.99	0.28	0.32	0.25	0.26	0.30	0.16	0.58
Maximum	2.33	7.16	12.68	3.43	7.84	4.36		2.21	5.18	2.45	4.06	5.71	5.10	14.00	3.76	3.14	3.28	3.13	3.85	2.49	6.13
stdev	0.63	2.25	4.02	0.90	2.05	1.16		0.58	1.56	0.64	1.05	1.49	1.33	3.68	0.99	0.82	0.87	0.83	1.23	0.71	1.67
Methyl-alkane																					
Average	0.08	0.33	0.73	0.14	0.38	0.58		0.12	0.40	0.15	0.55	0.40	0.17	0.76	0.22	0.20	0.05	0.30	0.28	0.16	0.44
Minimum	0.07	0.29	0.70	0.12	0.30	0.58		0.09	0.36	0.11	0.49	0.37	0.17	0.76	0.22	0.15	0.04	0.22	0.17	0.16	0.41
Maximum	0.08	0.37	0.76	0.16	0.45	0.58		0.14	0.45	0.20	0.61	0.42	0.17	0.76	0.22	0.24	0.07	0.38	0.40	0.16	0.47
stdev	0.01	0.05	0.04	0.03	0.11	0.00		0.04	0.06	0.07	0.08	0.03	0.00	0.00	0.00	0.07	0.03	0.11	0.17	0.00	0.04
Branched-alkane																					
Average	0.58	1.73	2.90	1.11	1.81	1.28		0.81	1.64	0.65	1.13	1.62	0.86	1.78	0.70	0.81	0.68	0.71	0.74	0.70	1.36
Minimum	0.30	0.51	1.05	0.49	0.75	0.47		0.34	0.69	0.31	0.46	0.37	0.38	1.07	0.43	0.42	0.23	0.43	0.27	0.35	0.53
Maximum	1.12	4.16	6.55	2.25	3.70	2.73		1.74	3.53	1.31	2.32	3.98	1.80	2.98	1.11	1.40	1.48	1.24	1.54	1.29	3.04
stdev	0.47	2.11	3.16	0.99	1.64	1.26		0.80	1.64	0.58	1.03	2.04	0.82	1.04	0.36	0.52	0.70	0.45	0.70	0.52	1.45
Cycloalkane																					
Average	0.19	1.01	1.59	0.26	0.87	1.20		0.23	0.83	0.17	0.80	1.37	0.83	2.35	0.61	0.28	0.18	0.30	0.39	0.56	1.33
Minimum	0.06	0.51	0.23	0.11	0.38	0.70		0.15	0.24	0.07	0.34	1.12	0.26	1.07	0.31	0.12	0.10	0.14	0.27	0.12	0.88
Maximum	0.40	1.39	3.13	0.45	1.43	1.92		0.38	1.47	0.32	1.25	1.59	1.95	3.82	0.86	0.55	0.36	0.54	0.50	1.60	1.64
stdev	0.14	0.40	1.37	0.14	0.44	0.46		0.09	0.55	0.09	0.42	0.23	0.68	1.14	0.23	0.17	0.11	0.20	0.10	0.59	0.30
Alkene	2.52	9.57	5.70	1.11	8.45	10.93		1.66	4.55	0.99	6.23	15.17	4.79	40.24	6.87	1.76	2.30	1.10	6.33	5.02	20.27
Levoglucosan	611.33	4549.86	3232.87	174.70	5097.58	4478.87		1381.39	1998.97	307.75	2457.67	4123.77	929.32	6188.00	4320.11	1317.94	1058.06	1015.06	4135.88	2157.66	7440.51

Annexure 2.3 : Average Concentration of Molecular Marker at Ten Different Sites During Three Seasons

	Pitampura			Prahladpur			SSIGTK		
	Sum	Post Mon	Win	Sum	Post Mon	Win	Sum	Post Mon	Win
PAHs									
Average	0.39	8.33	14.41	3.62	31.94	9.19	5.78	20.89	10.33
Minimum	0.00	0.08	0.12	0.03	0.18	0.03	0.03	0.22	0.05
Maximum	3.69	81.29	107.50	28.65	378.88	97.91	32.39	195.49	91.12
stdev	0.71	16.70	21.63	6.27	60.92	16.28	8.20	35.91	17.80
n-alkane									
Average	2.25	42.47	56.62	13.06	95.08	26.35	9.26	139.95	48.62
Minimum	0.19	3.45	2.93	0.76	5.29	1.68	0.91	15.89	3.34
Maximum	5.99	85.39	99.08	32.51	224.13	64.19	17.17	208.44	82.48
stdev	1.88	25.21	30.05	10.35	69.84	17.13	4.70	62.78	24.84
Hopane									
Average	0.19	2.90	3.35	0.45	3.05	0.55	1.46	6.91	2.66
Minimum	0.02	0.32	0.42	0.07	0.49	0.12	0.15	0.76	0.33
Maximum	0.63	11.96	13.62	1.55	11.32	1.87	5.07	27.21	9.74
stdev	0.18	3.16	3.51	0.44	2.98	0.53	1.38	7.07	2.60
Sterane									
Average	0.08	1.44	2.31	0.46	2.11	0.53	1.01	5.31	1.76
Minimum	0.02	0.56	0.72	0.07	0.74	0.09	0.33	1.85	0.71
Maximum	0.39	5.78	11.29	2.61	8.43	2.18	3.97	17.31	6.57
stdev	0.10	1.52	2.99	0.73	2.25	0.60	1.06	5.39	1.75
Methyl-alkane									
Average	0.04	0.44	0.57	0.12	0.40	0.09	0.24	1.47	0.52
Minimum	0.02	0.32	0.54	0.10	0.37	0.09	0.23	1.31	0.49
Maximum	0.05	0.56	0.60	0.13	0.43	0.09	0.25	1.63	0.55
stdev	0.03	0.17	0.04	0.02	0.04	0.00	0.01	0.23	0.04
Branched-alkane									
Average	0.13	1.07	1.47	0.37	2.77	0.37	1.65	5.59	2.02
Minimum	0.08	0.48	0.54	0.33	1.05	0.16	0.46	2.18	1.04
Maximum	0.20	2.17	3.28	0.46	5.97	0.78	3.98	11.97	3.67
stdev	0.06	0.95	1.57	0.08	2.77	0.35	2.02	5.53	1.43
Cycloalkane									
Average	0.02	0.90	1.33	0.44	4.40	0.80	0.63	4.64	1.86
Minimum	0.01	0.72	0.48	0.07	0.92	0.44	0.16	3.27	0.93
Maximum	0.04	1.12	2.27	0.83	15.19	1.15	1.43	5.55	2.35
stdev	0.01	0.21	0.76	0.36	6.07	0.29	0.58	0.89	0.59
Alkene	0.31	13.40	14.99	3.83	10.09	4.55	8.01	49.42	12.70
Levoglucosan	401.09	6428.43	7802.46	656.41	8633.22	3641.68	384.28	7523.97	3522.84

Annexure III: Emission Inventory

Table A3.1.1: Emission Factors: Area Sources

Fuel/Activity	Unit	Emission Factors (Kg/Unit)					Reference
		PM	SO_2	NOx	HC	CO	
LPG	MT	0.514	0.0004	3.45	18.8	15	CPCB* USEPA 2000 Reddy And Venkatraman
NG	10^3 m^3	0.1216	0.0096	1.6	1.344	0.176	CPCB* AP-42 http://epa.Gov
Kerosene	MT	0.61	4	2.5	19	62	CPCB*, USEPA 2000
Fuel wood	MT	15.3	0.2	1.4	115.4	0.2	CPCB* AP-42 Table 1.10-1
Wood for bakeries	MT	17.3	0.2	1.3	114.3	126.3	CPCB* AP42 (Sec.1.9, Pp. 1.10.4, Table 1.9.1)
Dung Cake	MT	1.9	0.48	1.4	29.8	31	CPCB* USEPA 2000 Reddy And Venkatraman
Coal	MT	20	13.3	1.4	10.5	24.92	CPCB TERI Report
Medical waste	MT	2.33	1.09	1.78	2.95	0.15	CPCB* EPA-AP42: Table 2.3.2
Diesel	KL	0.24	8.52	2.4	0.6	0.0067	CPCB* AP-42
Open Burning	MT	8	0.5	3	21.5	42	CPCB* USEPA 2000 AP-42
Diesel Generator sets	KW/hr	0.00133	0.00124	0.0188	0.0015	0.00406	CPCB* USEPA 2000 AP-42
Diesel Locomotives	(kg/l) for line Haul operation	0.0014	0.0043	0.0591		0.075	CPCB* USEPA 1992
Construction	Acre/ month	1.2					CPCB* USEPA 2000 AP-42

* EFs suggested by CPCB

Table A3.2.1: Emission Factors: Industrial Sources

Fuel/ Activity	Unit	% S	Emission Factors (Kg/Unit)					Reference
			PM	SO_2	NOx	HC	CO	
NG (Power Plant)	M^3		121.6×10^{-6}	9.6×10^{-6}	4480×10^{-6}	176×10^{-6}	1344×10^{-6}	EFs suggested by CPCB (feed basis) used for emission load estimation, AP-42 Table (1.4-1-2)
Coal (Power Plant)	MT	0.5	5 A*	19 S	11	0.05	0.25	EFs suggested by CPCB (feed basis) used for emission load estimation, AP-42 (Table 1.1-3-4) #A*=35% for beneficiated coal (DPCC)
DG Sets	KW-hr		1.24 E-03	9.6×10^{-6}	0.0188	1.5×10^{-3}	4.06×10^{-4}	EFs suggested by CPCB (Capacity basis: KW-hr) used for emission load estimation AP-42 (Table 3.3-1)
HSD	KL	0.5	0.24	18.81 x S	1.2	0.12	0.6	Emissions calculated using Revised AP-42 EFs (fuel basis) as the data made available by DPCC gives fuel related details only
LDO	KL	1.8	0.24	18.81 x S	1.2	0.12	0.6	Emissions calculated using Revised AP-42 Efs (fuel basis) as the data made available by DPCC gives fuel related details only
LPG	ML	0.02	2.1 (g/kg)	0.4 (g/kg)	1.8	0.07	0.252	Reddy And Venkatraman Http://Epa.Gov EFs suggested by CPCB (fuel basis) used for emission load estimation

Table A3.3.1: Emission Factors for Different Types and Makes of Vehicles (ARAI)

Vehicle Type	Model Year	PM	CO	HC	NOx
		g/km	g/km	g/km	g/km
2 Wheelers (2-Stroke) Scooters	1991-1995	0.073	6.00	3.68	0.02
	1996-2000	0.073	5.10	2.46	0.01
	2001-2005	0.025	2.76	2.16	0.03
	2006-2010	0.057	0.16	0.86	0.02
2 Wheelers (4 Stroke) Motorcycles	1991-1995	0.010	3.12	0.78	0.23
	1996-2000	0.015	1.58	0.74	0.30
	2001-2005	0.035	1.565	0.555	0.405
	2006-2010	0.035	1.565	0.555	0.405
3-Wheeler - CNG	1996-2000	0.00	0.00	0.00	0.00
	1996-2000	0.118	0.69	2.06	0.19
	2001-2005*	0.0665	0.845	1.16	0.345
	2006-2010	0.015	1.00	0.26	0.50
4 Wheeler - Petrol	1991-1995	0.008	4.75	0.84	0.95
	1996-2000	0.008	4.53	0.66	0.75
	2001-2005	0.005	2.35	0.21	0.18
	2006-2010	0.002	0.84	0.12	0.09
4 Wheeler - Diesel	1991-1995	0.163	0.77	0.24	0.53
	1996-2000	0.163	0.77	0.24	0.53
	2001-2005	0.125	0.51	0.20	0.67
	2006-2010	0.015	0.06	0.08	0.28
4 Wheeler - CNG	1991-1995	0.00	0.00	0.00	0.00
	1996-2000	0.001	0.85	0.79	0.53
	2001-2005**	0.004	0.33	0.41	0.375
	2006-2010	0.004	0.33	0.41	0.375
LCVs (Light Commercial Vehicles)	1991-1995	0.998	3.07	2.28	3.03
	1996-2000	0.655	3.00	1.28	2.48
	2001-2005	0.475	3.66	1.35	2.12
	2006-2010	0.475	3.66	1.35	2.12
Large Trucks + MAV	1991-1995	1.965	19.30	2.63	13.84
	1996-2000	1.965	19.30	2.63	13.84
	2001-2005	1.240	6.00	0.37	9.30
	2006-2010	1.240	6.00	0.37	9.30
Buses-Diesel	1991-1995	2.013	13.06	2.40	11.24
	1996-2000	1.213	4.48	1.46	15.25
	2001-2005	0.795	4.10	0.39	11.50
	2006-2010	0.300	3.92	0.16	6.53
Buses – CNG***	1991-1995	0.00	0.00	0.00	0.00
	1996-2000	0.001	0.00	0.00	0.00
	2001-2005	0.004	3.72	3.75	6.21
	2006-2010	0.004	3.72	3.75	6.21

(Source: ARAI Emission Factor Report, January 2008)

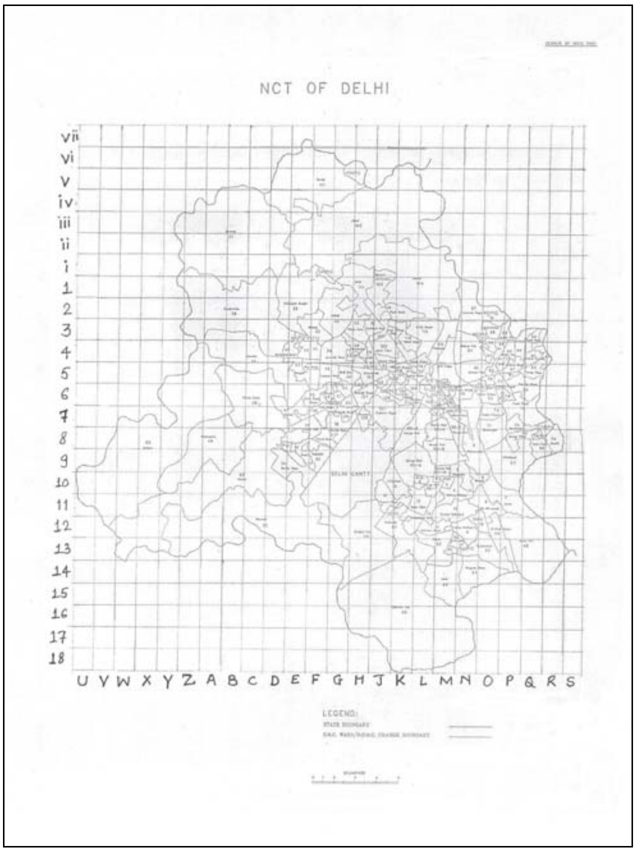
* Average of retro & new 3W CNG vehicles taken for the period during 2001-2006

** Average of 2 BS-II, CNG 4W (<1000 cc & 1000-1400 cc)

*** PM emission factor for CNG Buses is considered as that of 4W-CNG vehicles

Grid-wise Emission Load from Area, Industrial and Vehicular Sources (including Road dust Re-suspension) in Delhi

Table A3.4.1: Grid-wise Emission Load in Delhi: Area Sources
(As per Grid wise Map of Delhi)



Grid	Emission Load (kg/day)				
	PM10	SO2	NOx	CO	HC
U11	0.65	0.24	1.27	3.70	3.05
U10	1.77	0.64	3.43	10.05	8.29
U9	0.47	0.17	0.90	2.64	2.18
V12	3.73	0.28	1.55	26.91	8.38
V11	4.85	0.68	3.72	33.26	13.62
V10	8.02	0.75	4.18	57.00	19.38
V9	4.48	0.54	2.99	31.14	11.87
V8	3.88	0.39	1.53	27.25	8.77
W13	4.23	1.52	8.19	23.97	19.77
W12	8.36	1.94	10.52	53.17	30.04
W11	11.10	0.79	4.46	80.21	24.71
W10	1.87	0.67	3.62	10.58	8.72
W9	4.94	0.71	3.90	33.79	14.05
W8	8.75	1.20	4.66	59.60	21.84
W7	0.75	0.27	1.45	4.23	3.49
X13	5.72	0.99	5.40	38.19	17.69
X12	8.36	1.94	10.52	53.17	30.04
X11	4.60	1.66	8.92	26.09	21.51
X10	6.61	0.25	1.45	49.01	12.80

X9	4.94	0.71	3.90	33.79	14.05
X8	4.94	0.71	3.90	33.79	14.05
X7	3.92	0.34	1.91	27.97	9.26
X6	0.19	0.07	0.36	1.06	0.87
Y13	3.15	1.13	6.09	17.83	14.71
Y12	4.42	1.59	8.57	25.07	20.68
Y11	4.79	1.73	9.29	27.17	22.41
Y10	10.15	2.59	13.98	63.30	38.39
Y9	8.80	1.03	5.69	61.43	23.04
Y8	8.02	0.75	4.18	57.00	19.38
Y7	0.93	0.34	1.81	5.29	4.36
Y6	1.87	0.67	3.62	10.58	8.72
Y5	0.56	0.20	1.08	3.17	2.62
Y4	0.96	0.35	1.86	5.44	4.49
Y3	1.92	0.69	3.72	10.89	8.98
Y2	0.67	0.24	1.29	3.78	3.12
Y1	0.47	0.17	0.91	2.65	2.19
Yi	0.75	0.27	1.45	4.24	3.50
Z13	5.51	0.92	4.99	37.00	16.70
Z12	13.41	1.63	8.94	93.31	35.52
Z11	11.32	1.94	10.56	75.68	34.79
Z10	21.27	2.32	12.80	149.38	54.14
Z9	12.79	2.47	13.41	84.01	41.66
Z8	17.96	2.20	12.07	124.86	47.73
Z7	2.41	0.87	4.66	13.64	11.25
Z6	8.02	0.75	4.18	57.00	19.38
Z5	1.59	0.57	3.07	8.99	7.42
Z4	4.40	0.52	2.84	30.69	11.50
Z3	11.24	2.98	16.10	69.48	43.49
Z2	7.68	2.77	14.88	43.55	35.92
Z1	9.13	3.29	17.68	51.72	42.65
Zi	3.03	1.09	5.87	17.18	14.17
Zii	1.87	0.67	3.63	10.61	8.75
Ziii	1.87	0.67	3.63	10.61	8.75
Ziv	3.64	0.24	1.37	26.39	7.95
A13	1.01	0.37	1.96	5.74	4.74
A12	7.13	1.50	8.14	46.19	24.28
A11	7.62	1.68	9.09	48.98	26.59
A10	8.36	1.94	10.52	53.17	30.04
A9	16.01	2.56	13.97	108.03	47.66
A8	16.99	3.04	15.25	112.58	51.62
A7	3.76	1.35	7.28	21.30	17.57
A6	5.65	0.97	5.27	37.80	17.36
A5	6.12	2.20	11.84	34.66	28.58
A4	7.64	2.75	14.79	43.27	35.69
A3	9.58	3.45	18.56	54.32	44.80
A2	12.68	3.50	18.89	77.65	50.23
A1	17.29	3.02	16.45	115.30	53.66
Ai	4.95	0.71	3.91	33.82	14.08
Aii	8.03	0.75	4.19	57.03	19.41
Aiii	11.10	0.79	4.47	80.24	24.74
Aiv	7.46	0.55	3.10	53.85	16.78

B13	7.36	0.73	2.88	57.54	17.46
B12	3.04	1.10	5.89	17.23	14.21
B11	4.05	1.46	7.85	22.98	18.95
B10	17.35	1.98	10.89	121.40	44.88
B9	6.78	2.44	13.12	38.40	31.67
B8	7.07	2.55	13.70	40.09	33.06
B7	17.87	4.30	23.25	112.81	65.42
B6	127.66	10.42	36.89	1009.92	282.63
B5	15.55	5.97	28.25	85.04	70.76
B4	26.37	4.23	19.94	192.78	76.91
B3	36.11	4.49	20.87	268.69	94.54
B2	55.67	5.52	22.53	432.03	132.64
B1	30.69	3.24	13.23	238.22	74.66
Bi	9.97	1.46	7.96	68.07	28.51
Bii	8.03	0.75	4.19	57.03	19.41
Biii	11.10	0.79	4.47	80.24	24.74
Biv	8.03	0.75	4.19	57.03	19.41
Bv	0.28	0.10	0.54	1.59	1.31
C12	8.13	0.26	4.62	60.99	23.14
C11	10.62	0.50	9.72	79.30	38.82
C10	8.67	0.56	11.76	64.46	40.65
C9	10.03	1.32	12.84	69.78	45.59
C8	12.59	0.93	13.08	91.97	49.82
C7	21.45	2.77	35.27	151.20	115.54
C6	22.77	2.27	36.26	169.55	119.80
C5	9.66	1.93	10.39	62.42	39.68
C4	20.27	4.34	62.55	194.06	117.69
C3	18.83	3.58	19.44	124.04	60.86
C2	26.58	4.15	20.06	192.25	76.88
C1	8.45	3.04	16.36	47.87	39.48
Ci	2.65	0.95	5.12	14.99	12.36
Cii	8.03	0.75	4.19	57.03	19.41
Ciii	1.87	0.67	3.63	10.61	8.75
Civ	2.32	0.83	4.49	13.13	10.83
D13	1.10	0.10	2.25	8.10	6.93
D12	10.55	0.49	9.58	78.81	38.40
D11	4.39	1.12	10.98	26.84	32.95
D10	25.57	3.35	38.33	159.16	126.97
D9	33.89	3.59	76.89	240.33	233.34
D8	150.09	11.28	43.73	1199.35	344.55
D7	98.72	12.67	70.40	732.91	321.57
D6	25.16	2.74	43.89	181.31	141.10
D5	28.57	2.92	57.94	208.71	178.88
D4	106.03	12.96	119.16	879.40	394.49
D3	28.29	4.85	26.40	189.16	86.95
D2	47.53	6.12	27.03	359.84	125.37
D1	29.77	5.02	23.92	215.66	88.93
Di	30.95	4.10	18.25	233.37	82.60
Dii	4.45	0.72	3.42	32.44	13.06
Diii	40.18	3.13	10.77	320.94	87.99
Div	48.78	3.90	14.25	385.90	107.98
Dv	9.63	1.97	10.41	63.87	32.14

Dvi	2.13	0.77	4.12	12.07	9.95
E13	4.54	0.45	3.74	31.87	15.85
E12	7.65	0.86	2.26	52.73	17.30
E11	9.27	0.56	9.93	67.64	37.57
E10	17.92	5.42	29.26	102.63	98.38
E9	88.26	9.85	80.63	657.72	331.41
E8	205.42	17.42	92.43	1617.04	545.62
E7	365.60	32.19	115.80	2310.47	749.93
E6	62.88	5.14	61.09	499.67	253.37
E5	180.57	14.13	98.17	1078.60	466.23
E4	192.80	22.70	206.10	1064.52	650.24
E3	170.27	19.18	82.44	1302.64	425.87
E2	48.08	7.13	33.50	353.30	135.37
E1	40.82	6.47	30.99	296.07	118.64
Ei	60.95	4.62	15.53	488.01	132.28
Eii	27.14	1.35	5.28	211.07	54.07
Eiii	43.42	3.00	10.00	347.01	92.05
Eiv	40.98	3.13	11.85	321.89	89.83
Ev	14.23	2.57	12.47	101.65	44.06
Evi	25.54	2.82	11.74	197.22	63.22
Evii	1.22	0.44	2.36	6.90	5.69
F14	0.70	0.08	2.24	4.95	6.34
F13	22.76	1.69	7.04	182.24	52.61
F12	30.69	2.22	12.07	239.55	76.65
F11	32.52	2.55	17.30	251.63	91.84
F10	30.44	2.65	21.49	237.10	98.11
F9	70.51	7.69	139.11	512.24	432.78
F8	115.99	15.81	119.00	627.19	422.32
F7	111.22	22.80	113.31	649.83	426.38
F6	119.61	16.51	153.21	860.81	545.86
F5	107.79	29.65	144.15	659.58	540.16
F4	72.97	13.65	171.03	510.03	451.35
F3	339.55	28.11	134.55	657.73	387.54
F2	314.42	14.88	71.77	562.97	249.55
F1	340.10	15.21	50.49	1595.53	432.71
Fi	12.22	2.74	13.86	82.90	42.52
Fii	1.57	0.56	3.03	8.87	7.32
Fiii	7.35	0.91	3.94	55.99	19.03
Fiv	14.41	1.99	10.88	98.99	40.20
Fv	18.86	2.58	12.91	135.47	51.79
Fvi	40.47	3.81	14.27	333.47	117.43
G18	0.00	0.00	0.00	0.00	0.00
G17	0.00	0.00	0.00	0.00	0.00
G16	0.00	0.00	0.00	0.00	0.00
G15	0.39	0.05	1.26	2.79	3.58
G14	2.20	0.26	7.06	15.61	20.01
G13	8.58	2.63	8.01	48.48	33.05
G12	4.89	1.30	11.97	29.54	36.12
G11	4.76	0.80	14.03	32.04	40.49
G10	11.76	1.38	11.86	88.43	46.60
G9	12.92	2.72	19.16	90.23	64.19
G8	62.78	5.74	47.29	486.03	209.31

G7	128.02	19.70	133.16	892.05	524.28
G6	409.50	50.20	268.65	3078.34	1279.82
G5	120.99	16.26	135.10	908.11	535.92
G4	86.28	14.14	123.67	702.90	384.51
G3	35.52	8.65	92.98	239.19	294.77
G2	134.67	11.88	65.64	1060.02	375.38
G1	160.89	2.70	50.53	171.88	164.61
Gi	17.16	1.84	21.05	135.88	76.24
Gii	8.66	0.72	4.62	69.28	24.52
Giii	19.70	1.27	4.64	156.65	41.91
Giv	16.19	1.54	7.24	121.01	38.57
Gv	47.59	3.48	13.27	373.08	103.19
Gvi	7.38	0.52	2.94	53.36	16.39
H17	0.55	0.06	1.50	3.70	4.12
H16	2.21	0.24	6.02	14.80	16.48
H15	2.21	0.24	6.02	14.80	16.48
H14	6.31	1.19	15.16	39.19	43.06
H13	5.01	0.99	10.76	2.58	3.90
H12	19.95	4.07	14.55	66.34	30.95
H11	40.38	3.11	14.86	300.60	81.31
H10	5.31	0.74	16.42	36.81	46.89
H9	23.60	10.90	34.11	109.68	121.04
H8	36.66	12.72	91.64	274.02	234.95
H7	706.38	15.48	103.98	1587.00	520.13
H6	469.65	42.40	158.48	3697.86	1088.59
H5	140.95	14.56	113.68	1060.25	493.37
H4	167.50	23.39	154.47	1286.04	643.65
H3	203.37	23.11	121.96	1382.32	572.90
H2	159.14	7.52	78.86	473.23	261.17
H1	235.56	22.74	87.04	1859.34	556.02
Hi	14.21	1.98	35.77	108.94	105.54
Hii	3.67	0.64	11.71	28.28	33.05
Hiii	7.23	0.27	3.99	54.69	20.33
Hiv	1.57	0.56	3.03	8.87	7.32
Hv	1.38	0.50	2.68	7.83	6.46
Hvi	0.31	0.11	0.61	1.77	1.46
J18	6.38	0.10	1.16	47.90	12.31
J17	7.70	0.25	4.77	56.78	22.20
J16	2.21	0.24	6.02	14.80	16.48
J15	9.17	0.84	8.07	63.83	29.82
J14	3.40	0.43	10.06	22.29	25.02
J13	4.83	0.91	11.61	1.73	3.30
J12	21.13	4.14	21.54	87.47	35.38
J11	36.44	11.71	34.14	151.36	81.41
J10	28.65	8.87	64.78	164.00	197.27
J9	10.74	3.90	45.05	84.65	77.80
J8	3.40	1.88	8.23	19.71	16.15
J7	46.17	5.56	35.05	348.35	156.10
J6	101.19	30.65	149.78	626.89	566.76
J5	129.50	54.95	215.39	731.65	673.73
J4	96.78	12.41	114.65	731.06	454.33
J3	239.00	28.91	132.04	1769.45	703.42

J2	1079.30	27.50	97.24	2698.62	740.79
J1	333.06	12.44	68.18	275.88	257.09
Ji	17.19	2.01	35.73	131.36	109.94
Jii	69.30	1.88	17.13	216.60	83.23
Jiii	4.15	0.23	3.71	31.48	15.00
Jiv	4.64	0.60	3.31	32.08	12.65
Jv	0.86	0.31	1.67	4.88	4.02
Jvi	0.08	0.03	0.15	0.44	0.37
K18	5.07	0.26	5.70	36.53	20.16
K17	2.21	0.24	6.02	14.80	16.48
K16	8.61	0.47	6.74	62.08	27.96
K15	1.55	0.48	4.04	8.41	9.27
K14	1.95	0.58	5.95	10.64	11.97
K13	205.20	16.10	29.68	128.94	89.72
K12	216.20	5.86	25.21	216.65	72.61
K11	211.74	17.60	61.71	1652.19	451.62
K10	34.71	8.27	34.61	155.19	72.20
K9	11.42	3.66	21.65	15.29	17.24
K8	3.26	1.53	4.21	16.79	15.87
K7	21.29	7.42	38.59	137.47	130.03
K6	283.95	83.43	250.80	1764.19	1111.00
K5	572.56	40.70	251.05	960.18	780.43
K4	464.47	41.86	168.89	3678.55	1135.55
K3	268.30	18.44	128.85	1578.21	634.45
K2	84.08	8.53	76.29	660.75	328.15
K1	36.91	4.07	19.03	281.55	95.36
Ki	12.62	2.43	16.77	140.95	60.70
Kii	10.53	1.61	10.62	182.56	58.85
Kiii	3.15	0.64	3.17	21.97	10.36
Kiv	5.89	0.66	3.42	42.34	15.03
Kv	1.41	0.51	2.73	7.98	6.58
Kvi	0.23	0.08	0.45	1.33	1.10
L18	4.96	0.25	5.40	35.79	19.34
L17	2.21	0.24	6.02	14.80	16.48
L16	2.21	0.24	6.02	14.80	16.48
L15	8.28	0.99	18.95	56.32	54.14
L14	14.88	1.73	32.51	101.04	98.18
L13	22.24	3.08	45.90	150.56	127.42
L12	281.69	9.65	55.46	245.43	105.52
L11	62.59	19.56	44.00	331.84	141.27
L10	33.51	10.58	58.95	45.71	50.42
L9	58.45	6.20	25.64	427.09	122.97
L8	51.76	4.44	19.35	387.08	106.73
L7	41.76	20.70	45.67	113.67	110.49
L6	293.39	48.18	275.10	2148.14	1162.79
L5	106.08	39.03	261.43	703.91	695.54
L4	65.24	25.43	112.22	356.33	400.30
L3	33.07	11.53	53.75	185.16	160.93
L2	12.39	3.57	26.85	76.34	64.70
L1	8.99	2.59	16.56	54.46	46.79
Li	7.39	2.13	16.02	45.54	38.60
Lii	2.63	0.76	5.70	16.19	13.73

Liii	0.55	0.20	1.06	3.10	2.56
Liv	4.56	0.58	3.16	31.64	12.28
Lv	0.99	0.36	1.92	5.62	4.63
M18	4.74	0.22	4.79	34.31	17.69
M17	8.37	0.32	6.58	61.22	27.14
M16	8.37	0.32	6.58	61.22	27.14
M15	19.36	1.89	45.38	131.68	126.34
M14	25.39	3.54	57.78	165.96	163.35
M13	138.70	14.87	111.83	1035.87	469.79
M12	47.65	10.40	58.45	175.57	79.57
M11	58.01	16.73	47.93	279.00	131.20
M10	99.28	23.39	80.37	508.26	213.92
M9	39.80	12.06	36.64	175.88	88.55
M8	16.28	3.47	13.27	84.69	33.17
M7	72.62	42.73	82.85	271.44	209.33
M6	432.67	100.70	464.78	2991.41	1710.29
M5	60.10	22.05	114.26	434.09	237.09
M4	244.44	8.11	77.10	1826.98	562.88
M3	229.86	16.01	59.70	1054.70	367.53
M2	108.15	0.58	3.36	9.98	8.54
M1	0.98	0.36	1.76	5.42	4.68
Mi	4.43	1.28	9.61	27.33	23.16
Mii	1.48	0.43	3.20	9.11	7.72
N18	0.44	0.05	1.20	2.96	3.30
N17	1.88	0.21	5.11	12.58	14.01
N16	0.66	0.07	1.80	4.44	4.94
N15	18.19	2.12	48.96	120.92	134.53
N14	458.17	27.62	142.87	2896.06	901.91
N13	178.74	14.07	103.54	1203.38	477.92
N12	49.55	17.25	88.95	285.20	301.97
N11	91.19	16.63	83.31	647.28	372.97
N10	135.14	17.60	105.30	1022.86	476.23
N9	133.11	9.86	71.02	338.95	246.83
N8	466.73	6.44	88.33	412.05	226.25
N7	82.77	4.86	81.40	223.09	196.65
N6	234.49	20.76	78.69	1367.32	484.34
N5	24.76	10.76	48.37	174.77	75.94
N4	7.71	2.89	3.34	39.69	20.90
N3	4.54	0.94	1.25	28.41	10.25
N2	15.00	2.09	29.70	98.41	88.21
N1	0.00	0.00	0.00	0.00	0.00
O15	0.00	0.00	0.00	0.00	0.00
O14	67.32	4.98	31.68	530.34	177.55
O13	48.94	4.61	84.31	355.96	254.67
O12	442.21	24.39	100.41	1971.88	612.54
O11	40.20	10.06	63.21	252.57	185.05
O10	468.40	8.98	51.81	347.62	174.79
O9	390.27	7.16	16.59	64.34	55.75
O8	189.94	6.82	29.06	59.42	27.87
O7	42.29	10.37	25.88	277.91	120.74
O6	1094.06	11.96	34.94	127.18	79.35
O5	853.97	50.73	233.13	2962.66	878.82

O4	491.54	49.39	209.82	3748.85	1068.71
O3	251.68	30.63	152.28	1832.37	550.79
O2	45.53	10.05	72.38	247.50	100.36
O1	13.20	3.10	22.14	69.85	29.53
P15	3.20	0.49	10.49	23.53	23.50
P14	17.56	1.92	41.31	121.88	111.82
P13	24.60	2.24	13.01	192.64	63.95
P12	32.24	4.59	29.92	105.82	83.31
P11	75.98	12.51	61.57	545.07	239.66
P10	548.63	1.86	10.65	29.86	24.15
P9	10.21	3.56	17.24	56.74	45.59
P8	46.54	16.18	87.22	250.39	114.65
P7	479.52	44.02	169.66	3522.55	987.34
P6	686.52	27.49	124.00	661.15	268.59
P5	451.54	48.50	260.15	3661.49	1425.59
P4	313.81	30.66	297.71	2675.36	1567.62
P3	205.74	10.67	102.50	987.49	550.54
P2	79.66	7.53	95.28	702.67	479.12
P1	9.78	0.91	11.72	86.46	58.93
Q15	14.19	1.56	38.59	94.94	105.74
Q14	136.08	8.62	53.73	790.39	280.90
Q13	10.36	1.33	18.08	68.87	55.61
Q12	17.60	3.37	37.48	118.64	89.78
Q11	5.06	1.07	10.43	33.36	25.41
Q10	28.55	0.85	6.73	212.68	54.86
Q9	196.98	4.19	65.46	50.02	45.73
Q8	126.70	6.76	86.75	40.80	58.14
Q7	33.93	5.90	59.96	103.08	62.06
Q6	95.43	5.53	65.34	122.30	41.94
Q5	530.85	14.56	93.78	650.47	188.22
Q4	250.89	21.38	204.89	1678.13	1053.53
Q3	127.11	12.67	127.10	1012.15	647.45
R15	10.13	1.11	27.54	67.74	75.45
R14	6.55	0.84	17.31	43.06	47.82
R13	0.00	0.00	0.00	0.00	0.00
R12	0.00	0.00	0.00	0.00	0.00
R11	0.00	0.00	0.00	0.00	0.00
R10	0.00	0.00	0.00	0.00	0.00
R9	4.35	0.77	9.00	7.30	4.25
R8	86.88	7.63	72.51	217.27	76.63
R7	114.24	11.60	89.13	846.26	234.25
R6	1.67	0.30	4.87	1.58	2.60
R5	106.85	4.78	54.23	163.92	49.30
R4	305.93	23.37	132.20	2442.87	798.61
R3	19.63	2.43	64.00	144.24	184.57
S9	0.00	0.00	0.00	0.00	0.00
S8	5.57	0.83	12.83	10.07	8.81
S7	0.00	0.00	0.00	0.00	0.00
Total	**27747.23**	**2639.76**	**15334.10**	**132542.60**	**59949.64**

Table A3.4.2: Grid-wise Emission Load in Delhi: Industrial Sources

Grids	Pollutant Emission Load (kg/day)				
	PM	**SO_2**	**NOx**	**HC**	**CO**
C1	0	0	0	0	0
C2	0	0	0	0	0
C3	0	0	0	0	0
C4	0	0	0	0	0
C5	0	0	0	0	0
C6	0	0	0	0	0
C7	0	0	0	0	0
C8	0	0	0	0	0
C9	0	0	0	0	0
C10	0	0	0	0	0
C11	0	0	0	0	0
C12	0	0	0	0	0
C13	0	0	0	0	0
C14	0	0	0	0	0
C15	0	0	0	0	0
D1	0	0	0	0	0
D2	0	0	0	0	0
D3	0	0	0	0	0
D4	5.89	8.67	82.94	6.61	17.95
D5	0	0	0	0	0
D6	0	0	0	0	0
D7	0	0	0	0	0
D8	0	0	0	0	0
D9	0	0	0	0	0
D10	0	0	0	0	0
D11	0	0	0	0	0
D12	0	0	0	0	0
D13	0	0	0	0	0
D14	0	0	0	0	0
D15	0	0	0	0	0
E1	1.18	5.29	14.75	1.10	3.20
E2	0	0	0	0	0
E3	0	0	0	0	0
E4	9.93	19.24	139.39	11.11	30.22
E5	0	0	0	0	0
E6	1.19	72.46	8.35	0.75	3.11
E7	2.96	180.86	20.85	1.89	7.78
E8	0	0	0	0	0
E9	0	0	0	0	0
E10	0	0	0	0	0
E11	0	0	0	0	0
E12	0	0	0	0	0
E13	0	0	0	0	0
E14	0	0	0	0	0
E15	0	0	0	0	0

F1	0	0	0	0	0
F2	0	0	0	0	0
F3	0	0	0	0	0
F4	14.52	20.74	205.06	16.34	44.34
F5	0	0	0	0	0
F6	0	0	0	0	0
F7	8.89	543.74	62.67	5.69	23.34
F8	0	0	0	0	0
F9	0	0	0	0	0
F10	0	0	0	0	0
F11	0	0	0	0	0
F12	0	0	0	0	0
F13	0	0	0	0	0
F14	0	0	0	0	0
F15	0	0	0	0	0
G1	57.48	82.71	809.86	64.58	175.38
G2	0	0	0	0	0
G3	0	0	0	0	0
G4	0	0	0	0	0
G5	0	0	0	0	0
G6	0	0	0	0	0
G7	83.75	157.82	1175.04	94.02	255.39
G8	101.49	155.52	1428.48	114.05	309.55
G9	0	0	0	0	0
G10	0	0	0	0	0
G11	0	0	0	0	0
G12	0	0	0	0	0
G13	0	0	0	0	0
G14	0	0	0	0	0
G15	0	0	0	0	0
H1	53.91	81.91	760.32	60.68	164.69
H2	0	0	0	0	0
H3	0	0	0	0	0
H4	80.78	898.72	1044.52	85.12	246.36
H5	18.32	8.95	165.89	11.67	34.51
H6	80.99	101.38	1141.63	91.10	246.98
H7	57.95	69.47	816.77	65.20	52.99
H8	0	0	0	0	0
H9	0	0	0	0	0
H10	0	0	0	0	0
H11	0	0	0	0	0
H12	0	0	0	0	0
H13	0	0	0	0	0
H14	0	0	0	0	0
H15	0	0	0	0	0
J1	0	0	0	0	0
J2	184.32	364.03	2580.48	230.63	627.18
J3	122.11	206.21	1728.00	137.59	373.74
J4	36.96	361.56	417.33	33.94	97.23

J5	50.46	54.03	711.94	56.81	153.87
J6	5.66	14.99	79.46	7.07	20.91
J7	0	0	0	0	0
J8	0	0	0	0	0
J9	0	0	0	0	0
J10	0	0	0	0	0
J11	0	0	0	0	0
J12	0	0	0	0	0
J13	0	0	0	0	0
J14	0	0	0	0	0
J15	0	0	0	0	0
K1	0	0	0	0	0
K2	0	0	0	0	0
K3	0	0	0	0	0
K4	0	0	0	0	0
K5	0	0	0	0	0
K6	0	0	0	0	0
K7	0	0	0	0	0
K8	0	0	0	0	0
K9	0	0	0	0	0
K10	0	0	0	0	0
K11	0	0	0	0	0
K12	0	0	0	0	0
K13	0	0	0	0	0
K14	0	0	0	0	0
K15	0	0	0	0	0
L1	0	0	0	0	0
L2	0	0	0	0	0
L3	0	0	0	0	0
L4	0	0	0	0	0
L5	0	0	0	0	0
L6	0	0	0	0	0
L7	0	0	0	0	0
L8	0	0	0	0	0
L9	0	0	0	0	0
L10	0	0	0	0	0
L11	0	0	0	0	0
L12	0	0	0	0	0
L13	0	0	0	0	0
L14	0	0	0	0	0
L15	0	0	0	0	0
M1	0	0	0	0	0
M2	0	0	0	0	0
M3	0	0	0	0	0
M4	0	0	0	0	0
M5	0	0	0	0	0
M6	0	0	0	0	0
M7	0	0	0	0	0
M8	0	0	0	0	0

M9	0	0	0	0	0
M10	0	0	0	0	0
M11	0	0	0	0	0
M12	0	0	0	0	0
M13	0	0	0	0	0
M14	0	0	0	0	0
M15	0	0	0	0	0
N1	0	0	0	0	0
N2	0	0	0	0	0
N3	0	0	0	0	0
N4	0	0	0	0	0
N5	0	0	0	0	0
N6	120.00	1013.33	1173.33	128.00	640.00
N7	0.39	6.12	2857.02	1562.90	11935.00
N8	206.25	1741.71	2016.67	220.00	1100.00
N9	0	0	0	0	0
N10	0	0	0	0	0
N11	0	0	0	0	0
N12	0	0	0	0	0
N13	0	0	0	0	0
N14	0	0	0	0	0
N15	0	0	0	0	0
O1	0	0	0	0	0
O2	0	0	0	0	0
O3	0	0	0	0	0
O4	0	0	0	0	0
O5	0	0	0	0	0
O6	0	0	0	0	0
O7	0	0	0	0	0
O8	0	0	0	0	0
O9	0	0	0	0	0
O10	0	0	0	0	0
O11	10.96	11.31	154.37	12.34	33.43
O12	71.60	85.08	1010.62	81.41	222.14
O13	142.85	231.55	2016.00	42.60	115.35
O14	0	0	0	0	0
O15	0	0	0	0	0
P1	0	0	0	0	0
P2	0	0	0	0	0
P3	0	0	0	0	0
P4	2.36	12.79	32.49	2.60	7.15
P5	0	0	0	0	0
P6	0	0	0	0	0
P7	0	0	0	0	0
P8	1.20	169.29	6.00	14.40	72.00
P9	0	0	0	0	0
P10	0	0	0	0	0
P11	0	0	0	0	0
P12	80.87	87.78	1140.48	91.09	246.62

P13	35.14	42.97	495.36	39.55	107.17
P14	0	0	0	0	0
P15	0	0	0	0	0
Q1	0	0	0	0	0
Q2	0	0	0	0	0
Q3	0	0	0	0	0
Q4	0	0	0	0	0
Q5	37.32	61.75	525.31	41.96	113.94
Q6	0.00	0.00	0.00	0.00	0.00
Q7	41.59	78.68	2384.64	46.55	126.61
Q8	0	0	0	0	0
Q9	0	0	0	0	0
Q10	0	0	0	0	0
Q11	0	0	0	0	0
Q12	0	0	0	0	0
Q13	9.95	14.05	140.54	11.18	30.34
Q14	948.73	7905.97	9339.66	1012.80	5025.50
Q15	0	0	0	0	0
R1	0	0	0	0	0
R2	0	0	0	0	0
R3	0	0	0	0	0
R4	118.66	113.70	1670.40	133.43	361.20
R5	18.66	30.87	262.66	20.98	56.97
R6	122.11	79.49	9.56	0.50	2.50
R7	0	0	0	0	0
R8	0	0	0	0	0
R9	0	0	0	0	0
R10	0	0	0	0	0
R11	0	0	0	0	0
R12	0	0	0	0	0
R13	0	0	0	0	0
R14	0	0	0	0	0
R15	0	0	0	0	0
S1	0	0	0	0	0
S2	0	0	0	0	0
S3	0	0	0	0	0
S4	0	0	0	0	0
S5	0	0	0	0	0
S6	0	0	0	0	0
S7	0	0	0	0	0
S8	0	0	0	0	0
S9	0	0	0	0	0
S10	0	0	0	0	0
S11	0	0	0	0	0
S12	0	0	0	0	0
S13	0	0	0	0	0
S14	0	0	0	0	0
S15	0	0	0	0	0

Table A3.4.3: Grid-wise Emission Load in Delhi: Vehicular Sources and Re-suspended Road Dust (PM10)

Grid	Vehicular Emission Contribution (kg/d)					Re-suspended Road Dust, (kg/d)
	PM	CO	HC	NOx	SO_2	
C1	5.3	136.7	52.4	50.9	0.4	76.4
C2	11.8	309.7	117.0	113.6	0.9	178.9
C3	18.7	505.8	187.5	181.6	1.4	304.9
C4	34.9	920.5	237.0	320.0	2.6	164.9
C5	2.1	93.2	32.3	16.2	0.1	40.2
C6	2.8	122.7	42.5	21.3	0.2	52.9
C7	6.1	268.2	93.0	46.5	0.4	115.6
C8	17.2	753.6	265.2	195.5	1.0	392.4
C9	10.7	473.1	178.9	125.7	0.5	396.1
C10	8.9	395.4	149.5	105.1	0.4	331.0
C11	4.9	218.8	82.7	58.1	0.2	183.2
C12	10.0	323.7	129.5	109.5	0.7	175.0
C13	10.3	344.5	137.0	113.5	0.7	198.7
C14	8.8	295.3	117.3	96.9	0.6	172.2
C15	6.3	186.5	76.1	68.0	0.4	81.1
D1	14.6	396.5	147.0	142.4	1.1	239.1
D2	18.9	468.1	184.7	179.8	1.5	243.5
D3	9.7	255.2	96.7	93.8	0.7	146.6
D4	35.0	925.4	238.6	320.8	2.6	167.0
D5	2.3	100.4	34.8	17.4	0.1	43.3
D6	2.2	97.4	33.8	16.9	0.1	42.0
D7	20.4	634.9	186.0	180.1	1.5	171.1
D8	13.3	593.4	210.7	152.5	0.7	347.8
D9	10.3	456.4	172.6	121.3	0.5	382.1
D10	8.4	374.3	141.5	99.5	0.4	313.3
D11	8.4	374.3	141.5	99.5	0.4	313.3
D12	10.4	428.4	164.0	120.5	0.6	331.5
D13	11.6	393.3	156.1	128.6	0.8	231.3
D14	17.0	583.5	230.9	188.8	1.1	350.8
D15	17.3	523.8	212.5	186.8	1.2	244.5
E1	13.6	360.8	135.9	131.8	1.0	210.0
E2	19.9	509.7	196.1	190.6	1.5	282.4
E3	10.4	270.1	103.0	100.0	0.8	153.0
E4	36.8	990.2	259.3	335.7	2.7	189.7
E5	2.7	119.1	41.3	20.7	0.2	51.3
E6	30.9	844.2	223.6	281.2	2.3	168.9
E7	74.3	2050.3	566.1	688.5	5.5	383.2
E8	27.0	938.3	370.4	300.5	1.7	576.9
E9	12.6	557.5	210.8	148.2	0.6	466.7
E10	12.0	530.8	200.7	141.1	0.6	444.4
E11	9.0	366.2	140.5	104.0	0.5	279.5
E12	5.1	225.4	85.2	59.9	0.3	188.7
E13	17.2	514.0	209.3	185.7	1.2	230.1
E14	9.0	312.6	123.5	100.5	0.6	190.8
E15	17.4	764.2	249.2	191.1	1.1	178.3
F1	15.0	383.3	148.3	144.1	1.2	209.5
F2	16.8	433.4	166.4	161.6	1.3	241.5
F3	19.4	479.6	189.7	184.6	1.5	248.0
F4	80.8	2121.9	544.8	742.4	6.1	372.5

F5	35.5	945.8	245.7	324.4	2.7	175.8
F6	17.1	501.8	140.4	152.6	1.2	121.4
F7	63.9	1714.5	449.6	585.9	4.8	319.5
F8	23.1	794.0	300.2	251.7	1.6	322.9
F9	12.1	535.3	202.4	142.3	0.6	448.1
F10	15.2	549.4	215.4	171.1	0.9	357.7
F11	9.4	423.5	137.1	103.8	0.6	102.9
F12	17.4	642.5	233.5	190.2	1.2	241.4
F13	12.3	553.2	184.8	137.7	0.8	196.0
F14	10.4	459.0	151.5	114.9	0.7	131.5
F15	21.1	844.1	291.6	231.9	1.4	253.4
G1	17.6	475.1	141.6	125.3	1.5	300.7
G2	15.8	489.1	148.0	115.7	1.3	219.5
G3	51.1	933.7	271.6	384.7	4.0	383.5
G4	14.6	247.7	70.5	104.8	1.2	194.8
G5	35.8	989.3	264.5	324.6	2.7	205.1
G6	80.6	2122.5	545.3	739.8	6.1	377.4
G7	21.0	686.7	216.6	189.7	1.5	183.0
G8	49.4	1267.0	353.3	438.2	3.7	291.1
G9	22.5	724.3	185.5	195.9	1.8	138.8
G10	31.0	743.8	206.9	251.7	2.4	208.2
G11	29.9	700.1	198.4	250.1	2.3	191.9
G12	87.1	2129.4	612.7	803.3	6.3	480.2
G13	8.0	295.5	72.6	69.9	0.7	49.8
G14	5.6	204.2	50.2	48.3	0.5	34.4
G15	30.0	728.5	210.3	277.1	2.2	165.2
H1	19.2	478.8	142.1	137.8	1.6	289.5
H2	54.3	917.8	263.8	404.3	4.3	465.9
H3	38.8	710.2	204.8	281.7	3.2	470.0
H4	40.0	678.7	193.7	289.9	3.3	492.9
H5	101.7	2656.0	678.0	934.4	7.6	459.7
H6	59.0	1694.4	484.2	544.0	4.3	350.2
H7	50.6	1469.5	428.9	469.9	3.7	300.5
H8	48.7	1274.3	356.0	445.2	3.6	273.0
H9	49.4	1308.9	363.8	450.9	3.7	277.8
H10	64.6	1568.7	448.6	580.2	4.8	372.3
H11	35.0	885.4	251.0	321.5	2.6	194.6
H12	36.4	1015.7	276.5	330.4	2.8	207.7
H13	23.7	636.0	175.9	216.2	1.8	133.8
H14	6.7	246.2	60.5	58.3	0.6	41.5
H15	43.7	1142.9	319.4	399.5	3.3	244.9
J1	89.5	1386.9	394.3	666.5	7.1	738.4
J2	48.8	778.0	221.3	359.4	3.9	483.0
J3	45.7	746.9	213.3	337.3	3.7	438.2
J4	36.3	624.9	178.5	262.4	3.0	460.7
J5	77.5	2120.2	574.4	715.1	5.8	398.7
J6	50.6	1420.5	389.3	461.6	3.7	295.7
J7	16.2	572.7	192.7	146.9	1.1	164.5
J8	3.4	103.6	26.8	28.6	0.3	22.0
J9	115.9	2787.6	807.2	1067.9	8.4	639.8
J10	59.3	1461.7	414.9	529.8	4.4	345.2
J11	44.0	1173.0	325.3	401.7	3.3	248.0
J12	42.2	1082.3	305.2	387.6	3.1	235.7
J13	45.7	1138.1	321.6	407.7	3.4	267.7
J14	46.0	1192.8	334.6	421.0	3.4	257.3

J15	19.4	590.4	155.2	173.8	1.5	113.3
K1	37.4	599.9	171.2	278.3	3.0	322.4
K2	23.6	472.9	138.2	174.6	1.9	247.5
K3	91.9	1407.8	400.4	688.4	7.3	679.8
K4	22.2	459.5	134.1	159.9	1.8	301.0
K5	58.1	1666.9	478.9	538.8	4.3	335.9
K6	53.9	1540.1	438.7	498.2	4.0	312.4
K7	81.7	2218.4	598.4	755.6	6.1	405.5
K8	73.3	1832.8	522.4	674.7	5.4	406.6
K9	83.0	2118.0	598.3	761.7	6.1	462.5
K10	118.8	2975.7	844.7	1082.6	8.8	669.0
K11	96.4	2371.3	676.2	871.6	7.1	549.8
K12	40.4	975.2	274.5	342.9	3.1	255.1
K13	38.1	987.6	275.9	344.2	2.9	218.6
K14	61.9	1486.3	425.4	549.6	4.6	364.7
K15	20.2	538.8	144.7	166.2	1.6	133.1
L1	6.5	118.2	41.0	36.7	0.7	38.5
L2	47.7	692.3	208.3	366.6	3.7	286.2
L3	54.9	795.2	244.3	407.4	4.5	331.4
L4	49.8	742.5	229.4	367.4	4.1	298.5
L5	90.2	1272.2	385.8	681.0	7.2	545.8
L6	141.7	1976.5	598.0	1071.4	11.3	858.7
L7	109.7	1549.2	465.1	841.6	8.6	661.8
L8	129.9	3095.5	893.4	1172.4	9.5	743.0
L9	129.5	3136.8	904.6	1188.8	9.4	720.4
L10	68.6	1754.2	495.1	629.3	5.1	382.5
L11	44.6	1151.7	322.5	404.1	3.3	254.2
L12	89.0	2200.6	628.0	811.5	6.6	501.2
L13	59.7	1508.6	424.3	534.3	4.5	347.7
L14	10.2	376.6	92.5	89.1	0.9	63.5
L15	6.1	225.9	55.5	53.5	0.5	38.1
M1	0.7	28.6	9.3	5.0	0.1	2.3
M2	45.4	660.5	200.2	345.0	3.6	272.9
M3	63.1	920.5	277.1	484.8	5.0	378.1
M4	196.1	2728.1	820.2	1496.7	15.5	1187.2
M5	218.0	3026.5	910.4	1662.2	17.3	1321.0
M6	97.3	1379.8	417.3	738.2	7.7	587.4
M7	211.2	2936.9	884.6	1607.8	16.8	1280.0
M8	362.3	5012.4	1504.0	2771.3	28.6	2195.7
M9	168.6	3914.9	1200.5	1510.9	11.7	948.6
M10	59.9	1525.8	473.0	533.6	4.1	513.3
M11	108.5	2552.1	782.4	972.6	7.5	645.8
M12	59.2	1417.2	438.7	528.4	4.1	399.8
M13	71.0	1722.1	535.5	632.1	4.9	516.8
M14	8.4	314.4	103.2	70.7	0.5	214.9
M15	4.2	156.1	51.3	35.1	0.3	106.7
N1	3.7	52.0	18.6	19.5	0.4	23.1
N2	3.7	52.0	18.6	19.5	0.4	23.1
N3	46.5	641.2	192.5	354.9	3.7	281.9
N4	0.0	0.0	0.0	0.0	0.0	0.0
N5	129.9	1796.7	537.6	998.4	10.2	787.1
N6	100.6	1414.9	424.7	771.6	7.9	607.7
N7	201.5	2806.8	840.9	1547.0	15.8	1218.8
N8	158.7	2198.2	660.2	1212.5	12.5	961.7

N9	96.2	2267.4	692.4	863.9	6.6	564.9
N10	53.8	1378.3	427.7	479.0	3.7	472.1
N11	92.4	2218.6	687.6	823.9	6.4	636.1
N12	78.0	1851.5	577.4	693.0	5.4	530.6
N13	10.0	314.3	100.8	86.8	0.7	170.1
N14	43.3	1154.4	361.4	383.7	3.0	445.9
N15	2.9	109.9	36.1	24.7	0.2	75.2
O1	4.9	102.6	35.1	28.9	0.5	28.0
O2	5.0	110.6	37.6	29.6	0.5	27.4
O3	49.2	711.6	217.0	369.7	4.0	296.5
O4	5.0	107.3	36.6	29.5	0.5	28.0
O5	110.5	1567.3	472.9	841.8	8.8	666.9
O6	49.6	700.6	210.6	379.8	3.9	299.2
O7	75.2	1040.5	312.0	576.0	5.9	455.8
O8	10.9	150.3	45.0	83.7	0.9	66.0
O9	59.0	1380.9	421.0	530.5	4.1	332.1
O10	89.9	2113.8	648.3	805.3	6.2	536.5
O11	79.2	1878.2	585.4	704.4	5.5	533.9
O12	52.5	1265.7	407.0	459.8	3.7	436.1
O13	24.6	586.1	194.4	212.4	1.8	223.4
O14	46.3	1074.4	334.8	411.9	3.2	284.8
O15	7.7	195.9	64.9	66.1	0.6	85.4
P1	12.6	267.0	133.4	87.8	0.7	357.9
P2	13.5	294.3	144.5	94.2	0.7	378.9
P3	33.6	642.0	287.4	266.1	2.0	542.5
P4	27.1	529.6	278.5	188.5	1.4	798.4
P5	33.0	874.9	301.0	338.9	2.3	366.5
P6	15.6	493.9	156.6	151.1	1.1	458.8
P7	38.9	1072.0	362.6	395.1	2.7	576.7
P8	45.0	1159.1	408.0	465.5	3.0	397.2
P9	21.3	492.7	151.3	190.8	1.5	118.5
P10	36.7	848.3	258.0	330.2	2.5	191.9
P11	21.7	525.0	170.9	188.6	1.5	192.9
P12	51.4	1226.5	375.5	460.9	3.5	323.5
P13	33.0	820.6	259.2	291.0	2.3	283.0
P14	45.6	1096.6	342.3	404.9	3.2	328.0
P15	16.0	423.2	140.0	137.6	1.1	196.0
Q1	1.9	51.8	22.0	13.1	0.1	45.1
Q2	1.6	43.4	18.5	11.0	0.1	37.8
Q3	21.6	415.5	164.0	183.0	1.4	171.1
Q4	19.8	413.5	208.9	138.4	1.1	569.1
Q5	20.2	568.6	193.1	203.3	1.4	357.0
Q6	18.0	501.1	173.5	181.9	1.2	307.7
Q7	24.3	670.5	224.8	245.7	1.7	362.9
Q8	14.9	444.1	150.6	147.4	1.1	365.1
Q9	51.2	1205.1	389.9	447.0	3.7	402.1
Q10	116.1	2698.0	822.0	1043.7	8.0	629.8
Q11	2.6	98.9	32.5	22.3	0.2	67.6
Q12	44.3	1101.1	339.8	395.1	3.0	342.3
Q13	19.4	503.8	156.7	172.3	1.3	180.2
Q14	51.0	1221.4	374.2	457.1	3.5	327.5
Q15	35.6	888.8	274.5	317.9	2.4	279.3
R1	2.7	74.9	31.8	18.9	0.2	65.2
R2	2.8	77.5	33.0	19.6	0.2	67.5

R3	21.6	401.2	159.8	183.4	1.4	168.3
R4	12.3	264.0	131.2	86.1	0.7	349.7
R5	34.8	937.3	322.1	355.9	2.4	445.1
R6	35.9	930.7	328.3	370.5	2.4	346.7
R7	38.8	1007.7	351.1	399.8	2.6	368.2
R8	6.2	231.8	73.2	56.8	0.5	321.9
R9	48.8	1111.7	369.2	421.3	3.6	383.0
R10	92.7	2118.0	675.2	816.4	6.6	602.7
R11	102.9	2407.1	735.3	923.6	7.1	585.8
R12	16.1	401.2	123.8	143.9	1.1	125.0
R13	1.7	64.9	21.3	14.6	0.1	44.3
R14	5.6	211.0	69.3	47.5	0.4	144.3
R15	4.9	182.5	59.9	41.1	0.3	124.8
S1	1.9	52.7	22.4	13.3	0.1	45.9
S2	1.3	37.2	15.8	9.4	0.1	32.4
S3	2.9	59.5	23.9	23.7	0.2	30.6
S4	28.5	538.2	211.3	243.5	1.9	205.8
S5	12.9	360.4	124.7	131.1	0.9	218.8
S6	21.1	579.8	196.3	214.1	1.5	309.7
S7	19.6	551.5	183.1	197.6	1.4	325.2
S8	5.5	204.5	63.9	49.9	0.4	282.6
S9	18.4	436.7	147.4	160.1	1.4	224.6
S10	35.7	872.1	292.6	311.4	2.6	475.0
S11	41.6	1013.5	328.7	385.3	2.9	349.6
S12	0.0	0.0	0.0	0.0	0.0	0.0
S13	0.0	0.0	0.0	0.0	0.0	0.0
S14	0.0	0.0	0.0	0.0	0.0	0.0
S15	0.0	0.0	0.0	0.0	0.0	0.0
Total	**9747**	**217791**	**66741**	**84194**	**722**	**77275**

Form A3.1.1: Questionnaire for Survey of Households

1. Name & address of person :_______________________________
2. Ward No. :_______________________________
3. Total family members : _____________________________

   Male :___________

   Female :___________

   Children (upto 15 years):_________

4. Monthly income :
5. Average fuel consumption (Monthly): (Summer) (Winter)

Types of Chulha:	Coal: __________________ kg
Angithi -	Kerosene: _______________ Lit
Stove -	LPG (Cylinder): ___________ No.
Gas burner -	Wood: __________________ kg
	Dung cakes:________ _____ kg

6. Average power failure per day (in hrs): Summer____ (hrs) Winter____(hrs)
7. Invertors/Generator sets (Make) : _______________
8. Capacity of Gen sets (KVA) : _______________
9. Average fuel consumption in Gen Set (daily/monthly):

   Summer________ Winter_______

Form A3.1.2: Questionnaire for Survey of Commercial Sectors

Hotels/Restaurants/Bakery /Generator Sets Emission Inventory

1. Name & address of Hotel/Restaurant/Bakery/Establishments :
2. Ward No. :
3. Name & address of contact person :
4. Type of Hotel / Restaurant/Bakery : Small / Medium / Big
5. Quantity of fuel used / day : LPG/NG/Coal/ Kerosene / Other fuel
6. Capacity of gas cylinder :
7. Power failure (hrs/day)
8. Invertors/Generator sets (Make) : _______________
9. Capacity of Gen sets (KVA) : _______________
10. Average fuel consumption in Gen Set (daily/monthly): Summer______ Winter_______

Construction Activities Emission Inventory

1. Name & address of contact person :
2. Address of construction site :
3. Ward No. :
4. Type of construction (Road / Flyover / Building):
5. Whether new construction or renovation :
6. Area of construction (length & width) :
7. Duration of construction (months) :
8. Other useful information :

Form A3.2.1: Questionnaire for Survey of Industries

Name of Industrial Estate :

Name of Industry :

Address / Location of Industry :

Capacity / Production (TPD) :

Working Hours / Shift :

	Coal/coke	**HSD**	**LDO**	**FO**	**Gas**	**LSHS**	**Others**
Fuel Used / Quantity (TPD) :							
Sulphur % in fuel :							
Ash content in fuel % :							
Stack details :							

Height	**Dia**	**Velocity**	**Temp**	**Emission Concentration (ug/m^3)**					APC Details			
										Eff	**Standard**	
(m)	**(m)**	**(m/s)**	**(^{0}C)**	**SPM**	SO2	**NO$_X$**	**HC**	**CO**	**Type**	**(%)**	**SPM**	**SO2**

Consent File No. ____________________ APC / NEERI

Name of the Proj. Asst. ___________________

Date: ___________________ Source: _____________

Form A3.3.1: Questionnaire for Survey of Passenger Vehicles

City: ………………………

Location: Fuel Pump / Bus Terminal / Taxi Stand/ Auto Stand/Parking lot

Interviewer's Name:……………………………………… Contact Number:

Date: **Time:**

1. Vehicle Type: New Car / Old Car / 2-wheelers (2/4stroke)/ 2/4 stroke / Auto/Bus

   a) Make & Model:…………………………………………….
   b) Fuel Used: Petrol / Diesel / CNG / LPG / Propane

2. Details of your trip:

   a) Origin *(Starting From)* Destination *(Going to)*
   Locality :…………………………. Locality:
   City : ……………..…………….. City :………………

   b) Distance of this trip *(Km)*:……………………

   c) Time taken for this trip: ……. *(Hrs)…… (Mins)*

   d) Frequency of this trip: Daily / Bi-weekly / Tri-Weekly/ Weekly / Occasionally

   e) Garaging *(Place of Parking at night)*: Within City / Outside City

3. Fuel Consumption Rate *(Mileage): ……………(Km. / Litre)*

4. Average Kms. travelled per day within the city: ………………kms.

5. Vehicle Occupancy: ……………………..

6. a) How many litres of fuel filled currently: ……………*(in litres. or in Rs.)*
   b) Frequency of Filling: Daily/Alternate Days/Bi-weekly/Tri-weekly/Occasionally

7. Details of I & M practices: Frequency: Quarterly/Six-monthly/Yearly; Expenditure:

8. Date of last PUC: PUC attached: Yes/No
   At Idling, RPM
   Measured level of CO: Measured level of HC:
   At high Idle, Measured RPM -------- lambda:
   Measured level of CO: Measured level of HC:
   Measured level of CO_2: Measured level of O_2:

9. Any other useful information

Form A3.3.2: Questionnaire for Survey of Goods Vehicles

City: ……………………………

Location: Fuel Pump / Bus Terminal / Taxi Stand/ Auto Stand/Parking lot

Interviewer's Name:………………………………………Contact Number:

Date: **Time:**

1. Vehicle Type: LCVs/ Normal Trucks / Multi Axle Trucks
   a) Make & Model:
   b) Fuel Used: Petrol / Diesel / CNG / LPG / Propane

2. Details of your trip:

a) Origin *(Starting From)*	Destination *(Going to)*
Locality :………………………….	Locality : ……………………
City : …………………………….	City :…………………………
State : …………………………….	State : ………………………..

   b) Distance of this trip *(Km)*:……………………

   c) Time taken for this trip: ……. *(Hrs)…… (Mins)*

   d) Frequency of this trip: Daily / Bi-weekly / Tri-Weekly/ Weekly / Occasionally

   e) Garaging *(Place of Parking at night)*: Within City / Outside City

3. Fuel Consumption Rate *(Mileage): ……………(Km. / Litre)*

4. Average Kms. traveled per day : ………………kms.

5. Average Kms. traveled per day within the city: ………………kms.

6. a) How many litres of fuel filled currently : ……………*(in litres. or in Rs.)*
   b) Frequency of Filling: Daily/Alternate Days/Bi-weekly/Tri-weekly/Occasionally

7. Vehicle Load (MT): Empty / Loaded

8. Purpose of Entering the city *(only incase of out station vehicles):* Filling fuel/ Loading (or) Unloading/Passing through the City/Any other *(pl. specify)*

9. Details of I & M practices: Frequency:Quarterly/Six-monthly/Yearly; Expenditure:

10. Date of last PUC: PUC attached: Yes/No
    At Idling, RPM
    Measured level of CO: Measured level of HC:
    At high Idle, Measured RPM ______ lambda:
    Measured level of CO: Measured level of HC:
    Measured level of CO_2: Measured level of O_2:

11. Any other useful information

Annexure 4.1.1a

Factor loading matrix

Table 4.1.1.1: Factor loading matrix for Ashram Chowk: Summer

Species	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
AG	**0.985**	0.140	-0.011	-0.004	0.098
AL	0.228	**0.954**	-0.157	-0.043	0.060
AS	**0.985**	0.140	-0.011	-0.004	0.098
BA	-0.019	**0.946**	-0.110	0.279	0.045
CA	0.130	**0.967**	-0.183	-0.084	-0.002
CAION	**0.899**	0.422	-0.056	0.002	0.054
CD	**0.985**	0.140	-0.011	-0.004	0.098
CL	-0.021	-0.349	**0.636**	-0.181	-0.235
CO	**0.985**	0.140	-0.011	-0.004	0.098
CR	**0.985**	0.140	-0.011	-0.004	0.098
CU	0.205	-0.206	**0.940**	-0.050	-0.037
EC	-0.151	-0.464	0.113	**0.790**	0.051
F	**0.802**	0.216	0.200	-0.211	-0.235
FE	0.121	**0.967**	-0.209	-0.051	0.028
GA	**0.985**	0.140	-0.011	-0.004	0.098
KION	**0.946**	0.063	-0.106	-0.186	-0.168
LN	**0.985**	0.140	-0.011	-0.004	0.098
MG	0.307	**0.921**	-0.181	-0.097	0.098
MGION	**0.957**	0.189	-0.011	0.179	0.103
MN	0.215	**0.943**	-0.128	-0.105	0.045
MO	**0.985**	0.140	-0.011	-0.004	0.098
NA	**0.640**	0.353	0.194	-0.169	**0.596**
NAION	**0.919**	0.275	-0.114	0.212	0.025
NH3	**0.971**	0.161	-0.045	0.095	0.119
NI	**0.621**	0.252	0.074	-0.105	**0.707**
NO	**0.957**	0.177	-0.038	0.087	0.168
NO3	0.046	-0.263	**0.662**	0.435	0.275
OC	0.142	**0.604**	-0.127	**0.705**	-0.156
P	**0.716**	0.537	-0.165	0.215	0.348
PB	-0.149	-0.205	**0.915**	0.020	0.230
PD	**0.985**	0.140	-0.011	-0.004	0.098
RB	**0.986**	0.137	-0.013	-0.001	0.089
SB	**0.985**	0.140	-0.011	-0.004	0.098
SE	**0.985**	0.140	-0.011	-0.004	0.098
SI	0.498	**0.521**	0.153	0.183	**0.521**
SN	**0.985**	0.140	-0.011	-0.004	0.098
SO4	0.409	0.345	0.416	**0.640**	0.123
SR	**0.593**	**0.788**	-0.116	-0.029	0.070
TC	-0.025	0.020	0.007	**0.988**	-0.055
TI	0.337	0.911	-0.092	0.050	0.173
V	**0.952**	0.296	-0.027	-0.034	0.048
ZN	-0.417	-0.237	**0.739**	0.347	-0.052
ZR	**0.985**	0.140	-0.011	-0.004	0.098
% Var	53.852	21.863	8.517	7.580	4.207
Source	Combustion	Resuspended dust	Smelter	Auto exhaust	Soil dust

Table 4.1.1.2: Factor loading matrix for Mayapuri: Summer

Species	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
AG	**0.701**	-0.085	**0.705**	0.007	0.008
AL	-0.196	**0.833**	0.320	0.383	0.003
AS	**0.986**	-0.031	0.153	-0.046	0.013
BA	0.124	**0.945**	-0.206	-0.142	0.020
CA	-0.210	**0.830**	-0.201	0.463	-0.088
CAION	**0.820**	0.433	-0.008	0.100	-0.323
CD	**0.701**	-0.085	**0.705**	0.007	0.008
CL	0.073	0.372	0.339	**0.855**	0.007
CO	**0.701**	-0.085	**0.705**	0.007	0.008
CR	**0.701**	-0.085	**0.705**	0.007	0.008
CU	-0.241	**0.697**	-0.037	-0.436	-0.007
EC	0.029	**0.957**	-0.139	0.107	-0.078
F	0.490	0.509	0.082	-0.217	**0.582**
FE	-0.029	**0.944**	-0.077	0.296	-0.079
GA	**0.986**	-0.031	0.153	-0.046	0.013
KION	**0.770**	0.309	0.384	0.207	0.218
LN	**0.701**	-0.085	**0.705**	0.007	0.008
MG	-0.177	**0.788**	0.059	0.577	-0.086
MGION	**0.920**	0.208	0.146	0.061	-0.132
MO	**0.986**	-0.031	0.153	-0.046	0.013
NA	**0.857**	-0.121	0.064	0.387	0.177
NAION	**0.822**	0.001	0.479	0.116	-0.215
NH3	0.009	0.408	-0.328	**0.790**	-0.130
NI	**0.986**	-0.031	0.153	-0.046	0.013
NO	-0.363	-0.555	-0.500	-0.476	-0.040
NO3	0.273	**0.805**	-0.298	-0.225	-0.185
OC	0.196	**0.961**	0.039	0.126	0.115
P	**0.752**	0.577	-0.093	0.216	0.148
PB	-0.286	**0.713**	0.023	**0.593**	0.176
PD	**0.986**	-0.031	0.153	-0.046	0.013
RB	**0.986**	-0.031	0.153	-0.046	0.013
SB	**0.986**	-0.031	0.153	-0.046	0.013
SE	**0.986**	-0.031	0.153	-0.046	0.013
SI	-0.187	0.872	-0.128	0.211	0.298
SN	**0.945**	-0.002	0.084	-0.157	-0.032
SO4	0.302	**0.814**	0.261	-0.067	-0.358
SR	0.921	0.242	0.038	0.254	0.151
TC	0.132	**0.977**	-0.032	0.121	0.038
TI	0.054	**0.935**	0.169	0.260	0.057
V	**0.986**	-0.031	0.153	-0.046	0.013
ZN	-0.173	**0.960**	0.068	-0.056	0.187
ZR	**0.986**	-0.031	0.153	-0.046	0.013
HG	**0.986**	-0.031	0.153	-0.046	0.013
LA	0.701	-0.085	**0.705**	0.007	0.008
Y	**0.986**	-0.031	0.153	-0.046	0.013
% Var	47.534	29.123	10.198	7.922	2.256
Source	Combustion	Resuspended dust and Auto exhaust	Industries	Smelter	Misc.

Table 4.1.1.3: Factor loading matrix for ISBT: Summer

Species	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
AL	-0.092	**0.872**	0.354	-0.032	-0.091	0.309
AS	**0.967**	0.115	0.176	0.128	-0.022	0.063
BA	0.140	0.058	-0.080	**0.792**	-0.199	0.026
CA	**-0.610**	0.401	-0.432	-0.494	0.094	0.008
CAION	-0.209	0.032	-0.139	-0.229	0.819	0.368
CD	**0.967**	0.115	0.176	0.128	-0.022	0.063
CL	**0.728**	0.300	-0.048	-0.172	0.009	0.370
CO	**0.967**	0.115	0.176	0.128	-0.022	0.063
CR	**0.694**	0.109	**0.697**	-0.066	-0.015	-0.002
CU	**0.754**	0.201	0.404	0.403	-0.215	-0.039
EC	**0.786**	0.040	0.190	0.112	0.363	0.130
F	**0.821**	0.382	0.325	0.210	-0.156	-0.008
FE	0.212	**0.886**	0.298	-0.173	-0.069	0.073
GA	**0.967**	0.115	0.176	0.128	-0.022	0.063
KION	**0.911**	-0.059	0.085	0.152	-0.112	-0.219
LN	**0.967**	0.115	0.176	0.128	-0.022	0.063
MG	-0.494	0.522	-0.355	**-0.560**	-0.172	0.070
MGION	-0.163	0.273	-0.082	-0.031	**0.915**	-0.215
MO	**0.967**	0.115	0.176	0.128	-0.022	0.063
NA	**0.897**	-0.021	0.059	-0.381	-0.167	-0.026
NAION	**0.911**	0.117	-0.021	-0.281	-0.153	-0.014
NH3	0.542	**0.619**	-0.294	0.160	-0.120	0.064
NI	**0.958**	0.161	0.162	0.148	-0.024	0.086
NO	**0.948**	0.080	0.254	0.115	-0.099	0.025
NO3	0.014	**0.826**	-0.211	-0.055	0.340	-0.334
OC	**0.663**	0.266	-0.216	-0.337	0.011	0.488
PB	0.165	0.029	**0.782**	0.370	-0.378	-0.154
PD	**0.628**	-0.021	**0.735**	-0.167	-0.025	0.049
RB	0.425	0.467	-0.095	0.421	0.107	**0.619**
SB	**0.967**	0.115	0.176	0.128	-0.022	0.063
SE	**0.967**	0.115	0.176	0.128	-0.022	0.063
SI	0.315	**0.810**	-0.164	0.274	0.248	0.212
SO4	**0.620**	0.437	-0.204	0.427	0.375	-0.128
SR	**0.967**	0.115	0.176	0.128	-0.022	0.063
TC	**0.802**	0.190	-0.048	-0.163	0.180	0.376
TI	**0.531**	**0.753**	0.035	0.067	0.303	-0.031
V	**0.967**	0.115	0.176	0.128	-0.022	0.063
ZN	**0.788**	0.125	0.483	0.253	-0.004	-0.186
ZR	**0.967**	0.115	0.176	0.128	-0.022	0.063
HG	**0.967**	0.115	0.176	0.128	-0.022	0.063
LA	**0.967**	0.115	0.176	0.128	-0.022	0.063
MN	**0.744**	0.360	0.469	0.051	0.154	-0.184
P	**0.927**	0.094	0.192	0.123	-0.236	0.017
AG	0.504	-0.050	**0.804**	-0.220	-0.024	0.042
SN	**0.967**	0.115	0.176	0.128	-0.022	0.063
% Var	57.834	12.321	9.860	6.526	5.723	3.541
Source	Combustion	Soil dust	Industrial	Auto Exhaust	Soil dust	Misc.

Table 4.1.1.4: Factor loading matrix for Loni Road: Summer

Species	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
AG	**0.962**	0.262	-0.013	-0.008	0.022	0.023	-0.043
AL	-0.045	0.057	**0.941**	0.112	0.261	0.056	-0.121
AS	**0.962**	0.262	-0.013	-0.008	0.022	0.023	-0.043
BA	0.110	**0.631**	**0.747**	0.109	-0.128	0.018	0.035
CA	0.039	-0.032	**0.989**	-0.022	-0.084	0.067	0.017
CAION	-0.195	0.166	0.438	0.133	0.054	0.143	**0.836**
CD	**0.962**	0.262	-0.013	-0.008	0.022	0.023	-0.043
CL	-0.527	-0.391	0.129	0.601	0.005	-0.366	0.174
CO	**0.962**	0.262	-0.013	-0.008	0.022	0.023	-0.043
CR	0.436	**0.812**	0.302	-0.120	-0.130	0.023	0.040
CU	-0.172	-0.172	**0.828**	-0.126	-0.040	-0.287	0.385
EC	-0.462	-0.235	0.535	0.395	-0.308	-0.138	0.400
F	0.289	0.030	0.444	0.003	-0.288	**0.646**	-0.020
FE	0.010	0.053	**0.990**	0.040	-0.060	-0.016	0.059
GA	0.356	**0.926**	0.038	0.006	0.084	-0.036	-0.024
KION	0.523	-0.187	0.273	-0.017	**0.674**	-0.175	0.069
LN	0.356	**0.926**	0.038	0.006	0.084	-0.036	-0.024
MG	0.098	0.141	**0.961**	-0.116	-0.073	0.057	0.014
MGION	0.157	-0.013	0.370	0.832	0.168	0.183	0.280
MO	0.356	**0.926**	0.038	0.006	0.084	-0.036	-0.024
NA	-0.048	-0.423	0.030	-0.699	0.414	0.017	0.354
NAION	**-0.691**	0.378	0.351	0.261	-0.391	-0.097	0.131
NH3	-0.175	-0.424	-0.135	0.005	-0.163	**0.826**	0.079
NI	-0.079	-0.074	0.370	0.640	0.262	-0.481	0.317
NO	0.514	**0.562**	0.284	-0.125	-0.138	0.257	-0.406
NO3	0.114	**-0.799**	0.284	0.105	0.254	-0.025	-0.180
OC	-0.155	**-0.758**	**0.573**	0.198	0.072	0.039	0.018
PB	-0.099	-0.120	**0.848**	0.049	-0.245	-0.248	0.319
PD	0.356	**0.926**	0.038	0.006	0.084	-0.036	-0.024
RB	-0.098	0.334	-0.301	0.382	**0.783**	-0.110	-0.041
SB	**0.962**	0.262	-0.013	-0.008	0.022	0.023	-0.043
SE	**0.962**	0.262	-0.013	-0.008	0.022	0.023	-0.043
SI	0.240	**0.575**	**0.644**	-0.162	-0.039	0.263	-0.236
SN	0.460	0.094	-0.240	0.003	0.489	**0.665**	0.137
SO4	0.319	0.257	-0.338	0.416	**0.601**	-0.311	0.180
SR	0.297	**0.889**	0.212	0.155	0.075	-0.129	0.027
TC	-0.207	**-0.722**	**0.597**	0.236	0.021	0.016	0.074
TI	-0.022	0.009	**0.987**	0.094	-0.009	-0.024	0.055
V	**0.962**	0.257	-0.030	-0.017	0.023	0.068	-0.002
ZN	-0.111	-0.214	-0.020	0.923	0.247	0.033	-0.068
ZR	**0.962**	0.262	-0.013	-0.008	0.022	0.023	-0.043
HG	0.526	0.495	0.248	-0.255	-0.565	-0.013	0.123
LA	0.356	**0.926**	0.038	0.006	0.084	-0.036	-0.024
Y	**0.962**	0.262	-0.013	-0.008	0.022	0.023	-0.043
MN	-0.094	0.038	**0.902**	0.400	-0.096	0.003	0.024
% Var	26.134	23.244	23.181	8.535	6.669	5.460	4.101
Source	Combustion	Auto exhaust	Resuspended dust	Soil dust	Misc.	Agricultural	Soil dust

Table 4.1.1.5: Factor loading matrix for Anand Vihar

Species	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
AG	**0.955**	0.255	0.136	-0.011	-0.061
AL	0.521	-0.244	0.335	0.455	-0.488
AS	**0.955**	0.255	0.136	-0.011	-0.061
BA	0.368	**0.782**	0.457	0.125	-0.118
CA	0.367	**0.740**	0.511	0.116	-0.144
CAION	**0.759**	0.482	0.427	0.004	-0.004
CD	**0.955**	0.255	0.136	-0.011	-0.061
CL	0.085	0.059	**0.830**	0.341	0.002
CO	**0.955**	0.255	0.136	-0.011	-0.061
CR	**0.955**	0.255	0.136	-0.011	-0.061
CU	0.505	-0.019	-0.300	0.216	0.257
EC	0.304	**0.699**	-0.491	0.129	0.258
F	0.184	**0.817**	0.481	-0.146	0.127
FE	0.492	**0.818**	0.239	0.087	-0.092
GA	**0.955**	0.255	0.136	-0.011	-0.061
KION	0.432	0.137	**0.715**	-0.130	-0.031
LN	**0.955**	0.255	0.136	-0.011	-0.061
MG	0.542	**0.760**	0.328	0.040	-0.129
MGION	**0.651**	0.297	**0.642**	-0.196	-0.054
MO	**0.955**	0.255	0.136	-0.011	-0.061
NA	0.584	**0.762**	-0.040	0.079	0.195
NAION	0.209	0.196	**0.895**	-0.285	-0.060
NH3	-0.242	-0.156	0.079	**0.884**	-0.284
NI	0.539	**0.803**	0.033	0.127	0.047
NO	0.249	0.230	**0.864**	-0.317	-0.066
NO3	0.221	0.383	0.014	**0.779**	0.032
OC	0.093	0.146	-0.418	**0.748**	0.473
PB	-0.158	0.074	-0.095	0.090	**0.945**
PD	**0.955**	0.255	0.136	-0.011	-0.061
RB	**0.955**	0.255	0.136	-0.011	-0.061
SB	**0.955**	0.255	0.136	-0.011	-0.061
SE	**0.955**	0.255	0.136	-0.011	-0.061
SI	**0.711**	**0.650**	-0.024	0.051	-0.157
SN	**0.955**	0.255	0.136	-0.011	-0.061
SO4	-0.226	0.054	-0.058	**0.927**	0.166
SR	**0.837**	0.519	0.032	0.010	-0.117
TC	0.145	0.274	-0.467	**0.678**	0.466
TI	0.554	**0.768**	0.226	0.078	-0.148
V	**0.955**	0.255	0.136	-0.011	-0.061
ZN	-0.385	-0.189	-0.003	0.100	**0.856**
ZR	**0.955**	0.255	0.136	-0.011	-0.061
HG	**0.955**	0.255	0.136	-0.011	-0.061
LA	**0.955**	0.255	0.136	-0.011	-0.061
Y	**0.955**	0.255	0.136	-0.011	-0.061
MN	0.494	**0.723**	0.216	0.047	0.398
P	0.125	0.531	**0.791**	0.164	-0.101
% Var	47.697	19.226	13.309	8.765	6.458
Source	Combustion	Resuspended dust	Soil dust	Auto exhaust	Smelters

Table 4.1.1.6: Factor loading matrix for Naraina: Summer

Species	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
AL	0.235	**0.932**	0.120	-0.176	-0.060
AS	**0.995**	-0.005	0.028	0.069	0.052
BA	-0.032	0.169	**0.955**	-0.093	0.108
CA	-0.413	**0.894**	0.053	-0.059	-0.023
CAION	**0.744**	0.131	-0.169	0.105	**0.588**
CD	**0.995**	-0.005	0.028	0.069	0.052
CL	**0.805**	0.440	0.024	-0.163	0.235
CO	**0.995**	-0.005	0.028	0.069	0.052
CR	**0.995**	-0.005	0.028	0.069	0.052
CU	0.423	0.155	**0.749**	0.076	-0.375
EC	-0.249	0.518	-0.188	-0.511	-0.218
F	**0.872**	-0.043	-0.154	-0.033	0.159
FE	-0.135	**0.965**	0.073	0.032	0.015
GA	**0.995**	-0.005	0.028	0.069	0.052
KION	0.501	0.215	-0.228	0.060	**0.730**
LN	**0.995**	-0.005	0.028	0.069	0.052
MG	0.339	**0.865**	-0.032	0.017	0.324
MGION	**0.722**	0.103	-0.283	-0.089	0.585
MO	**0.995**	-0.005	0.028	0.069	0.052
NA	**0.603**	**0.671**	0.166	-0.264	-0.063
NAION	**0.977**	-0.046	-0.044	0.055	0.108
NH3	-0.229	0.504	-0.230	-0.571	-0.092
NI	**0.995**	-0.005	0.028	0.069	0.052
NO	**0.994**	0.013	0.022	0.047	0.076
NO3	0.237	-0.148	0.031	**0.950**	0.059
OC	-0.407	**0.832**	0.237	-0.266	0.057
PB	-0.028	**0.706**	**0.631**	-0.185	-0.232
PD	**0.995**	-0.005	0.028	0.069	0.052
RB	**0.960**	0.015	-0.070	0.068	0.184
SB	**0.995**	-0.005	0.028	0.069	0.052
SE	**0.995**	-0.005	0.028	0.069	0.052
SI	**0.602**	**0.645**	0.174	-0.365	-0.038
SN	**0.995**	-0.005	0.028	0.069	0.052
SO4	-0.025	-0.241	-0.162	**0.879**	-0.111
SR	**0.856**	0.495	0.080	-0.046	0.030
TC	-0.406	**0.831**	0.200	-0.303	0.030
TI	0.383	**0.883**	0.065	-0.115	-0.032
V	**0.995**	-0.005	0.028	0.069	0.052
ZN	-0.096	0.289	0.924	0.105	-0.124
ZR	**0.995**	-0.005	0.028	0.069	0.052
HG	**0.995**	-0.005	0.028	0.069	0.052
LA	**0.995**	-0.005	0.028	0.069	0.052
Y	**0.995**	-0.005	0.028	0.069	0.052
MN	0.036	**0.868**	0.218	0.067	0.420
P	**0.824**	-0.322	0.002	0.047	0.247
% Var	57.242	19.966	7.296	6.410	4.555
Source	Combustion	Resuspended dust	Smelter	Secondary aerosol formation	Soil dust

Table 4.1.1.7: Factor loading matrix for SSI-GTK: Summer

Species	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
AL	-0.018	**0.954**	-0.057	0.087	-0.255	-0.002
AS	**0.983**	-0.015	0.100	-0.046	0.139	0.033
BA	**0.633**	-0.123	-0.489	-0.201	0.187	0.487
CA	-0.514	0.127	-0.218	0.789	-0.048	0.214
CAION	**0.923**	0.315	-0.078	-0.034	-0.048	-0.124
CD	**0.983**	-0.015	0.100	-0.046	0.139	0.033
CL	0.146	**0.883**	-0.097	-0.262	-0.138	-0.198
CO	**0.983**	-0.015	0.100	-0.046	0.139	0.033
CR	-0.476	0.199	-0.097	-0.148	**-0.802**	0.091
CU	0.348	-0.066	**0.907**	-0.052	-0.116	0.056
EC	0.406	-0.311	0.678	0.205	0.216	-0.239
F	-0.037	**0.967**	0.095	-0.147	0.002	0.005
FE	-0.487	0.272	-0.005	-0.036	**-0.823**	0.003
GA	**0.983**	-0.015	0.100	-0.046	0.139	0.033
KION	**0.890**	-0.273	0.301	-0.031	-0.056	-0.065
LN	**0.983**	-0.015	0.100	-0.046	0.139	0.033
MG	-0.230	0.075	-0.192	**0.914**	0.152	0.216
MGION	**0.914**	0.345	-0.023	-0.132	0.126	0.045
MO	**0.983**	-0.015	0.100	-0.046	0.139	0.033
NA	**0.932**	0.021	-0.201	-0.021	0.220	0.201
NAION	**0.870**	-0.169	0.227	0.158	-0.140	-0.297
NH3	**0.871**	0.173	0.170	0.120	0.247	-0.316
NI	**0.599**	0.260	0.206	-0.355	-0.443	0.329
NO	**0.968**	-0.023	0.189	-0.013	0.157	0.028
NO3	0.178	0.382	**0.692**	-0.207	0.436	0.083
OC	-0.004	-0.013	-0.049	**0.985**	0.037	-0.134
PB	0.269	-0.214	**0.853**	-0.140	-0.277	0.207
PD	**0.916**	-0.002	0.347	-0.006	0.186	-0.013
SB	**0.983**	-0.015	0.100	-0.046	0.139	0.033
SE	**0.983**	-0.015	0.100	-0.046	0.139	0.033
SI	0.228	0.541	-0.354	0.270	0.509	0.340
SO4	-0.386	0.441	0.297	-0.450	-0.146	-0.391
SR	**0.983**	-0.015	0.100	-0.046	0.139	0.033
TC	0.113	-0.101	0.149	**0.952**	0.095	-0.190
TI	0.008	**0.905**	0.045	0.390	-0.076	0.125
V	**0.983**	-0.015	0.100	-0.046	0.139	0.033
ZN	0.155	0.241	**0.821**	-0.119	0.174	-0.347
ZR	**0.983**	-0.015	0.100	-0.046	0.139	0.033
HG	**0.983**	-0.015	0.100	-0.046	0.139	0.033
LA	**0.983**	-0.015	0.100	-0.046	0.139	0.033
MN	-0.440	0.169	-0.010	-0.128	**-0.859**	-0.100
P	**0.970**	-0.010	0.214	-0.006	0.033	0.078
AG	**0.983**	-0.015	0.100	-0.046	0.139	0.033
SN	**0.983**	-0.015	0.100	-0.046	0.139	0.033
Y	**0.983**	-0.015	0.100	-0.046	0.139	0.033
% Var	56.493	10.877	9.731	9.517	7.938	2.972
Source	Combustion	Industries	Smelter	Auto exhaust	Soil dust	Misc.

Table 4.1.1.8: Factor loading matrix for Pitampura: Summer

Species	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
AL	0.020	0.217	**0.970**	-0.026	0.031	0.053
AS	**0.995**	-0.068	-0.021	-0.033	-0.019	-0.048
BA	**0.909**	0.036	0.096	0.196	0.034	0.345
CA	**-0.813**	0.341	0.401	-0.130	-0.017	0.077
CAION	0.044	**0.884**	0.082	-0.265	0.087	0.049
CD	**0.995**	-0.068	-0.021	-0.033	-0.019	-0.048
CL	-0.471	**0.774**	0.285	0.138	0.003	0.007
CO	**0.995**	-0.068	-0.021	-0.033	-0.019	-0.048
CR	**0.841**	-0.070	0.002	-0.135	-0.349	0.107
CU	-0.392	-0.101	-0.229	-0.259	**0.782**	0.235
EC	-0.302	0.008	-0.050	**0.879**	-0.292	-0.174
F	0.161	**0.881**	0.088	0.315	-0.113	0.040
FE	-0.391	0.449	**0.740**	-0.073	0.250	0.161
GA	**0.995**	-0.068	-0.021	-0.033	-0.019	-0.048
KION	-0.286	**0.610**	0.538	0.087	0.129	0.441
LN	**0.995**	-0.068	-0.021	-0.033	-0.019	-0.048
MG	**-0.639**	0.296	**0.599**	-0.324	-0.100	-0.038
MGION	0.021	-0.133	0.093	**-0.826**	-0.277	-0.084
MO	**0.995**	-0.068	-0.021	-0.033	-0.019	-0.048
NA	**0.784**	-0.359	-0.012	0.408	-0.205	-0.210
NAION	-0.160	0.358	0.297	-0.136	0.105	**0.830**
NH3	-0.424	**0.783**	0.071	0.136	0.307	0.003
NI	**0.995**	-0.068	-0.021	-0.033	-0.019	-0.048
NO	**0.987**	0.012	-0.077	-0.031	-0.073	-0.091
NO3	0.005	**0.917**	0.105	0.080	-0.371	-0.001
OC	0.444	0.575	0.293	0.486	-0.203	0.320
PB	-0.408	-0.386	-0.435	-0.377	0.409	0.417
PD	**0.995**	-0.068	-0.021	-0.033	-0.019	-0.048
RB	**0.995**	-0.068	-0.021	-0.033	-0.019	-0.048
SB	**0.995**	-0.068	-0.021	-0.033	-0.019	-0.048
SE	**0.995**	-0.068	-0.021	-0.033	-0.019	-0.048
SI	**0.995**	-0.068	-0.021	-0.033	-0.019	-0.048
SO4	-0.288	**0.879**	0.156	0.090	0.158	0.132
SR	**0.995**	-0.068	-0.021	-0.033	-0.019	-0.048
TC	-0.145	0.166	0.036	**0.914**	-0.315	-0.066
TI	0.156	0.073	**0.968**	0.046	-0.019	0.093
V	**0.995**	-0.068	-0.021	-0.033	-0.019	-0.048
ZN	0.216	0.116	0.357	-0.096	**0.885**	-0.040
ZR	**0.976**	-0.009	0.115	-0.091	-0.109	-0.050
HG	**0.995**	-0.068	-0.021	-0.033	-0.019	-0.048
LA	**0.995**	-0.068	-0.021	-0.033	-0.019	-0.048
Y	**0.995**	-0.068	-0.021	-0.033	-0.019	-0.048
MN	**0.607**	0.448	0.438	-0.244	0.310	-0.249
P	**0.917**	0.153	0.252	0.063	0.179	0.037
AG	**0.995**	-0.068	-0.021	-0.033	-0.019	-0.048
% Var	57.032	14.073	9.376	7.642	5.692	3.590
Source	Combustion	Auto exhaust	Resuspended dust	Auto exhaust	Smelter	Misc.

Table 4.1.1.9: Factor loading matrix for Prahladpur: Summer

Species	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8
AG	**0.987**	-0.079	0.064	0.031	0.034	-0.002	0.081	0.078
AL	0.360	-0.200	0.236	0.739	-0.245	-0.094	0.078	0.365
AS	0.524	**0.843**	-0.009	-0.030	-0.044	0.047	-0.047	0.001
BA	**0.626**	0.406	0.081	0.452	-0.021	0.037	0.285	-0.109
CA	**-0.946**	0.202	0.149	0.034	-0.015	-0.057	0.173	-0.071
CAION	-0.075	0.288	**0.855**	0.111	0.185	-0.322	0.094	-0.117
CD	**0.738**	0.529	0.329	-0.065	0.070	-0.023	0.227	0.048
CL	**-0.696**	0.226	-0.135	-0.003	-0.145	0.133	-0.189	**-0.605**
CO	**0.987**	-0.079	0.064	0.031	0.034	-0.002	0.081	0.078
CR	**0.934**	0.317	-0.118	0.039	-0.039	0.047	-0.079	0.047
CU	-0.381	**0.898**	0.129	0.074	0.022	0.013	0.135	-0.076
EC	0.287	-0.197	-0.087	0.111	-0.190	-0.084	-0.060	**0.900**
F	-0.229	-0.369	-0.277	0.475	-0.254	**0.650**	0.141	-0.029
FE	**-0.933**	0.260	-0.024	0.178	-0.143	0.006	0.025	-0.019
GA	**0.987**	-0.079	0.064	0.031	0.034	-0.002	0.081	0.078
KION	-0.287	-0.084	-0.014	-0.030	-0.026	0.081	**-0.927**	-0.017
LN	**0.987**	-0.079	0.064	0.031	0.034	-0.002	0.081	0.078
MG	**-0.883**	0.101	0.013	-0.025	-0.201	-0.059	0.380	-0.097
MGION	0.332	-0.008	**0.820**	0.045	0.192	0.412	-0.089	-0.024
MO	**0.987**	-0.079	0.064	0.031	0.034	-0.002	0.081	0.078
NA	**0.967**	0.045	-0.018	0.015	-0.051	0.214	-0.038	-0.080
NAION	-0.078	-0.404	**0.569**	**-0.672**	0.209	-0.010	-0.052	0.089
NH3	0.240	0.172	0.050	-0.094	0.143	**0.921**	-0.150	-0.101
NI	**0.987**	-0.079	0.064	0.031	0.034	-0.002	0.081	0.078
NO	**0.779**	-0.011	-0.155	-0.324	-0.039	0.222	0.359	0.129
NO3	-0.390	0.007	-0.548	0.464	-0.310	0.417	0.072	-0.228
OC	0.067	-0.039	0.202	-0.260	**0.921**	0.035	0.009	-0.188
PB	-0.452	**0.749**	0.243	-0.192	0.315	-0.014	0.142	-0.115
PD	**0.987**	-0.079	0.064	0.031	0.034	-0.002	0.081	0.078
RB	**0.980**	-0.043	0.098	-0.108	0.055	0.012	0.022	0.084
SB	0.224	**0.742**	0.367	-0.244	-0.035	-0.127	0.419	-0.103
SE	**0.987**	-0.079	0.064	0.031	0.034	-0.002	0.081	0.078
SI	0.319	-0.464	-0.205	0.392	0.398	0.366	0.176	0.383
SN	-0.105	**0.924**	-0.253	0.006	-0.151	0.062	-0.180	-0.084
SO4	-0.087	**0.693**	-0.467	0.307	-0.351	-0.006	-0.211	-0.103
SR	**0.918**	0.029	0.267	0.085	0.031	0.083	0.265	-0.019
TC	0.147	-0.093	0.192	-0.248	**0.932**	0.016	-0.006	0.035
TI	-0.115	-0.090	0.009	**0.935**	-0.274	0.032	-0.106	0.042
V	**0.995**	-0.006	0.031	0.033	0.021	0.007	0.053	0.073
ZN	-0.356	**0.924**	0.060	-0.054	-0.005	0.022	0.046	-0.096
ZR	**0.987**	-0.079	0.064	0.031	0.034	-0.002	0.081	0.078
HG	0.096	**0.801**	0.474	-0.122	0.086	-0.045	0.303	-0.002
LA	**0.987**	-0.079	0.064	0.031	0.034	-0.002	0.081	0.078
Y	**0.987**	-0.079	0.064	0.031	0.034	-0.002	0.081	0.078
MN	-0.418	**0.759**	-0.344	0.168	-0.151	0.044	-0.244	-0.037
P	**-0.837**	0.296	-0.127	0.209	-0.144	0.210	-0.051	-0.278
% Var	48.722	16.612	7.533	7.173	5.988	4.518	4.467	4.020
Source	Combustion & Resuspended dust	Soil dust	Soil dust	Soil dust	Auto exhaust	Agricultural	Misc.	Misc.

Table 4.1.1.10: Factor loading matrix for Ashram Chowk: Post Monsoon

Species	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
AG	0.107	-0.387	-0.036	-0.027	0.056	0.123	0.870
AL	0.193	**0.897**	0.109	0.263	-0.143	0.093	-0.126
AS	**0.981**	0.105	0.091	0.116	-0.043	0.008	0.017
BA	0.188	**0.648**	0.275	0.524	-0.183	-0.124	0.057
CA	0.015	**0.934**	0.034	0.142	0.167	0.163	-0.187
CAION	0.415	**0.621**	0.281	0.083	0.347	0.277	0.059
CD	**0.981**	0.105	0.091	0.116	-0.043	0.008	0.017
CL	0.344	0.368	0.405	0.389	0.606	0.094	-0.035
CO	**0.981**	0.105	0.091	0.116	-0.043	0.008	0.017
CR	**0.830**	0.096	0.396	0.098	0.087	0.232	-0.126
CU	0.364	0.383	0.046	**0.778**	0.082	-0.212	0.020
EC	**0.715**	0.114	0.414	0.490	0.117	0.110	0.062
F	0.216	-0.023	0.376	-0.038	-0.047	**0.821**	0.052
FE	-0.016	**0.928**	0.129	0.253	0.025	0.075	-0.141
GA	**0.981**	0.105	0.091	0.116	-0.043	0.008	0.017
HG	**0.981**	0.105	0.091	0.116	-0.043	0.008	0.017
KION	0.348	0.570	0.150	0.106	**0.616**	0.068	0.048
LA	**0.981**	0.105	0.091	0.116	-0.043	0.008	0.017
LN	**0.845**	0.071	0.433	0.062	0.060	0.197	-0.090
MG	-0.026	**0.945**	-0.040	0.112	0.066	0.190	-0.177
MGION	0.225	0.324	**0.794**	0.123	-0.088	-0.086	0.050
MN	0.157	**0.707**	0.260	0.503	0.098	0.025	-0.207
MO	**0.981**	0.105	0.091	0.116	-0.043	0.008	0.017
NA	0.442	0.100	-0.074	-0.156	**-0.769**	0.064	-0.141
NAION	0.515	0.309	0.213	0.580	0.266	-0.049	-0.099
NH3	-0.030	-0.317	-0.011	-0.051	0.088	-0.026	**0.926**
NI	**0.714**	-0.105	0.493	0.205	-0.150	0.152	-0.242
NO	0.221	0.162	**0.777**	0.006	0.233	0.431	-0.105
NO3	0.372	0.410	0.433	-0.071	0.255	0.394	0.114
OC	0.397	**0.611**	0.560	0.164	0.111	0.092	-0.058
P	**0.673**	0.432	0.432	0.187	0.126	0.050	-0.023
PB	0.217	0.451	-0.089	**0.803**	0.127	0.130	0.043
PD	**0.981**	0.105	0.091	0.116	-0.043	0.008	0.017
RB	**0.982**	0.103	0.091	0.111	-0.040	0.003	0.016
SB	**0.981**	0.105	0.091	0.116	-0.043	0.008	0.017
SE	**0.981**	0.105	0.091	0.116	-0.043	0.008	0.017
SI	0.497	0.075	0.085	0.016	**-0.808**	0.015	-0.050
SN	**0.842**	0.097	0.405	0.061	0.045	0.133	-0.105
SO4	-0.167	0.440	-0.084	0.036	-0.013	**0.822**	0.048
SR	-0.032	**-0.781**	-0.177	0.158	0.154	0.280	0.378
TC	0.496	0.534	0.561	0.251	0.120	0.102	-0.034
TI	0.493	**0.645**	0.347	0.275	-0.294	0.003	-0.055
V	**0.978**	0.104	0.123	0.119	-0.038	0.028	0.008
Y	**0.981**	0.105	0.091	0.116	-0.043	0.008	0.017
ZN	0.445	0.312	0.326	**0.621**	0.058	0.155	-0.261
ZR	**0.981**	0.105	0.091	0.116	-0.043	0.008	0.017
% Var	42.628	18.638	9.123	7.821	5.813	4.863	4.685
Source	Combustion	Resuspended dust	Soil dust	Smelter	Soil dust	Secondary aerosol formation	Misc.

Table 4.1.1.11: Factor loading matrix for Dhaula Kuan: Post Monsoon

Species	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
AG	**0.901**	0.155	0.299	0.203	0.174
AL	**0.613**	0.475	0.275	0.414	0.362
AS	**0.862**	0.284	0.170	0.002	0.003
BA	**0.883**	0.102	0.306	0.218	0.206
CA	-0.167	**0.948**	-0.033	-0.077	0.233
CAION	**0.671**	0.421	0.490	0.234	0.225
CD	**0.901**	0.155	0.299	0.203	0.174
CL	**0.825**	0.280	0.178	0.426	0.137
CO	**0.939**	0.212	0.177	0.179	0.081
CR	**0.939**	0.212	0.177	0.179	0.081
CU	**0.644**	0.452	0.543	0.058	-0.070
EC	0.191	-0.139	**0.817**	0.130	0.416
F	0.563	0.138	0.295	0.490	0.431
FE	0.562	**0.587**	0.339	0.222	0.416
GA	**0.901**	0.155	0.299	0.203	0.174
HG	**0.823**	0.157	0.373	0.184	0.241
KION	**0.874**	0.250	0.128	0.250	0.242
LA	**0.939**	0.212	0.177	0.179	0.081
LN	**0.855**	0.155	0.269	0.179	0.296
MG	0.171	**0.785**	0.061	0.081	0.506
MGION	0.254	-0.059	0.094	**0.883**	0.038
MN	0.502	0.471	0.502	0.072	0.112
MO	**0.939**	0.212	0.177	0.179	0.081
NA	0.727	0.309	0.439	0.408	0.093
NAION	0.180	0.025	-0.032	**0.944**	-0.101
NH3	0.309	0.327	0.078	-0.090	**0.798**
NI	**0.901**	0.155	0.299	0.203	0.174
NO	**0.935**	-0.161	-0.262	-0.005	0.095
NO3	0.522	**0.647**	0.061	0.373	0.242
OC	0.538	**0.718**	0.269	0.025	0.129
P	**0.901**	0.155	0.299	0.203	0.174
PB	**0.621**	**0.597**	0.034	-0.086	-0.296
PD	**0.885**	0.208	0.240	0.318	0.058
RB	**0.901**	0.155	0.299	0.203	0.174
SB	**0.939**	0.212	0.177	0.179	0.081
SE	**0.939**	0.212	0.177	0.179	0.081
SI	**0.901**	0.155	0.299	0.203	0.174
SN	**0.636**	0.118	0.315	**0.653**	-0.038
SO4	0.067	0.398	0.289	-0.020	**0.823**
SR	**0.901**	0.155	0.299	0.203	0.174
TC	0.525	0.573	0.496	0.064	0.245
TI	**0.690**	0.278	0.389	0.439	0.297
V	**0.935**	0.267	0.026	0.143	-0.031

Y	**0.939**	0.212	0.177	0.179	0.081
ZN	0.479	0.290	**0.770**	0.070	0.041
ZR	**0.908**	0.157	0.278	0.213	0.160
% Var	55.807	12.694	10.255	9.245	7.129
Source	Combustion, Soil dust	Resuspended dust	Auto exhaust	Soil dust	Secondary aerosol formation

Table 4.1.1.12: Factor loading matrix for Mayapuri: Post Monsoon

Species	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
AG	0.368	**0.923**	0.088	0.060	0.015
AL	0.482	**0.615**	0.522	0.305	0.099
AS	0.368	**0.923**	0.088	0.060	0.015
BA	**0.788**	0.392	0.223	0.393	0.055
CA	0.373	**0.673**	0.548	0.245	0.156
CAION	**0.788**	0.528	0.042	0.170	-0.226
CD	**0.847**	0.476	0.174	0.125	0.054
CL	**0.708**	0.440	0.190	0.058	0.483
CO	**0.847**	0.476	0.174	0.125	0.054
CU	**0.803**	0.203	0.035	0.104	0.445
EC	**0.934**	0.267	0.094	0.089	-0.071
F	**0.825**	0.418	0.105	-0.008	-0.299
FE	**0.695**	0.528	0.366	0.263	0.168
GA	0.368	**0.923**	0.088	0.060	0.015
HG	0.368	**0.923**	0.088	0.060	0.015
KION	**0.774**	0.089	0.298	0.246	-0.396
LA	0.368	**0.923**	0.088	0.060	0.015
LN	0.368	**0.923**	0.088	0.060	0.015
MG	0.396	**0.683**	0.519	0.250	0.118
MGION	**0.796**	0.467	0.070	0.139	-0.307
MN	**0.812**	0.479	0.164	0.160	0.213
MO	0.368	**0.923**	0.088	0.060	0.015
NA	0.296	0.055	**0.883**	-0.109	-0.055
NAION	0.292	0.025	**0.818**	-0.083	0.077
NH3	0.459	0.084	0.100	**0.792**	-0.206
NI	0.368	**0.923**	0.088	0.060	0.015
NO	0.021	-0.047	-0.121	**0.927**	0.125
NO3	0.552	0.459	0.090	**0.655**	-0.006
OC	**0.693**	0.521	0.389	0.182	0.231
P	**0.847**	0.476	0.174	0.125	0.054
PB	**0.884**	0.388	0.102	0.034	0.044
PD	**0.884**	0.388	0.102	0.034	0.044
RB	**0.847**	0.476	0.174	0.125	0.054
SB	0.368	**0.923**	0.088	0.060	0.015
SE	0.368	**0.923**	0.088	0.060	0.015
SI	-0.105	0.071	**0.860**	0.057	-0.053

SN	**0.863**	0.460	0.150	0.117	0.019
SO4	**0.690**	0.330	0.324	0.231	0.037
SR	**0.841**	0.487	0.177	0.123	0.054
TC	**0.744**	0.497	0.356	0.173	0.194
TI	0.485	0.522	0.516	0.448	-0.031
V	0.368	**0.923**	0.088	0.060	0.015
Y	0.368	**0.923**	0.088	0.060	0.015
ZN	**0.869**	0.413	0.045	0.150	0.046
ZR	**0.829**	0.443	0.243	0.124	0.038
% Var	40.547	36.278	9.832	6.726	2.536
Source	Auto exhaust	Combustion	Soil dust	Industries	Misc.

Table 4.1.1.13: Factor loading matrix for Loni Road: Post Monsoon

Species	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
AG	0.038	0.275	-0.175	0.934	-0.024	-0.018
AL	-0.050	**0.936**	0.196	0.170	0.008	0.110
AS	0.920	0.230	0.230	0.155	0.101	0.032
BA	-0.098	0.542	-0.087	**0.820**	-0.011	-0.054
CA	-0.220	**0.903**	0.060	0.328	0.020	-0.088
CAION	**0.797**	0.082	-0.060	-0.003	0.575	0.006
CD	-0.014	0.404	**0.758**	-0.109	0.088	-0.186
CL	**0.839**	0.146	0.084	0.184	-0.041	0.143
CO	**0.988**	-0.004	0.002	-0.063	0.086	-0.039
CR	**0.988**	-0.004	0.002	-0.063	0.086	-0.039
CU	-0.148	-0.018	**0.928**	-0.004	0.211	-0.026
EC	**0.912**	0.290	-0.090	0.026	0.111	-0.191
F	**0.820**	0.023	0.374	0.066	-0.202	-0.107
FE	0.132	**0.956**	0.175	0.041	0.074	-0.054
GA	**0.969**	-0.033	0.090	-0.024	-0.190	-0.064
HG	**0.988**	-0.004	0.002	-0.063	0.086	-0.039
KION	**0.898**	0.134	0.261	0.007	-0.018	0.207
LA	**0.988**	-0.004	0.002	-0.063	0.086	-0.039
LN	**0.627**	0.078	-0.259	-0.278	-0.141	-0.540
MG	-0.016	**0.954**	0.122	0.228	0.026	-0.013
MGION	**0.720**	0.035	-0.121	-0.032	**0.665**	0.015
MN	0.288	**0.934**	-0.002	0.040	-0.023	-0.025
MO	**0.988**	-0.004	0.002	-0.063	0.086	-0.039
NA	-0.104	0.461	-0.104	**0.860**	-0.050	0.026
NAION	**0.839**	0.116	-0.128	-0.256	0.069	0.331
NH3	**0.923**	-0.041	0.189	0.015	-0.177	-0.032
NI	**0.796**	0.538	0.195	0.086	0.063	-0.082
NO	**0.961**	0.087	0.090	0.044	0.161	-0.147
NO3	**0.803**	0.003	0.015	-0.059	-0.461	0.282
OC	**0.781**	0.461	0.095	0.211	0.237	-0.141

P	0.118	**0.906**	0.064	-0.125	-0.104	0.148
PB	0.076	0.171	**0.947**	-0.108	0.003	0.150
PD	**0.986**	-0.023	0.006	-0.061	0.086	-0.043
RB	**0.988**	-0.004	0.002	-0.063	0.086	-0.039
SB	**0.988**	-0.004	0.002	-0.063	0.086	-0.039
SE	**0.988**	-0.004	0.002	-0.063	0.086	-0.039
SI	-0.342	0.562	-0.030	-0.143	-0.114	**0.653**
SN	0.281	0.423	**0.785**	-0.048	-0.041	-0.005
SO4	0.372	-0.022	**0.620**	-0.179	-0.355	0.417
SR	0.046	**0.945**	0.107	0.194	0.164	-0.020
TC	**0.801**	0.447	0.076	0.193	0.225	-0.147
TI	0.138	**0.926**	0.056	0.298	0.021	0.130
V	0.589	0.615	0.285	0.267	0.030	-0.069
Y	**0.988**	-0.004	0.002	-0.063	0.086	-0.039
ZN	0.319	0.106	0.419	-0.109	0.792	-0.019
ZR	**0.988**	-0.004	0.002	-0.063	0.086	-0.039
% Var	50.222	20.732	9.190	6.795	4.851	3.078
Source	Combustion	Soil dust	Smelter	Industries	Soil dust	Soil dust

Table 4.1.1.14: Factor loading matrix for Anand Vihar: Post Monsoon

Species	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
AG	**0.964**	0.188	0.092	0.104	0.102	0.038	-0.018
AL	0.226	**0.917**	0.157	0.133	0.091	0.120	0.052
AS	**0.964**	0.188	0.092	0.104	0.102	0.038	-0.018
BA	-0.068	**0.780**	0.007	0.022	0.072	0.017	0.041
CA	0.110	**0.856**	0.390	0.182	0.040	-0.119	-0.077
CAION	0.033	0.071	0.030	0.191	0.227	0.870	0.053
CD	0.198	0.471	**0.637**	-0.109	0.124	0.120	0.405
CL	0.285	0.251	0.247	**0.740**	0.106	0.216	-0.286
CO	**0.964**	0.188	0.092	0.104	0.102	0.038	-0.018
CR	0.397	**0.759**	-0.070	0.245	-0.077	-0.108	0.022
CU	0.026	0.087	**0.896**	0.238	0.050	-0.251	-0.075
EC	0.482	0.158	0.025	**0.660**	0.139	-0.271	0.011
F	**0.569**	0.422	0.358	0.359	0.390	0.081	-0.011
FE	0.330	**0.870**	0.139	0.197	0.139	0.065	0.039
GA	**0.964**	0.188	0.092	0.105	0.103	0.038	-0.018
HG	**0.964**	0.188	0.092	0.104	0.102	0.038	-0.018
KION	0.457	0.214	0.038	-0.004	**0.812**	0.185	0.124
LA	**0.964**	0.188	0.092	0.104	0.102	0.038	-0.018
LN	**0.941**	0.209	0.053	0.053	0.025	0.031	-0.024
MG	0.225	**0.924**	0.088	0.137	0.092	0.069	0.060
MGION	0.570	0.488	0.003	0.048	0.221	-0.027	-0.499
MN	0.409	**0.786**	0.166	0.112	0.147	-0.052	0.037
MO	**0.964**	0.188	0.092	0.104	0.102	0.038	-0.018
NA	0.577	0.454	0.451	-0.039	-0.121	0.060	0.363

NAION	0.440	0.091	-0.016	0.235	**0.796**	0.125	-0.126
NH3	0.551	0.167	0.103	0.410	**0.596**	0.068	-0.005
NI	**0.886**	0.218	0.216	0.126	0.124	0.008	0.261
NO	**0.757**	-0.021	-0.007	0.048	0.248	-0.107	0.119
NO3	-0.083	0.235	0.085	**0.719**	0.242	-0.026	0.337
OC	0.151	**0.580**	0.273	0.469	0.070	0.248	0.457
P	**0.764**	0.507	0.187	0.189	0.248	0.003	0.107
PB	0.191	0.215	**0.738**	0.195	0.013	0.415	0.360
PD	**0.964**	0.188	0.092	0.104	0.102	0.038	-0.018
RB	**0.964**	0.188	0.092	0.105	0.103	0.038	-0.018
SB	**0.964**	0.188	0.092	0.104	0.102	0.038	-0.018
SE	**0.964**	0.188	0.092	0.104	0.102	0.038	-0.018
SI	0.097	0.433	**0.690**	-0.125	-0.112	0.368	-0.181
SN	**0.716**	0.128	**0.617**	0.090	0.008	0.128	0.206
SO4	0.226	0.192	0.062	**0.838**	-0.041	0.233	-0.092
SR	0.476	**0.761**	0.172	0.208	-0.062	-0.090	-0.174
TC	0.252	0.541	0.242	**0.572**	0.096	0.145	0.398
TI	0.293	**0.843**	0.264	0.079	0.065	0.285	-0.038
V	**0.893**	0.242	0.135	0.240	0.139	-0.033	0.004
Y	**0.964**	0.188	0.092	0.104	0.102	0.038	-0.018
ZN	0.343	0.385	**0.698**	0.387	0.107	-0.136	-0.097
ZR	**0.964**	0.188	0.092	0.104	0.102	0.038	-0.018
% Var	42.256	20.191	9.120	8.503	5.297	3.639	3.299
Source	Combustion	Resuspended dust	Smelter/incinerator	Auto exhaust	Soil dust	Soil dust	Misc.

Table 4.1.1.15: Factor loading matrix for Naraina: Post monsoon

Species	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
AL	0.240	**0.934**	0.096	-0.052	-0.063	0.121
AS	**0.928**	0.149	0.230	0.246	0.023	0.025
BA	-0.229	0.346	-0.131	**0.745**	-0.132	-0.039
CA	0.127	**0.953**	0.130	0.139	-0.030	0.019
CAION	0.270	0.277	0.389	**0.659**	0.267	-0.091
CL	0.364	0.516	**0.707**	0.175	0.016	-0.150
CU	0.249	-0.028	0.074	**0.931**	-0.068	-0.165
EC	0.432	0.202	0.686	0.422	0.259	-0.044
F	**0.595**	0.287	0.471	0.121	0.423	-0.235
FE	0.178	**0.946**	0.192	0.128	0.034	-0.069
HG	**0.928**	0.149	0.230	0.246	0.023	0.025
KION	0.490	0.297	**0.777**	0.107	-0.004	0.083
MG	0.328	**0.915**	0.176	0.057	0.020	-0.024
MGION	**0.673**	0.265	0.433	-0.004	0.289	-0.036
MN	0.226	**0.815**	0.229	0.418	0.066	-0.122
MO	**0.928**	0.149	0.230	0.246	0.023	0.025
NA	0.035	0.523	0.145	0.184	**0.686**	0.241

NAION	0.369	-0.061	**0.649**	-0.052	-0.326	0.500
NH3	0.191	0.013	**0.908**	0.064	-0.170	-0.018
NI	**0.928**	0.149	0.230	0.246	0.023	0.025
NO	0.522	0.310	**0.743**	0.008	0.246	-0.066
NO3	0.512	**0.650**	0.512	0.080	0.121	-0.108
OC	0.390	0.242	0.550	0.594	0.036	0.165
P	**0.835**	0.394	0.282	-0.216	0.067	0.056
PB	0.325	-0.074	0.031	**0.894**	0.075	0.154
PD	**0.791**	0.391	0.331	-0.286	0.005	0.018
RB	**0.835**	0.394	0.282	-0.216	0.067	0.056
SB	**0.928**	0.149	0.230	0.246	0.023	0.025
SE	**0.928**	0.149	0.230	0.246	0.023	0.025
SI	-0.010	0.066	-0.044	-0.048	0.228	**0.950**
SN	**0.623**	0.234	**0.604**	0.343	0.218	-0.017
SO4	-0.119	0.402	0.071	0.168	**-0.628**	-0.245
SR	0.481	0.579	0.594	0.011	0.208	-0.066
TC	0.404	0.239	0.582	0.574	0.075	0.131
TI	0.281	**0.792**	0.071	0.108	0.150	0.455
V	**0.928**	0.149	0.230	0.246	0.023	0.025
Y	**0.928**	0.149	0.230	0.246	0.023	0.025
ZN	0.354	0.561	0.333	**0.610**	-0.111	-0.153
ZR	0.532	0.430	**0.659**	-0.033	0.244	-0.015
% Var	33.278	20.933	17.927	12.892	4.543	4.514
Source	Combustion	Soil dust	Industries	Smelter	Secondary aerosol formation	Soil dust

Table 4.1.1.16: Factor loading matrix for SSI-GTK: Post monsoon

Species	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
AL	-0.404	**0.901**	0.145	0.010	0.064
BA	-0.312	**0.923**	0.017	0.056	0.217
CA	-0.528	**0.836**	0.013	0.125	0.083
CAION	-0.330	**0.885**	-0.301	-0.041	0.124
CL	0.095	0.435	0.540	0.021	**0.714**
CR	**-0.695**	0.345	0.588	-0.106	0.203
CU	0.521	0.097	0.022	0.344	**0.775**
EC	**0.767**	-0.247	0.038	-0.513	0.294
F	-0.052	0.148	**0.961**	-0.211	0.083
FE	-0.373	**0.871**	0.219	0.109	0.206
KION	**-0.675**	0.112	**0.723**	0.006	0.097
MG	-0.439	**0.889**	0.101	0.058	0.054
MGION	-0.179	-0.161	**0.931**	-0.275	0.018
MN	-0.276	**0.611**	0.367	0.016	**0.645**
NA	-0.350	**0.912**	-0.085	-0.114	-0.158
NAION	-0.369	0.028	**0.901**	0.222	-0.035
NH3	0.193	**-0.610**	**0.670**	0.334	0.172

NI	**0.807**	0.470	-0.050	0.353	-0.046
NO	0.498	-0.037	-0.023	**0.775**	0.386
NO3	-0.310	0.484	**0.773**	0.265	0.051
OC	-0.548	0.534	0.505	-0.132	0.377
P	-0.034	**0.987**	0.024	0.150	0.032
PB	**0.842**	-0.065	-0.229	0.319	0.363
SB	**0.958**	-0.260	-0.117	0.017	0.012
SE	**0.958**	-0.260	-0.117	0.017	0.012
SI	0.196	-0.162	-0.150	**-0.951**	-0.087
SN	**0.916**	-0.105	-0.082	-0.313	0.216
SO4	0.000	-0.134	**0.891**	0.434	0.016
SR	0.051	**0.983**	0.057	0.168	0.022
TC	-0.481	0.525	0.526	-0.193	0.422
TI	-0.273	**0.925**	0.157	-0.120	0.178
ZN	**0.607**	0.324	-0.076	0.382	**0.612**
RB	**0.958**	-0.260	-0.117	0.017	0.012
ZR	**0.958**	-0.260	-0.117	0.017	0.012
Y	**0.958**	-0.260	-0.117	0.017	0.012
V	**0.958**	-0.260	-0.117	0.017	0.012
PD	**0.958**	-0.260	-0.117	0.017	0.012
AS	**0.958**	-0.260	-0.117	0.017	0.012
MO	**0.958**	-0.260	-0.117	0.017	0.012
CD	**0.958**	-0.260	-0.117	0.017	0.012
AG	**0.958**	-0.260	-0.117	0.017	0.012
GA	**0.958**	-0.260	-0.117	0.017	0.012
LA	**0.958**	-0.260	-0.117	0.017	0.012
LN	**0.958**	-0.260	-0.117	0.017	0.012
% Var	44.563	26.447	15.365	7.003	6.622
Source	Combustion/Industries	Resuspended dust	Secondary aerosol formation	Soil dust	Smelter

Table 4.1.1.17: Factor loading matrix for Pitampura: Post monsoon

Species	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
AG	**0.973**	-0.125	0.166	0.093	0.041
AL	-0.277	**0.951**	-0.098	-0.070	-0.059
AS	**0.973**	-0.125	0.166	0.093	0.041
BA	-0.321	0.584	0.081	0.569	-0.475
CA	**-0.641**	**0.686**	-0.324	-0.013	0.116
CAION	**0.629**	0.087	**0.742**	0.184	-0.109
CD	**0.994**	-0.087	-0.014	-0.065	0.023
CL	0.379	-0.025	0.716	0.379	0.447
CO	**0.973**	-0.125	0.166	0.093	0.041
CR	**0.754**	0.239	-0.070	0.420	-0.440
CU	0.013	-0.205	0.360	**0.906**	0.082
EC	-0.171	**0.783**	-0.154	0.093	-0.570

F	**0.879**	0.281	0.139	-0.351	-0.073
FE	-0.122	**0.988**	0.072	-0.058	0.010
GA	**0.973**	-0.125	0.166	0.093	0.041
HG	0.270	-0.142	**0.689**	**0.657**	0.019
KION	0.021	0.360	**0.885**	0.158	-0.248
LA	**0.973**	-0.125	0.166	0.093	0.041
LN	**0.973**	-0.125	0.166	0.093	0.041
MG	-0.232	**0.858**	-0.418	-0.012	0.186
MGION	-0.376	**-0.914**	-0.101	-0.042	0.103
MN	-0.122	**0.691**	0.317	0.196	**0.608**
MO	**0.973**	-0.125	0.166	0.093	0.041
NA	0.335	-0.133	**0.650**	**0.668**	0.033
NAION	0.083	**-0.667**	0.713	-0.150	0.133
NH3	0.503	0.066	**0.772**	0.383	-0.019
NI	**0.973**	-0.125	0.166	0.093	0.041
NO	**0.764**	-0.129	**0.618**	0.134	-0.018
NO3	0.483	0.176	**0.775**	0.130	0.345
OC	0.202	-0.419	0.177	**0.837**	0.225
P	**0.926**	0.072	0.045	0.287	-0.230
PB	0.386	**0.688**	-0.063	**0.611**	0.027
PD	**0.973**	-0.125	0.166	0.093	0.041
RB	**0.973**	-0.125	0.166	0.093	0.041
SB	**0.973**	-0.125	0.166	0.093	0.041
SE	**0.973**	-0.125	0.166	0.093	0.041
SI	-0.241	**0.897**	-0.083	-0.303	-0.197
SN	-0.361	**0.861**	0.285	-0.149	0.161
SO4	0.554	0.159	**0.765**	0.032	0.285
SR	0.126	**-0.837**	-0.382	0.248	-0.277
TC	0.162	-0.181	0.140	**0.959**	0.043
TI	**0.973**	-0.125	0.166	0.093	0.041
V	0.001	**0.955**	0.230	-0.158	-0.101
Y	**0.973**	-0.125	0.166	0.093	0.041
ZN	0.064	0.186	-0.009	**0.947**	-0.255
ZR	**0.973**	-0.125	0.166	0.093	0.041
% Var	45.131	22.510	14.701	13.250	4.409
Source	Combustion	Resuspended dust	Secondary aerosol formation	Auto exhaust	Soil dust

Table 4.1.1.18: Factor loading matrix for Prahladpur: Post monsoon

Species	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
AG	0.185	-0.312	-0.064	-0.174	**-0.843**
AL	0.026	**0.771**	**0.612**	-0.003	0.109
AS	**0.964**	-0.140	0.220	0.031	-0.032
BA	0.146	0.110	0.155	**0.947**	0.111
CA	-0.318	**0.919**	0.000	0.014	-0.012

CAION	**0.990**	0.099	-0.079	0.005	0.032
CD	0.540	**0.787**	0.096	-0.068	0.227
CL	**0.852**	0.395	0.324	0.050	-0.078
CR	**0.865**	-0.100	-0.475	0.113	0.044
CU	-0.376	**0.874**	-0.127	0.106	-0.184
EC	**0.909**	-0.105	0.397	0.014	-0.060
F	**0.985**	0.033	-0.059	0.062	-0.063
FE	0.097	**0.790**	0.595	-0.033	0.026
HG	0.930	-0.056	0.210	-0.142	0.153
KION	0.525	**0.760**	0.241	0.235	-0.131
MG	-0.215	**0.881**	0.404	0.086	0.054
MGION	**0.912**	0.104	-0.373	0.081	0.083
MN	-0.102	**0.971**	0.076	0.052	0.001
MO	**0.797**	-0.125	-0.576	0.108	0.062
NA	0.252	0.228	**0.829**	0.271	0.317
NAION	**0.968**	0.091	-0.122	0.084	0.126
NH3	**0.911**	0.086	0.395	-0.006	-0.017
NI	**0.964**	-0.140	0.220	0.031	-0.032
NO	**0.968**	-0.156	0.175	0.022	0.053
NO3	**0.750**	0.586	0.111	0.240	-0.032
OC	0.481	0.133	**0.861**	0.002	-0.076
P	**0.964**	-0.140	0.220	0.031	-0.032
PB	-0.097	**0.920**	0.016	0.058	0.202
PD	**0.964**	-0.140	0.220	0.031	-0.032
RB	**0.964**	-0.140	0.220	0.031	-0.032
SB	**0.806**	-0.148	0.568	0.064	-0.039
SE	**0.964**	-0.140	0.220	0.031	-0.032
SI	**0.964**	-0.140	0.220	0.031	-0.032
SN	0.482	0.466	**0.600**	0.404	0.141
SO4	**0.615**	-0.328	0.167	-0.351	0.495
SR	-0.042	**0.925**	0.044	0.116	0.038
TC	0.532	0.113	**0.833**	0.003	-0.076
TI	**0.960**	0.104	0.213	0.115	-0.075
V	0.128	**0.664**	0.725	0.085	0.042
Y	**0.964**	-0.140	0.220	0.031	-0.032
ZN	**0.964**	-0.140	0.220	0.031	-0.032
ZR	-0.245	**0.857**	-0.075	-0.225	0.084
% Var	52.352	23.685	14.486	3.792	3.227
Source	Resuspended dust /Combustion	Soil dust	Auto exhaust	Misc.	Misc.

Table 4.1.1.19: Factor loading matrix for Ashram Chowk: Winter

Species	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
AG	-0.197	-0.214	-0.066	-0.117	0.098	-0.024	**0.896**
AL	**0.817**	0.147	0.386	-0.085	-0.261	-0.139	-0.124
BA	**0.920**	0.045	0.060	-0.159	0.169	0.098	0.162
CA	**0.941**	-0.217	-0.053	0.069	0.060	0.201	-0.065
CAION	0.159	**-0.754**	0.047	-0.076	0.367	-0.362	-0.127
CL	**0.757**	0.451	-0.194	0.011	0.161	-0.047	0.175
CU	0.479	-0.239	-0.166	-0.109	0.564	0.387	0.355
EC	0.047	**0.638**	-0.548	0.228	0.014	-0.407	0.207
F	-0.098	-0.097	-0.083	-0.200	**-0.918**	-0.017	-0.010
FE	**0.934**	-0.119	0.099	0.130	0.027	0.205	-0.107
KION	**0.613**	0.111	0.578	-0.236	0.129	-0.193	0.212
MG	**0.952**	-0.025	0.012	0.172	-0.064	0.107	-0.060
MGION	0.038	**-0.868**	-0.017	-0.317	-0.094	-0.263	0.179
NA	-0.111	**0.896**	0.110	-0.340	0.146	0.020	-0.159
NH3	**0.602**	-0.083	0.435	-0.367	0.232	-0.276	0.108
NO	-0.096	-0.098	-0.114	**0.913**	-0.065	0.090	-0.124
NO3	0.299	0.224	0.022	0.031	0.079	**0.883**	-0.074
OC	**0.888**	-0.233	0.109	-0.134	0.104	0.056	0.006
P	**0.882**	-0.033	0.128	0.137	-0.016	-0.116	-0.138
PB	-0.117	-0.281	-0.171	-0.395	0.389	0.350	-0.547
SI	-0.306	**0.743**	0.489	-0.242	0.006	-0.189	-0.040
SN	0.055	-0.071	-0.353	**0.771**	0.326	-0.199	-0.036
SO4	0.347	0.228	0.337	**0.677**	0.262	0.126	0.370
SR	**0.956**	0.034	-0.020	0.149	0.044	0.171	-0.048
TC	**0.925**	-0.086	-0.020	-0.083	0.111	-0.040	0.056
TI	0.262	0.572	**0.675**	-0.191	-0.178	-0.215	-0.073
ZN	-0.178	-0.067	**0.935**	-0.061	0.084	-0.034	0.002
MN	0.412	0.151	**0.839**	0.046	-0.057	0.201	-0.032
% Var	34.795	14.709	13.082	10.084	6.931	6.759	6.017
Source	Combustion/ Resuspended dust /Autoexhaust	Resuspended dust	Soil dust	Soil dust	Misc.	Misc.	Misc.

Table 4.1.1.20: Factor loading matrix for Dhaula Kuan: Winter

Species	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
AL	**0.788**	-0.343	-0.272	0.363	0.125	0.114	0.120
BA	**0.978**	0.077	0.172	0.054	-0.032	0.018	0.013
CA	0.561	0.071	0.232	**0.747**	-0.143	-0.149	0.131
CAION	**0.688**	-0.022	0.070	0.279	0.590	0.233	0.155
CL	0.086	0.507	0.234	-0.036	**-0.642**	-0.410	-0.223
CR	0.217	-0.179	**0.872**	-0.010	0.037	-0.265	0.003
CU	-0.168	0.522	0.116	-0.245	-0.361	-0.339	-0.558
EC	**0.919**	-0.249	0.029	-0.023	0.146	0.244	0.065
F	**0.970**	0.024	-0.025	0.164	-0.063	0.053	0.036
FE	0.793	-0.053	0.214	0.543	-0.039	0.052	0.149
KION	0.470	0.456	-0.221	0.662	0.233	0.008	-0.115
LN	-0.257	-0.003	-0.068	-0.085	-0.127	0.010	**-0.937**
MG	0.371	-0.133	0.170	**0.866**	-0.087	-0.128	0.159
MGION	0.200	**0.951**	-0.067	0.068	0.032	-0.077	0.003
MN	**0.777**	0.068	0.393	0.455	-0.055	-0.088	0.119
NA	-0.037	0.558	0.370	0.338	-0.145	-0.314	0.329
NH3	-0.243	**0.887**	0.095	-0.075	-0.161	0.253	-0.106
NO	-0.033	-0.126	-0.164	-0.194	**0.947**	-0.025	0.103
NO3	0.214	0.157	0.065	-0.175	0.014	**0.912**	-0.017
OC	0.580	0.320	0.458	0.528	0.021	0.104	0.226
P	**0.654**	0.307	**0.675**	0.040	-0.071	0.066	0.094
PB	0.208	**0.668**	**0.589**	0.130	-0.074	0.236	0.065
PD	-0.228	-0.018	-0.199	-0.582	-0.300	-0.481	0.420
SI	0.199	0.278	**0.735**	0.076	-0.156	0.306	-0.292
SN	-0.191	0.415	0.445	0.413	0.580	0.017	-0.242
SO4	0.426	-0.394	-0.016	0.216	0.372	**0.605**	0.238
SR	0.176	0.076	**0.742**	0.427	-0.131	0.121	0.184
TC	**0.782**	0.155	0.363	0.397	0.070	0.169	0.197
TI	**0.869**	0.033	0.200	0.280	0.027	0.267	0.011
ZN	**0.869**	0.181	0.396	0.055	-0.124	-0.031	0.038
% Var	31.027	13.805	13.750	13.429	8.733	8.034	6.734
Source	Combustion	Soil dust	Soil dust	Soil dust	Industries	Secondary aerosol formation	Misc.

Table 4.1.1.21: Factor loading matrix for ISBT: Winter

Species	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
AL	**0.625**	0.074	0.281	0.570	0.435
BA	0.055	**0.835**	-0.088	0.478	-0.121
CA	**0.588**	0.548	0.473	0.058	0.121
CAION	**0.927**	0.015	-0.034	0.162	0.253
CL	0.402	0.529	0.369	-0.352	0.498
CD	**0.899**	0.067	0.171	0.163	0.350
EC	**0.676**	0.089	**0.633**	0.041	0.219
F	0.315	**0.649**	0.455	-0.074	0.479
FE	**0.817**	0.203	0.313	0.269	0.341
KION	0.147	**0.799**	0.031	0.026	0.458
MG	**0.857**	-0.151	-0.243	0.388	0.070
MGION	**0.577**	**-0.663**	-0.248	-0.030	-0.189
MN	**0.791**	0.378	-0.045	-0.350	0.125
NA	0.270	0.291	-0.001	**0.834**	0.050
NH3	-0.128	0.952	0.124	0.108	-0.077
NO	0.308	-0.086	0.236	0.130	**0.898**
NO3	-0.182	0.227	**0.929**	-0.033	-0.051
OC	**0.687**	0.439	0.464	0.109	0.202
ZN	0.222	**0.787**	0.394	0.206	-0.028
TI	0.445	0.034	0.183	**0.785**	0.314
TC	**0.713**	0.377	0.522	0.098	0.214
SO4	0.257	0.204	**0.916**	0.042	0.093
SR	**0.806**	-0.097	0.170	0.543	0.021
SN	0.090	0.120	-0.441	0.033	**0.864**
SI	-0.015	0.243	-0.091	**0.937**	-0.044
PB	0.486	**0.682**	0.367	0.280	0.002
P	0.511	0.165	0.381	0.136	**0.740**
% Var	30.266	20.832	15.802	13.945	13.407
Source	Resuspended dust	Industries	Auto exhaust	Soil dust	Industries

Table 4.1.1.22: Factor loading matrix for Loni Road: Winter

Species	Factor 1	Factor 2	Factor 3
AL	**0.845**	0.317	0.430
BA	0.466	-0.115	**0.878**
CA	**0.788**	-0.049	**0.614**
CAION	0.474	0.495	**0.728**
CU	0.209	-0.466	**0.860**
EC	-0.099	**0.967**	-0.236
F	**0.855**	0.429	0.291
FE	**0.865**	0.193	0.462
MG	**0.881**	0.170	0.441
MGION	**-0.641**	**0.746**	-0.179
MN	0.152	**0.928**	0.340
NA	0.416	**0.868**	0.270
NH3	0.000	0.431	**-0.902**
NO3	**-0.986**	0.059	-0.158
NO	**0.867**	0.494	0.063
OC	0.329	0.136	**0.935**
P	**0.814**	0.176	0.553
PB	**0.795**	0.590	0.140
SI	0.303	**0.942**	-0.145
SN	**0.700**	**0.713**	0.041
SO4	0.357	0.934	-0.014
SR	**0.653**	-0.027	**0.757**
TC	**0.308**	0.349	**0.885**
TI	**0.834**	0.411	0.369
ZN	0.310	**0.943**	-0.125
% Var	39.362	32.857	27.780
Source	Combustion	Resuspended dust	Auto exhaust

Table 4.1.1.23: Factor loading matrix for Naraina: Winter

Species	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
AL	**0.911**	0.110	0.355	0.043	0.093
BA	**0.920**	-0.122	-0.058	-0.054	0.200
CA	**0.971**	0.209	-0.022	-0.025	0.012
CAION	0.389	**0.873**	-0.137	0.012	0.147
CU	0.451	-0.077	-0.337	0.111	**-0.773**
EC	-0.238	-0.208	-0.143	**0.893**	-0.001
F	**0.801**	-0.074	0.322	0.142	-0.341
FE	**0.971**	0.179	0.118	0.006	0.083
KION	0.028	**0.967**	0.081	-0.161	0.123
MG	**0.882**	0.435	0.107	-0.053	0.008
MGION	0.502	**0.815**	-0.222	0.006	-0.140
MN	**0.829**	0.471	0.056	-0.005	0.262
NA	0.410	-0.047	0.527	**0.609**	0.233
NH3	-0.069	**0.922**	-0.015	-0.225	0.059
NO	-0.086	-0.220	0.324	**0.821**	-0.019
NO3	-0.121	-0.149	**0.864**	-0.073	-0.221
OC	0.454	0.150	-0.243	0.082	**0.787**
P	**0.971**	0.081	0.134	0.094	0.032
PB	**0.914**	0.100	-0.099	-0.147	0.100
SI	0.380	-0.249	**0.771**	0.199	0.273
SN	0.221	**0.635**	0.003	**0.669**	0.097
SO4	0.304	0.305	**0.787**	0.187	-0.233
SR	**0.956**	0.244	0.068	0.035	0.063
TC	0.434	0.132	-0.255	0.155	**0.786**
TI	**0.789**	-0.122	0.523	0.160	0.202
ZN	**0.704**	0.456	-0.303	-0.196	0.177
% Var	42.375	18.267	12.827	10.045	9.469
Source	Resuspended dust	Industries	Soil dust	Auto exhaust	Auto exhaust

Table 4.1.1.24: Factor loading matrix for SSI-GTK: Winter

Species	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
AL	-0.299	**0.798**	-0.120	0.422	0.256	-0.087
BA	0.115	**0.909**	0.011	-0.058	-0.089	0.175
CA	0.237	**0.922**	0.226	-0.073	-0.041	0.177
CAION	0.425	**0.675**	0.551	-0.194	0.086	0.099
CL	**0.925**	0.043	0.186	0.092	-0.087	0.103
CR	-0.062	0.532	**-0.724**	0.199	-0.266	0.129
CU	-0.034	0.322	**0.687**	0.546	0.269	0.208
EC	0.553	-0.146	0.006	0.302	-0.162	**0.729**
F	**0.852**	-0.099	-0.033	0.202	0.373	0.169
FE	-0.100	**0.980**	0.011	-0.053	0.018	-0.085
KION	**0.842**	0.398	0.173	0.123	-0.085	0.253
MG	0.060	**0.974**	0.194	0.012	0.000	0.029
MGION	0.384	0.082	**0.862**	-0.075	-0.284	0.047
MN	0.058	**0.860**	-0.421	0.043	-0.132	-0.078
NA	0.362	**0.690**	-0.342	0.485	0.007	-0.041
NH3	**0.787**	-0.024	0.012	0.555	0.020	0.238
NI	**0.852**	0.401	0.147	-0.056	-0.270	0.110
NO	**0.845**	0.145	0.247	-0.203	-0.366	0.137
NO3	**0.930**	-0.278	-0.081	0.012	0.140	-0.027
OC	-0.145	**0.716**	0.091	0.161	0.355	0.486
P	**0.822**	0.334	0.204	-0.147	-0.354	0.114
PB	-0.017	-0.007	0.145	**0.928**	0.168	0.225
SI	0.494	0.217	-0.413	**0.662**	0.156	0.156
SN	**0.925**	0.090	0.284	0.130	-0.026	-0.167
SO4	**0.974**	0.035	-0.037	0.002	-0.094	0.038
SR	0.554	-0.016	**0.696**	0.311	-0.231	0.058
TC	0.207	0.457	0.072	0.295	0.174	**0.784**
TI	0.326	**0.782**	-0.140	0.442	0.019	0.131
ZN	-0.178	0.060	-0.036	0.205	**0.949**	0.056
% Var	32.388	28.423	11.824	10.697	6.996	6.454
Source	Combustion	Soil dust	Industries	Soil dust	Smelter	Auto exhaust

Table 4.1.1.25: Factor loading matrix for Pitampura: Winter

Species	Factor 1	Factor 2	Factor 3	Factor 4
AL	0.078	**-0.921**	0.286	-0.160
BA	**0.837**	-0.001	-0.012	-0.354
CA	**0.873**	-0.114	0.224	0.094
CAION	0.473	**0.792**	-0.206	-0.079
CL	0.160	**0.907**	-0.128	-0.116
CU	**0.775**	-0.048	-0.009	0.423
EC	0.549	0.225	0.083	0.767
F	**0.686**	0.222	0.542	0.091
FE	**0.917**	-0.122	0.347	0.145
KION	**0.738**	-0.391	-0.347	-0.179
MG	**0.779**	-0.131	0.580	0.009
MGION	0.093	0.547	-0.420	**-0.649**
MN	**0.931**	-0.037	0.111	0.266
NA	0.106	-0.275	**0.884**	0.168
NH3	0.453	**-0.743**	-0.132	0.254
NO	-0.098	**0.943**	-0.243	0.142
NO3	**0.892**	0.241	-0.017	0.221
OC	**0.950**	0.007	0.044	0.284
P	**0.901**	0.136	0.261	0.281
PB	**0.867**	0.005	-0.380	0.048
SI	-0.051	-0.294	**0.778**	-0.092
SN	**0.746**	-0.391	0.494	-0.044
SO4	**0.929**	0.152	0.149	0.159
SR	0.191	-0.047	-0.011	**0.901**
TC	**0.934**	0.028	0.048	0.336
TI	**0.584**	-0.223	**0.724**	0.152
ZN	**0.781**	0.018	0.106	-0.263
% Var	47.135	17.805	13.854	10.656
Source	Auto exhaust/ Resuspended dust	Soil dust	Soil dust	Auto exhaust

Table 4.1.1.26: Factor loading matrix for Prahladpur: Winter

Species	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
AL	**0.912**	0.010	0.291	0.251	0.032	-0.089	-0.043
BA	0.446	-0.190	0.190	0.322	-0.106	-0.592	0.075
CA	**0.983**	0.003	0.030	0.006	0.089	-0.035	0.061
CAION	0.281	-0.023	0.111	**0.905**	-0.127	-0.184	0.000
CL	-0.259	**0.828**	-0.101	-0.125	0.337	0.144	0.294
EC	0.142	0.218	-0.289	-0.132	0.048	**0.681**	0.496
F	0.295	-0.295	**0.749**	0.242	-0.114	-0.221	-0.231
FE	**0.920**	-0.032	0.257	0.171	0.162	0.095	0.075
KION	0.389	0.525	0.443	0.001	-0.206	0.005	0.558
MG	**0.880**	0.015	0.290	0.135	-0.010	-0.108	-0.111
MGION	0.242	-0.083	0.135	**0.930**	-0.108	-0.074	-0.011
MN	-0.131	-0.484	-0.133	0.024	**0.645**	0.552	0.006
NA	**0.884**	-0.179	-0.320	0.261	-0.011	0.031	0.108
NH3	0.250	0.247	0.304	-0.049	-0.095	**0.856**	0.061
NO	-0.239	**0.849**	-0.056	-0.150	0.348	0.133	0.237
NO3	0.033	0.335	0.016	-0.068	0.000	0.133	**0.905**
OC	0.030	**0.982**	-0.134	0.107	-0.045	0.052	0.007
P	**0.885**	-0.017	0.081	-0.173	0.189	0.344	0.140
PB	0.167	0.093	-0.223	-0.359	**0.729**	-0.057	-0.215
SI	0.137	-0.029	**0.961**	-0.003	0.067	0.116	0.044
SN	-0.268	-0.422	-0.348	0.278	**-0.649**	-0.011	0.011
SO4	0.094	-0.390	0.054	**-0.728**	-0.018	-0.027	0.533
TC	0.050	**0.964**	-0.170	0.081	-0.036	0.152	0.081
TI	0.104	-0.185	**0.960**	0.118	0.041	-0.024	0.106
ZN	-0.375	-0.284	-0.339	-0.229	**-0.706**	0.040	-0.282
% Var	24.261	18.593	14.225	11.757	9.154	8.761	8.267
Source	Soil dust	Auto exhaust	Soil dust	Secondary aerosol formation	Smelter	Auto exhaust	Secondary aerosol formation

Annexure 4.1.1b

Factor analysis results

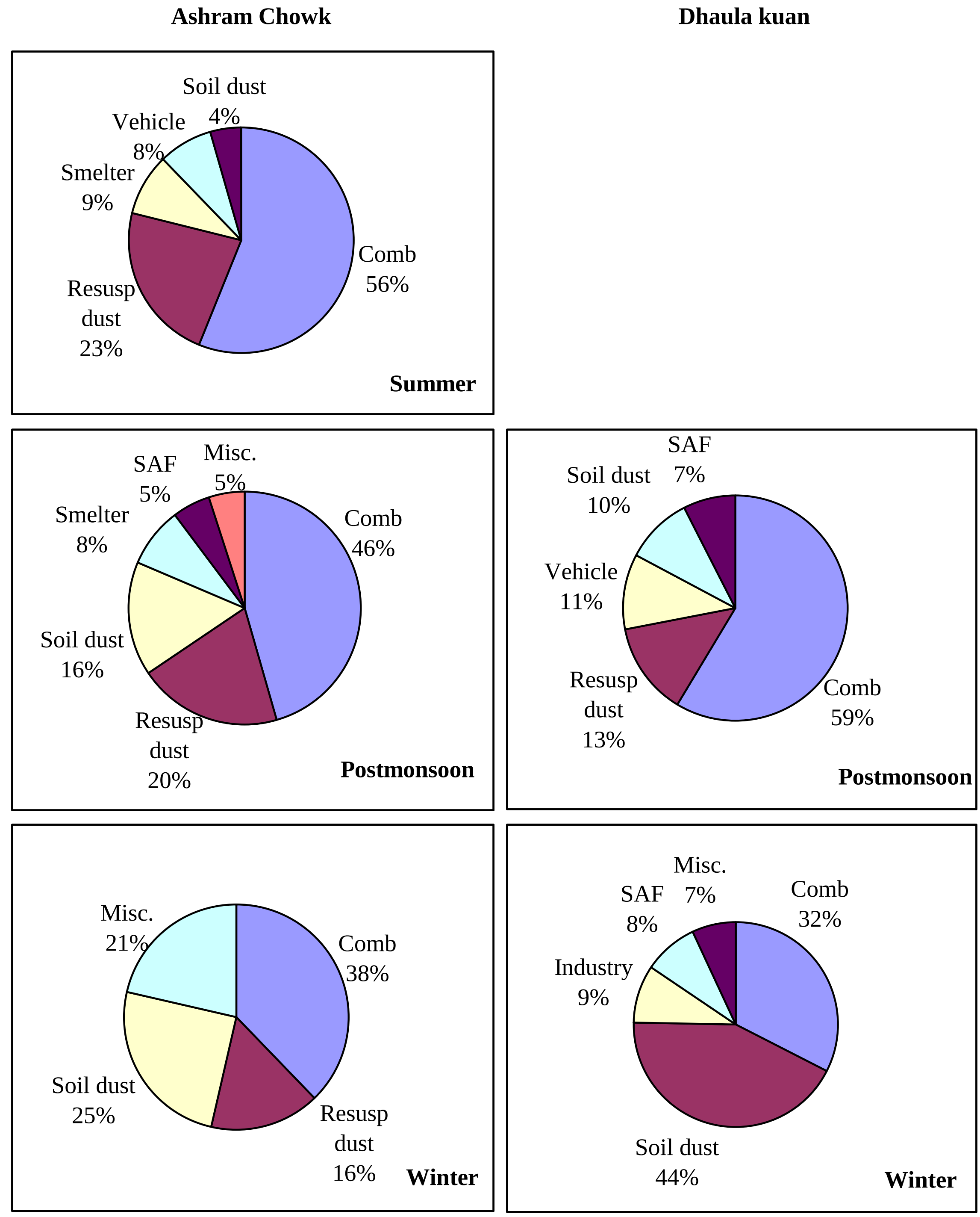


Figure 4.1.1.1. Source contribution estimates using factor analysis

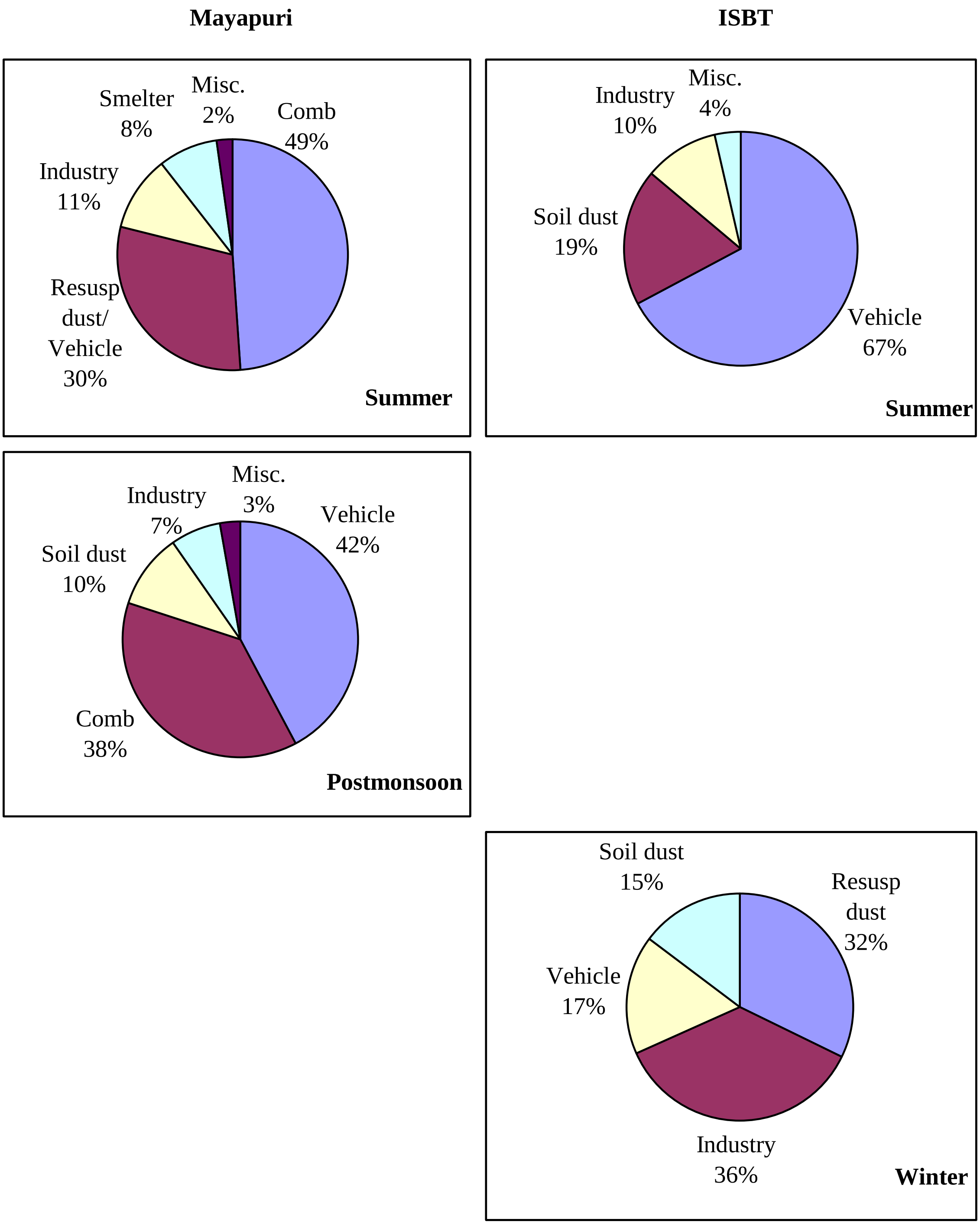


Figure 4.1.1.2. Source contribution estimates using factor analysis

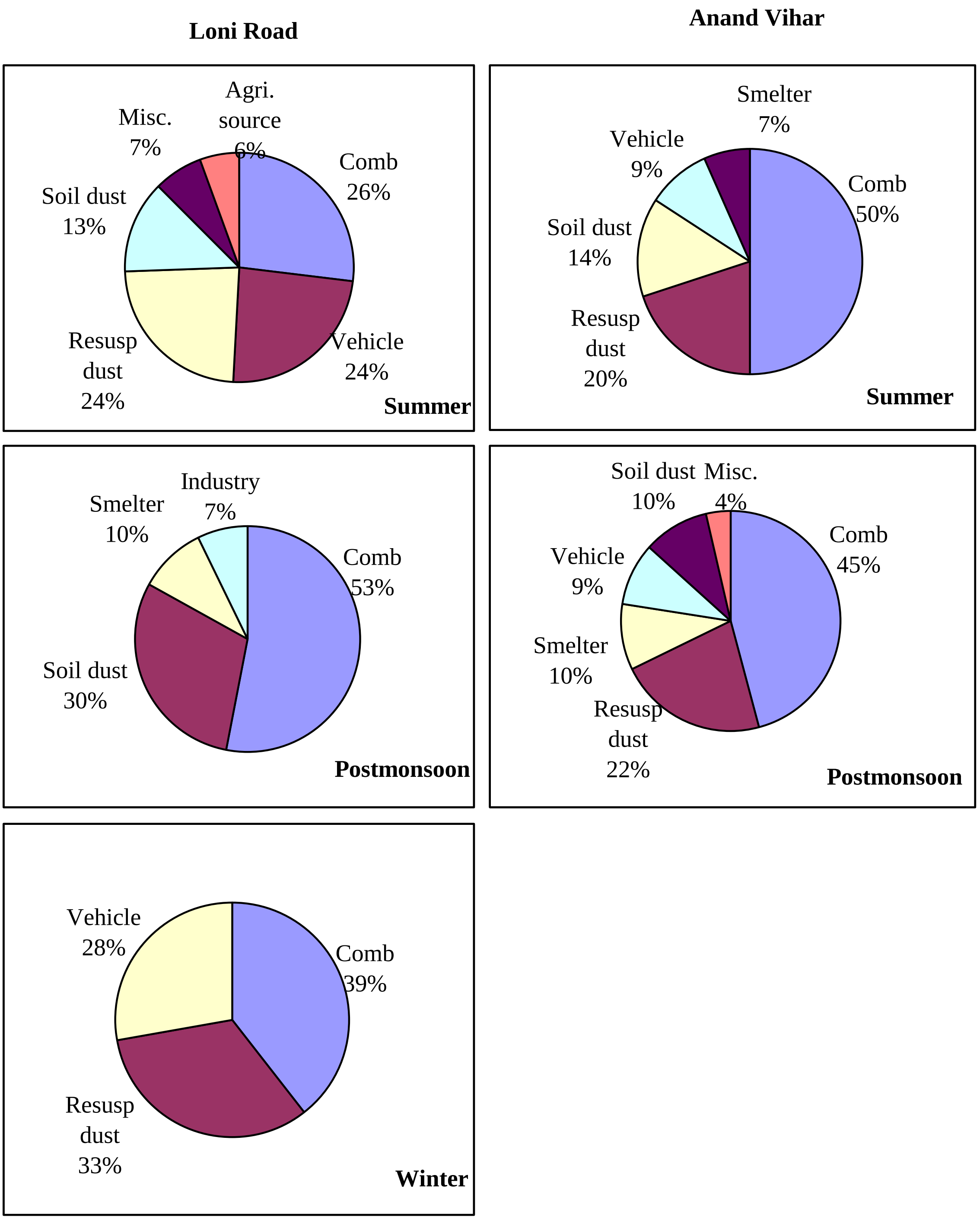


Figure 4.1.1.3. Source contribution estimates using factor analysis

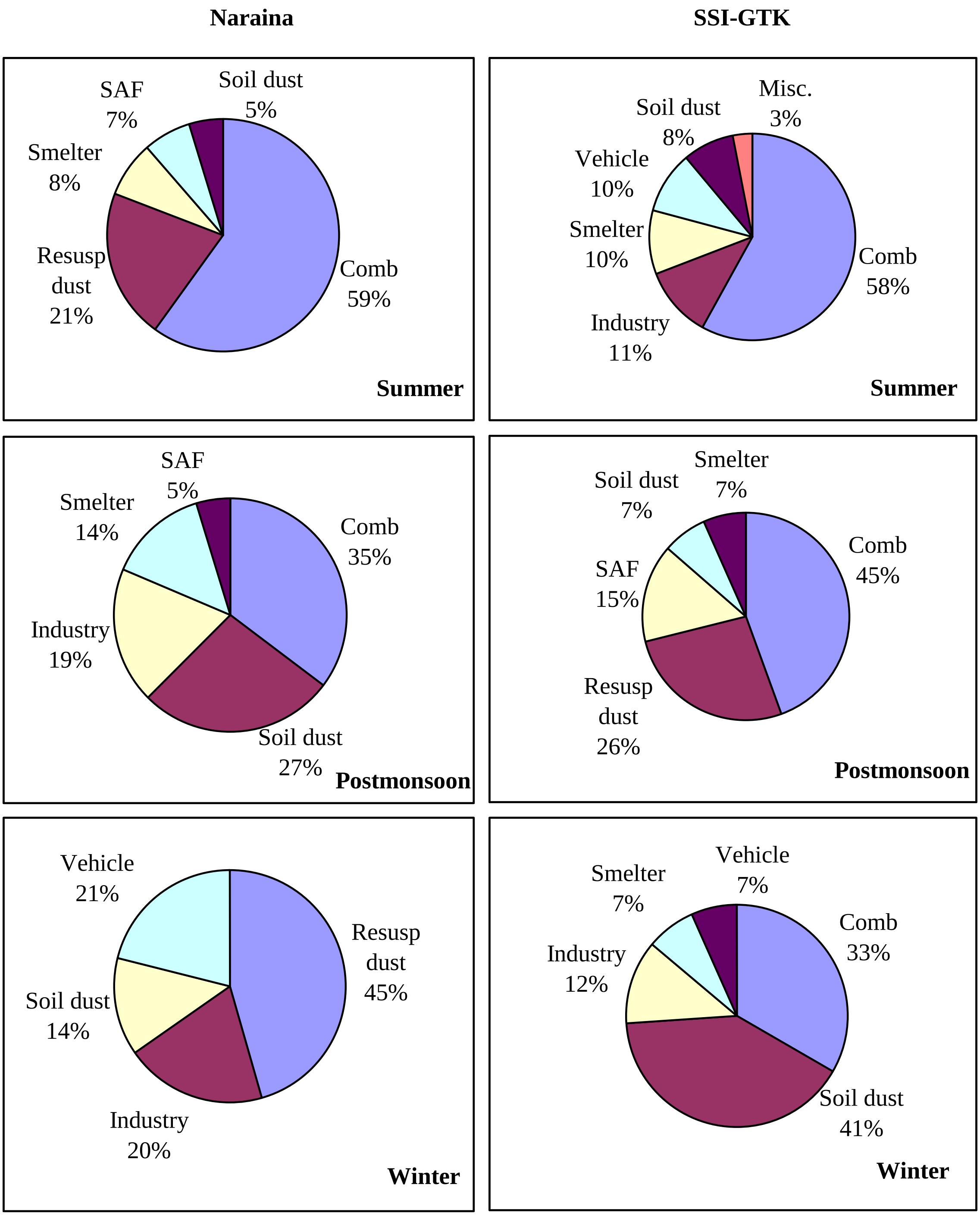


Figure 4.1.1.4. Source contribution estimates using factor analysis

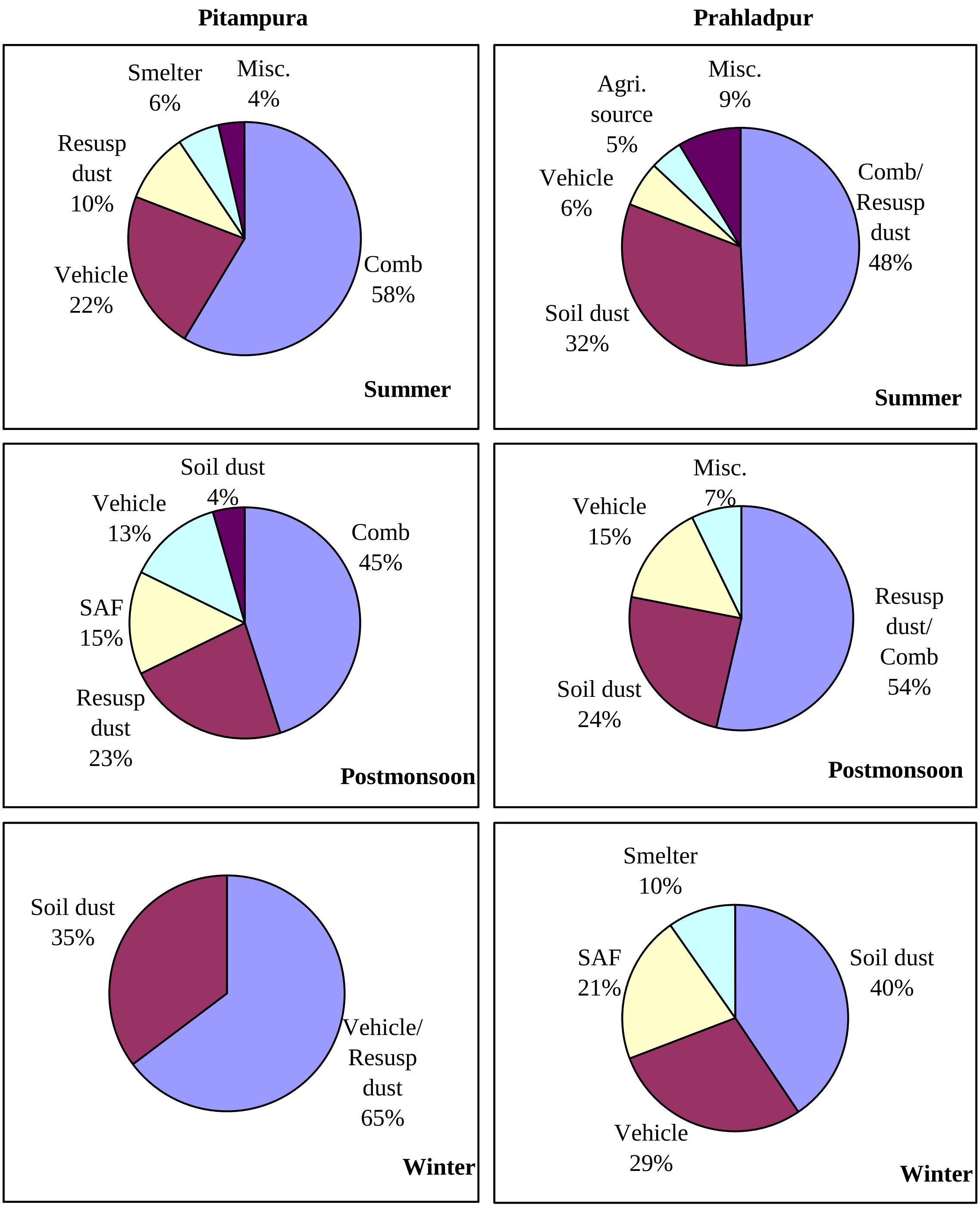


Figure 4.1.1.5. Source contribution estimates using factor analysis

Annexure 4.1.2a

Statistical measures of CMB model performance for PM10

Table 4.1.2.1: Statistical measures of CMB model performance for PM10- Summer

Sample No.	Date	R^2	Chi^2	% Mass	DF	Calculated Concentration	Measured Concentration
Ashram Chowk							
1	21/05/07	0.97	2.66	81.6	12	237.91	291.5
2	23/05/07	0.97	2.72	116.8	12	375.63	321.5
3	25/05/07	0.99	1.97	84.5	7	167.23	198
4	26/05/07	0.97	3.7	68.8	9	136.12	198
5	28/05/07	0.98	2.56	91.1	7	186.75	205
6	29/05/07	0.97	2.51	92.3	11	175.74	190.5
7	04/06/07	0.91	2.51	77.1	13	293.32	380.5
8	07/06/07	0.97	3.26	77.9	12	238.01	305.7
9	09/06/07	0.91	3.31	96.7	12	434.71	449.3
Mayapuri							
1	28/04/07	0.97	2.91	138.3	14	304.31	220
2	03/05/07	0.95	3.15	60	14	50.38	84
3	04/05/07	0.98	3.26	101.8	11	281.05	276
4	05/05/07	0.96	3.92	96.8	11	159.69	165
5	06/05/07	0.98	1.87	72.1	11	124.80	173
6	08/05/07	0.98	1.98	63.1	12	90.25	143
7	12/05/07	0.91	3.87	62.5	15	85.62	137
8	14/05/07	0.94	3.8	92.5	14	250.77	271
9	18/05/07	0.96	3.19	78	11	144.30	185
ISBT							
1	14/06/07	0.96	3.6	110.1	14	164.05	149.0
2	22/06/07	0.97	3.23	97.3	12	119.62	123.0
3	24/06/07	0.96	3.71	105.1	15	112.49	107.0
4	25/06/07	0.97	2.35	98.3	15	90.41	92.0
5	26/06/07	0.99	1.29	75.6	14	99.82	132.0
6	27/06/07	0.98	3.38	92.9	12	105.90	114.0
7	28/06/07	0.96	2.91	109.8	13	207.57	189.0
8	30/06/07	0.98	2.44	109.9	11	142.85	130.0
9	02/07/07	0.94	3.95	111.7	16	123.99	111.0
Loni Road							
1	21/05/07	0.96	3.52	99.9	13	202.81	203
2	23/05/07	0.98	1.75	98.4	13	394.59	401
3	25/05/07	0.97	2.5	80.2	12	379.48	473
4	27/05/07	0.97	3.32	108	14	776.19	719
5	29/05/07	0.96	3.41	93.4	13	203.60	218
6	31/05/07	0.96	2.97	109.1	15	357.71	328
7	03/06/07	0.96	3.8	42.8	14	144.33	337
8	04/06/07	0.96	3.29	111.8	16	391.14	350
9	06/06/07	0.96	3.13	90.4	16	174.47	193
10	09/06/07	0.96	3.97	93.9	11	593.58	632
Anand Vihar							
1	21/05/07	0.98	3.75	92	11	240.93	262
2	23/05/07	0.98	3.85	82.2	11	245.01	298
3	25/05/07	0.98	3.42	96.8	10	202.25	209
4	27/05/07	0.98	1.56	93.6	15	289.29	309

5	29/05/07	0.98	3.35	99.1	13	170.39	172
6	31/05/07	0.97	3.96	78.6	9	233.50	297
7	05/06/07	0.98	2.92	111	11	276.32	249
8	07/06/07	0.97	3.23	78.8	12	349.10	443
9	09/06/07	0.98	3.05	110.4	14	536.49	486
Naraina							
1	28/04/07	0.98	4.05	91.5	9	292.67	320
2	30/04/07	0.99	3.67	87.7	11	198.98	227
3	04/05/07	0.98	4.78	91.6	13	157.54	172
4	06/05/07	0.98	3.65	84	9	104.11	124
5	08/05/07	0.95	3.75	43.6	13	101.20	232
6	10/05/07	0.99	2.83	58.9	10	121.30	206
7	13/05/07	0.98	2.6	66.5	9	144.91	218
8	16/05/07	0.99	1.95	97.3	8	158.65	163
9	12/07/07	0.99	2.3	90.6	11	188.38	208
SSI-GTK							
1	06/14/07	0.99	1.15	87.3	7	151.88	174
2	06/15/07	0.96	2.13	87.3	12	130.02	149
3	06/22/07	0.96	3.41	99.9	8	179.88	180
4	06/23/07	0.99	2.48	87.3	6	132.67	152
5	06/24/07	0.96	3.97	107.1	10	157.48	147
6	06/25/07	0.98	1.93	105.6	7	141.47	134
7	06/27/07	0.97	3.4	99.3	13	168.80	170
8	06/28/07	0.97	2.85	95.2	12	161.82	170
9	06/30/07	0.96	3.14	107	11	161.58	151
10	07/02/07	0.97	2.78	68.2	11	64.77	95
Pitampura							
1	15/06/07	0.92	5.29	94.2	15	117.71	125
2	17/06/07	0.97	1.51	94.6	17	136.26	144
3	29/06/07	0.95	3.67	72	17	69.15	96
4	01/07/07	0.96	2.84	139.8	13	93.65	67
5	03/07/07	0.83	6.44	113.7	18	31.82	28
6	SSI-GTK						
7	14/06/07	0.99	1.15	87.3	7	151.88	174
8	15/06/07	0.96	2.13	87.3	12	130.02	149
9	22/06/07	0.96	3.41	99.9	8	179.88	180
10	23/06/07	0.99	2.48	87.3	6	132.67	152
11	24/06/07	0.96	3.97	107.1	10	157.48	147
12	25/06/07	0.98	1.93	105.6	7	141.47	134
13	27/06/07	0.97	3.4	99.3	13	168.80	170
14	28/06/07	0.97	2.85	95.2	12	161.82	170
15	30/06/07	0.96	3.14	107	11	161.58	151
16	02/07/07	0.97	2.78	68.2	11	64.77	95
Prahladpur							
1	30/04/07	0.97	3.7	99.3	7	238.27	240
2	02/05/07	0.97	3.47	83.5	8	228.72	274
3	04/05/07	0.99	2.72	101.3	8	251.26	248
4	21/05/07	0.97	2.82	102.8	9	221.09	215
5	23/05/07	0.96	3.54	109.4	9	261.98	239.5
6	14/06/07	0.97	2.65	89.5	10	124.19	138.7
7	16/06/07	0.97	3.51	98.4	6	106.29	108
8	18/06/07	0.92	3.97	93.6	12	133.61	142.8

Table 4.1.2.2: Statistical measures of CMB model performance for PM10- Post Monsoon

Sample No.	Date	R^2	Chi^2	% Mass	DF	Calculated Concentration	Measured Concentration
Ashram Chowk							
1	11/10/07	0.98	4.41	64.0	12	259.79	406.0
2	12/10/07	0.99	2.93	76.7	10	262.07	341.5
3	14/10/07	0.97	5.89	84.5	13	266.30	315.0
4	15/10/07	0.98	2.76	78.1	11	266.27	341.0
5	16/10/07	0.98	4.92	62.7	7	86.54	138.0
6	19/10/07	0.97	6.89	50.2	11	196.57	391.5
7	20/10/07	0.98	3.67	64.4	15	306.36	476.0
8	21/10/07	0.99	2.77	84.5	10	343.83	407.0
9	22/10/07	0.96	5.73	73.9	12	397.10	537.5
10	23/10/07	0.98	2.33	71.9	11	573.71	798.0
11	24/10/07	0.97	3.24	82.7	13	401.87	486.0
12	25/10/07	0.98	3.49	79.3	9	458.59	578.3
13	26/10/07	0.99	1.21	63.7	13	334.91	525.8
14	27/10/07	0.98	2.14	114.7	13	596.40	519.8
15	28/10/07	0.97	3.92	79.8	13	441.15	552.5
16	29/10/07	0.98	3.90	64.5	11	463.08	717.7
17	30/10/07	0.96	4.70	110.9	11	709.95	640.0
Dhaula kuan							
1	17/09/07	0.98	2.78	76.5	15	131.54	172.0
2	18/09/07	0.99	1.54	77.8	10	171.88	221.0
3	19/09/07	0.97	2.96	85.9	13	173.95	202.5
4	22/09/07	0.99	1.67	94.5	11	127.10	134.5
5	24/09/07	0.98	3.22	90.4	8	113.04	125.0
6	25/09/07	0.98	3.28	79.9	12	89.455	112.0
7	27/09/07	0.97	4.43	98.6	13	115.83	117.5
8	29/09/07	0.99	2.05	86.3	8	165.32	191.5
9	30/10/07	0.98	3.76	62.3	9	125.54	201.5
Mayapuri							
1	17/09/07	0.97	3.62	78.5	12	160.84	205.0
2	18/09/07	0.97	3.84	65.3	12	138.10	211.5
3	19/09/07	0.99	1.93	63.3	10	135.71	214.5
4	20/09/07	0.99	1.34	61.8	10	117.99	191.0
5	21/09/07	0.97	3.71	95.2	11	177.03	186.0
6	25/09/07	0.97	3.85	94.2	10	100.79	107.0
7	26/09/07	0.96	3.97	85.1	11	71.52	84.0
8	27/09/07	0.96	2.83	83	10	89.24	107.5
9	28/09/07	0.97	2.64	65.5	11	80.590	123.0
10	30/09/07	0.97	2.93	81.4	12	175.44	215.5
11	03/10/07	0.97	3.58	99	12	452.73	457.5
12	04/10/07	0.97	2.75	93.9	12	468.33	499.0
ISBT							
1	01/12/07	1.00	2.98	97.1	11	294.27	303
2	03/12/07	0.98	2.54	102.8	12	302.10	294
1							
2	26/10/07	0.96	2.62	100.7	13	1299.4	1290.5
3	28/10/07	0.97	1.47	94.4	14	1204.0	1275.0
4	24/10/07	0.97	1.87	71.5	13	922.82	1290.5
5	25/10/07	0.95	3.19	78.3	14	1171.0	1495.0
6	23/10/07	0.95	2.94	81.7	10	1220.8	1495.0

7	11/10/07	0.97	0.74	94.3	13	555.67	589.0
8	13/10/07	0.98	0.69	90	13	618.48	687.5
9	15/10/07	0.98	0.74	81.7	12	598.12	732.5
10	16/10/07	0.98	0.76	81.9	12	727.98	888.5
11	17/10/07	0.97	0.97	80.2	12	520.18	648.5
12	19/10/07	0.93	2.53	87.3	13	477.02	546.5
Anand Vihar							
1	12/10/07	0.98	3.85	65.0	13	197.57	304.0
2	13/10/07	0.99	2.20	64.8	11	254.06	392
3	15/10/07	0.98	3.91	61.5	12	201.96	328.5
4	16/10/07	0.98	3.15	82.0	8	145.11	177
5	18/10/07	0.98	3.31	90.0	7	325.83	362
6	19/10/07	0.96	2.97	86.7	10	329.29	380
7	20/10/07	0.97	1.56	93.5	13	484.09	517.5
8	21/10/07	0.97	3.54	72.0	15	316.94	440.5
9	22/10/07	0.95	2.67	84.7	10	621.90	734
10	23/10/07	0.97	1.70	81.2	10	522.99	644
11	24/10/07	0.99	2.23	82.5	12	422.68	512.5
12	25/10/07	0.98	2.85	86.9	11	569.22	655
13	26/10/07	0.98	3.27	70.2	9	558.17	795.2
14	27/10/07	0.99	1.94	61.2	11	282.27	461
15	29/10/07	0.99	3.72	93.0	10	707.77	761
16	30/10/07	0.99	2.14	63.4	12	534.12	842.3
17	03/10/07	0.98	3.96	88.3	11	273.19	309.5
18	04/10/07	0.97	3.55	90.4	13	319.03	352.8
19	05/10/07	0.97	3.73	82.0	9	190.15	231.8
Naraina							
1	17/09/07	0.99	3.22	65.2	14	153.31	235.0
2	18/09/07	0.99	1.95	76.7	9	187.03	244.0
3	19/09/07	0.99	2.58	95.8	9	227.55	237.5
4	20/09/07	0.99	2.41	77.7	11	184.99	238.0
5	21/09/07	0.99	2.59	93.5	12	178.95	191.5
6	22/09/07	0.99	3.80	76.4	9	145.11	190.0
7	23/09/07	0.99	2.92	90.6	9	183.04	202.0
8	24/09/07	0.99	2.09	68.8	10	133.50	194.0
9	27/09/07	0.90	3.75	74.3	16	141.18	190.0
10	28/09/07	0.99	3.35	80.9	10	139.87	173.0
11	30/09/07	0.96	3.89	116.3	10	10.80	215.0
12	03/10/07	0.99	3.07	80.2	9	389.19	485.0
13	05/10/07	0.99	2.67	95.2	9	316.12	332.0
14	06/10/07	0.96	4.86	71	11	174.86	246.3
15	06/10/07	0.98	4.65	97.5	11	240.22	246.3
SSI-GTK							
1	11/21/07	0.92	3.8	118.2	19	1684.56	1425.0
2	11/24/07	0.89	4.09	82.5	13	974.21	1181.0
3	11/28/07	0.99	3.62	77.4	7	776.29	1003.0
4	12/01/07	0.97	3.68	88.4	10	624.33	706.0
5	12/03/07	0.98	3.00	87.3	9	400.93	459.0
6	12/05/07	0.98	3.97	72.4	7	676.41	934.0
Pitampura							
1	21/11/07	1.00	2.81	59.4	9	562.69	947.0
2	22/11/07	0.98	2.75	64.0	12	569.92	890.0

3	27/11/07	0.98	4.79	112.4	9	346.15	308.0
4	05/12/07	0.97	1.16	93.9	16	679.71	724.0
5	06/12/07	0.97	1.99	73.0	12	614.64	842.0
6	08/12/07	0.93	3.17	82.8	16	671.46	811.0
Prahladpur							
1	17/09/07	0.99	2.21	82.4	9	131.82	159.2
2	19/09/07	0.97	3.98	82.4	10	171.18	207.6
3	20/09/07	0.97	3.75	75.3	10	265.14	352.0
4	21/09/07	0.97	2.07	87	9	142.49	163.8
5	22/09/07	0.97	3.76	65.9	10	102.77	156.0
6	23/09/07	0.99	2.84	78.9	9	168.85	213.9
7	29/10/07	0.98	2.2	67.5	9	385.14	571.0
8	26/11/07	0.98	2.29	72.1	7	1088.73	1511
9	02/12/07	0.93	3.14	87.1	15	276.09	317.0

Table 4.1.2.3: Statistical measures of CMB model performance for PM10- Winter

Sample No.	Date	R^2	Chi^2	% Mass	DF	Calculated Concentration	Measured Concentration
Ashram Chowk							
1	21/01/08	0.96	3.35	97	15	354.42	365.4
2	22/01/08	0.96	3.08	89.1	16	364.21	408.7
3	15/01/08	0.95	2.85	95.5	12	309.51	324.2
4	23/01/08	0.98	1.72	76.5	16	248.320	324.6
5	26/01/08	0.97	2.17	88.8	12	250.084	281.5
6	19/01/08	0.95	3.37	88.2	15	286.816	325.1
7	17/01/08	0.98	1.13	92.5	13	372.209	402.4
8	24/01/08	0.96	3.82	87	12	245.998	282.6
9	16/01/08	0.96	3.38	65.3	13	246.775	378.1
10	28/01/08	0.94	2.22	78	14	401.693	515.2
11	25/01/08	0.93	2.52	71.5	14	227.748	318.7
12	27/01/08	0.92	3.55	86.8	14	341.25	393
Dhaula kuan							
1	02/22/08	0.95	2.79	85.8	15	233.24	272
2	02/21/08	0.97	1.85	83.0	14	284.51	343
3	02/16/08	0.97	3.68	82.1	11	210.15	256
4	02/18/08	0.96	3.95	92.2	14	317.67	345
5	02/12/08	0.97	3.75	66.0	12	137.89	209
6	02/19/08	0.96	2.47	96.8	14	419.17	433
7	02/20/08	0.96	3.22	113.3	12	607.44	536
8	02/24/08	0.89	4.15	64.0	16	245.05	383
9	02/14/08	0.96	2.03	54.0	10	243.88	451.5
Mayapuri							
1	12/02/08	0.92	3.89	74.4	17	217.62	292.5
2	13/02/08	0.95	3.76	68.5	16	241.79	353
ISBT							
1	21/12/07	0.97	2.93	75.9	10	211.55	278.9
2	27/12/07	0.99	1.61	75.3	12	222.61	295.6
3	29/12/07	0.99	1.27	119.9	10	370.24	308.9

4	01/01/08	0.98	2.07	94.8	10	792.88	836
5	22/12/07	0.97	2.75	82.8	11	223.22	269.5
6	30/12/07	0.98	3.1	103.1	8	218.49	212
7	26/12/07	0.98	2.18	81.9	8	304.27	371.5
8	28/12/07	0.99	2.77	104	10	461.61	444
9	23/12/07	0.99	0.81	135.6	10	691.64	510
Loni Road							
1	27/01/08	0.97	1.82	86.3	13	310.54	360
2	28/01/08	0.97	1.93	75.8	14	454.22	599
3	24/01/08	0.98	2.21	97.9	13	613.12	626
4	25/01/08	0.99	1.97	86.3	10	327.32	380
Naraina							
1	16/02/08	0.97	0.94	91.60	16	323.05	352.5
2	13/02/08	0.94	3.12	90.2	14	265.31	294.0
3	21/02/08	0.98	0.84	104.3	15	442.93	424.5
4	15/02/08	0.96	1.61	86.2	16	318.04	369.0
5	11/02/08	0.92	2.62	80.7	12	259.57	321.5
6	22/02/08	0.98	1.08	62.1	11	252.84	407.0
7	23/02/08	0.95	2.11	103.5	15	536.44	518.5
8	20/02/08	0.95	3.65	105.5	12	406.01	385.0
9	18/02/08	0.93	3.07	83.2	11	579.37	696.0
10	14/02/08	0.95	3.96	77.8	8	199.36	725.0
11	23/02/08	0.93	3.00	120.4	17	624.13	518.5
12	17/02/08	0.93	1.71	85.6	13	377.55	441.0
SSI-GTK							
1	03/01/08	0.95	3.1	95.6	15	868.97	909.0
2	30/12/07	0.94	3.98	64.1	13	497.24	775.4
3	21/12/07	0.96	3.41	67.1	12	594.50	885.8
4	27/12/07	0.96	3	76.9	11	571.90	743.6
5	26/12/07	0.96	3.65	62.1	12	501.03	806.4
6	24/12/07	0.96	3.54	93.7	10	881.55	940.4
7	23/12/07	0.91	2.68	67.4	14	666.34	989.2
Pitampura							
1	21/12/07	0.97	3.78	98.7	10	288.28	292.2
2	22/12/07	0.97	2.49	69.4	11	197.46	284.5
3	26/12/07	0.97	2.98	70.8	9	294.28	415.8
4	31/12/07	0.99	1.38	51.2	9	255.79	499.8
5	27/12/07	0.97	2.75	64	8	215.70	336.8
6	19/12/07	0.97	3.77	116.4	8	1049.5	901.3
7	23/12/07	0.96	3.37	117.7	8	670.70	570
8	20/12/07	0.99	1.02	90.6	8	428.84	473.4
9	28/12/07	0.98	3.72	81.7	9	399.82	489.5
10	30/12/07	0.99	1.46	84.7	8	384.16	453.7
11	29/12/07	0.97	3.68	92.8	7	405.37	436.6
Prahladpur							
1	28/12/07	0.94	2.99	78.9	17	275.07	348
2	27/01/08	0.98	2.39	57.7	12	186.10	322

3	28/01/08	0.96	2.16	71.5	12	368.44	515
4	29/12/07	0.96	3.17	82.4	13	316.27	384
5	28/01/08	0.96	2.16	71.5	12	368.44	515
6	25/01/08	0.96	3.19	81.5	13	215.43	264
7	26/12/07	0.97	2.45	71.7	12	255.36	356
8	27/12/07	0.97	3.13	72	12	243.01	337
9	24/01/08	0.94	3.91	83.3	11	207.49	249
10	27/01/08	0.96	2	86.8	12	279.82	322
11	30/01/08	0.96	3.77	105.4	12	382.17	362
12	26/01/08	0.98	2.81	110	13	278.21	253
13	26/12/07	0.97	2.45	71.7	12	255.36	356
14	24/01/08	0.94	3.91	83.3	11	207.49	249
15	30/01/08	0.96	3.77	105.4	12	382.17	362
16	26/01/08	0.98	2.81	110	13	278.21	253

Annexure 4.1.2b

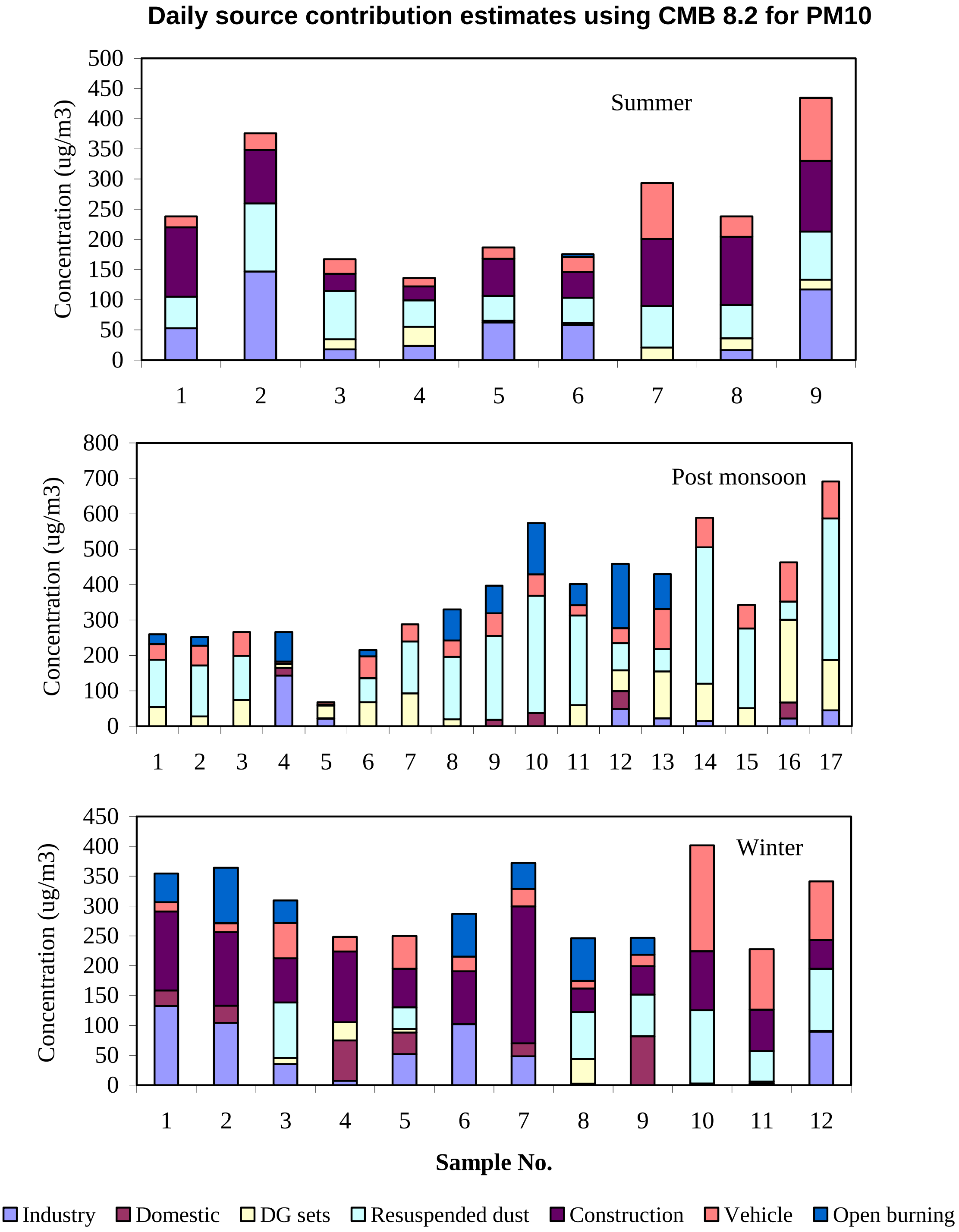


Figure 4.1.2b.1. Source contribution estimates using CMB at Ashram Chowk

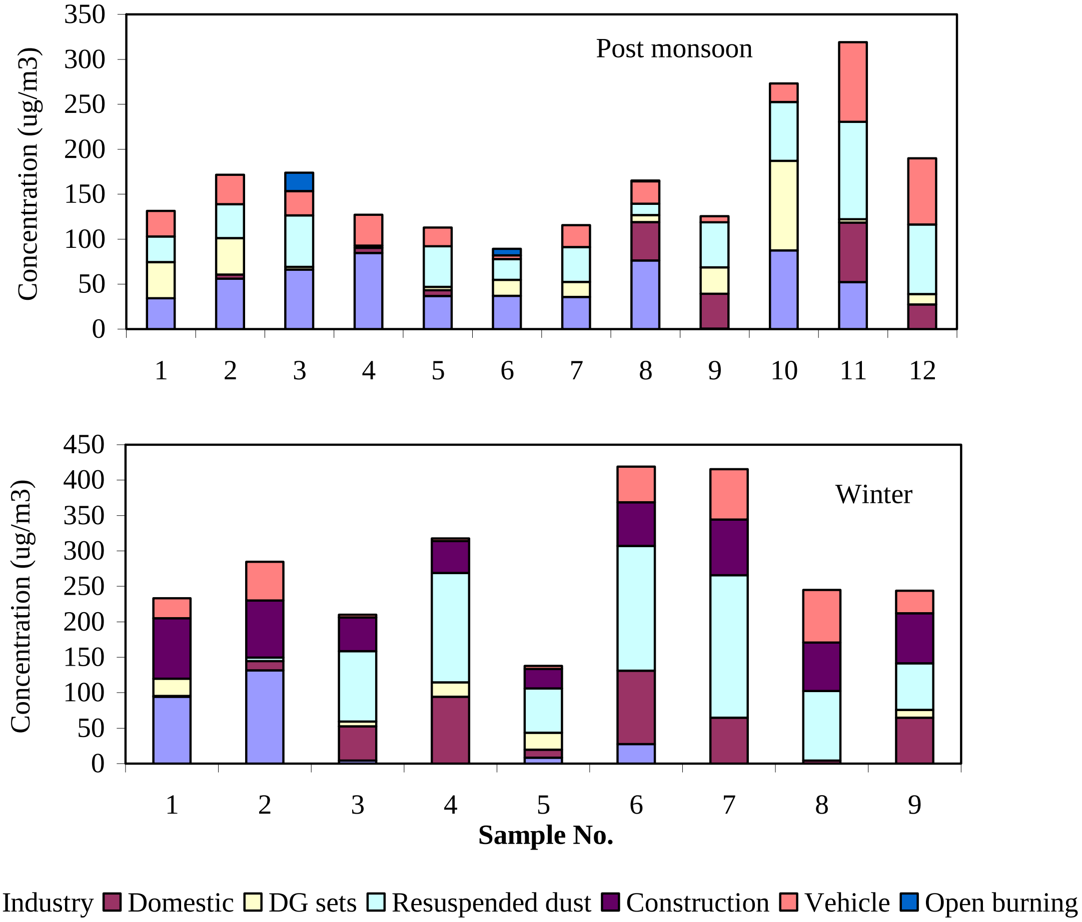


Figure 4.1.2b.2. Source contribution estimates using CMB at Dhaula kuan

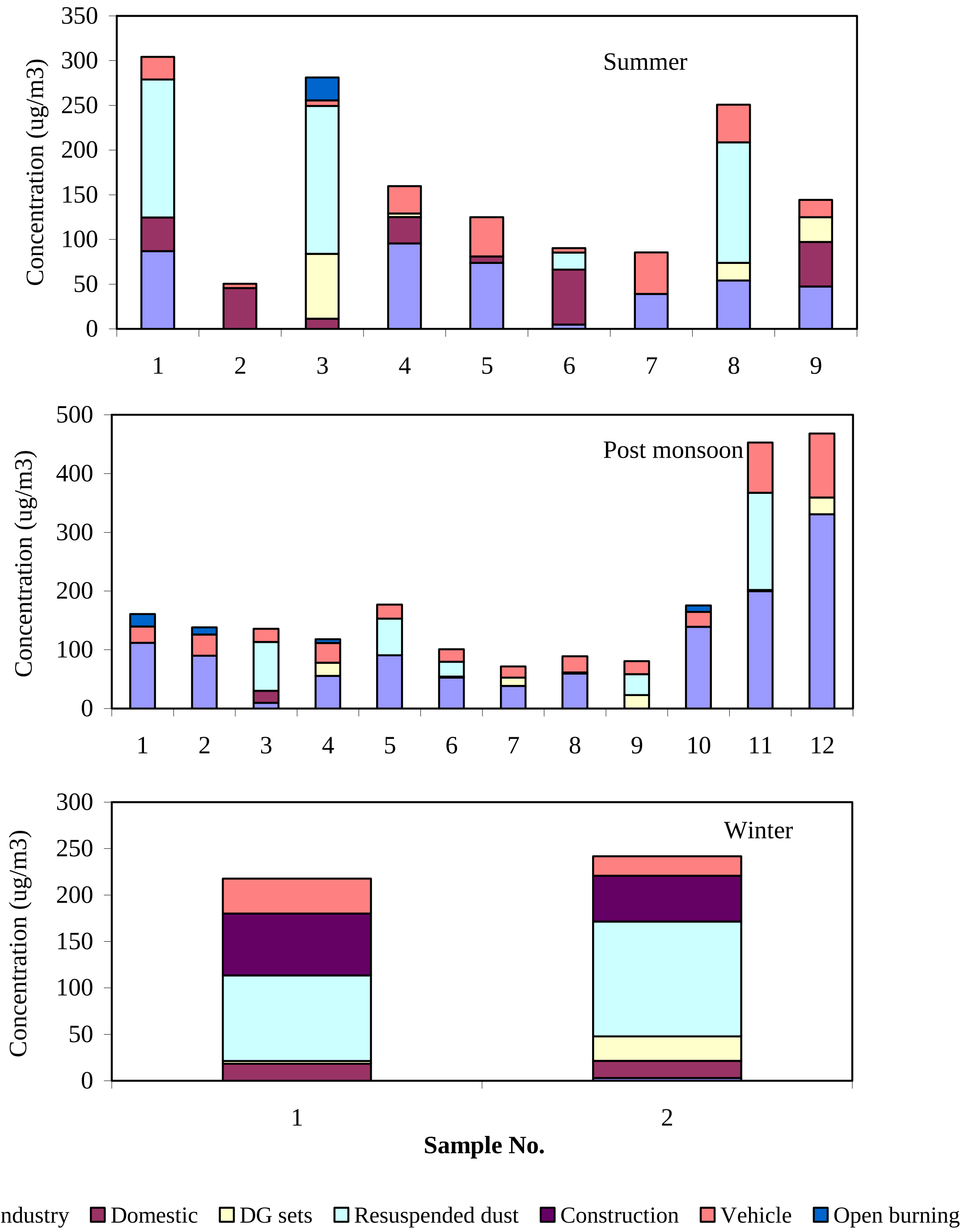


Figure 4.1.2b.3. Source contribution estimates using CMB at Mayapuri

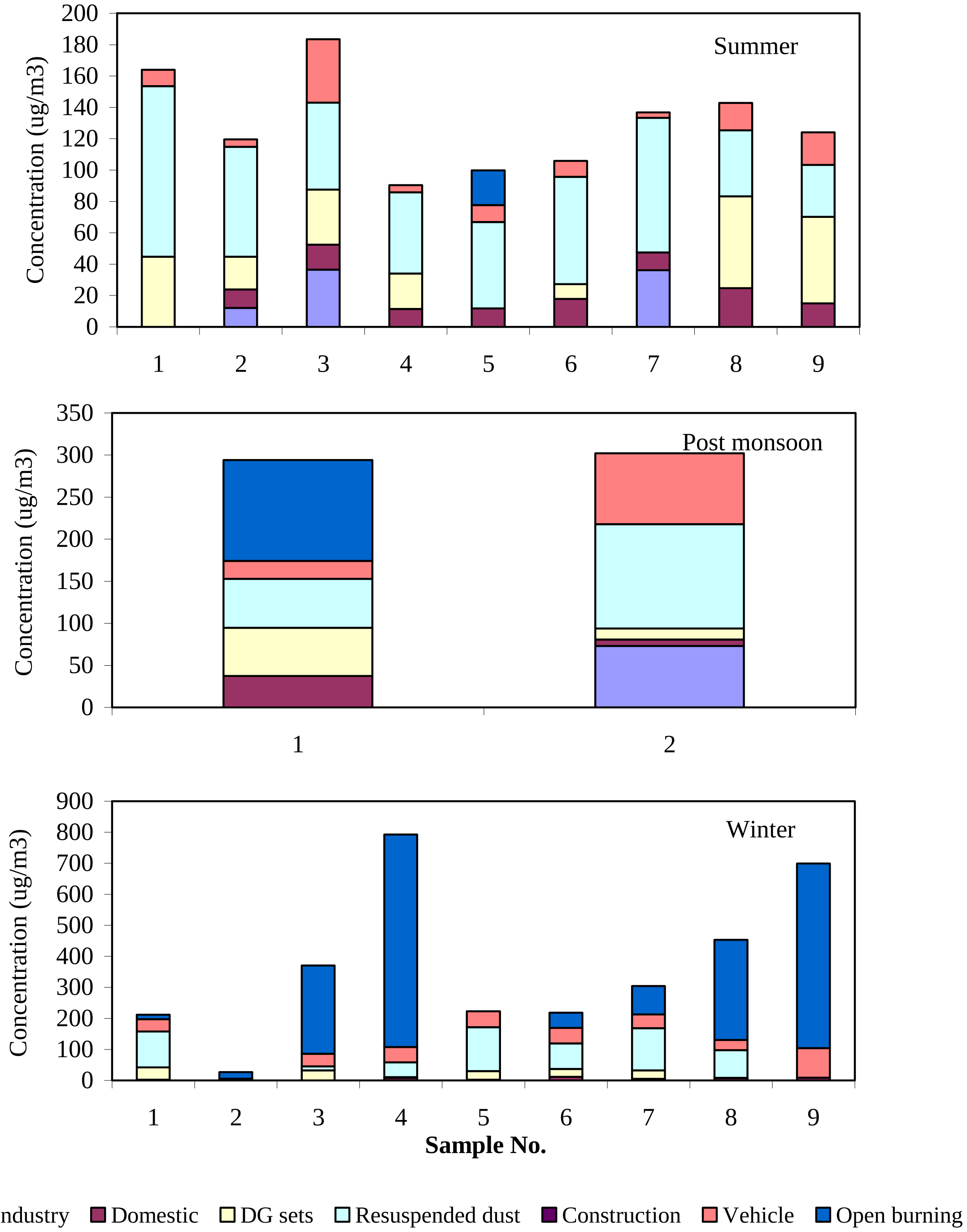


Figure 4.1.2b.4. Source contribution estimates using CMB at ISBT

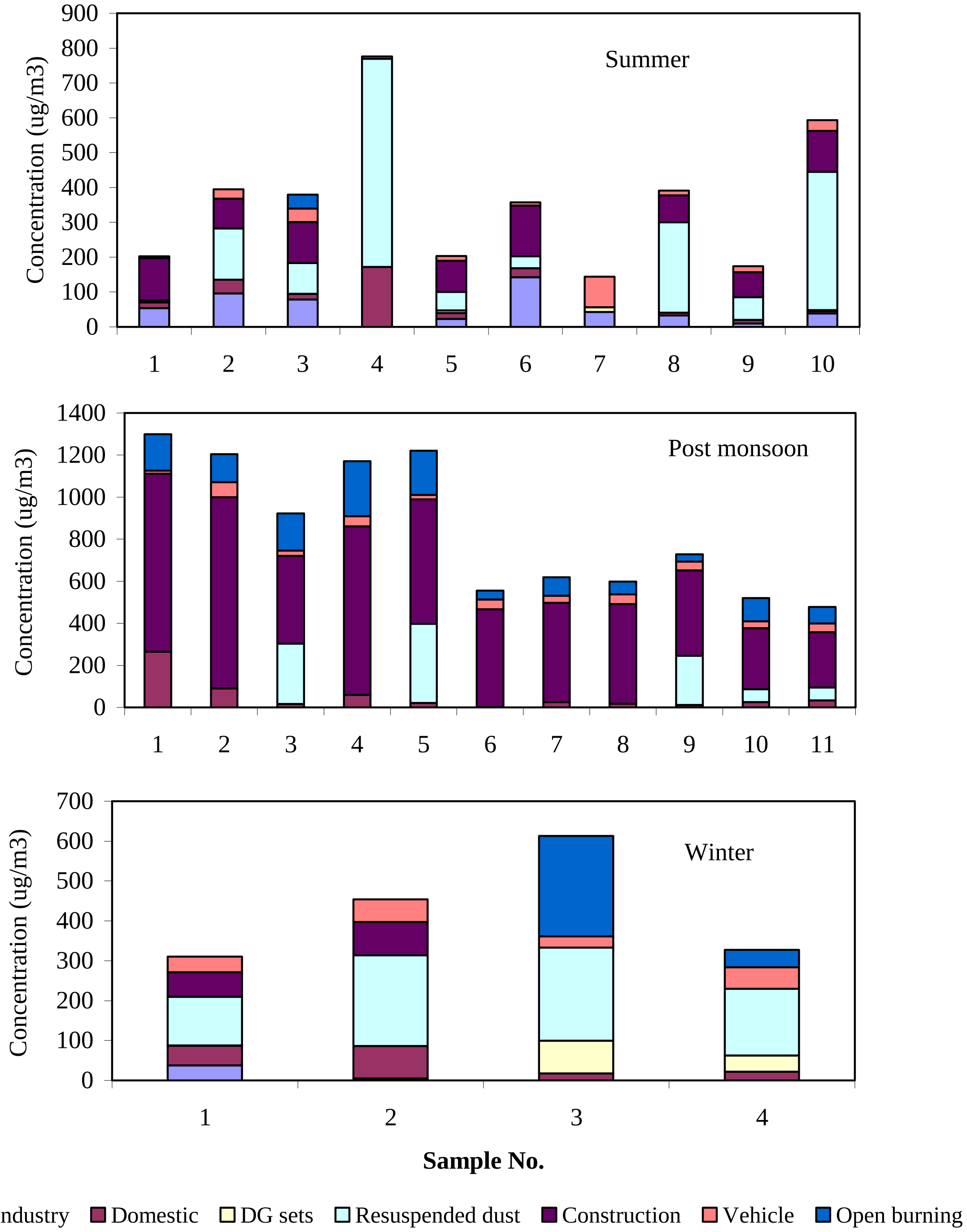


Figure 4.1.2b.5. Source contribution estimates using CMB at Loni Road

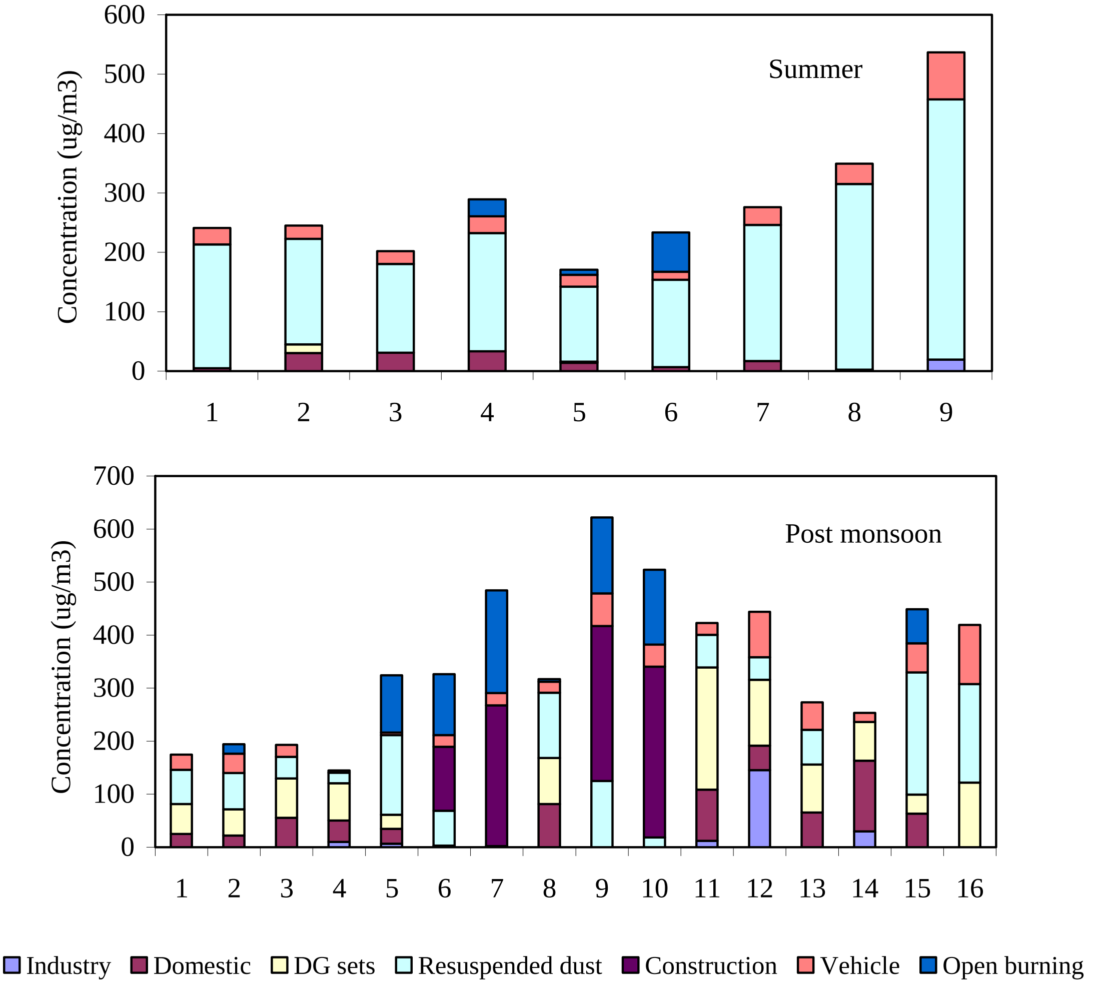


Figure 4.1.2b.6. Source contribution estimates using CMB at Anand Vihar

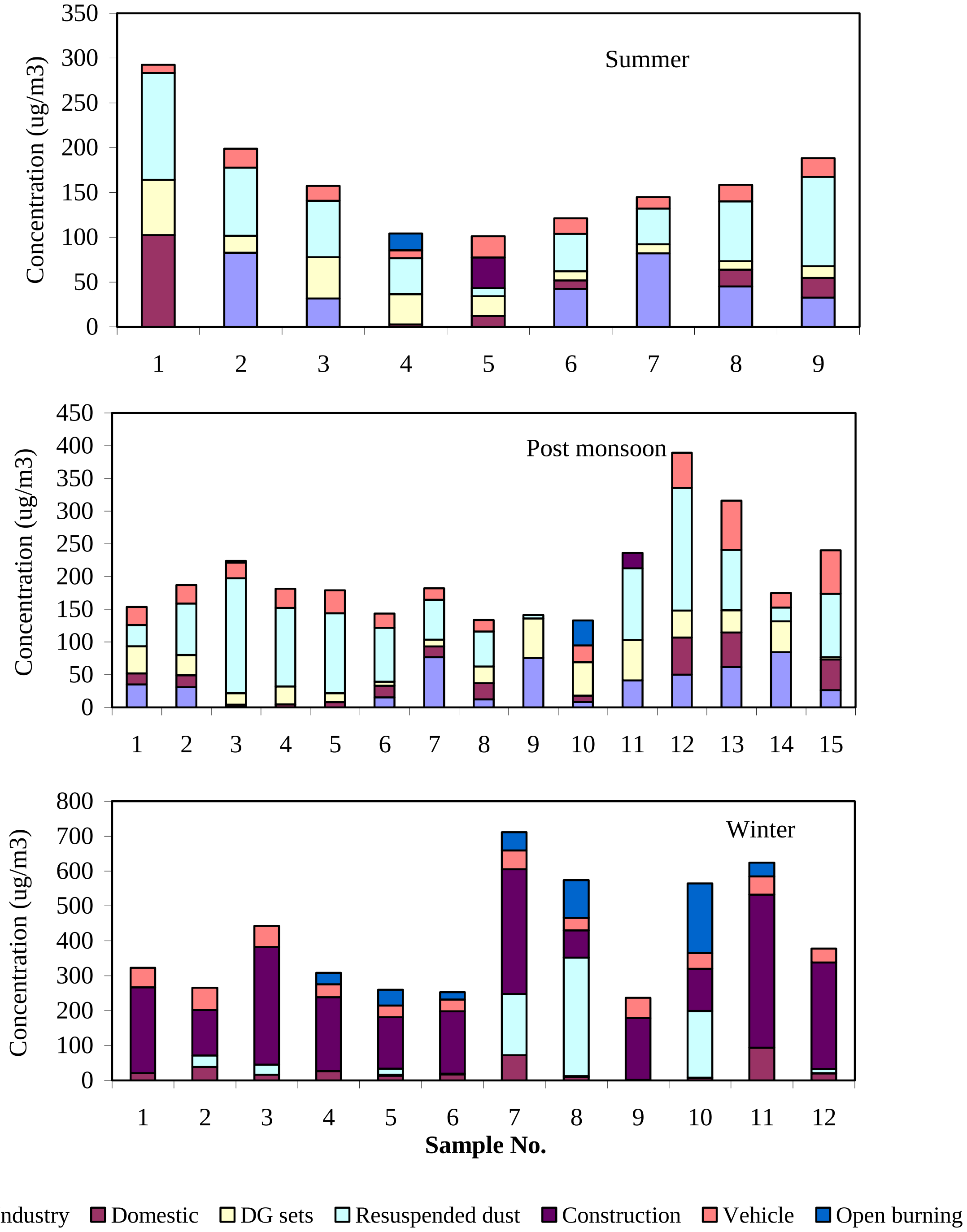


Figure 4.1.2b.7. Source contribution estimates using CMB at Naraina

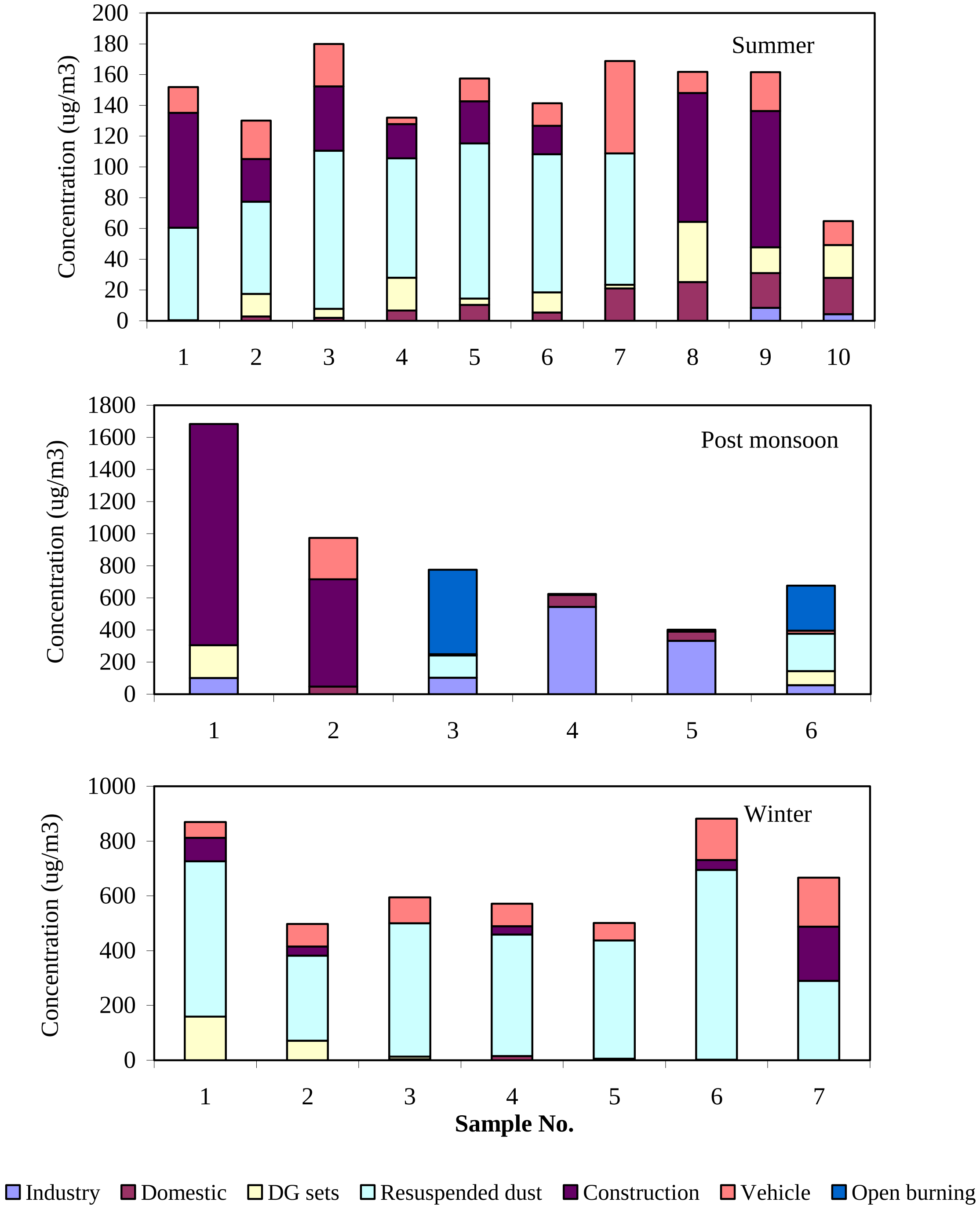


Figure 4.1.2b.8. Source contribution estimates using CMB at SSI-GTK

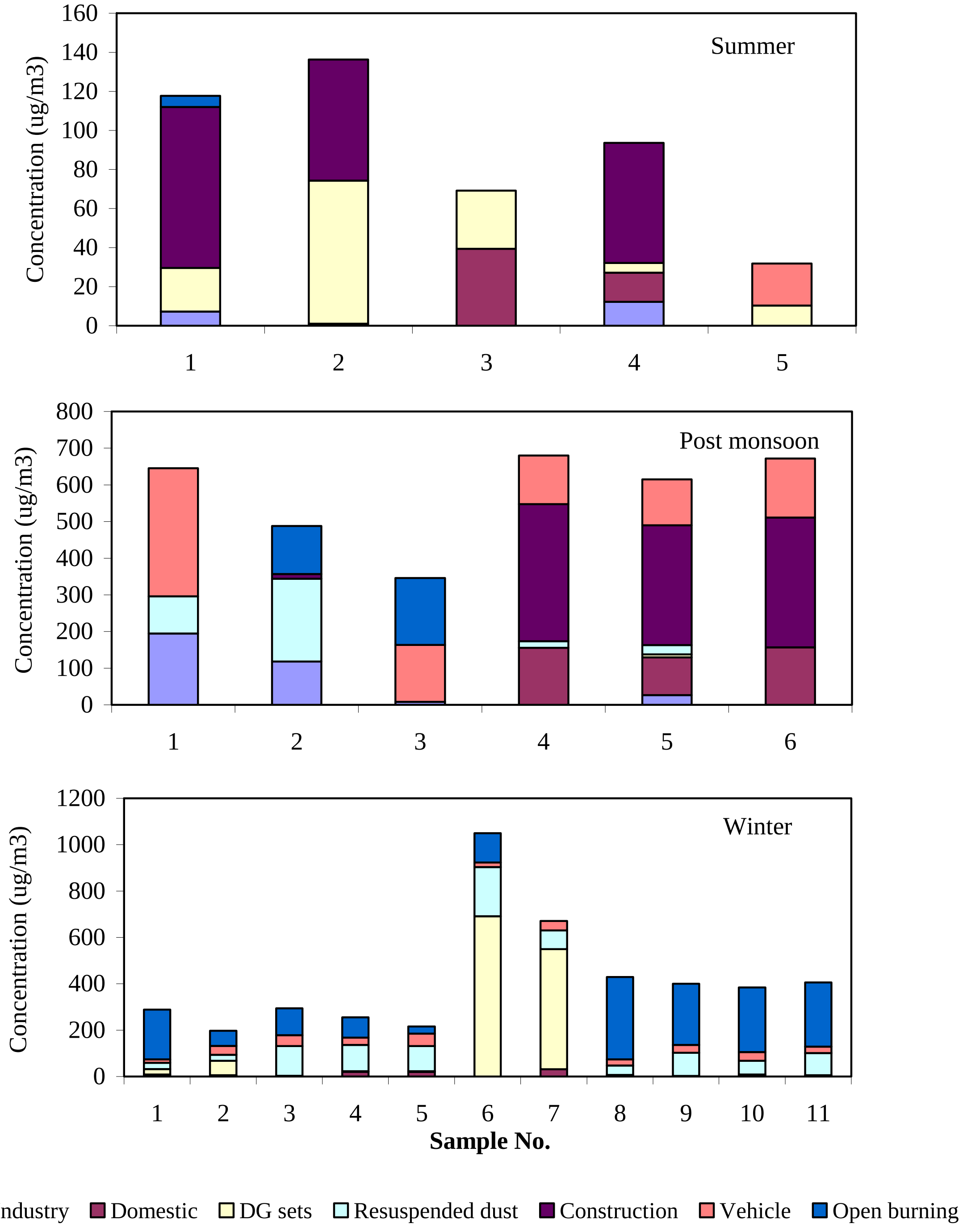


Figure 4.1.2b.9. Source contribution estimates using CMB at Pitampura

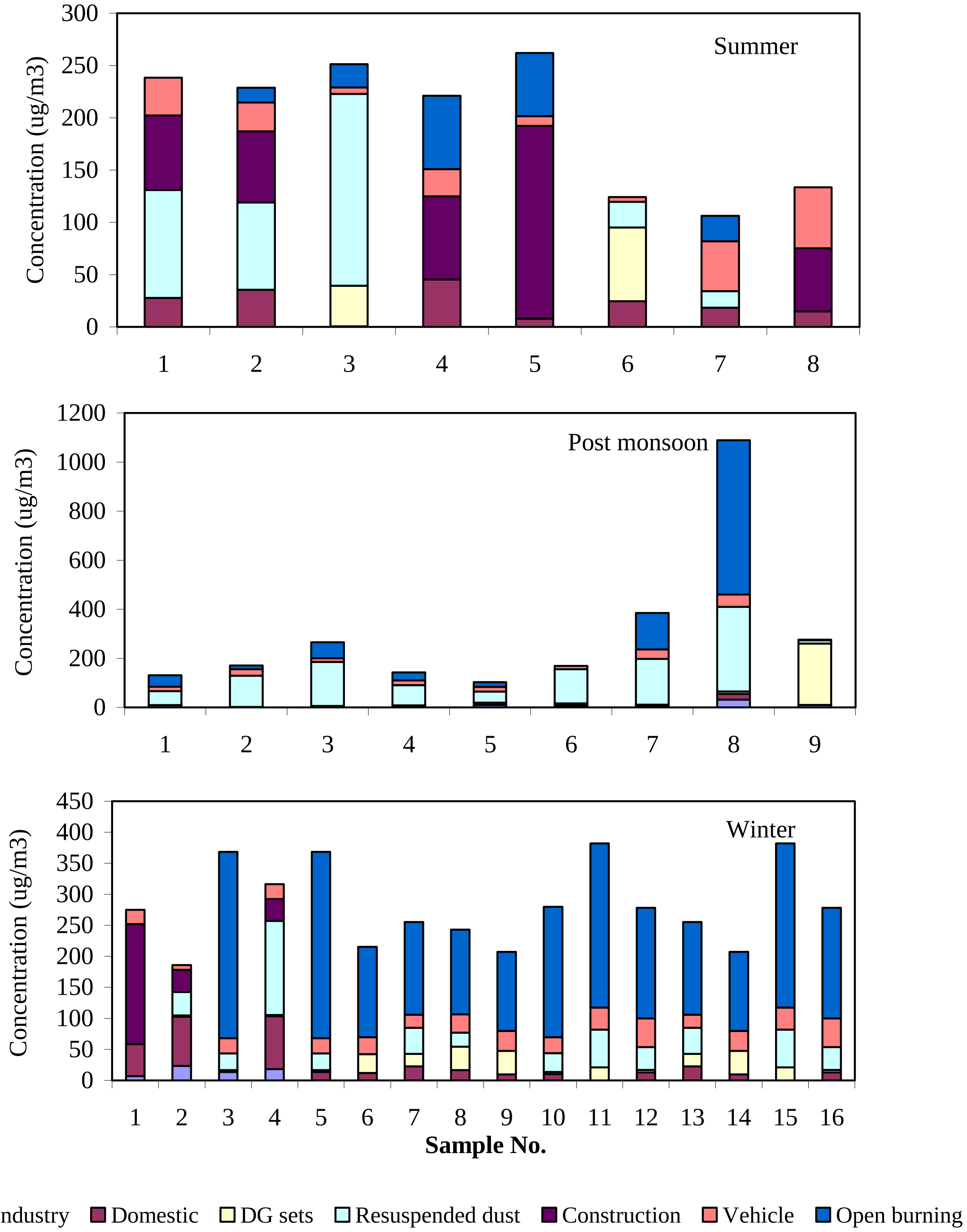


Figure 4.1.2b.10. Source contribution estimates using CMB at Prahladpur

Annexure 5

Annexure 5.1: Emission Loads/Rates for 2 km x 2 km Study Zones: Existing Scenario

5.2.1 Emission Rates: Area Sources

Table A5.1.1: Study Zone and Grid-wise PM Emission Rate (g/s-m^2): Area Sources

(Summer - Existing Scenario)

Grids	AC	DK	MP	ISBT	LR	AV	NR	GTK	PP	PR
A1	2.32E-06	1.25E-07	2.67E-06	6.76E-07	9.67E-06	2.22E-06	1.37E-07	1.05E-06	6.17E-06	5.94E-07
A2	1.11E-05	1.55E-07	1.22E-06	8.17E-07	5.59E-07	0.00E+00	4.44E-07	8.43E-07	2.90E-06	2.97E-07
A3	3.62E-07	4.64E-07	0.00E+00	9.02E-07	2.89E-05	0.00E+00	1.27E-06	3.86E-07	8.27E-06	2.97E-07
A4	1.85E-06	3.10E-07	0.00E+00	1.44E-06	1.41E-06	1.07E-06	2.66E-06	1.49E-06	2.05E-06	0.00E+00
B1	3.88E-06	0.00E+00	2.03E-06	9.62E-07	1.33E-06	9.81E-07	5.60E-05	7.11E-06	3.05E-06	1.19E-06
B2	2.83E-06	6.49E-07	6.33E-07	1.92E-06	0.00E+00	0.00E+00	5.79E-05	0.00E+00	9.42E-07	1.78E-06
B3	1.29E-05	0.00E+00	2.09E-06	1.41E-06	7.55E-07	0.00E+00	5.46E-05	1.07E-03	4.42E-06	1.78E-06
B4	2.41E-06	3.39E-07	1.72E-06	7.33E-07	1.74E-07	1.23E-06	2.09E-06	0.00E+00	9.75E-07	0.00E+00
C1	2.34E-06	5.37E-07	1.76E-06	4.51E-07	1.27E-06	6.03E-07	2.80E-06	4.15E-08	3.01E-06	1.19E-06
C2	6.40E-06	5.61E-09	9.51E-07	3.94E-07	1.31E-06	9.90E-06	4.22E-06	4.62E-07	7.95E-07	2.08E-06
C3	2.46E-06	0.00E+00	3.58E-07	0.00E+00	1.31E-07	3.97E-06	4.82E-05	7.90E-05	5.74E-07	2.04E-06
C4	2.12E-06	6.78E-07	1.54E-06	0.00E+00	0.00E+00	0.00E+00	7.57E-07	4.33E-07	1.78E-07	0.00E+00
D1	4.01E-06	1.55E-07	1.04E-06	5.62E-07	1.39E-06	1.07E-05	2.74E-05	1.96E-06	7.95E-07	8.91E-07
D2	2.95E-06	0.00E+00	2.72E-07	6.74E-07	1.34E-06	8.92E-06	4.29E-05	2.58E-06	6.53E-07	1.48E-06
D3	1.32E-06	0.00E+00	4.49E-07	4.49E-07	1.05E-06	0.00E+00	1.77E-05	5.60E-05	1.12E-06	1.15E-06
D4	9.07E-07	0.00E+00	1.37E-06	3.37E-07	0.00E+00	0.00E+00	7.66E-07	6.15E-07	3.99E-07	0.00E+00

Table A5.1.2: Study Zone and Grid-wise PM Emission Rate (g/s-m^2): Area Sources

(Winter - Existing Scenario)

Grids	AC	DK	MP	ISBT	LR	AV	NR	GTK	PP	PR
A1	2.17E-06	1.16E-07	2.31E-06	1.23E-06	9.59E-06	2.22E-06	1.37E-07	4.75E-07	3.89E-06	5.84E-07
A2	1.10E-05	2.32E-07	1.06E-06	1.58E-06	5.34E-07	0.00E+00	2.93E-07	3.84E-07	2.77E-06	2.92E-07
A3	3.12E-07	6.97E-07	0.00E+00	2.38E-06	2.88E-05	0.00E+00	8.95E-07	1.64E-07	8.13E-06	2.92E-07
A4	1.80E-06	4.65E-07	0.00E+00	2.53E-06	1.40E-06	1.03E-06	1.90E-06	6.91E-07	1.90E-06	0.00E+00
B1	3.78E-06	0.00E+00	1.88E-06	2.67E-06	1.31E-06	3.06E-07	5.58E-05	6.19E-06	2.89E-06	1.17E-06
B2	2.73E-06	1.05E-06	5.81E-07	3.87E-06	0.00E+00	0.00E+00	5.79E-05	0.00E+00	8.17E-07	1.75E-06
B3	1.28E-05	0.00E+00	1.99E-06	2.76E-06	7.55E-07	0.00E+00	5.46E-05	1.07E-03	4.35E-06	1.75E-06
B4	2.31E-06	5.81E-07	1.51E-06	1.52E-06	1.74E-07	1.17E-06	1.56E-06	0.00E+00	8.68E-07	0.00E+00
C1	2.31E-06	9.30E-07	1.61E-06	1.79E-06	1.24E-06	4.22E-07	2.50E-06	4.15E-08	2.85E-06	1.17E-06
C2	6.44E-06	4.67E-10	9.51E-07	1.50E-06	1.29E-06	7.54E-06	3.99E-06	2.34E-07	7.06E-07	2.04E-06
C3	2.38E-06	0.00E+00	1.50E-07	0.00E+00	8.05E-08	3.98E-06	4.79E-05	7.81E-05	5.38E-07	2.01E-06
C4	2.12E-06	1.16E-06	1.44E-06	0.00E+00	0.00E+00	0.00E+00	5.31E-07	2.01E-07	1.78E-07	0.00E+00
D1	3.95E-06	2.32E-07	9.89E-07	1.60E-06	1.39E-06	8.16E-06	2.71E-05	1.39E-06	7.06E-07	8.76E-07
D2	2.90E-06	0.00E+00	2.72E-07	1.92E-06	1.32E-06	6.83E-06	4.26E-05	1.89E-06	5.63E-07	1.46E-06
D3	1.33E-06	0.00E+00	1.89E-07	1.28E-06	1.05E-06	0.00E+00	1.73E-05	5.55E-05	9.95E-07	1.13E-06
D4	8.09E-07	0.00E+00	1.37E-06	9.62E-07	0.00E+00	0.00E+00	6.15E-07	2.74E-07	3.45E-07	0.00E+00

Table A5.1.3: Study Zone and Grid-wise NOx Emission Rate (g/s-m^2): Area Sources (Summer - Existing Scenario)

Grids	AC	DK	MP	ISBT	LR	AV	NR	GTK	PP	PR
A1	1.57E-05	1.53E-06	1.18E-05	8.18E-06	8.51E-06	8.33E-07	5.79E-06	1.35E-05	5.86E-05	2.19E-06
A2	1.62E-05	1.71E-06	5.19E-06	9.94E-06	3.32E-06	0.00E+00	3.89E-06	1.08E-05	1.08E-05	1.10E-06
A3	5.51E-06	5.13E-06	0.00E+00	1.14E-05	1.22E-05	0.00E+00	1.02E-05	5.10E-06	1.32E-05	1.10E-06
A4	6.39E-06	3.42E-06	0.00E+00	1.73E-05	8.54E-06	6.40E-06	2.08E-05	2.08E-05	1.20E-05	0.00E+00
B1	1.22E-05	0.00E+00	6.67E-06	1.22E-05	8.01E-06	1.42E-05	9.18E-06	2.18E-05	1.29E-05	4.38E-06
B2	1.21E-05	7.02E-06	2.14E-06	2.34E-05	0.00E+00	0.00E+00	8.55E-06	0.00E+00	9.88E-06	6.58E-06
B3	1.65E-05	0.00E+00	4.11E-06	1.72E-05	3.82E-06	0.00E+00	0.00E+00	2.80E-06	8.35E-06	6.58E-06
B4	1.18E-05	3.60E-06	7.10E-06	8.98E-06	1.06E-06	7.34E-06	1.52E-05	0.00E+00	9.49E-06	0.00E+00
C1	7.98E-06	5.57E-06	6.18E-06	6.37E-06	7.63E-06	5.88E-06	9.94E-06	1.75E-06	1.32E-05	4.38E-06
C2	5.44E-06	3.41E-08	1.72E-06	5.57E-06	7.60E-06	1.39E-04	6.73E-06	7.50E-06	7.80E-06	7.67E-06
C3	1.19E-05	0.00E+00	4.62E-06	0.00E+00	3.45E-07	2.77E-06	2.20E-05	3.25E-05	4.68E-06	6.60E-06
C4	4.35E-07	7.20E-06	4.80E-06	0.00E+00	0.00E+00	0.00E+00	9.69E-06	5.53E-06	1.08E-06	0.00E+00
D1	1.38E-05	1.71E-06	2.88E-06	7.94E-06	8.47E-06	1.49E-04	1.71E-05	1.42E-05	7.80E-06	3.29E-06
D2	1.03E-05	0.00E+00	4.92E-07	9.53E-06	8.08E-06	1.24E-04	2.21E-05	1.63E-05	6.94E-06	5.48E-06
D3	1.57E-06	0.00E+00	5.79E-06	6.35E-06	6.35E-06	0.00E+00	2.22E-05	1.87E-05	1.10E-05	3.31E-06
D4	9.98E-06	0.00E+00	2.49E-06	4.76E-06	0.00E+00	0.00E+00	1.11E-05	7.97E-06	4.20E-06	0.00E+00

Table A5.1.4: Study Zone and Grid-wise NOx Emission Rate (g/s-m^2): Area Sources (Winter - Existing Scenario)

Grids	AC	DK	MP	ISBT	LR	AV	NR	GTK	PP	PR
A1	1.36E-05	1.40E-06	6.26E-06	1.61E-05	8.20E-06	8.33E-07	5.79E-06	5.40E-06	2.57E-05	2.05E-06
A2	1.41E-05	2.81E-06	2.81E-06	2.08E-05	3.22E-06	0.00E+00	2.29E-06	4.35E-06	9.02E-06	1.02E-06
A3	4.82E-06	8.42E-06	0.00E+00	3.23E-05	1.20E-05	0.00E+00	6.21E-06	1.96E-06	1.12E-05	1.02E-06
A4	5.69E-06	5.61E-06	0.00E+00	3.28E-05	8.49E-06	6.26E-06	1.28E-05	9.55E-06	9.95E-06	0.00E+00
B1	1.08E-05	0.00E+00	4.29E-06	3.64E-05	7.96E-06	4.44E-06	6.79E-06	8.86E-06	1.06E-05	4.10E-06
B2	1.07E-05	1.26E-05	1.35E-06	5.10E-05	0.00E+00	0.00E+00	8.55E-06	0.00E+00	8.12E-06	6.15E-06
B3	1.48E-05	0.00E+00	2.74E-06	3.62E-05	3.82E-06	0.00E+00	0.00E+00	2.80E-06	7.34E-06	6.15E-06
B4	1.04E-05	7.02E-06	3.93E-06	2.01E-05	1.06E-06	7.10E-06	9.62E-06	0.00E+00	7.98E-06	0.00E+00
C1	7.63E-06	1.12E-05	3.80E-06	2.53E-05	7.48E-06	3.26E-06	6.73E-06	1.75E-06	1.09E-05	4.10E-06
C2	6.08E-06	2.85E-09	1.72E-06	2.12E-05	7.50E-06	1.05E-04	4.34E-06	4.29E-06	6.54E-06	7.17E-06
C3	1.08E-05	0.00E+00	1.45E-06	0.00E+00	1.40E-07	2.81E-06	1.88E-05	1.96E-05	4.18E-06	6.17E-06
C4	4.35E-07	1.40E-05	3.21E-06	0.00E+00	0.00E+00	0.00E+00	7.30E-06	2.25E-06	1.08E-06	0.00E+00
D1	1.29E-05	2.81E-06	2.09E-06	2.27E-05	8.47E-06	1.12E-04	1.47E-05	6.19E-06	6.54E-06	3.07E-06
D2	9.62E-06	0.00E+00	4.92E-07	2.72E-05	7.98E-06	9.38E-05	1.89E-05	6.50E-06	5.67E-06	5.12E-06
D3	1.79E-06	0.00E+00	1.82E-06	1.81E-05	6.35E-06	0.00E+00	1.74E-05	1.22E-05	9.20E-06	3.10E-06
D4	8.59E-06	0.00E+00	2.49E-06	1.36E-05	0.00E+00	0.00E+00	9.53E-06	3.16E-06	3.45E-06	0.00E+00

5.2.2 Emission Rates: Industrial Sources

Table A5.1.5: Study Zone and Grid-wise PM10 Emission Rate (g/s-m^2): Industrial Sources (Existing Scenario)

Grid	Anand Vihar	Naraina	Lajwanti garden	GTK
A1	1.71E-06	2.43E-06	0	0
A2	1.71E-06	2.84E-06	0	0
A3	0	0	0	0
A4	0	0	0	0
B1	8.55E-07	2.03E-07	0	0
B2	1.49E-06	2.03E-06	0	6.02E-06
B3	0	1.62E-06	0	0
B4	0	4.06E-07	0	0
C1	0	8.12E-07	0	1.05E-05
C2	0	3.25E-06	8.55E-07	7.53E-06
C3	4.06E-06	2.43E-06	1.28E-06	0
C4	2.70E-06	4.06E-07	0	0
D1	0	0	0	1.51E-06
D2	0	0	2.14E-06	0
D3	4.05E-06	0	7.69E-06	0
D4	6.09E-06	3.24E-06	2.14E-06	0
Total	**2.27E-05**	**1.97E-05**	**1.41E-05**	**2.56E-05**

Table A5.1.6: Study Zone and Grid-wise NOx Emission Rate (g/s-m^2): Industrial Sources (Existing Scenario)

Grid	Anand Vihar	Naraina	Lajwanti Garden (Mayapuri)	GTK
A1	9.79E-05	3.43E-05	0	0
A2	9.79E-05	4.00E-05	0	0
A3	0	0	0	0
A4	0	0	0	0
B1	4.89E-05	2.86E-06	0	0
B2	8.57E-05	2.86E-05	0	8.44E-05
B3	0	2.28E-05	0	0
B4	0	5.71E-06	0	0
C1	0	1.14E-05	0	1.48E-04
C2	0	4.57E-05	1.20E-05	1.05E-04
C3	3.19E-07	3.43E-05	1.80E-05	0
C4	2.13E-07	5.71E-06	0	0
D1	0	0	0	2.11E-05
D2	0	0	3.01E-05	0
D3	3.19E-07	0	0.000108	0
D4	4.78E-07	4.57E-05	3.01E-05	0
Total	**3.32E-04**	**2.77E-04**	**1.98E-04**	**3.59E-04**

5.2.3 Emission Rates: Vehicular Sources

Table A5.1.7: Study Zone and Grid-wise PM (kg/d) Emissions: Vehicular Sources (Existing Scenario)

Grid	AC	DK	MP	ISBT	LR	AV	Nar	SSI	PP	Prah
A1	10.00	2.04	2.28	0.91	0.72	4.08	0.04	0.80	0.55	0.14
A2	2.14	12.67	0.22	0.06	6.70	0.16	3.34	0.61	5.00	0.00
A3	0.29	3.62	0.00	15.07	0.35	0.04	12.18	10.85	8.44	0.11
A4	5.60	2.93	3.11	11.77	0.17	0.17	8.90	2.54	8.12	0.84
B1	0.87	0.15	2.43	10.93	0.17	6.05	10.59	0.67	1.87	0.51
B2	10.52	8.86	0.42	12.16	4.67	3.47	6.41	0.61	1.46	0.56
B3	12.13	3.16	2.79	25.88	0.35	0.12	0.74	8.15	0.83	1.34
B4	4.51	11.55	1.17	10.86	0.46	0.13	3.33	25.24	0.83	0.88
C1	6.45	2.34	1.56	35.32	2.52	0.16	1.15	1.08	0.83	0.40
C2	8.96	12.17	2.79	27.13	7.14	0.83	2.96	13.59	1.26	0.72
C3	10.38	17.32	2.59	0.00	2.47	7.12	1.79	6.46	1.63	1.87
C4	0.68	0.00	0.11	0.00	2.06	4.08	0.09	11.12	0.18	0.00
D1	4.78	6.45	1.99	11.44	0.29	0.16	0.18	15.06	0.55	0.19
D2	3.35	0.33	1.66	0.00	4.96	0.08	0.13	1.43	0.55	0.72
D3	4.65	9.02	1.12	0.00	0.23	3.93	10.40	12.07	1.35	1.71
D4	14.15	0.00	1.72	0.00	0.17	0.44	4.21	0.86	0.81	0.00
Total	99.45	92.61	25.95	161.52	33.44	31.03	66.45	111.14	34.27	10.00

Table A5.1.8: Study Zone and Grid-wise NOx (kg/d) Emissions: Vehicular Sources (Existing Scenario)

Grid	AC	DK	MP	ISBT	LR	AV	Nar	SSI	PP	Prah
A1	89.30	18.64	24.20	4.94	5.03	42.33	0.34	5.19	3.90	1.41
A2	19.08	116.91	2.60	0.44	54.28	1.40	30.93	4.00	38.14	0.00
A3	2.45	33.03	0.00	115.75	2.43	0.35	113.44	80.97	64.71	1.02
A4	50.27	26.93	33.68	88.35	1.22	1.62	81.99	18.59	62.17	7.93
B1	7.34	1.32	26.08	83.50	1.22	62.97	98.15	4.40	13.79	4.92
B2	94.31	81.65	4.79	93.39	40.37	35.99	59.00	4.00	11.00	5.48
B3	108.86	29.07	30.44	198.81	2.43	1.12	6.91	60.58	5.85	12.83
B4	40.24	102.38	12.86	83.41	3.24	1.13	31.80	188.48	5.85	8.40
C1	57.69	21.63	16.83	271.38	17.58	1.40	10.36	7.06	5.85	3.94
C2	80.12	110.33	30.44	208.42	57.91	8.45	27.99	100.89	9.33	7.03
C3	92.88	156.05	27.63	0.00	17.18	74.10	16.93	47.28	12.35	17.82
C4	5.71	0.00	1.30	0.00	14.34	42.33	0.69	83.06	1.30	0.00
D1	42.46	59.52	21.46	87.89	2.03	1.40	1.38	111.52	3.90	1.88
D2	28.88	2.86	18.15	0.00	42.69	0.70	1.03	9.32	3.90	7.03
D3	40.62	83.25	11.97	0.00	1.62	40.62	96.50	88.96	10.07	16.30
D4	127.21	0.00	18.38	0.00	1.22	4.11	40.21	5.59	6.32	0.00
Total	887.4	843.6	280.8	1236.3	264.8	320.0	617.6	819.9	258.4	96.0

Annexure 5.2: Emission Loads for Delhi City - Existing Scenario

5.2.1 Area Sources

Table A5.2.1: Grid-wise Emission Rates for PM, SO_2 and NOx during Summer and Winter: Area Sources in Delhi (Existing Scenario)

Grid	Emission Rate (g/s-m^2)					
	PM		SO_2		NOx	
	Summer	Winter	Summer	Winter	Summer	Winter
C1	5.87E-07	5.61E-07	2.11E-07	1.88E-07	1.14E-06	7.81E-07
C2	1.85E-06	1.82E-06	2.88E-07	2.62E-07	1.39E-06	9.9E-07
C3	1.31E-06	1.28E-06	2.49E-07	2.22E-07	1.35E-06	9.47E-07
C4	1.41E-06	1.36E-06	3.02E-07	2.6E-07	4.34E-06	3.71E-06
C5	6.71E-07	6.59E-07	1.34E-07	1.23E-07	7.22E-07	5.61E-07
C6	1.58E-06	1.53E-06	1.58E-07	1.13E-07	2.52E-06	1.84E-06
C7	1.49E-06	1.44E-06	1.93E-07	1.51E-07	2.45E-06	1.81E-06
C8	8.74E-07	8.58E-07	6.49E-08	4.97E-08	9.09E-07	6.78E-07
C9	6.96E-07	6.81E-07	9.2E-08	7.74E-08	8.92E-07	6.7E-07
C10	6.02E-07	5.87E-07	3.9E-08	2.47E-08	8.17E-07	6E-07
C11	7.37E-07	7.25E-07	3.45E-08	2.31E-08	6.75E-07	5.02E-07
C12	5.65E-07	5.59E-07	1.84E-08	1.33E-08	3.21E-07	2.44E-07
C13	-	-	-	-	-	-
C14	-	-	-	-	-	-
C15	-	-	-	-	-	-
D1	2.07E-06	2.03E-06	3.48E-07	3.16E-07	1.66E-06	1.18E-06
D2	3.30E-06	3.26E-06	4.25E-07	3.91E-07	1.88E-06	1.36E-06
D3	1.96E-06	1.93E-06	3.37E-07	3.01E-07	1.83E-06	1.29E-06
D4	7.36E-06	7.25E-06	9E-07	7.94E-07	8.28E-06	6.66E-06
D5	1.98E-06	1.91E-06	2.03E-07	1.31E-07	4.02E-06	2.94E-06
D6	1.75E-06	1.69E-06	1.9E-07	1.37E-07	3.05E-06	2.24E-06
D7	6.86E-06	6.78E-06	8.8E-07	8.05E-07	4.89E-06	3.75E-06
D8	1.04E-05	1.04E-05	7.83E-07	7.39E-07	3.04E-06	2.36E-06
D9	2.35E-06	2.25E-06	2.5E-07	1.55E-07	5.34E-06	3.91E-06
D10	1.78E-06	1.73E-06	2.33E-07	1.88E-07	2.66E-06	1.99E-06
D11	3.05E-07	2.91E-07	7.77E-08	6.49E-08	7.63E-07	5.69E-07
D12	7.33E-07	7.2E-07	3.4E-08	2.28E-08	6.65E-07	4.95E-07
D13	7.63E-08	7.33E-08	7.11E-09	4.31E-09	1.57E-07	1.14E-07
D14	-	-	-	-	-	-
D15	-	-	-	-	-	-
E1	2.83E-06	2.79E-06	4.49E-07	4.08E-07	2.15E-06	1.53E-06
E2	3.34E-06	3.29E-06	4.95E-07	4.51E-07	2.33E-06	1.66E-06
E3	1.18E-05	1.17E-05	1.33E-06	1.23E-06	5.72E-06	4.18E-06
E4	1.34E-05	1.32E-05	1.58E-06	1.37E-06	1.43E-05	1.12E-05
E5	1.25E-05	1.24E-05	9.81E-07	8.78E-07	6.82E-06	5.24E-06
E6	4.37E-06	4.29E-06	3.57E-07	2.88E-07	4.24E-06	3.2E-06
E7	2.54E-05	2.53E-05	2.24E-06	2.12E-06	8.04E-06	6.36E-06
E8	1.43E-05	1.42E-05	1.21E-06	1.11E-06	6.42E-06	4.9E-06
E9	6.13E-06	6.03E-06	6.84E-07	5.92E-07	5.6E-06	4.21E-06
E10	1.24E-06	1.21E-06	3.76E-07	3.46E-07	2.03E-06	1.57E-06
E11	6.43E-07	6.31E-07	3.91E-08	2.76E-08	6.89E-07	5.14E-07

E12	5.31E-07	5.3E-07	6E-08	5.88E-08	1.57E-07	1.4E-07
E13	3.15E-07	3.11E-07	3.15E-08	2.76E-08	2.6E-07	2E-07
E14	-	-	-	-	-	-
E15	-	-	-	-	-	-
F1	2.36E-05	2.36E-05	1.06E-06	1.01E-06	3.51E-06	2.76E-06
F2	2.18E-05	2.17E-05	1.03E-06	9.37E-07	4.98E-06	3.52E-06
F3	2.36E-05	2.34E-05	1.95E-06	1.77E-06	9.34E-06	6.55E-06
F4	5.07E-06	4.88E-06	9.48E-07	7.76E-07	1.19E-05	9.27E-06
F5	7.49E-06	7.34E-06	2.06E-06	1.93E-06	1E-05	7.98E-06
F6	8.31E-06	8.12E-06	1.15E-06	9.68E-07	1.06E-05	7.94E-06
F7	7.72E-06	7.6E-06	1.58E-06	1.47E-06	7.87E-06	6.1E-06
F8	8.05E-06	7.91E-06	1.1E-06	9.64E-07	8.26E-06	6.24E-06
F9	4.90E-06	4.71E-06	5.34E-07	3.63E-07	9.66E-06	7.06E-06
F10	2.11E-06	2.09E-06	1.84E-07	1.59E-07	1.49E-06	1.12E-06
F11	2.26E-06	2.24E-06	1.77E-07	1.58E-07	1.2E-06	9.16E-07
F12	2.13E-06	2.12E-06	1.54E-07	1.42E-07	8.38E-07	6.49E-07
F13	1.58E-06	1.57E-06	1.17E-07	1.1E-07	4.89E-07	3.78E-07
F14	4.84E-08	4.54E-08	5.63E-09	2.82E-09	1.55E-07	1.13E-07
F15	-	-	-	-	-	-
G1	1.12E-05	1.11E-05	1.88E-07	1.3E-07	3.51E-06	2.63E-06
G2	9.35E-06	9.28E-06	8.25E-07	7.57E-07	4.56E-06	3.53E-06
G3	2.47E-06	2.36E-06	6.01E-07	4.99E-07	6.46E-06	4.91E-06
G4	5.99E-06	5.87E-06	9.77E-07	8.7E-07	8.52E-06	6.9E-06
G5	8.40E-06	8.24E-06	1.12E-06	9.82E-07	9.31E-06	7.15E-06
G6	2.84E-05	2.81E-05	3.49E-06	3.2E-06	1.87E-05	1.43E-05
G7	8.89E-06	8.73E-06	1.37E-06	1.22E-06	9.25E-06	7.02E-06
G8	4.36E-06	4.3E-06	3.98E-07	3.44E-07	3.28E-06	2.45E-06
G9	8.97E-07	8.74E-07	1.89E-07	1.67E-07	1.33E-06	9.99E-07
G10	8.17E-07	8.02E-07	9.61E-08	8.24E-08	8.24E-07	6.16E-07
G11	3.30E-07	3.12E-07	5.53E-08	3.81E-08	9.74E-07	7.13E-07
G12	3.40E-07	3.25E-07	9.02E-08	7.64E-08	8.31E-07	6.22E-07
G13	5.96E-07	5.89E-07	1.83E-07	1.76E-07	5.56E-07	4.58E-07
G14	1.53E-07	1.43E-07	1.77E-08	8.89E-09	4.9E-07	3.56E-07
G15	2.73E-08	2.56E-08	3.17E-09	1.59E-09	8.76E-08	6.36E-08
H1	1.64E-05	1.63E-05	1.58E-06	1.51E-06	6.04E-06	4.95E-06
H2	1.10E-05	1.09E-05	4.81E-07	4.12E-07	4.85E-06	3.8E-06
H3	1.41E-05	1.4E-05	1.54E-06	1.46E-06	7.49E-06	6.2E-06
H4	1.16E-05	1.15E-05	1.62E-06	1.49E-06	1.06E-05	8.7E-06
H5	9.78E-06	9.66E-06	1E-06	8.87E-07	7.75E-06	6.03E-06
H6	3.26E-05	3.25E-05	2.94E-06	2.8E-06	1.09E-05	8.87E-06
H7	4.91E-05	4.9E-05	1.07E-06	9.81E-07	7.22E-06	5.8E-06
H8	2.55E-06	2.46E-06	8.83E-07	8.06E-07	6.36E-06	5.19E-06
H9	1.64E-06	1.61E-06	7.57E-07	7.28E-07	2.37E-06	1.93E-06
H10	3.69E-07	3.47E-07	5.13E-08	3.09E-08	1.14E-06	8.31E-07
H11	2.80E-06	2.78E-06	2.16E-07	1.94E-07	1.03E-06	6.96E-07
H12	1.39E-06	1.36E-06	2.83E-07	2.59E-07	1.01E-06	6.48E-07
H13	3.48E-07	3.22E-07	6.87E-08	4.48E-08	7.48E-07	3.85E-07
H14	4.39E-07	4.18E-07	8.24E-08	6.33E-08	1.05E-06	7.63E-07
H15	1.54E-07	1.45E-07	1.69E-08	8.96E-09	4.18E-07	2.98E-07
J1	2.31E-05	2.31E-05	8.64E-07	7.91E-07	4.73E-06	3.63E-06
J2	7.50E-05	7.49E-05	1.91E-06	1.83E-06	6.75E-06	5.54E-06
J3	1.65E-05	1.64E-05	1.96E-06	1.87E-06	8.47E-06	7.03E-06

J4	6.72E-06	6.58E-06	8.57E-07	7.35E-07	7.89E-06	6.04E-06
J5	8.99E-06	8.83E-06	3.81E-06	3.67E-06	1.49E-05	1.27E-05
J6	7.03E-06	6.88E-06	2.13E-06	1.99E-06	1.04E-05	8.35E-06
J7	3.21E-06	3.16E-06	3.86E-07	3.47E-07	2.43E-06	1.85E-06
J8	2.36E-07	2.33E-07	1.31E-07	1.27E-07	5.71E-07	5.18E-07
J9	7.36E-07	7.07E-07	2.62E-07	2.35E-07	2.99E-06	2.58E-06
J10	1.98E-06	1.91E-06	6.11E-07	5.42E-07	4.43E-06	3.38E-06
J11	2.53E-06	2.47E-06	8.08E-07	7.61E-07	2.3E-06	1.59E-06
J12	1.46E-06	1.42E-06	2.83E-07	2.46E-07	1.43E-06	8.73E-07
J13	3.31E-07	3.07E-07	5.82E-08	3.6E-08	7.36E-07	3.99E-07
J14	2.31E-07	2.2E-07	2.54E-08	1.51E-08	6.29E-07	4.73E-07
J15	6.32E-07	6.25E-07	5.37E-08	4.74E-08	4.9E-07	3.95E-07
K1	2.56E-06	2.54E-06	2.82E-07	2.59E-07	1.32E-06	9.67E-07
K2	5.84E-06	5.74E-06	5.93E-07	5.02E-07	5.3E-06	3.92E-06
K3	1.86E-05	1.85E-05	1.28E-06	1.15E-06	8.95E-06	7.02E-06
K4	3.22E-05	3.21E-05	2.9E-06	2.75E-06	1.16E-05	9.34E-06
K5	3.98E-05	3.95E-05	2.82E-06	2.62E-06	1.73E-05	1.43E-05
K6	1.97E-05	1.95E-05	5.78E-06	5.59E-06	1.73E-05	1.43E-05
K7	1.48E-06	1.44E-06	5.15E-07	4.75E-07	2.68E-06	2.08E-06
K8	2.27E-07	2.23E-07	1.06E-07	1.03E-07	2.93E-07	2.42E-07
K9	7.84E-07	7.45E-07	2.45E-07	2.09E-07	1.36E-06	8.2E-07
K10	2.41E-06	2.34E-06	5.7E-07	5.13E-07	2.33E-06	1.47E-06
K11	1.47E-05	1.46E-05	1.22E-06	1.15E-06	4.22E-06	3.19E-06
K12	1.50E-05	1.5E-05	4.02E-07	3.64E-07	1.68E-06	1.1E-06
K13	1.42E-05	1.42E-05	1.11E-06	1.09E-06	1.99E-06	1.67E-06
K14	1.26E-07	1.24E-07	3.1E-08	2.95E-08	2.73E-07	2.5E-07
K15	1.03E-07	1.01E-07	2.84E-08	2.65E-08	2.1E-07	1.81E-07
L1	6.24E-07	5.99E-07	1.8E-07	1.57E-07	1.15E-06	7.96E-07
L2	8.60E-07	8.18E-07	2.48E-07	2.09E-07	1.86E-06	1.27E-06
L3	2.30E-06	2.22E-06	8.01E-07	7.31E-07	3.73E-06	2.67E-06
L4	4.53E-06	4.42E-06	1.77E-06	1.66E-06	7.79E-06	6.22E-06
L5	7.37E-06	7.16E-06	2.71E-06	2.52E-06	1.82E-05	1.52E-05
L6	2.04E-05	2.01E-05	3.35E-06	3.07E-06	1.91E-05	1.49E-05
L7	2.90E-06	2.84E-06	1.44E-06	1.38E-06	3.17E-06	2.28E-06
L8	3.59E-06	3.56E-06	3.08E-07	2.8E-07	1.34E-06	9.18E-07
L9	4.04E-06	4.02E-06	4.17E-07	3.9E-07	1.57E-06	1.17E-06
L10	2.32E-06	2.2E-06	7.3E-07	6.17E-07	4.02E-06	2.31E-06
L11	4.34E-06	4.28E-06	1.35E-06	1.3E-06	2.99E-06	2.17E-06
L12	1.96E-05	1.94E-05	6.66E-07	5.63E-07	3.78E-06	2.22E-06
L13	1.53E-06	1.48E-06	2E-07	1.5E-07	2.98E-06	2.22E-06
L14	1.03E-06	9.88E-07	1.2E-07	7.78E-08	2.26E-06	1.62E-06
L15	5.75E-07	5.49E-07	6.86E-08	4.4E-08	1.32E-06	9.42E-07
M1	6.83E-08	6.57E-08	2.52E-08	2.29E-08	1.22E-07	8.69E-08
M2	7.51E-06	7.51E-06	4E-08	3.53E-08	2.34E-07	1.63E-07
M3	1.60E-05	1.59E-05	1.11E-06	1.04E-06	4.15E-06	3.13E-06
M4	1.70E-05	1.69E-05	5.63E-07	4.99E-07	5.35E-06	4.39E-06
M5	4.17E-06	4.12E-06	1.53E-06	1.49E-06	7.93E-06	7.25E-06
M6	3.00E-05	2.96E-05	6.99E-06	6.6E-06	3.23E-05	2.63E-05
M7	5.04E-06	5E-06	2.97E-06	2.93E-06	5.75E-06	5.12E-06
M8	1.13E-06	1.11E-06	2.41E-07	2.19E-07	9.21E-07	5.87E-07
M9	2.76E-06	2.7E-06	8.33E-07	7.81E-07	2.47E-06	1.69E-06
M10	6.89E-06	6.76E-06	1.62E-06	1.5E-06	5.51E-06	3.63E-06

M11	4.02E-06	3.95E-06	1.16E-06	1.09E-06	3.26E-06	2.26E-06
M12	3.30E-06	3.19E-06	7.18E-07	6.08E-07	3.99E-06	2.33E-06
M13	9.63E-06	9.49E-06	1.03E-06	8.99E-07	7.7E-06	5.74E-06
M14	1.76E-06	1.68E-06	2.41E-07	1.7E-07	3.94E-06	2.87E-06
M15	1.34E-06	1.28E-06	1.26E-07	7.01E-08	3.08E-06	2.23E-06
N1	-	-	-	-	-	-
N2	1.04E-06	1E-06	1.45E-07	1.08E-07	2.06E-06	1.49E-06
N3	3.15E-07	3.15E-07	6.53E-08	6.53E-08	8.66E-08	8.66E-08
N4	5.35E-07	5.35E-07	2.01E-07	2.01E-07	2.32E-07	2.32E-07
N5	1.72E-06	1.71E-06	7.48E-07	7.41E-07	3.36E-06	3.26E-06
N6	1.63E-05	1.62E-05	1.44E-06	1.37E-06	5.46E-06	4.33E-06
N7	5.75E-06	5.67E-06	3.38E-07	2.65E-07	5.65E-06	4.55E-06
N8	3.24E-05	3.23E-05	4.47E-07	3.77E-07	6.13E-06	5.07E-06
N9	9.24E-06	9.16E-06	6.8E-07	6.1E-07	4.86E-06	3.8E-06
N10	9.38E-06	9.27E-06	1.22E-06	1.11E-06	7.24E-06	5.66E-06
N11	6.33E-06	6.25E-06	1.15E-06	1.07E-06	5.72E-06	4.56E-06
N12	3.44E-06	3.35E-06	1.19E-06	1.11E-06	6.11E-06	4.82E-06
N13	1.24E-05	1.23E-05	9.77E-07	8.54E-07	7.19E-06	5.33E-06
N14	3.18E-05	3.16E-05	1.92E-06	1.76E-06	9.92E-06	7.51E-06
N15	1.26E-06	1.19E-06	1.47E-07	8.31E-08	3.4E-06	2.43E-06
O1	9.17E-07	8.7E-07	2.15E-07	1.71E-07	1.54E-06	8.75E-07
O2	3.16E-06	3.01E-06	6.93E-07	5.55E-07	4.96E-06	2.85E-06
O3	1.75E-05	1.72E-05	2.12E-06	1.88E-06	1.05E-05	6.76E-06
O4	3.41E-05	3.38E-05	3.43E-06	3.13E-06	1.45E-05	9.95E-06
O5	5.93E-05	5.9E-05	3.52E-06	3.22E-06	1.61E-05	1.16E-05
O6	7.60E-05	7.59E-05	8.26E-07	7.78E-07	2.36E-06	1.64E-06
O7	2.93E-06	2.91E-06	7.16E-07	6.95E-07	1.73E-06	1.42E-06
O8	1.32E-05	1.32E-05	4.74E-07	4.74E-07	2.02E-06	2.02E-06
O9	2.71E-05	2.71E-05	4.93E-07	4.81E-07	1.08E-06	9.05E-07
O10	3.25E-05	3.25E-05	6.19E-07	5.53E-07	3.53E-06	2.53E-06
O11	2.79E-06	2.7E-06	6.94E-07	6.1E-07	4.32E-06	3.05E-06
O12	3.07E-05	3.06E-05	1.69E-06	1.58E-06	6.97E-06	5.29E-06
O13	3.40E-06	3.28E-06	3.2E-07	2.15E-07	5.86E-06	4.25E-06
O14	4.68E-06	4.64E-06	3.46E-07	3.09E-07	2.2E-06	1.65E-06
O15	-	-	-	-	-	-
P1	6.79E-07	6.66E-07	6.31E-08	5.06E-08	8.14E-07	6.25E-07
P2	5.53E-06	5.42E-06	5.23E-07	4.21E-07	6.62E-06	5.08E-06
P3	1.43E-05	1.42E-05	7.41E-07	6.33E-07	7.12E-06	5.49E-06
P4	2.18E-05	2.15E-05	2.12E-06	1.82E-06	2.06E-05	1.59E-05
P5	3.13E-05	3.11E-05	3.36E-06	3.15E-06	1.79E-05	1.47E-05
P6	4.77E-05	4.74E-05	1.9E-06	1.69E-06	8.47E-06	5.33E-06
P7	3.33E-05	3.31E-05	3.05E-06	2.85E-06	1.16E-05	8.64E-06
P8	3.23E-06	3.1E-06	1.12E-06	1E-06	5.99E-06	4.22E-06
P9	7.04E-07	6.84E-07	2.43E-07	2.23E-07	1.13E-06	8.36E-07
P10	3.81E-05	3.81E-05	1.2E-07	1.12E-07	6E-07	4.77E-07
P11	5.28E-06	5.19E-06	8.69E-07	7.9E-07	4.28E-06	3.09E-06
P12	2.24E-06	2.19E-06	3.19E-07	2.77E-07	2.08E-06	1.45E-06
P13	1.71E-06	1.69E-06	1.56E-07	1.39E-07	9.03E-07	6.47E-07
P14	1.22E-06	1.16E-06	1.33E-07	8.23E-08	2.87E-06	2.1E-06
P15	2.22E-07	2.1E-07	3.37E-08	2.25E-08	7.29E-07	5.58E-07
Q1	-	-	-	-	-	-
Q2	-	-	-	-	-	-

Q3	8.82E-06	8.68E-06	8.75E-07	7.45E-07	8.76E-06	6.79E-06
Q4	1.74E-05	1.72E-05	1.48E-06	1.27E-06	1.42E-05	1.1E-05
Q5	3.69E-05	3.68E-05	1E-06	9.05E-07	6.37E-06	4.9E-06
Q6	6.62E-06	6.55E-06	3.8E-07	3.11E-07	4.47E-06	3.43E-06
Q7	2.34E-06	2.22E-06	3.96E-07	2.86E-07	3.95E-06	2.29E-06
Q8	8.77E-06	8.6E-06	4.42E-07	2.83E-07	5.6E-06	3.19E-06
Q9	1.37E-05	1.35E-05	2.86E-07	1.51E-07	4.48E-06	2.43E-06
Q10	1.98E-06	1.97E-06	5.41E-08	5.11E-08	3.97E-07	3.51E-07
Q11	3.52E-07	3.35E-07	7.45E-08	5.91E-08	7.24E-07	4.9E-07
Q12	1.22E-06	1.16E-06	2.34E-07	1.78E-07	2.6E-06	1.75E-06
Q13	7.19E-07	6.95E-07	9.26E-08	7E-08	1.26E-06	9.13E-07
Q14	9.45E-06	9.38E-06	5.99E-07	5.37E-07	3.73E-06	2.79E-06
Q15	9.85E-07	9.31E-07	1.08E-07	5.75E-08	2.68E-06	1.91E-06
R1	-	-	-	-	-	-
R2	-	-	-	-	-	-
R3	1.36E-06	1.28E-06	1.64E-07	8.9E-08	4.37E-06	3.24E-06
R4	2.12E-05	2.11E-05	1.62E-06	1.48E-06	9.11E-06	6.97E-06
R5	7.42E-06	7.36E-06	3.27E-07	2.73E-07	3.7E-06	2.87E-06
R6	1.11E-07	1.04E-07	1.65E-08	9.87E-09	2.68E-07	1.68E-07
R7	7.93E-06	7.83E-06	8.01E-07	7.05E-07	6.12E-06	4.67E-06
R8	6.03E-06	5.87E-06	5.25E-07	3.75E-07	4.97E-06	2.68E-06
R9	2.97E-07	2.8E-07	4.92E-08	3.31E-08	5.55E-07	3.11E-07
R10	-	-	-	-	-	-
R11	-	-	-	-	-	-
R12	-	-	-	-	-	-
R13	-	-	-	-	-	-
R14	4.55E-07	4.31E-07	5.85E-08	3.6E-08	1.2E-06	8.6E-07
R15	7.03E-07	6.64E-07	7.72E-08	4.1E-08	1.91E-06	1.36E-06
S1	-	-	-	-	-	-
S2	-	-	-	-	-	-
S3	-	-	-	-	-	-
S4	-	-	-	-	-	-
S5	-	-	-	-	-	-
S6	-	-	-	-	-	-
S7	-	-	-	-	-	-
S8	3.82E-07	3.57E-07	5.31E-08	2.97E-08	8.21E-07	4.66E-07
S9	-	-	-	-	-	-
S10	-	-	-	-	-	-
S11	-	-	-	-	-	-
S12	-	-	-	-	-	-
S13	-	-	-	-	-	-
S14	-	-	-	-	-	-
S15	-	-	-	-	-	-

5.2.2 Industrial Sources

Table A5.2.2: Grid-wise Emission Rates for PM, SO_2 and NOx during Summer and Winter: Industrial Sources (Large, Medium and Small Scale Industries) in Delhi (Existing Scenario)

Grid	Industrial Emission Rate (g/s-m^2) (Small Scale Industries)			Industrial Emission Rate (g/s-m^2) (Large &Medium Scale Industries)		
	PM	SO_2	NOx	PM	SO_2	NOx
C1	0	0	0	0	0	0
C2	0	0	0	0	0	0
C3	0	0	0	0	0	0
C4	0	0	0	0	0	0
C5	0	0	0	0	0	0
C6	0	0	0	0	0	0
C7	0	0	0	0	0	0
C8	0	0	0	0	0	0
C9	0	0	0	0	0	0
C10	0	0	0	0	0	0
C11	0	0	0	0	0	0
C12	0	0	0	0	0	0
C13	0	0	0	0	0	0
C14	0	0	0	0	0	0
C15	0	0	0	0	0	0
D1	0	0	0	0	0	0
D2	0	0	0	0	0	0
D3	0	0	0	0	0	0
D4	5.11E-08	7.53E-08	7.2E-07	0	0	0
D5	0	0	0	0	0	0
D6	0	0	0	0	0	0
D7	0	0	0	0	0	0
D8	0	0	0	0	0	0
D9	0	0	0	0	0	0
D10	0	0	0	0	0	0
D11	0	0	0	0	0	0
D12	0	0	0	0	0	0
D13	0	0	0	0	0	0
D14	0	0	0	0	0	0
D15	0	0	0	0	0	0
E1	1.02E-08	4.59E-08	1.28E-07	0	0	0
E2	0	0	0	0	0	0
E3	0	0	0	0	0	0
E4	8.62E-08	1.67E-07	1.21E-06	0	0	0
E5	0	0	0	0	0	0
E6	1.03E-08	6.29E-07	7.25E-08	0	0	0
E7	2.57E-08	1.57E-06	1.81E-07	0	0	0
E8	0	0	0	0	0	0
E9	0	0	0	0	0	0
E10	0	0	0	0	0	0
E11	0	0	0	0	0	0
E12	0	0	0	0	0	0
E13	0	0	0	0	0	0
E14	0	0	0	0	0	0
E15	0	0	0	0	0	0
F1	0	0	0	0	0	0

F2	0	0	0	0	0	0
F3	0	0	0	0	0	0
F4	1.26E-07	1.8E-07	1.78E-06	0	0	0
F5	0	0	0	0	0	0
F6	0	0	0	0	0	0
F7	7.72E-08	4.72E-06	5.44E-07	0	0	0
F8	0	0	0	0	0	0
F9	0	0	0	0	0	0
F10	0	0	0	0	0	0
F11	0	0	0	0	0	0
F12	0	0	0	0	0	0
F13	0	0	0	0	0	0
F14	0	0	0	0	0	0
F15	0	0	0	0	0	0
G1	4.99E-07	7.18E-07	7.03E-06	0	0	0
G2	0	0	0	0	0	0
G3	0	0	0	0	0	0
G4	0	0	0	0	0	0
G5	0	0	0	0	0	0
G6	0	0	0	0	0	0
G7	7.27E-07	1.37E-06	1.02E-05	0	0	0
G8	8.81E-07	1.35E-06	1.24E-05	0	0	0
G9	0	0	0	0	0	0
G10	0	0	0	0	0	0
G11	0	0	0	0	0	0
G12	0	0	0	0	0	0
G13	0	0	0	0	0	0
G14	0	0	0	0	0	0
G15	0	0	0	0	0	0
H1	4.68E-07	7.11E-07	6.6E-06	0	0	0
H2	0	0	0	0	0	0
H3	0	0	0	0	0	0
H4	7.01E-07	7.8E-06	9.06E-06	0.006	0.04	0.22
H5	1.59E-07	7.77E-08	1.44E-06	0	0	0
H6	7.03E-07	8.8E-07	9.91E-06	0	0	0
H7	5.03E-07	6.03E-07	7.09E-06	0	0	0
H8	0	0	0	0	0	0
H9	0	0	0	0	0	0
H10	0	0	0	0	0	0
H11	0	0	0	0	0	0
H12	0	0	0	0	0	0
H13	0	0	0	0	0	0
H14	0	0	0	0	0	0
H15	0	0	0	0	0	0
J1	0	0	0	0	0	0
J2	1.6E-06	3.16E-06	2.24E-05	0	0	0
J3	1.06E-06	1.79E-06	1.5E-05	0	0	0
J4	2.8E-07	3.12E-06	3.62E-06	1.30	0.59	0.08
J5	4.38E-07	4.69E-07	6.18E-06	0	0	0
J6	4.86E-08	5.22E-08	6.87E-07	0.01	2.49	0.08
J7	0	0	0	0	0	0
J8	0	0	0	0	0	0
J9	0	0	0	0	0	0
J10	0	0	0	0	0	0
J11	0	0	0	0	0	0
J12	0	0	0	0	0	0
J13	0	0	0	0	0	0
J14	0	0	0	0	0	0

J15	0	0	0	0	0	0
K1	0	0	0	0	0	0
K2	0	0	0	0	0	0
K3	4.26E-07	7.15E-07	5.98E-06	0	0	0
K4	0	0	0	0	0	0
K5	3.21E-06	9.36E-07	3.57E-06	0	0	0
K6	7.64E-07	1.98E-07	3.54E-07	0	0	0
K7	0	0	0	0	0	0
K8	0	0	0	0	0	0
K9	0	0	0	0	0	0
K10	0	0	0	0	0	0
K11	0	0	0	0	0	0
K12	0	0	0	0	0	0
K13	0	0	0	0	0	0
K14	0	0	0	0	0	0
K15	0	0	0	0	0	0
L1	0	0	0	0	0	0
L2	0	0	0	0	0	0
L3	0	0	0	0	0	0
L4	0	0	0	0	0	0
L5	0	0	0	0	0	0
L6	0	0	0	0	0	0
L7	0	0	0	0	0	0
L8	0	0	0	0	0	0
L9	0	0	0	0	0	0
L10	0	0	0	0	0	0
L11	0	0	0	0	0	0
L12	0	0	0	0	0	0
L13	0	0	0	0	0	0
L14	0	0	0	0	0	0
L15	0	0	0	0	0	0
M1	0	0	0	0	0	0
M2	0	0	0	0	0	0
M3	0	0	0	0	0	0
M4	0	0	0	0	0	0
M5	0	0	0	0	0	0
M6	0	0	0	0	0	0
M7	0	0	0	0	0	0
M8	0	0	0	0	0	0
M9	0	0	0	0	0	0
M10	0	0	0	0	0	0
M11	0	0	0	0	0	0
M12	0	0	0	0	0	0
M13	0	0	0	0	0	0
M14	0	0	0	0	0	0
M15	0	0	0	0	0	0
N1	0	0	0	0	0	0
N2	0	0	0	0	0	0
N3	0	0	0	0	0	0
N4	0	0	0	0	0	0
N5	0	0	0	0	0	0
N6	0	0	0	33.33	281.48	325.92
N7	0	0	0	0.10	1.70	793.61
N8	0	0	0	57.29	483.80	560.18
N9	0	0	0	0	0	0
N10	0	0	0	0	0	0
N11	0	0	0	0	0	0
N12	0	0	0	0	0	0

N13	0	0	0	0	0	0
N14	0	0	0	0	0	0
N15	0	0	0	0	0	0
O1	0	0	0	0	0	0
O2	0	0	0	0	0	0
O3	0	0	0	0	0	0
O4	0	0	0	0	0	0
O5	0	0	0	0	0	0
O6	0	0	0	0	0	0
O7	0	0	0	0	0	0
O8	0	0	0	0	0	0
O9	0	0	0	0	0	0
O10	0	0	0	0	0	0
O11	9.51E-08	9.82E-08	1.34E-06	0	0	0
O12	6.21E-07	6.7E-07	8.77E-06	0.01	2.19	0.0
O13	1.24E-06	2.01E-06	1.75E-05	0	0	0
O14	0	0	0	0	0	0
O15	0	0	0	0	0	0
P1	0	0	0	0	0	0
P2	0	0	0	0	0	0
P3	0	0	0	0	0	0
P4	2.05E-08	1.11E-07	2.82E-07	0	0	0
P5	0	0	0	0	0	0
P6	0	0	0	0	0	0
P7	0	0	0	0	0	0
P8	0	0	0	0.33	47.02	1.66
P9	0	0	0	0	0	0
P10	0	0	0	0	0	0
P11	0	0	0	0	0	0
P12	7.02E-07	7.62E-07	9.9E-06	0	0	0
P13	3.05E-07	3.73E-07	4.3E-06	0	0	0
P14	0	0	0	0	0	0
P15	0	0	0	0	0	0
Q1	0	0	0	0	0	0
Q2	0	0	0	0	0	0
Q3	0	0	0	0	0	0
Q4	0	0	0	0	0	0
Q5	3.24E-07	5.36E-07	4.56E-06	0	0	0
Q6	0	0	0	0	0	0
Q7	3.61E-07	6.83E-07	2.07E-05	0	0	0
Q8	0	0	0	0	0	0
Q9	0	0	0	0	0	0
Q10	0	0	0	0	0	0
Q11	0	0	0	0	0	0
Q12	0	0	0	0	0	0
Q13	8.64E-08	1.22E-07	1.22E-06	0	0	0
Q14	1.3E-07	1.82E-07	1.82E-06	259.37	2190.27	2536.11
Q15	0	0	0	0	0	0
R1	0	0	0	0	0	0
R2	0	0	0	0	0	0
R3	0	0	0	0	0	0
R4	1.03E-06	9.87E-07	1.45E-05	0	0	0
R5	1.62E-07	2.68E-07	2.28E-06	0	0	0
R6	1.06E-06	6.9E-07	8.3E-08	0	0	0
R7	0	0	0	0	0	0
R8	0	0	0	0	0	0
R9	0	0	0	0	0	0
R10	0	0	0	0	0	0

R11	0	0	0	0	0	0
R12	0	0	0	0	0	0
R13	0	0	0	0	0	0
R14	0	0	0	0	0	0
R15	0	0	0	0	0	0
S1	0	0	0	0	0	0
S2	0	0	0	0	0	0
S3	0	0	0	0	0	0
S4	0	0	0	0	0	0
S5	0	0	0	0	0	0
S6	0	0	0	0	0	0
S7	0	0	0	0	0	0
S8	0	0	0	0	0	0
S9	0	0	0	0	0	0
S10	0	0	0	0	0	0
S11	0	0	0	0	0	0
S12	0	0	0	0	0	0
S13	0	0	0	0	0	0
S14	0	0	0	0	0	0
S15	0	0	0	0	0	0

5.2.3 Vehicular Sources and Road Dust Re-suspension

Table A5.2.3: Grid-wise Emission Rates for PM, SO_2 and NOx and Road Dust (PM10): Vehicular Sources and Road Dust Re-suspension in Delhi (Existing Scenario)

Grid	Study Zone Coverage	Vehicular Emission Rate ($g/s-m^2$)			Road Dust (PM10) Emission Rate ($g/s-m^2$)
		PM	NOx	SO_2	
C1	Prah	1.53E-08	1.47E-07	1.39E-09	2.21E-07
C2	Prah	3.40E-08	3.28E-07	3.08E-09	5.17E-07
C3	Prah	5.40E-08	5.25E-07	4.89E-09	8.81E-07
C4	Nar	1.01E-07	9.25E-07	8.96E-09	4.77E-07
C5	Nar	6.09E-09	4.67E-08	4.48E-10	1.16E-07
C6	Nar	8.01E-09	6.15E-08	5.89E-10	1.53E-07
C7	Nar	1.75E-08	1.34E-07	1.29E-09	3.34E-07
C8	MP	4.97E-08	5.65E-07	3.45E-09	1.13E-06
C9	MP	3.08E-08	3.63E-07	1.84E-09	1.14E-06
C10	MP	2.57E-08	3.04E-07	1.54E-09	9.57E-07
C11	MP	1.42E-08	1.68E-07	8.51E-10	5.29E-07
C12	MP	2.89E-08	3.17E-07	2.27E-09	5.06E-07
C13	MP	2.97E-08	3.28E-07	2.29E-09	5.74E-07
C14	MP	2.53E-08	2.80E-07	1.94E-09	4.98E-07
C15	MP	1.82E-08	1.96E-07	1.52E-09	2.34E-07
D1	Prah	4.23E-08	4.12E-07	3.83E-09	6.91E-07
D2	Prah	5.46E-08	5.20E-07	4.98E-09	7.04E-07
D3	Prah	2.81E-08	2.71E-07	2.55E-09	4.24E-07
D4	Nar	1.01E-07	9.27E-07	8.98E-09	4.83E-07
D5	Nar	6.56E-09	5.03E-08	4.82E-10	1.25E-07
D6	Nar	6.36E-09	4.88E-08	4.68E-10	1.21E-07
D7	Nar	5.90E-08	5.21E-07	5.01E-09	4.95E-07
D8	MP	3.84E-08	4.41E-07	2.56E-09	1.01E-06
D9	MP	2.97E-08	3.51E-07	1.77E-09	1.10E-06
D10	MP	2.44E-08	2.87E-07	1.46E-09	9.05E-07
D11	MP	2.44E-08	2.87E-07	1.46E-09	9.05E-07
D12	MP	3.01E-08	3.48E-07	1.95E-09	9.58E-07
D13	MP	3.36E-08	3.72E-07	2.57E-09	6.68E-07
D14	MP	4.92E-08	5.46E-07	3.72E-09	1.01E-06
D15	MP	4.99E-08	5.40E-07	4.09E-09	7.07E-07
E1	Prah	3.94E-08	3.81E-07	3.57E-09	6.07E-07
E2	Prah	5.74E-08	5.51E-07	5.22E-09	8.16E-07
E3	Prah	3.00E-08	2.89E-07	2.73E-09	4.42E-07
E4	Nar	1.06E-07	9.70E-07	9.39E-09	5.48E-07
E5	Nar	7.77E-09	5.97E-08	5.72E-10	1.48E-07
E6	Nar	8.94E-08	8.13E-07	7.87E-09	4.88E-07
E7	Nar	2.15E-07	1.99E-06	1.89E-08	1.11E-06
E8	MP	7.80E-08	8.68E-07	5.85E-09	1.67E-06
E9	MP	3.63E-08	4.28E-07	2.17E-09	1.35E-06
E10	MP	3.46E-08	4.08E-07	2.06E-09	1.28E-06
E11	MP	2.60E-08	3.00E-07	1.71E-09	8.08E-07
E12	MP	1.47E-08	1.73E-07	8.77E-10	5.45E-07
E13	MP	4.97E-08	5.37E-07	4.11E-09	6.65E-07
E14	MP	2.61E-08	2.90E-07	1.96E-09	5.51E-07
E15	MP	5.02E-08	5.52E-07	3.89E-09	5.15E-07

F1	Prah	4.35E-08	4.17E-07	3.96E-09	6.05E-07
F2	Prah	4.86E-08	4.67E-07	4.42E-09	6.98E-07
F3	Prah	5.61E-08	5.34E-07	5.11E-09	7.17E-07
F4	Nar	2.34E-07	2.15E-06	2.08E-08	1.08E-06
F5	Nar	1.02E-07	9.37E-07	9.08E-09	5.08E-07
F6	Nar	4.94E-08	4.41E-07	4.27E-09	3.51E-07
F7	Nar	1.85E-07	1.69E-06	1.64E-08	9.23E-07
F8	MP	6.67E-08	7.27E-07	5.33E-09	9.33E-07
F9	MP	3.48E-08	4.11E-07	2.08E-09	1.30E-06
F10	MP	4.41E-08	4.94E-07	3.22E-09	1.03E-06
F11	MP	2.72E-08	3.00E-07	2.08E-09	2.97E-07
F12	MP	5.02E-08	5.50E-07	3.95E-09	6.98E-07
F13	MP	3.56E-08	3.98E-07	2.61E-09	5.66E-07
F14	MP	3.00E-08	3.32E-07	2.27E-09	3.80E-07
F15	MP	6.11E-08	6.70E-07	4.80E-09	7.32E-07
G1	SSI+PP	5.09E-08	3.62E-07	5.04E-09	8.69E-07
G2	SSI+PP	4.55E-08	3.34E-07	4.39E-09	6.34E-07
G3	SSI+PP	1.48E-07	1.11E-06	1.38E-08	1.11E-06
G4	SSI+PP	4.22E-08	3.03E-07	4.11E-09	5.63E-07
G5	Nar	1.03E-07	9.38E-07	9.08E-09	5.93E-07
G6	Nar	2.33E-07	2.14E-06	2.07E-08	1.09E-06
G7	Nar	6.06E-08	5.48E-07	5.10E-09	5.29E-07
G8	DK	1.43E-07	1.27E-06	1.28E-08	8.41E-07
G9	DK	6.51E-08	5.66E-07	6.28E-09	4.01E-07
G10	DK	8.97E-08	7.28E-07	8.33E-09	6.02E-07
G11	DK	8.64E-08	7.23E-07	7.84E-09	5.54E-07
G12	DK	2.52E-07	2.32E-06	2.17E-08	1.39E-06
G13	DK	2.32E-08	2.02E-07	2.34E-09	1.44E-07
G14	DK	1.61E-08	1.40E-07	1.61E-09	9.95E-08
G15	DK	8.67E-08	8.01E-07	7.46E-09	4.77E-07
H1	SSI+PP	5.54E-08	3.98E-07	5.42E-09	8.37E-07
H2	SSI+PP	1.57E-07	1.17E-06	1.48E-08	1.35E-06
H3	SSI+PP	1.12E-07	8.14E-07	1.08E-08	1.36E-06
H4	SSI+PP	1.16E-07	8.38E-07	1.12E-08	1.42E-06
H5	Nar	2.94E-07	2.70E-06	2.62E-08	1.33E-06
H6	Nar	1.70E-07	1.57E-06	1.49E-08	1.01E-06
H7	Nar	1.46E-07	1.36E-06	1.27E-08	8.68E-07
H8	DK	1.41E-07	1.29E-06	1.24E-08	7.89E-07
H9	DK	1.43E-07	1.30E-06	1.26E-08	8.03E-07
H10	DK	1.87E-07	1.68E-06	1.63E-08	1.08E-06
H11	DK	1.01E-07	9.29E-07	8.82E-09	5.62E-07
H12	DK	1.05E-07	9.55E-07	9.49E-09	6.00E-07
H13	DK	6.85E-08	6.25E-07	6.10E-09	3.87E-07
H14	DK	1.94E-08	1.68E-07	1.95E-09	1.20E-07
H15	DK	1.26E-07	1.15E-06	1.11E-08	7.08E-07
J1	SSI+PP	2.59E-07	1.93E-06	2.44E-08	2.13E-06
J2	SSI+PP	1.41E-07	1.04E-06	1.34E-08	1.40E-06
J3	SSI+PP	1.32E-07	9.75E-07	1.25E-08	1.27E-06
J4	SSI+PP	1.05E-07	7.58E-07	1.02E-08	1.33E-06
J5	Nar	2.24E-07	2.07E-06	1.98E-08	1.15E-06
J6	Nar	1.46E-07	1.33E-06	1.28E-08	8.54E-07
J7	Nar	4.67E-08	4.24E-07	3.85E-09	4.75E-07
J8	DK	9.84E-09	8.27E-08	9.52E-10	6.35E-08
J9	DK	3.35E-07	3.09E-06	2.88E-08	1.85E-06

J10	DK	1.71E-07	1.53E-06	1.51E-08	9.98E-07
J11	DK	1.27E-07	1.16E-06	1.13E-08	7.17E-07
J12	DK	1.22E-07	1.12E-06	1.07E-08	6.81E-07
J13	DK	1.32E-07	1.18E-06	1.17E-08	7.74E-07
J14	DK	1.33E-07	1.22E-06	1.17E-08	7.44E-07
J15	DK	5.60E-08	5.02E-07	5.22E-09	3.27E-07
K1	SSI+PP	1.08E-07	8.04E-07	1.02E-08	9.32E-07
K2	SSI+PP	6.83E-08	5.05E-07	6.50E-09	7.15E-07
K3	SSI+PP	2.66E-07	1.99E-06	2.49E-08	1.96E-06
K4	SSI+PP	6.40E-08	4.62E-07	6.22E-09	8.70E-07
K5	Nar	1.68E-07	1.56E-06	1.47E-08	9.71E-07
K6	Nar	1.56E-07	1.44E-06	1.36E-08	9.03E-07
K7	Nar	2.36E-07	2.18E-06	2.09E-08	1.17E-06
K8	DK	2.12E-07	1.95E-06	1.84E-08	1.17E-06
K9	DK	2.40E-07	2.20E-06	2.10E-08	1.34E-06
K10	DK	3.43E-07	3.13E-06	3.00E-08	1.93E-06
K11	DK	2.78E-07	2.52E-06	2.44E-08	1.59E-06
K12	DK	1.17E-07	9.91E-07	1.06E-08	7.37E-07
K13	DK	1.10E-07	9.95E-07	9.77E-09	6.32E-07
K14	DK	1.79E-07	1.59E-06	1.58E-08	1.05E-06
K15	DK	5.83E-08	4.80E-07	5.51E-09	3.85E-07
L1	ISBT	1.88E-08	1.06E-07	2.29E-09	1.11E-07
L2	ISBT	1.38E-07	1.06E-06	1.28E-08	8.27E-07
L3	ISBT	1.59E-07	1.18E-06	1.53E-08	9.58E-07
L4	ISBT	1.44E-07	1.06E-06	1.40E-08	8.63E-07
L5	ISBT	2.61E-07	1.97E-06	2.47E-08	1.58E-06
L6	ISBT	4.09E-07	3.10E-06	3.87E-08	2.48E-06
L7	ISBT	3.17E-07	2.43E-06	2.95E-08	1.91E-06
L8	DK	3.75E-07	3.39E-06	3.26E-08	2.15E-06
L9	DK	3.74E-07	3.44E-06	3.23E-08	2.08E-06
L10	DK	1.98E-07	1.82E-06	1.73E-08	1.11E-06
L11	DK	1.29E-07	1.17E-06	1.14E-08	7.35E-07
L12	DK	2.57E-07	2.35E-06	2.24E-08	1.45E-06
L13	DK	1.73E-07	1.54E-06	1.53E-08	1.00E-06
L14	DK	2.96E-08	2.58E-07	2.98E-09	1.83E-07
L15	DK	1.78E-08	1.55E-07	1.79E-09	1.10E-07
M1	ISBT	1.92E-09	1.45E-08	1.76E-10	6.59E-09
M2	ISBT	1.31E-07	9.97E-07	1.24E-08	7.89E-07
M3	ISBT	1.82E-07	1.40E-06	1.69E-08	1.09E-06
M4	ISBT	5.67E-07	4.33E-06	5.30E-08	3.43E-06
M5	ISBT	6.30E-07	4.80E-06	5.90E-08	3.82E-06
M6	ISBT	2.81E-07	2.13E-06	2.65E-08	1.70E-06
M7	ISBT	6.10E-07	4.65E-06	5.73E-08	3.70E-06
M8	ISBT	1.05E-06	8.01E-06	9.78E-08	6.35E-06
M9	AC	4.87E-07	4.37E-06	4.00E-08	2.74E-06
M10	AC	1.73E-07	1.54E-06	1.40E-08	1.48E-06
M11	AC	3.14E-07	2.81E-06	2.56E-08	1.87E-06
M12	AC	1.71E-07	1.53E-06	1.40E-08	1.16E-06
M13	AC	2.05E-07	1.83E-06	1.68E-08	1.49E-06
M14	AC	2.42E-08	2.04E-07	1.87E-09	6.21E-07
M15	AC	1.20E-08	1.01E-07	9.30E-10	3.08E-07
N1	ISBT	1.06E-08	5.65E-08	1.34E-09	6.68E-08
N2	ISBT	1.06E-08	5.65E-08	1.34E-09	6.68E-08
N3	ISBT	1.34E-07	1.03E-06	1.26E-08	8.15E-07

N4	ISBT	0.00E+00	0.00E+00	0.00E+00	0.00E+00
N5	ISBT	3.76E-07	2.89E-06	3.49E-08	2.27E-06
N6	ISBT	2.91E-07	2.23E-06	2.71E-08	1.76E-06
N7	ISBT	5.82E-07	4.47E-06	5.41E-08	3.52E-06
N8	ISBT	4.59E-07	3.50E-06	4.29E-08	2.78E-06
N9	AC	2.78E-07	2.50E-06	2.27E-08	1.63E-06
N10	AC	1.56E-07	1.38E-06	1.26E-08	1.36E-06
N11	AC	2.67E-07	2.38E-06	2.19E-08	1.84E-06
N12	AC	2.25E-07	2.00E-06	1.86E-08	1.53E-06
N13	AC	2.89E-08	2.51E-07	2.29E-09	4.92E-07
N14	AC	1.25E-07	1.11E-06	1.01E-08	1.29E-06
N15	AC	8.45E-09	7.15E-08	6.55E-10	2.17E-07
O1	ISBT	1.43E-08	8.35E-08	1.69E-09	8.09E-08
O2	ISBT	1.44E-08	8.56E-08	1.68E-09	7.91E-08
O3	ISBT	1.42E-07	1.07E-06	1.36E-08	8.57E-07
O4	ISBT	1.45E-08	8.52E-08	1.70E-09	8.08E-08
O5	ISBT	3.19E-07	2.43E-06	3.00E-08	1.93E-06
O6	ISBT	1.43E-07	1.10E-06	1.34E-08	8.65E-07
O7	ISBT	2.17E-07	1.66E-06	2.03E-08	1.32E-06
O8	ISBT	3.15E-08	2.42E-07	2.93E-09	1.91E-07
O9	AC	1.71E-07	1.53E-06	1.39E-08	9.60E-07
O10	AC	2.60E-07	2.33E-06	2.12E-08	1.55E-06
O11	AC	2.29E-07	2.04E-06	1.89E-08	1.54E-06
O12	AC	1.52E-07	1.33E-06	1.27E-08	1.26E-06
O13	AC	7.12E-08	6.14E-07	6.12E-09	6.46E-07
O14	AC	1.34E-07	1.19E-06	1.11E-08	8.23E-07
O15	AC	2.22E-08	1.91E-07	1.89E-09	2.47E-07
P1	Loni	3.64E-08	2.54E-07	2.32E-09	1.03E-06
P2	Loni	3.90E-08	2.72E-07	2.51E-09	1.09E-06
P3	Loni	9.72E-08	7.69E-07	6.98E-09	1.57E-06
P4	Loni	7.82E-08	5.45E-07	4.89E-09	2.31E-06
P5	AV	9.54E-08	9.79E-07	7.70E-09	1.06E-06
P6	AV	4.51E-08	4.37E-07	3.88E-09	1.33E-06
P7	AV	1.13E-07	1.14E-06	9.20E-09	1.67E-06
P8	AV	1.30E-07	1.35E-06	1.04E-08	1.15E-06
P9	AC	6.16E-08	5.52E-07	5.06E-09	3.42E-07
P10	AC	1.06E-07	9.54E-07	8.67E-09	5.55E-07
P11	AC	6.26E-08	5.45E-07	5.30E-09	5.57E-07
P12	AC	1.49E-07	1.33E-06	1.21E-08	9.35E-07
P13	AC	9.53E-08	8.41E-07	7.86E-09	8.18E-07
P14	AC	1.32E-07	1.17E-06	1.08E-08	9.48E-07
P15	AC	4.63E-08	3.98E-07	3.90E-09	5.66E-07
Q1	Loni	5.39E-09	3.78E-08	3.73E-10	1.30E-07
Q2	Loni	4.52E-09	3.17E-08	3.12E-10	1.09E-07
Q3	Loni	6.24E-08	5.29E-07	4.84E-09	4.94E-07
Q4	Loni	5.73E-08	4.00E-07	3.64E-09	1.64E-06
Q5	AV	5.83E-08	5.88E-07	4.80E-09	1.03E-06
Q6	AV	5.19E-08	5.26E-07	4.27E-09	8.89E-07
Q7	AV	7.01E-08	7.10E-07	5.74E-09	1.05E-06
Q8	AV	4.30E-08	4.26E-07	3.62E-09	1.06E-06
Q9	AC	1.48E-07	1.29E-06	1.25E-08	1.16E-06
Q10	AC	3.36E-07	3.02E-06	2.74E-08	1.82E-06
Q11	AC	7.61E-09	6.43E-08	5.89E-10	1.95E-07
Q12	AC	1.28E-07	1.14E-06	1.04E-08	9.89E-07
Q13	AC	5.60E-08	4.98E-07	4.53E-09	5.21E-07

Q14	AC	1.47E-07	1.32E-06	1.20E-08	9.47E-07
Q15	AC	1.03E-07	9.19E-07	8.35E-09	8.07E-07
R1	Loni	7.79E-09	5.46E-08	5.39E-10	1.88E-07
R2	Loni	8.07E-09	5.66E-08	5.58E-10	1.95E-07
R3	Loni	6.23E-08	5.30E-07	4.83E-09	4.86E-07
R4	Loni	3.57E-08	2.49E-07	2.28E-09	1.01E-06
R5	AV	1.01E-07	1.03E-06	8.16E-09	1.29E-06
R6	AV	1.04E-07	1.07E-06	8.30E-09	1.00E-06
R7	AV	1.12E-07	1.16E-06	8.98E-09	1.06E-06
R8	AV	1.80E-08	1.64E-07	1.65E-09	9.30E-07
R9	AC	1.41E-07	1.22E-06	1.22E-08	1.11E-06
R10	AC	2.68E-07	2.36E-06	2.26E-08	1.74E-06
R11	AC	2.97E-07	2.67E-06	2.43E-08	1.69E-06
R12	AC	4.66E-08	4.16E-07	3.78E-09	3.61E-07
R13	AC	4.99E-09	4.22E-08	3.86E-10	1.28E-07
R14	AC	1.62E-08	1.37E-07	1.26E-09	4.17E-07
R15	AC	1.40E-08	1.19E-07	1.09E-09	3.61E-07
S1	Loni	5.49E-09	3.85E-08	3.79E-10	1.33E-07
S2	Loni	3.87E-09	2.71E-08	2.68E-10	9.37E-08
S3	Loni	8.32E-09	6.85E-08	6.34E-10	8.84E-08
S4	Loni	8.24E-08	7.04E-07	6.43E-09	5.95E-07
S5	AV	0.00E+00	0.00E+00	0.00E+00	6.32E-07
S6	AV	0.00E+00	0.00E+00	0.00E+00	8.95E-07
S7	AV	5.67E-08	5.71E-07	4.67E-09	9.40E-07
S8	AV	1.58E-08	1.44E-07	1.46E-09	8.17E-07
S9	AV+AC	5.31E-08	4.63E-07	4.63E-09	6.49E-07
S10	AV+AC	1.03E-07	9.00E-07	8.99E-09	1.37E-06
S11	AV+AC	1.20E-07	1.11E-06	9.92E-09	1.01E-06
S12	AV+AC	0.00E+00	0.00E+00	0.00E+00	0.00E+00
S13	AV+AC	0.00E+00	0.00E+00	0.00E+00	0.00E+00
S14	AV+AC	0.00E+00	0.00E+00	0.00E+00	0.00E+00
S15	AV+AC	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Annexure 5.3: Wind rose Diagrams during Different Seasons for 10 Study Zones

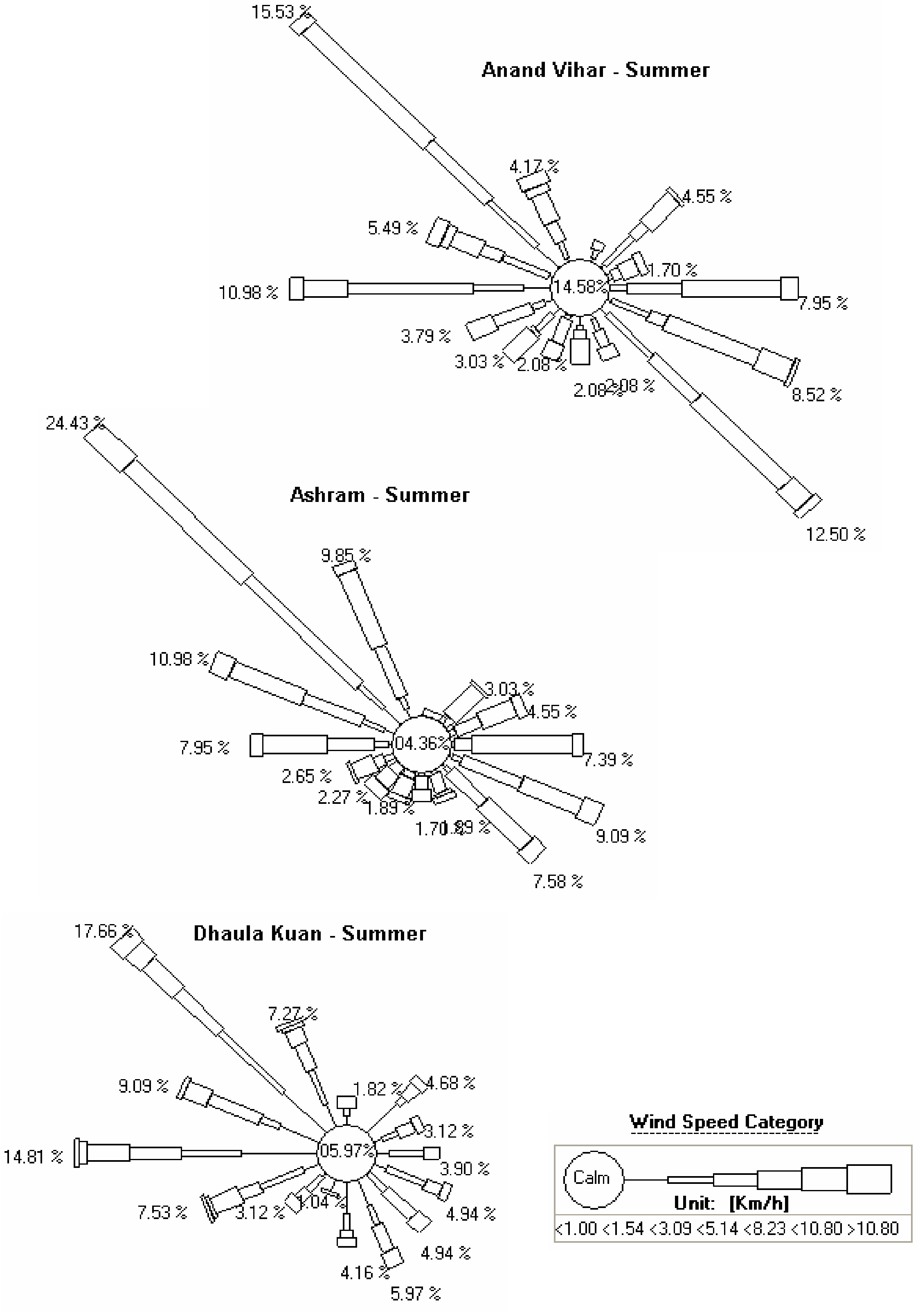


Fig. A5.3.1a: Station-wise Windrose Diagram for Summer Season : 2 km x 2 km Study Zones (Anand Vihar, Ashram Chowk & Dhaula Kuan)

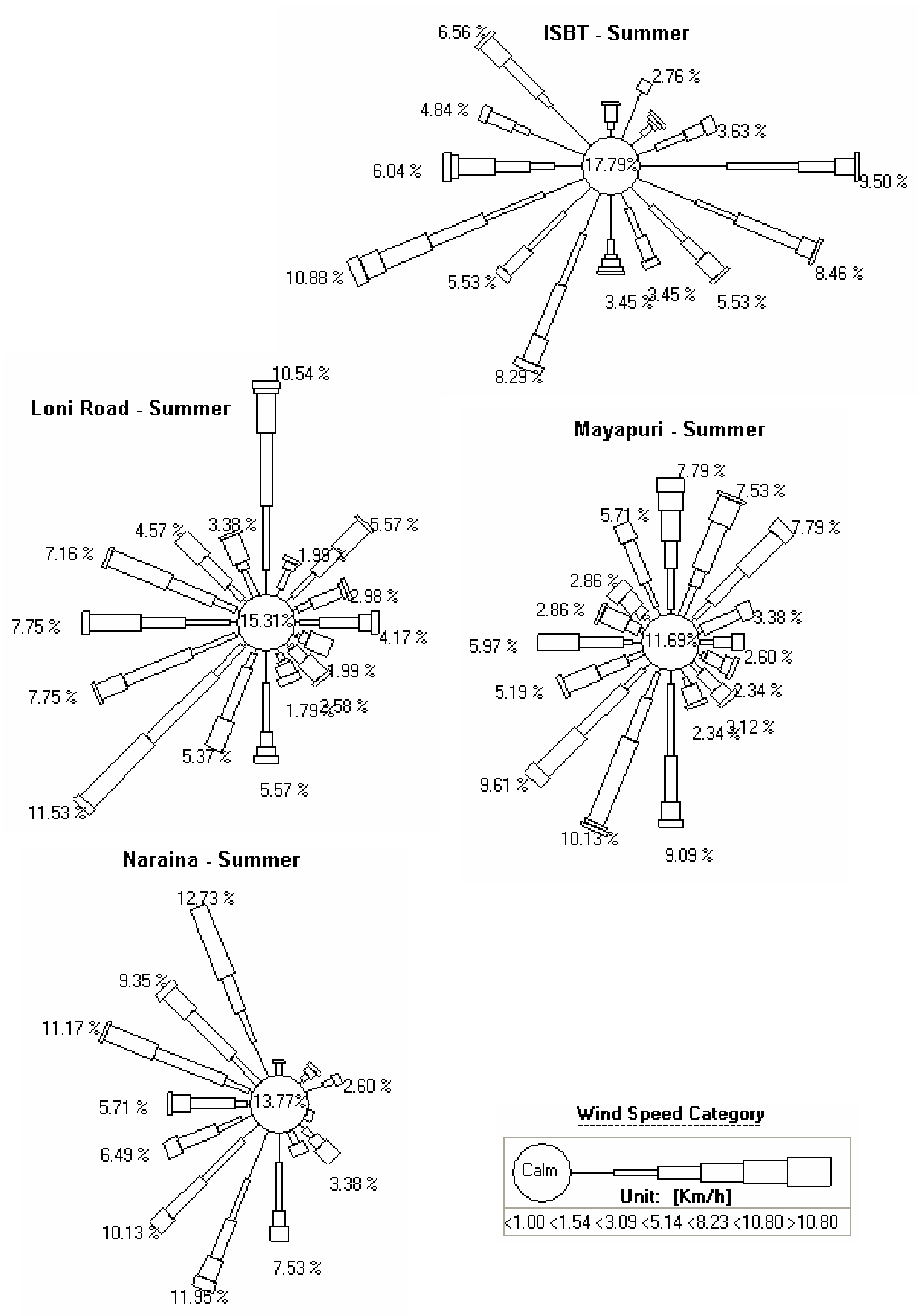
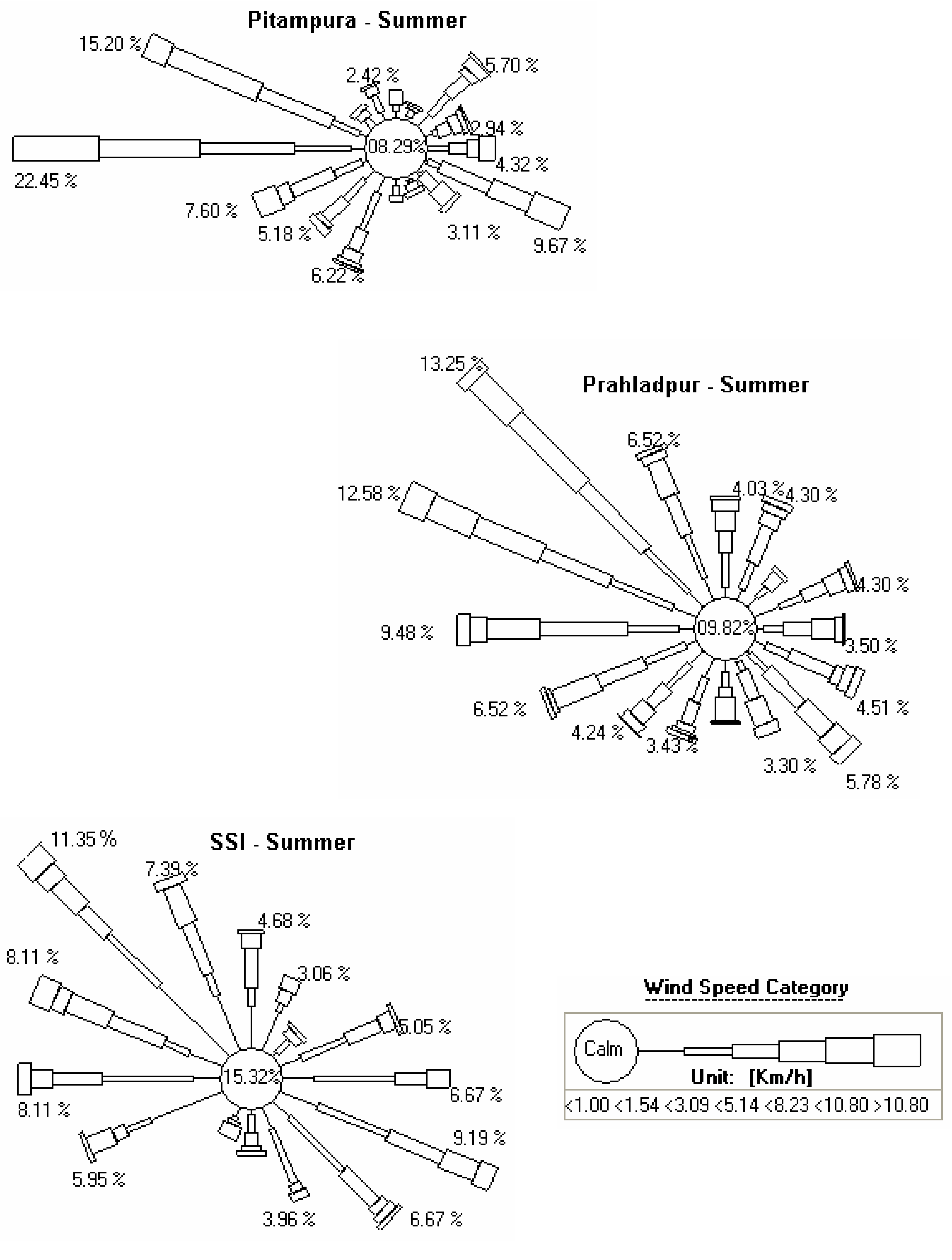


Fig. A5.3.1b: Station-wise Windrose Diagram for Summer Season: 2 km x 2 km Study Zones (ISBT, Loni Road, Mayapuri & Naraina)



Pitampura - Summer

Prahladpur - Summer

SSI - Summer

Wind Speed Category

Fig. A5.3.1c: Station-wise Windrose Diagram for Summer Season: 2 km x 2 km Study Zones (Pitampura, Prahladpur & SSI-GTK)

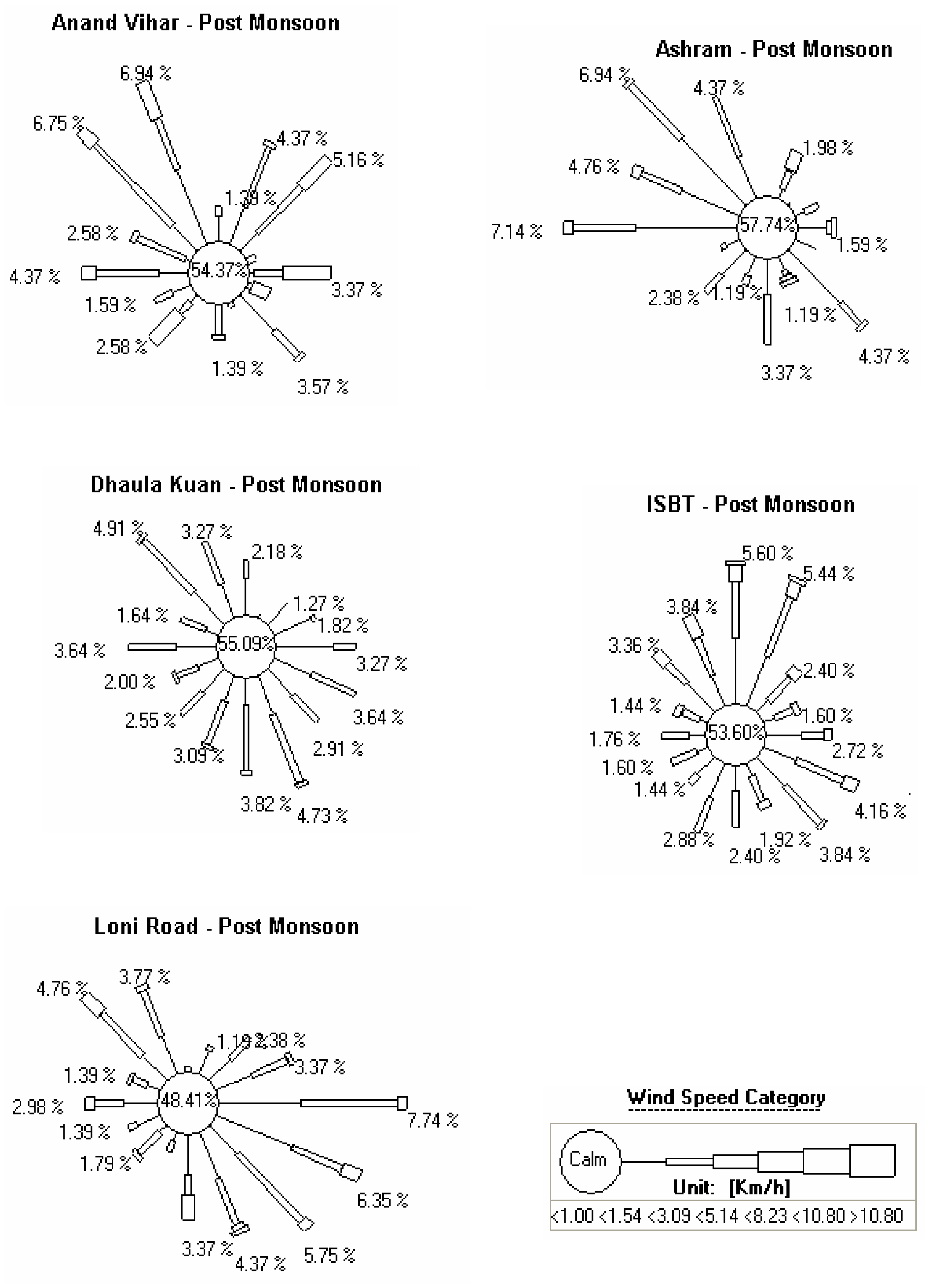
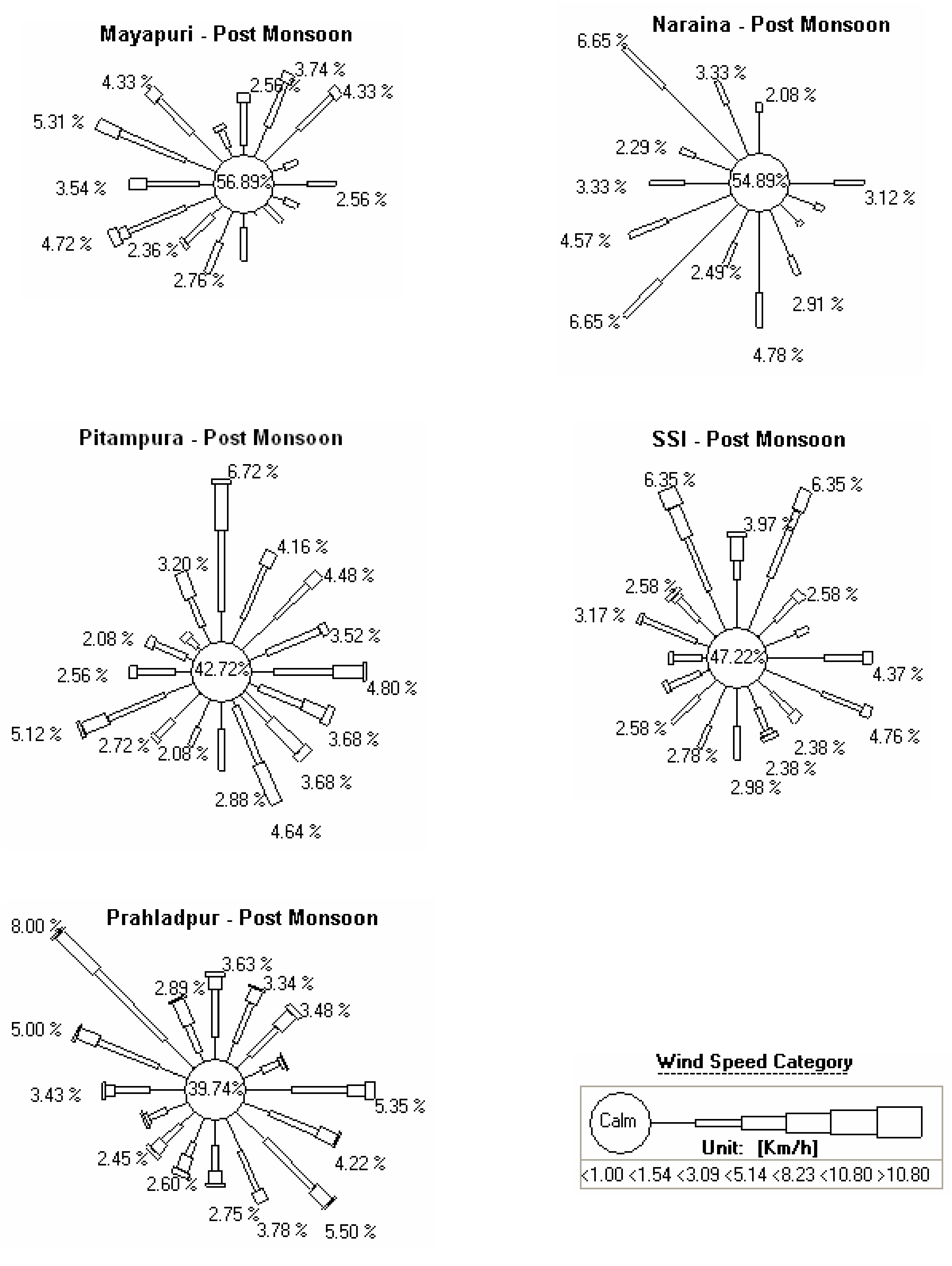


Fig. A5.3.2a: Station-wise Windrose Diagram for Post Monsoon Period: 2km x 2 km Study Zones (Anand Vihar, Ashram, Dhaula Kuan, ISBT & Loni Road)



Mayapuri - Post Monsoon

Naraina - Post Monsoon

Pitampura - Post Monsoon

SSI - Post Monsoon

Prahladpur - Post Monsoon

Fig. A5.3.2b: Station-wise Windrose Diagram for Post Monsoon Period: 2km x 2 km Study Zones (Mayapuri, Naraina, Pitampura, SSI & Prahladpur)

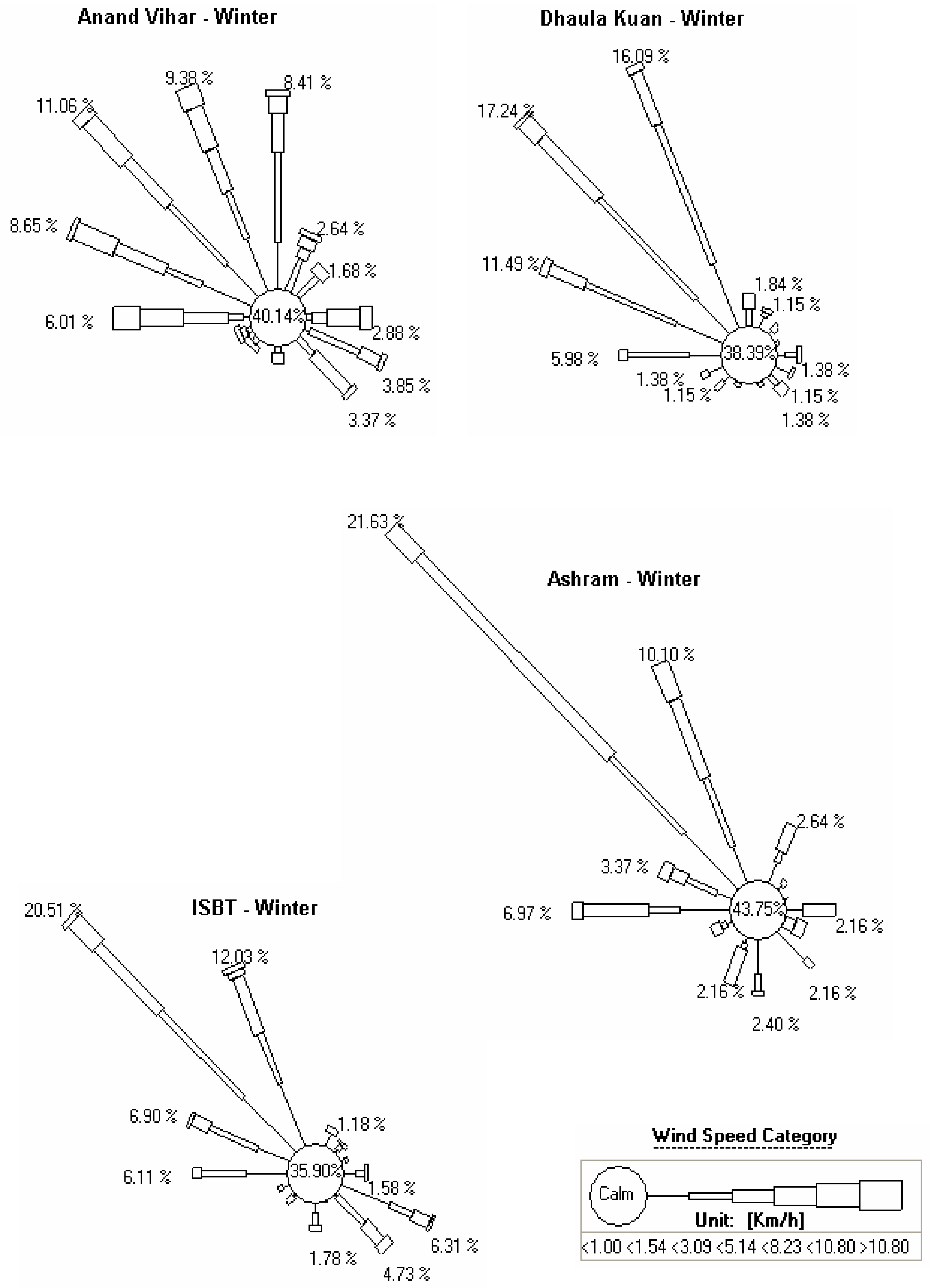


Fig. A5.3.3a: Station-wise Windrose Diagram for Winter Season: 2km x 2 km Study Zones (Anand Vihar, Dhaula Kuan, Ashram Chowk & ISBT)

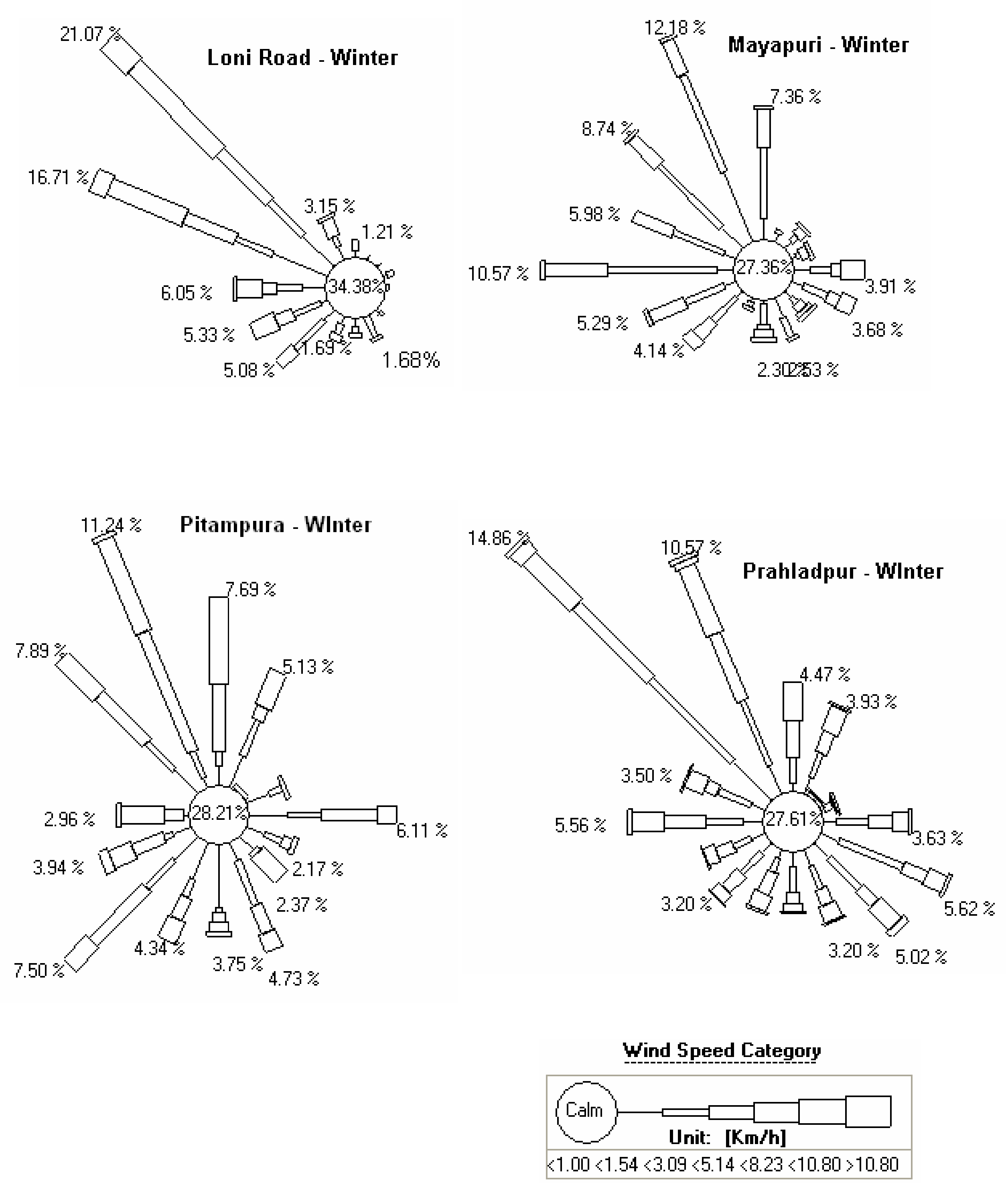


Fig. A5.3.3b: Station-wise Windrose Diagram for Winter Season: 2km x 2 km Study Zones (Loni Road, Mayapuri, Pitampura & Prahladpur)

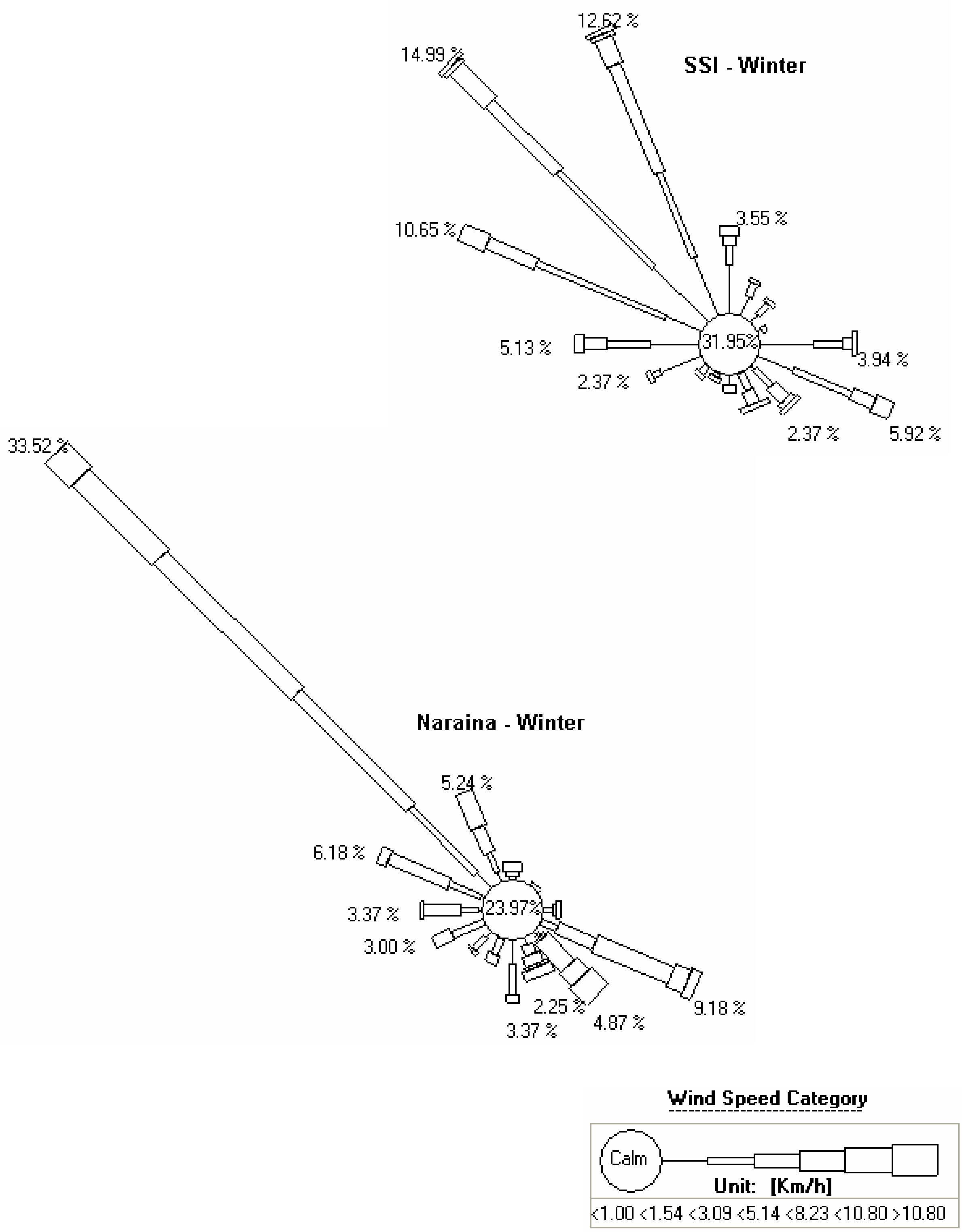


Fig. A5.3.3c: Station-wise Windrose Diagram for Winter Season: 2km x 2 km Study Zones (SSI and Naraina)

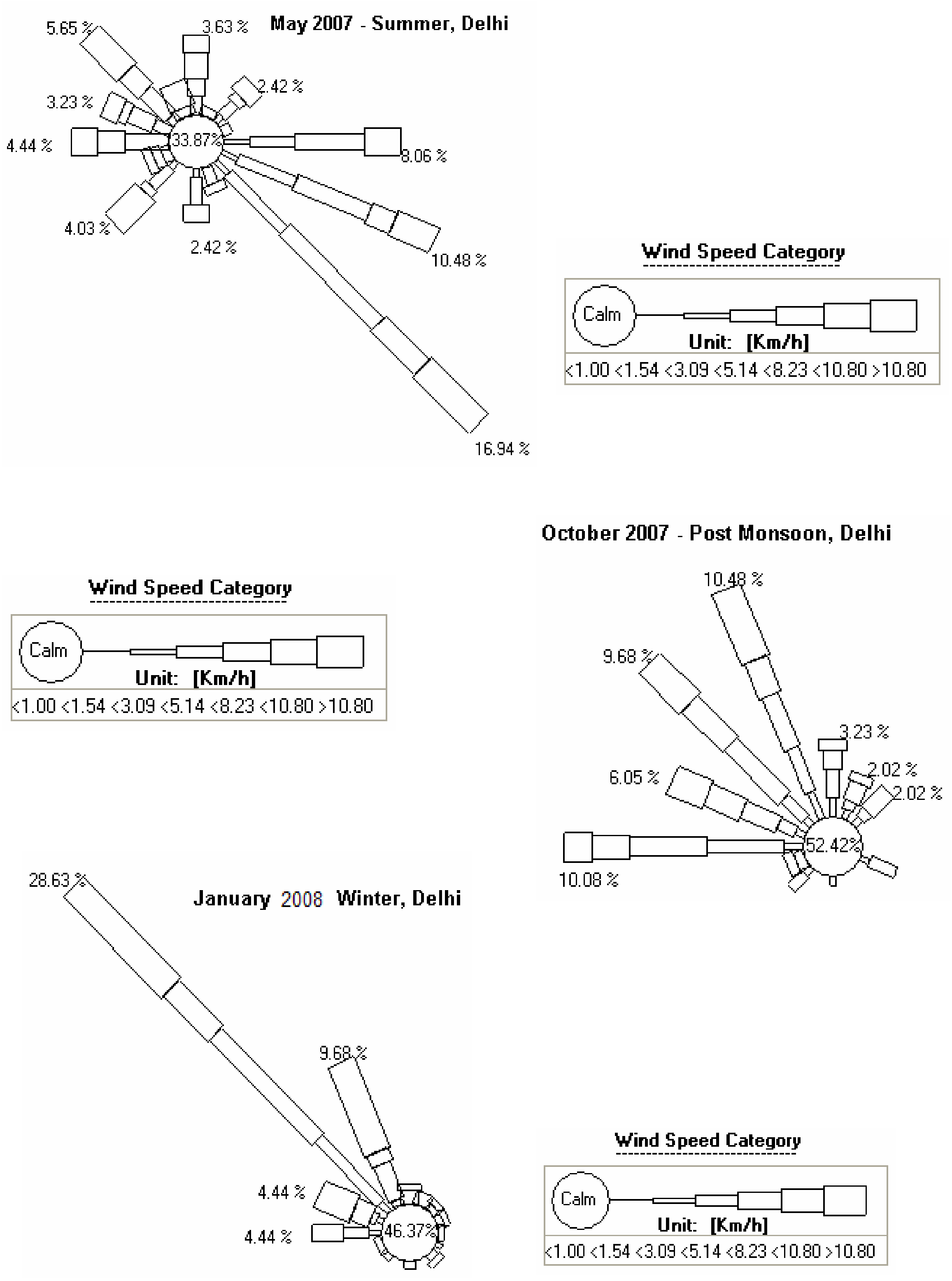


Fig. A5.3.4: Wind rose Diagram for Summer, Post Monsoon and Winter Seasons: Delhi (based on IMD 2007-2008 Data)

Annexure 5.4: Modeling Results – Predicted Highest Ten GLCs for 2km x 2km Study Zones

5.4.1 Modeling Results for 2 km x 2 km Study Zones: Area Sources (Existing Scenario)

Table A5.4.1: Study Zone and Season-wise Predicted Highest Ten PM GLCs: Area Sources (Existing Scenario)

Ashram Chowk: PM (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m³)	Occurrence E, N (m)	GLC (µg/m³)	Occurrence E, N (m)	GLC (µg/m³)	Occurrence E, N (m)
1	8.8	0, 50	16.8	-50, 50	20.9	0,50
2	8.8	0, 100	16.6	-100, 100	20.5	-50, 50
3	8.7	-50, 50	16.4	-150, 150	20.4	0, 100
4	8.6	-50, 100	16.4	-50, 100	20.1	-50, 100
5	8.6	0, 150	16.4	-100, 150	20.0	0, 0
6	8.5	-100, 50	16.3	-150, 100	20.0	0, 0
7	8.5	-50, 150	16.3	-100, 50	19.8	0, 150
8	8.5	-100, 100	16.3	0,0	19.7	-100, 50
9	8.5	0, 200	16.3	0, 0	19.5	-50, 150
10	8.4	-100, 150	16.1	-200,200	19.5	-50, 0
At Centre	8.4	-	16.3	-	20.0	-

Dhaula Kuan: PM (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m³)	Occurrence E, N (m)	GLC (µg/m³)	Occurrence E, N (m)	GLC (µg/m³)	Occurrence E, N (m)
1	0.3	500, 650	0.8	100, 800	1.2	500, 550
2	0.3	500, 700	0.8	150, 800	1.2	500, 600
3	0.3	500, 600	0.8	100, 850	1.2	450, 550
4	0.3	450, 650	0.8	50, 800	1.2	450, 600
5	0.3	500, 750	0.8	150, 850	1.2	500, 650
6	0.3	450, 700	0.8	100, 750	1.2	400, 550
7	0.3	450, 600	0.8	150, 750	1.1	450, 650
8	0.3	450, 750	0.8	200, 800	1.1	400, 600
9	0.3	400, 650	0.8	50, 850	1.1	500, 500
10	0.3	500, 800	0.8	-350, -200	1.1	350, 550
At Centre	0.12	-	0.05	-	0.17	-

Mayapuri: PM (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m³)	Occurrence E, N (m)	GLC (µg/m³)	Occurrence E, N (m)	GLC (µg/m³)	Occurrence E, N (m)
1	1.39	-550 -650	3.05	-500-650	3.76	-550 -950
2	1.38	-550 -700	3.04	-500 -600	3.74	-550 -950
3	1.38	-550 -600	3.03	-550 -650	3.69	-500 -900
4	1.38	-600 -650	3.02	-550 -600	3.69	-600 -950
5	1.37	-600 -700	3.02	-500 -700	3.68	-550 -900
6	1.37	-600 -600	3.001	-500 -700	3.63	-600 -900
7	1.37	-550 -750	3.0	-550-550	3.62	-500 -850
8	1.36	-600-750	2.97	-550 -550	3.61	-650-950
9	1.36	-650 -650	2.97	-500 -550	3.61	-550 -850
10	1.36	-650 -700	2.96	-600 -650	3.56	-600 -850
At Centre	0.6	-	1.7	-	2.2	-

ISBT: PM (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC ($\mu g/m^3$)	Occurrence E, N (m)	GLC ($\mu g/m^3$)	Occurrence E, N (m)	GLC ($\mu g/m^3$)	Occurrence E, N (m)
1	0.7	-100, -50	2.8	-250, -50	3.9	0, -500
2	0.7	-150, -50	2.8	-250, -100	3.9	0, -450
3	0.7	-200, -50	2.8	-200, -50	3.9	0, -400
4	0.7	-100, -100	2.8	-200, -100	3.9	-50, -500
5	0.7	-150, -100	2.8	-250, -150	3.9	-50, -450
6	0.7	-200, -100	2.8	-200, -150	3.9	0, -350
7	0.7	-250, -50	2.8	-150, -50	3.9	-50, -400
8	0.7	-50, -50	2.8	-300, -100	3.9	-100, -500
9	0.7	-100, 0	2.8	-150, -100	3.8	-50, -350
10	0.7	-100, -150	2.8	-300, -50	3.8	-100, -450
At Centre	0.6	-	2.4	-	2.8	-

Loni Road: PM (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC ($\mu g/m^3$)	Occurrence E, N (m)	GLC ($\mu g/m^3$)	Occurrence E, N (m)	GLC ($\mu g/m^3$)	Occurrence E, N (m)
1	16.2	-500, 400	35.0	-900, 300	45.4	-500, 100
2	16.2	-500, 350	34.7	-850, 300	45.2	-500, 150
3	16.0	-500, 450	34.6	-900, 350	45.1	-500, 200
4	15.9	-500, 300	34.4	-900, 250	45.0	-500, 50
5	15.9	-550, 400	34.3	-950, 350	44.5	-500, 250
6	15.9	-550, 350	34.3	-950, 300	43.8	-550, 100
7	15.8	-550, 450	34.3	-800, 300	43.6	-550, 150
8	15.7	-550, 300	34.2	-850, 250	43.4	-550, 200
9	15.6	-500, 250	34.1	-850, 350	43.4	-500, 300
10	15.6	-600, 400	34.1	-800, 250	43.4	-550, 50
At Centre	1.0	-	1.5	-	8.1	-

Anand Vihar: PM (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC ($\mu g/m^3$)	Occurrence E, N (m)	GLC ($\mu g/m^3$)	Occurrence E, N (m)	GLC ($\mu g/m^3$)	Occurrence E, N (m)
1	3.6	750, -600	4.5	950, -900	4.5	800, -850
2	3.6	750, -650	4.5	950, -950	4.5	800, -800
3	3.6	700, -600	4.5	950, -850	4.5	750, -800
4	3.6	700, -550	4.5	900, -900	4.4	800, -900
5	3.6	750, -550	4.5	900, -950	4.4	750, -750
6	3.6	750, -700	4.5	900, -850	4.4	750, -850
7	3.6	700, -650	4.5	950, -800	4.4	800, -750
8	3.6	650, -550	4.5	850, -900	4.4	850, -850
9	3.6	800, -650	4.5	900, -800	4.4	850, -900
10	3.6	800, -600	4.5	850, -850	4.4	750, -700
At Centre	1.3	-	0.5	-	1.1	-

Naraina: PM (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC ($\mu g/m^3$)	Occurrence E, N (m)	GLC ($\mu g/m^3$)	Occurrence E, N (m)	GLC ($\mu g/m^3$)	Occurrence E, N (m)
1	32.1	-50, -50	52.6	-100, -50	76.5	100, 250
2	32.1	-50, -100	52.5	-100, -100	76.3	100, 300
3	31.9	-50, -150	52.3	-100, -150	75.9	150, 300
4	31.9	-100, -50	52.1	-100, 0	75.4	100, 200
5	31.9	-50,0	52.0	-50, -50	75.2	50, 150
6	31.9	-100, -100	51.9	-150, -50	75.2	150, 250
7	31.8	-50, -200	51.9	-100, -200	74.7	200, 300
8	31.8	-100, -150	51.9	-50, -100	74.4	100, 150
9	31.7	-100,0	51.9	-100, -250	74.2	150, 350
10	31.6	-100, -200	51.8	-150, -100	73.9	50, 200
At Centre	28.9	-	42.5	-	68.0	-

SSI-GTK: PM (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC ($\mu g/m^3$)	Occurrence E, N (m)	GLC ($\mu g/m^3$)	Occurrence E, N (m)	GLC ($\mu g/m^3$)	Occurrence E, N (m)
1	302	-500,1000	283	-350,650	270	0,850
2	300	-500,950	282	-350,600	270	0,800
3	299	-450,1000	282	-400,650	269	0,750
4	298	-450,950	282	-300,650	268	0,700
5	297	-500,900	282	-300,600	267	0,900
6	296	-450,900	281	-400,600	265	0,650
7	293	-500,850	281	-350,700	263	0,600
8	293	-400,1000	280	-400,700	263	-50,850
9	292	-450,850	279	-450,650	262	-50,800
10	292	-400,950	279	-450, 700	262	-50,750
At Centre	1.0	-	87	-	68	-

Pitampura: PM (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC ($\mu g/m^3$)	Occurrence E, N (m)	GLC ($\mu g/m^3$)	Occurrence E, N (m)	GLC ($\mu g/m^3$)	Occurrence E, N (m)
1	11.8	900, -50	18.8	950, -300	27.0	950, -200
2	11.8	950, -50	18.7	950, -250	27.0	900, -200
3	11.8	900, -100	18.7	900, -250	26.9	850, -200
4	11.8	850, -50	18.7	900, -150	26.8	900, -100
5	11.8	950, -100	18.7	900, -200	26.8	950, -100
6	11.7	900, 0	18.7	900, -300	26.8	950, -250
7	11.7	850, -100	18.7	950, -200	26.7	850, -100
8	11.7	900, -150	18.7	900, -100	26.7	900, -150
9	11.7	950, 0	18.6	850, -250	26.7	900, -250
10	11.7	950, -150	18.6	950, -350	26.7	800, -200
At Centre	3.44	-	4.7	-	6.5	-

Prahladpur: PM (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)
1	1.5	500, -400	4.9	100, -100	4.5	500, -500
2	1.5	500, -500	4.9	100, -200	4.5	500, -400
3	1.5	500, -300	4.9	200, -200	4.4	400, -400
4	1.5	400, -500	4.9	200, -100	4.4	400, -500
5	1.5	400, -400	4.9	200, -300	4.4	300, -400
6	1.5	400, -300	4.9	100, -300	4.4	500, -300
7	1.5	500, -200	4.8	0, -100	4.4	400, -300
8	1.5	300, -400	4.8	0, -200	4.3	300, -300
9	1.5	300, -500	4.8	200, -400	4.3	300, -500
10	1.5	400, -200	4.8	300, -200	4.3	200, -400
At Centre	1.2	-	4.7	-	3.6	-

Table A5.4.2: Study Zone and Season-wise Predicted Highest Ten NOx GLCs: Area Sources (Existing Scenario)

Ashram Chowk: NOx (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)
1	9.1	0, 50	13.1	-250, 300	14.5	0,50
2	9.0	0, 100	13.1	-250, 250	14.5	-50,50
3	9.0	0, 0	13.0	-250, 350	14.4	0,0
4	9.0	0, 0	13.0	-200, 300	14.4	0,0
5	9.0	-50, 50	13.0	-200, 250	14.3	-50,100
6	9.0	0, 150	13.0	-250, 200	14.3	0,100
7	9.1	-50, 100	13.0	-200, 200	14.3	-50,0
8	9.1	-50, 0	13.0	-300., 300	14.2	-100,50
9	9.1	0, 200	12.9	-250, 400	14.1	-50,150
10	9.1	-50, 150	12.9	-200, 350	14.1	-100,100
At Centre	9.1	-	8.8	-	14.4	-

Dhaula Kuan: NOx (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)
1	3.2	500, 650	9.6	100 , 850	13.4	500, 550
2	3.2	500, 700	9.6	50 , 850	13.3	500, 600
3	3.2	500, 750	9.6	100 , 800	13.2	450, 550
4	3.2	450, 650	9.6	50 , 900	13.1	500, 650
5	3.2	450, 700	9.6	100, 900	13.1	450, 600
6	3.2	500, 600	9.6	50, 800	13.0	400, 550
7	3.2	500, 800	9.5	150, 850	13.0	450, 650
8	3.2	450, 750	9.5	150, 800	13.0	500, 500
9	3.1	400, 650	9.5	150, 900	12.9	450, 500
10	3.1	450, 600	9.4	100, 750	12.9	400, 600
At Centre	1.3	-	0.5	-	1.6	-

Mayapuri: NOx (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)
1	6.0	-550, -550	9.8	-500, -750	10.3	-500, -950
2	6.0	-550, -600	9.8	-500, -700	10.3	-500, -900
3	6.0	-600, -600	9.7	-500, -650	10.3	-550, -950
4	6.0	-600, -550	9.7	-500, -800	10.3	-550, -900
5	6.0	-550, -650	9.7	-550, -700	10.2	-500, -850
6	5.9	-600, -650	9.7	-550, -650	10.2	-550, -850
7	5.9	-650, -600	9.7	-550, -750	10.1	-600, -950
8	5.9	-500, -550	9.6	-550, -800	10.1	-600, -900
9	5.9	-650, -550	9.6	-500, -600	10.0	-600, -850
10	5.9	-500, -600	9.5	-550, -600	10.0	-500, -800
At Centre	1.7	-	3.6	-	4.3	-

ISBT: NOx (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)
1	8.8	-100, -50	36.2	-100, -50	49.1	0,-500
2	8.7	-100, 0	36.2	-200, -50	49.0	0, -450
3	8.7	-150, -50	36.1	-150, -50	48.8	0, -400
4	8.7	-200, -50	36.1	-100, 0	48.5	-50,-500
5	8.7	-50, -50	36.1	-200, 0	48.5	-50,-450
6	8.7	-50, -50	36.1	-150, 0	48.4	0,-350
7	8.7	-150, 0	36.0	-250, -50	48.3	-50,-400
8	8.7	-100, -100	36.0	-100, -100	48.0	-50,-350
9	8.7	-200, 0	36.0	-200, -100	47.9	0,-300
10	8.7	-250, -50	36.0	-150, -100	47.8	-100,-500
At Centre	8.0	-	33.2	-	35.1	-

Loni Road: NOx (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)
1	7.0	-500, 450	16.3	-800, 300	19.1	-500, 200
2	7.0	-500, 400	16.3	-750, 300	19.1	-500, 100
3	7.0	-500, 350	16.3	-850, 400	19.1	-500, 150
4	6.9	-500, 300	16.2	-800, 400	19.1	-500, 250
5	6.9	-550, 450	16.2	-850, 300	18.9	-500, 50
6	6.8	-550, 400	16.2	-750, 400	18.9	-500, 300
7	6.8	-550, 350	16.2	-800, 350	18.6	-500, 350
8	6.8	-500, 250	16.2	-850, 350	18.4	-550, 200
9	6.7	-550, 300	16.1	-750, 350	18.3	-550, 100
10	6.7	-600, 450	16.1	-900, 400	18.3	-550, 150
At Centre	1.4	-	8.8	-	8.7	-

Anand Vihar: NOx (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)
1	48.6	750, -600	55.9	950, -900	52.0	800, -850
2	48.6	750, -650	55.8	950, -950	51.9	800, -900
3	48.5	700, -600	55.7	950, -850	51.8	800, -800
4	48.4	750, -700	55.7	900, -900	51.8	750, -850
5	48.4	700, -550	55.6	900, -950	51.7	750, -800
6	48.3	700, -650	55.5	900, -850	51.7	850, -850
7	48.3	650, -550	55.3	950, -800	51.7	850, -900
8	48.3	750, -550	55.3	850, -900	51.6	700, -800
9	48.2	650, -600	55.1	850, -850	51.6	700, -750
10	48.1	750, -750	55.1	900, -800	51.5	700, -850
At Centre	16.3	-	1.8		14.0	-

Naraina: NOx (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)
1	11.7	-550 -650	18.8	-500-650	27.0	-550 -950
2	11.7	-550 -700	18.7	-500 -600	27.0	-550 -950
3	11.7	-550 -600	18.7	-550 -650	26.9	-500 -900
4	11.7	-600 -650	18.7	-550 -600	26.8	-600 -950
5	11.7	-600 -700	18.7	-500 -700	26.8	-550 -900
6	11.6	-600 -600	18.7	-500 -700	26.8	-600 -900
7	11.6	-550 -750	18.7	-550-550	26.7	-500 -850
8	11.6	-600-750	18.7	-550 -550	26.7	-650-950
9	11.6	-650 -650	18.6	-500 -550	26.7	-550 -850
10	11.6	-650 -700	18.6	-600 -650	26.7	-600 -850
At Centre	3.4	-	4.7	-	6.5	-

SSI-GTK: NOx (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)
1	11.3	250, 200	19.4	150, 300	16.7	450,100
2	11.3	250, 250	19.4	100, 350	16.7	500, 50
3	11.3	250, 150	19.4	100, 300	16.7	450, 50
4	11.3	200, 200	19.4	150, 350	16.7	500,100
5	11.3	200, 250	19.4	200, 300	16.6	450,150
6	11.3	300, 200	19.3	200, 250	16.5	400,100
7	11.2	300, 150	19.3	150, 250	16.5	500,150
8	11.2	300, 250	19.3	50, 350	16.4	400,50
9	11.2	200, 150	19.3	50, 300	16.4	400,150
10	11.2	250, 300	19.3	100, 400	16.4	350,100
At Centre	3.8	-	8.6	-	3.4	-

Pitampura: NOx (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)
1	17.5	-700, -750	19.5	-750, -600	20.9	-800, -550
2	17.5	-700, -700	19.4	-750, -650	20.9	-750, -550
3	17.5	-700, -800	19.4	-800, -600	20.8	-700, -550
4	17.5	-650, -750	19.4	-700, -600	20.8	-800, -600
5	17.5	-650, -800	19.4	-750, -550	20.8	-750, -600
6	17.4	-650, -700	19.4	-700, -550	20.7	-700, -600
7	17.4	-700, -850	19.4	-800, -650	20.7	-850, -550
8	17.4	-700, -650	19.3	-700, -650	20.7	-850, -600
9	17.4	-750, -700	19.3	-650, -600	20.6	-800, -650
10	17.4	-750, -750	19.3	-650, -600	20.5	-750, -650
At Centre	3.7	-	7.4	-	9.1	-

Prahladpur: NOx (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)
1	0.67	500,-400	2.64	100,-100	2.79	500,-400
2	0.67	500,-500	2.64	0,-100	2.78	500,-500
3	0.66	500,-300	2.62	0,0	2.77	400,-400
4	0.65	400,-400	2.62	0,0	2.74	300,-400
5	0.65	500,-200	2.62	100,-200	2.72	400,-300
6	0.65	400,-300	2.61	0,-200	2.72	400,-500
7	0.65	400,-500	2.60	200,-200	2.72	500,-300
8	0.64	400,-200	2.60	200,-100	2.72	300,-300
9	0.63	500,-100	2.58	100,-300	2.67	200,-400
10	0.63	300,-400	2.57	200,-300	2.67	300,-500
At Centre	0.4	-	2.6	-	2.2	-

5.4.2 Modeling Results for 2 km x 2 km Study Zones: Industrial Sources (Existing Scenario)

Table A5.4.3: Study Zone and Season-wise Predicted Highest Ten PM GLCs: Industrial Sources (Existing Scenario)

Anand Vihar: PM10 (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)
1	3.1	700,650	6.0	950, 450	4.4	850, 450
2	3.1	700, 600	6.0	900, 450	4.4	800, 450
3	3.1	750, 650	5.9	950, 400	4.4	900,450
4	3.1	750, 600	5.9	850, 450	4.4	850, 400
5	3.1	700,700	5.9	900, 400	4.4	800, 400
6	3.0	750,700	5.9	950, 500	4.4	950,450
7	3.0	700, 550	5.9	900, 500	4.4	900,400
8	3.0	650, 650	5.8	850, 400	4.4	800, 500
9	3.0	750, 550	5.8	1000, 450	4.4	750, 450
10	3.0	650, 600	5.8	950,350	4.3	850,500
At Centre	0.9		0.4		0.2	

SSI-GTK: PM10 (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)
1	5.7	500, -850	8.31	300-700	7.8	500 -950
2	5.6	500, -900	8.26	250-650	7.8	500 -900
3	5.6	500, -800	8.2	300-750	7.7	500 -850
4	5.6	350, -850	8.2	300-650	7.7	500 -1000
5	5.6	350, -800	8.2	250-700	7.6	450 -900
6	5.6	450, -850	8.1	350-750	7.6	450 -950
7	5.5	400, -850	8.1	350-700	7.6	500 -800
8	5.5	350, -900	8.1	250,-600	7.6	450 -850
9	5.5	450, -900	8.1	350,-800	7.5	550 -950
10	5.5	450, -800	8.1	300,,-800	7.5	550 -900
At Centre	1.0		2.0		0.8	

Mayapuri: PM10 (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)
1	7.0	950, 350	9.4	1000, 50	4.0	950, 100
2	7.0	900, 350	9.3	1000,100	4.0	900,100
3	6.9	950, 400	9.2	1000,0	4.0	850,100
4	6.9	900,400	9.1	1000,150	4.0	950, 150
5	6.9	950, 300	9.0	950,50	4.0	900,150
6	6.9	900,300	8.9	950,100	3.9	850,150
7	6.8	850, 350	8.8	1000, 200	3.9	850, 50
8	6.8	900, 450	8.8	950, 0	3.9	900, 50
9	6.8	950,450	8.7	950,50	3.9	800, 100
10	6.8	850, 400	8.5	900, 50	3.9	950, 50
At Centre	0.09		0.0		0.4	

Naraina: PM10 (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)
1	1.8	400, 0	3.1	150, -250	2.2	450, -150
2	1.8	350,50	3.1	150, -300	2.2	450, -200
3	1.8	350, 0	3.1	200, -250	2.2	400, -150
4	1.8	400,50	3.1	200, -300	2.2	400, -200
5	1.8	400,-150	3.1	150, -200	2.2	450, -100
6	1.8	400,-100	3.1	150, -350	2.2	450,-250
7	1.8	350,-100	3.1	200, -350	2.2	350,-150
8	1.8	350,-150	3.1	200, -200	2.2	400,-100
9	1.8	300, 50	3.1	100, -250	2.2	450, 0
10	1.8	350, -50	3.1	100, -300	2.2	350, -200
At Centre	1.3		2.5		1.6	

Table A5.4.4: Study Zone and Season-wise Predicted Highest Ten NOx GLCs: Industrial Sources (Existing Scenario)

Anand Vihar: NOx (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)
1	57.7	-450, -350	110.5	-500, -900	86.9	-500, -800
2	57.6	-500, 350	110.5	-500, -950	86.9	-500, 850
3	57.5	-650, -450	110.0	-550, -900	86.3	-500, -750
4	57.5	-650, -400	109.9	-500, -850	85.9	-500, -900
5	57.4	-600, -350	109.7	-550, -950	85.3	-500, -700
6	57.4	-450, 400	109.3	-550, -850	85.2	-550, -800
7	57.4	-650, 350	108.8	-500, 800	85.1	-550, 850
8	57.4	-500, 400	108.1	-550, -800	84.8	-450, 850
9	57.3	-550, 350	107.8	-500, 1000	84.7	-450, -800
10	57.3	-600, -400	107.3	-550, -1000	84.7	-550, -750
At Centre	10.7		7.4		5.6	

GTK: NOx (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)
1	79.95	500, -850	116.3	300, -700	109.56	500,-950
2	79.68	500, -900	115.73	250, -650	109.52	500,-900
3	79.36	500,-800	115.61	300,-650	108.57	500,-850
4	78.93	350, -850	115.61	300,-750	107.93	500,1000
5	78.75	350, -800	115.14	250,-700	107.26	450,-900
6	78.67	450, -850.	114.76	350,-750	106.96	450,-950
7	78.50	400,-850	114.48	350,-700	106.87	500,-800
8	78.38	350,-900	114.02	250,-600	106.71	450 , -850
9	78.35	450,-900	113.94	350,-800	106.20	550,-950
10	78.20	450,-800	113.78	300,-800	105.85	550, -900
At Centre	14.1		29.1		11.5	

Mayapuri: NOx (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (μg/m^3)	Occurrence E, N (m)	GLC (μg/m^3)	Occurrence E, N (m)	GLC (μg/m^3)	Occurrence E, N (m)
1	98.8	950, 350	132.85	1000, 50	57.32	950,100
2	98.7	900, 350	131.4	1000, 100	57.25	900,100
3	98.0	950, 400	129.9	1000, 0	57.14	850, 100
4	97.9	900, 400	128.7	1000, 150	56.90	950, 150
5	97.4	950, 300	127.4	950, 50	59.69	900, 150
6	97.3	900, 300	126.1	950, 100	56.49	850,150
7	96.6	850, 350	125	1000, 200	56.24	850, 50
8	96.1	900, 450	124.3	950, 0	56.17	900, 50
9	96.1	950, 450	123.7	950, 150	56.16	800, 100
10	95.8	850, 400	120.9	900, 50	56.10	950, 50
At Centre	1.3		0.0		6.4	

Naraina: NOx (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (μg/m^3)	Occurrence E, N (m)	GLC (μg/m^3)	Occurrence E, N (m)	GLC (μg/m^3)	Occurrence E, N (m)
1	25.8	400, 0	44.5	150, -250	32.1	450, 150
2	25.8	350, 50	44.4	150, -300	32.1	450, -200
3	25.8	350, 0	44.3	200, -250	31.9	400, -150
4	25.7	400, 50	44.3	200, -300	31.9	400, 200
5	25.6	400, -150	44.3	150, -200	31.8	450, -100
6	25.6	400, -100	44.0	150, -350	31.7	450, 250
7	25.6	350, -100	44.0	200, -350	31.6	400, -100
8	25.6	350, -150	43.9	200, -200	31.6	350, -150
9	25.6	300, 50	43.9	100, -250	31.5	450, 0
10	25.6	350, -50	43.7	100, -200	31.5	350, -200
At Centre	18.9		36.4		22.5	

5.4.3 Modeling Results for 2 km x 2 km Study Zones: Vehicular Sources (Existing Scenario)

Table A5.4.5: Study Zone and Season-wise Predicted Highest Ten PM GLCs: Vehicular Sources (Existing Scenario)

1. Ashram Chowk: PM (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC ($\mu g/m^3$)	Occurrence E, N (m)	GLC ($\mu g/m^3$)	Occurrence E, N (m)	GLC ($\mu g/m^3$)	Occurrence E, N (m)
1	28.8	050, 000	23.6	-150, 250	32.4	100, -150
2	28.8	200, -300	23.2	100, -150	30.9	200, -300
3	28.4	-250, 450	23.0	050, -150	30.8	300, -500
4	28.2	200, 300	21.8	-050, -050	30.7	050, 000
5	28.1	100, -150	21.3	000, -050	29.7	-150, 250
6	27.3	300, -500	21.3	300, -500	29.5	000, -050
7	26.8	-150, 250	20.5	050, 000	29.2	500, -900
8	26.7	500, -900	20.3	150, -300	28.7	750, 800
9	26.4	-450, -400	19.4	050, -200	28.4	-250, 450
10	26.0	050, 150	19.3	-450, -400	27.5	000, 100
at Centre	11.3		15.6		16.3	

2. Dhaula Kuan: PM (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC ($\mu g/m^3$)	Occurrence E, N (m)	GLC ($\mu g/m^3$)	Occurrence E, N (m)	GLC ($\mu g/m^3$)	Occurrence E, N (m)
1	29.3	250, -100	34.5	150, 050	46.9	200, -100
2	27.9	250, -050	29.5	200, -100	42.6	250, -100
3	24.5	300, 000	27.8	100, 050	38.9	300, -250
4	21.3	300, -100	26.7	250, -100	33.6	250, -050
5	20.9	250, 000	26.2	300, -250	33.0	300, 000
6	20.6	300, -050	23.3	200, -150	32.4	650, -900
7	20.6	350, -200	22.9	400, -400	32.4	250, -150
8	20.1	100, 250	22.9	050, 200	32.0	400, -400
9	19.8	350, 000	21.6	100, 200	31.5	200, -150
10	19.6	300, -250	20.8	500, -550	29.6	550, -700
at Centre	2.7		8.3		2.8	

3. Mayapuri: PM (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC ($\mu g/m^3$)	Occurrence E, N (m)	GLC ($\mu g/m^3$)	Occurrence E, N (m)	GLC ($\mu g/m^3$)	Occurrence E, N (m)
1	4.6	100, 300	6.7	000, 150	7.6	-050, -900
2	4.5	-050, -800	6.2	000, 200	6.5	100, 200
3	3.6	000, 200	6.0	050, 200	6.0	-250, -800
4	3.4	450, 600	5.6	-200, -750	5.9	450, 500
5	3.1	650, 750	5.4	150, 250	5.8	000, 100
6	3.1	700, -950	5.3	250, 400	5.3	-800, 950
7	3.0	-500, 950	5.1	250, 350	5.3	-800, -550
8	2.9	250, 400	5.0	150, 300	5.0	-050, 050
9	2.8	-050, 250	4.9	650, 700	4.8	-200, -800
10	2.7	050, 200	4.8	-950, 1000	4.8	650, 650
at Centre	1.0		1.1		4.4	

4. ISBT: PM (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC ($\mu g/m^3$)	Occurrence E, N (m)	GLC ($\mu g/m^3$)	Occurrence E, N (m)	GLC ($\mu g/m^3$)	Occurrence E, N (m)
1	37.1	100, -400	54.7	050, -600	86.3	100, -550
2	36.9	200, -450	54.3	050, -700	81.1	300, -1000
3	36.2	200, -300	52.6	-000, -600	77.4	200, -700
4	34.6	200, -500	52.2	050, -650	76.3	150, -600
5	33.9	100, -350	50.2	050, -450	73.7	200, -550
6	33.7	200, -600	49.1	100, -800	71.2	150, -650
7	33.7	250, -850	48.1	050, -800	70.8	200, -400
8	33.5	250, -800	48.0	100, -700	67.7	200, -600
9	32.9	200, -550	47.0	000, -650	66.3	200, -750
10	32.8	200, -400	46.4	100, -600	65.0	250, -950
at Centre	12.9		17.0		37.7	

5. Loni Road: PM (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC ($\mu g/m^3$)	Occurrence E, N (m)	GLC ($\mu g/m^3$)	Occurrence E, N (m)	GLC ($\mu g/m^3$)	Occurrence E, N (m)
1	6.9	050, -050	11.0	200, -200	18.5	550, -250
2	6.3	350, -100	10.0	550, -250	16.4	200, -200
3	6.3	-600, -100	9.8	-300, -150	15.7	-850, -300
4	6.2	-900, -400	9.6	--800, -100	15.4	050, -150
5	6.1	100, -200	9.3	-450, -100	15.4	-300, -150
6	5.9	-100, -100	9.3	-600, -100	14.0	100, -200
7	5.8	700, -150	9.2	050, -250	13.7	-450, -100
8	5.8	-100, -150	8.9	050, -200	12.7	350, -250
9	5.8	-050, -200	8.7	-500, -150	12.4	900, -300
10	5.7	-300, -050	8.7	-950, -100	12.4	700, -300
at Centre	3.3		1.9		0.6	

6. Anand Vihar: PM (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC ($\mu g/m^3$)	Occurrence E, N (m)	GLC ($\mu g/m^3$)	Occurrence E, N (m)	GLC ($\mu g/m^3$)	Occurrence E, N (m)
1	12.1	350, 100	12.6	350, 100	11.4	550, 100
2	9.5	750, 150	11.2	550, 100	10.4	350, 100
3	9.4	550, 100	10.6	150, 050	10.3	300, 050
4	9.3	-650, -950	10.1	750, 150	10.2	350, 050
5	8.6	150, 050	9.8	350, 050	10.1	150, 050
6	8.3	350, 050	9.7	700, 100	10.0	-700, -1000
7	7.9	700, 100	9.7	-650, -950	8.8	700, 100
8	7.8	750, 100	9.5	-700, -1000	8.8	-850, -1000
9	7.6	-700, -1000	9.3	300, 050	8.6	-650, -1000
10	7.5	200, 050	8.9	750, 100	8.1	200, 100
at Centre	0.1		0.5		0.1	

7. Naraina: PM (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)
1	14.9	-650, 450	21.5	-600, 350	25.0	-650, 450
2	12.5	-250, -750	19.6	-650, 450	22.8	-200, -900
3	12.5	-500, -050	19.4	-600, 400	22.5	-500, -050
4	12.3	-200, -900	18.2	-600, 300	21.6	-250, -750
5	12.2	-400, -250	17.8	-300, -500	21.2	-550, 100
6	12.1	-300, -600	17.3	-250, -700	21.1	-400, -400
7	12.0	-700, 600	16.2	-500, -050	20.9	-400, -250
8	12.0	-350, -400	16.2	-200, -800	20.6	-700, 600
9	11.9	-600, 300	16.1	-650, 550	20.6	-600, 300
10	11.9	-550, 100	16.0	-350, -350	20.5	-300, -600
at Centre	2.1		3.4		3.1	

8. SSI-GTK: PM (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)
1	33.1	-250, 600	44.4	-250, 600	48.6	-250, 600
2	23.9	-250, 550	36.0	-250, 550	36.1	300, -200
3	23.6	550, -500	33.2	300, -200	35.2	-250, 550
4	23.1	-350, 750	31.3	200, -050	31.6	-150, 400
5	22.9	300, -200	31.2	-150, 400	30.0	800, -900
6	22.3	-200, 600	30.7	550, -500	28.4	-450, 500
7	22.1	-150, 400	29.5	800, -900	28.3	-300, 550
8	21.8	450, -350	29.1	450, -400	28.1	100, 050
9	21.6	450, -400	28.3	550, -550	27.5	050, 150
10	21.5	-100, 450	28.1	450, -350	27.2	200, -050
at Centre	3.7		8.7		10.2	

9. Pitampura: PM (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)
1	9.0	-500, 650	9.3	-700, 500	12.4	-700, 200
2	8.5	-700, 150	9.1	-750, 350	11.3	-600, 350
3	8.2	-450, 800	8.5	-600, 850	11.2	-550, 550
4	7.8	-850, -150	8.5	-700, 550	11.2	-900, -200
5	7.4	-450, 850	8.3	-900, 050	10.8	-650, 350
6	7.1	-500, 700	8.0	-600, 750	10.7	-750, 050
7	7.0	-850, -100	8.0	-650, 600	9.9	-800, -050
8	6.9	-500, 500	7.9	-850, 200	9.8	-650, 200
9	6.7	-750, 000	7.9	-650, 700	9.7	-600, 400
10	6.6	-600, 300	7.6	-950, -050	9.6	-500, 750
at Centre	0.9		0.9		0.8	

10. Prahladpur: PM (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)
1	2.0	350, 350	3.2	-550, 700	3.7	-400, 600
2	1.8	-250, 550	3.1	-400, 600	3.6	350, 350
3	1.7	500, 300	2.8	350, 350	3.1	-250, 550
4	1.7	-450, 650	2.7	-250, 550	2.8	-450, 650
5	1.6	1000, 100	2.7	-550, 750	2.8	500, 300
6	1.5	250, 400	2.6	-350, 600	2.6	850, 150
7	1.4	750, 250	2.5	250, 400	2.6	-550, 700
8	1.4	-550, 750	2.4	-450, 650	2.6	1000, 100
9	1.4	-400, 600	2.3	400, 350	2.5	-550, 750
10	1.3	1000, 150	2.2	-100, 500	2.5	000, 450
at Centre	0.06		0.1		0.2	

Table A5.4.6: Study Zone and Season-wise Predicted Highest Ten NOx GLCs: Vehicular Sources (Existing Scenario)

1. Ashram Chowk: NOx (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)
1	226	050, 000	200	-150, 250	277	100, -150
2	226	200, -300	196	100, -150	268	050, 000
3	222	-250, 450	186	050, -150	266	200, -300
4	220	100, -150	177	-050, -050	265	300, -500
5	220	200, 300	177	300, -500	254	-150, 250
6	215	300, -500	171	000, -050	249	500, -900
7	211	-150, 250	166	050, 000	247	750, 800
8	210	500, -900	161	300, -550	246	000, -050
9	208	-450, -400	161	-450, -400	246	-250, 450
10	202	050, 150	161	-250, 450	237	000, 100
at Centre	90		135		137	

2. Dhaula Kuan: NOx (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)
1	249	250, -100	293	150, 050	406	200, -100
2	240	250, -050	246	200, -100	382	250, -100
3	206	300, 000	233	100, 050	341	300, -250
4	181	300, -100	226	250, -100	303	250, -050
5	177	300, -050	220	300, -250	292	300, 000
6	176	250, 000	195	200, -150	285	250, -150
7	175	350, -200	192	400, -400	283	400, -400
8	170	100, 250	190	050, 200	282	650, -900
9	167	350, 000	182	100, 200	271	200, -150
10	166	300, -250	175	500, -550	259	500, -550
at Centre	23		77		24	

3. Mayapuri: NOx (ES)

Rank	**Summer**		**Post-Monsoon**		**Winter**	
	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)
1	47.1	100, 300	72.0	000, 150	81.8	-050, -900
2	46.1	-050, -800	60.5	050, 200	69.6	100, 200
3	39.2	000, 200	60.2	-200, -750	66.4	-250, -800
4	35.3	450, 600	59.4	000, 200	62.6	450, 500
5	33.4	650, 750	55.9	150, 250	61.1	000, 100
6	32.4	700, -950	54.8	250, 350	56.8	-800, 950
7	32.0	-500, 950	52.7	650, 700	56.2	-800, -550
8	31.3	250, 400	51.5	000, -850	53.0	-050, 050
9	29.1	-050, 250	50.5	-950, 1000	52.6	600, 650
10	28.5	050, 200	50.4	250, 400	51.2	150, -950
at Centre	9.8		11.9		46.8	

4. ISBT: NOx (ES)

Rank	**Summer**		**Post-Monsoon**		**Winter**	
	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)
1	263	100, -400	402	050, -600	654	100, -550
2	260	200, -450	394	050, -700	615	300, -1000
3	254	200, -300	383	050, -650	585	200, -700
4	245	200, -500	382	000, -600	579	150, -600
5	239	100, -350	373	050, -450	554	200, -550
6	239	250, -850	364	100, -800	539	150, -650
7	238	250, -800	358	100, -700	532	200, -400
8	237	200, -600	349	050, -800	510	200, -600
9	233	200, -550	346	100, -600	504	200, -750
10	232	200, -400	344	150, -950	497	250, -950
at Centre	90		126		285	

5. Loni Road: NOx (ES)

Rank	**Summer**		**Post-Monsoon**		**Winter**	
	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)
1	51.4	050, -050	85.2	200, -200	149	550, -250
2	47.6	350, -100	78.4	550, -250	128	200, -200
3	46.2	-600, -100	76.5	-300, -150	126	050, -150
4	44.2	-100, -100	75.0	-800, -100	125	-300, -150
5	44.2	700, -150	73.9	-450, -100	124	850, -300
6	43.9	100, -200	72.8	-600, -100	114	-450, -100
7	43.5	-300, -050	68.4	050, -200	107	100, -200
8	42.7	-600, 000	67.7	-500, -150	102	900, -300
9	42.7	-100, -150	67.6	050, -250	101	350, -250
10	42.6	-150, -050	67.0	-950, -100	100	-600, -100
at Centre	25.0		15.7		5.7	

6. Anand Vihar: NOx (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC ($\mu g/m^3$)	Occurrence E, N (m)	GLC ($\mu g/m^3$)	Occurrence E, N (m)	GLC ($\mu g/m^3$)	Occurrence E, N (m)
1	105	350, 100	109	350, 100	114	550, 100
2	81.0	750, 150	104	550, 100	106	350, 100
3	80.3	550, 100	102	150, 050	103	300, 050
4	79.9	-650, -950	92.4	-700, -1000	102	350, 050
5	73.5	150, 050	92.0	300, 050	101	150, 050
6	72.1	350, 050	91.9	700, 100	100	-700, -1000
7	68.4	700, 100	91.0	350, 050	87.8	700, 100
8	66.7	750, 100	85.8	750, 150	87.6	-850, -1000
9	66.6	-700, -1000	84.5	050, -050	86.6	-650, -1000
10	64.8	200, 050	83.2	-650, -950	82.6	200, 100
at Centre	1.0		6.4		1.0	

7. Naraina: NOx (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC ($\mu g/m^3$)	Occurrence E, N (m)	GLC ($\mu g/m^3$)	Occurrence E, N (m)	GLC ($\mu g/m^3$)	Occurrence E, N (m)
1	120	-650, 450	170	-600, 350	231	-650, 450
2	101	-250, -750	161	-650, 450	210	-200, -900
3	100	-500, -050	158	-600, 400	205	-500, -050
4	98.4	-200, -900	148	-600, 300	197	-250, -750
5	97.8	-300, -600	143	-300, -500	193	-550, 100
6	97.0	-400, -250	138	-250, -700	192	-600, 300
7	96.8	-700, 600	135	-500, -050	191	-400, -400
8	95.1	-550, 100	132	-650, 550	190	-700, 600
9	94.9	-350, -400	132	-200, -800	187	-300, -600
10	94.5	-600, 300	128	-450, 000	186	-400, -250
at Centre	16.0		27.0		28.0	

8. SSI-GTK: NOx (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC ($\mu g/m^3$)	Occurrence E, N (m)	GLC ($\mu g/m^3$)	Occurrence E, N (m)	GLC ($\mu g/m^3$)	Occurrence E, N (m)
1	235	-250, 600	319	-250, 600	362	-250, 600
2	170	-250, 550	261	-250, 550	269	300, -200
3	167	550, -500	239	300, -200	261	-250, 550
4	164	-350, 750	227	-150, 400	234	-150, 400
5	161	300, -200	226	200, -050	224	800, -900
6	159	-200, 600	220	550, -500	211	-450, 500
7	158	-150, 400	212	800, -900	209	100, 050
8	154	450, -350	211	450, -400	208	-300, 550
9	153	450, -400	205	-350, 750	205	050, 150
10	153	-100, 450	204	550, -550	204	200, -050
at Centre	27.1		64.7		74.2	

9. Pitampura: NOx (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)
1	63.8	-500, 650	71.0	-700, 500	97.1	-700, 200
2	60.1	-700, 150	64.9	-750, 350	88.4	-550, 550
3	58.5	-450, 800	63.3	-600, 850	86.8	-650, 350
4	56.8	-850, -150	62.4	-700, 550	85.3	-600, 350
5	52.1	-450, 850	60.6	-900, 050	84.6	-900, -200
6	49.3	-500, 700	59.6	-650, 650	82.1	-750, 050
7	49.0	-500, 500	58.7	-600, 750	77.4	-500, 750
8	48.9	-850, -100	58.6	-850, 200	76.7	-800, -050
9	48.2	-750, 000	58.5	-650, 600	74.1	-600, 400
10	46.7	-600, 300	58.1	-650, 700	74.0	-650, 200
at Centre	6.6		6.9		6.3	

10. Prahladpur: NOx (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)
1	15.3	350, 350	28.7	-550, 700	34.5	-400, 600
2	14.0	-250, 550	25.0	-400, 600	32.6	350, 350
3	13.2	500, 300	23.4	350, 350	28.9	-250, 550
4	13.0	-450, 650	23.3	-350, 600	26.8	-450, 650
5	12.1	1000, 100	22.8	-250, 550	25.8	500, 300
6	11.3	250, 400	22.7	-550, 750	24.6	-550, 700
7	10.7	-400, 600	21.8	250, 400	23.9	850, 150
8	10.6	750, 250	20.9	400, 350	23.2	-550, 750
9	10.6	-550, 750	19.9	-450, 650	23.1	1000, 100
10	10.1	850, 150	19.4	750, 250	22.4	000, 450
at Centre	0.5		1.2		2.1	

Table A5.4.7: Study Zone and Season-wise Predicted Highest Ten PM10 GLCs: Road Dust Re-suspension (Existing Scenario)

1. Ashram Chowk: RD-PM10 (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)
1	113	050, 000	96	-450, -400	155	100, -150
2	112	200, 300	88	300, -450	150	200, -300
3	111	200, -300	85	-150, 250	146	300, -500
4	110	-250, 450	82	500, 450	144	-150, 250
5	109	100, -150	81	-050, -050	143	050, 000
6	107	300, -500	81	050, 050	142	500, -900
7	106	-450, -400	81	100, -150	139	750, 800
8	105	500, -900	81	-100, 250	138	-250, 450
9	105	-150, 250	80	050, 000	138	000, -050
10	100	050, 150	79	400, 500	129	000, 100
at Centre	46		65		76	

2. Dhaula Kuan: RD-PM10 (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)
1	127	250, -050	180	150, 050	249	200, -100
2	116	250, 000	142	100, 050	241	250, -100
3	115	250, -100	110	150, 100	215	300, -250
4	110	300, 000	107	050, 200	182	400, -400
5	92	300, -050	103	200, 050	182	650, -900
6	92	350, 050	100	200, 100	181	250, -150
7	89	250, 050	100	100, 200	173	300, 000
8	89	350, 000	100	100, 100	171	250, -050
9	88	350, -200	96	250, 150	166	550, -700
10	88	300, -100	96	-050, 400	165	200, -150
at Centre	18		57		12	

3. Mayapuri: RD-PM10 (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)
1	45	-050, -800	56	000, 150	91	-050, -900
2	40	100, 300	52	250, 350	78	450, 500
3	31	-250, -700	51	-200, -750	75	100, 200
4	30	450, 600	50	650, 700	66	-250, -800
5	30	700, -950	48	000, 200	62	-800, 950
6	28	-850, -450	48	050, 200	62	-800, -550
7	27	-250, -800	48	000, -850	60	000, 100
8	27	750, 900	47	250, 400	57	650, 650
9	25	-050, 250	46	150, 250	56	-200, -800
10	25	100, -850	45	-350, -700	53	-600, -600
at Centre	12		10		35	

4. ISBT: RD-PM10 (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)
1	168	100, -400	307	050, -600	498	100, -550
2	160	100, -350	296	050, -700	465	300, -1000
3	157	200, -500	294	050, -650	444	150, -600
4	156	200, -300	293	000, -600	442	200, -700
5	153	200, -450	286	100, -800	414	200, -550
6	147	250, -850	276	050, -450	410	150, -650
7	146	100, -300	273	100, -700	397	200, -400
8	145	250, -800	265	150, -950	386	200, -600
9	141	150, -400	263	000, -650	383	200, -750
10	140	150, -550	262	050, -800	383	250, -950
at Centre	47		83		218	

5. Loni Road: RD-PM10 (ES)

Rank	**Summer**		**Post-Monsoon**		**Winter**	
	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)
1	168	-900, -400	224	-850, -400	368	050, 300
2	161	050, 350	208	050, -550	331	050, -050
3	142	050, 200	191	000, 600	324	-900, -500
4	141	050, -300	178	050, -400	283	050, -550
5	131	-850, -300	174	-900, -500	274	-850, -400
6	123	050, -450	171	050, -250	263	050, 450
7	122	-800, -300	155	050, -050	255	050, 100
8	119	050, 050	152	050, -900	251	-950, -700
9	114	100, -800	144	050, 100	249	100, -850
10	108	050, 700	140	000, 100	240	050, 600
at Centre	30		21		5.1	

6. Anand Vihar: RD-PM10 (ES)

Rank	**Summer**		**Post-Monsoon**		**Winter**	
	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)
1	67	350, 100	78	550, 100	107	-900, -1000
2	65	750, 150	77	-900, -1000	100	550, 100
3	61	550, 100	64	550, 150	75	-850, -1000
4	60	-650, -950	63	350, 100	74	600, 600
5	57	550, 150	61	750, 150	70	-700, -1000
6	55	-900, -950	59	700, 100	69	700, 100
7	54	600, 150	58	600, 150	69	300, 050
8	50	600, 100	58	-900, -950	68	150, 050
9	49	-850, -1000	57	150, 050	65	550, 150
10	49	350, 150	57	-850, -1000	63	550, 050
at Centre	1.0		6.0		1.0	

7. Naraina: RD-PM10 (ES)

Rank	**Summer**		**Post-Monsoon**		**Winter**	
	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)	GLC (µg/m^3)	Occurrence E, N (m)
1	56	-650, 450	88	-600, 350	114	-200, -900
2	53	-600, 300	86	-600, 300	108	-500, -050
3	52	-500, -050	76	1000, 500	105	-600, 300
4	51	-200, -900	74	-650, 450	104	-650, 450
5	50	800, 650	73	800, 650	101	-350, -550
6	50	-600, 350	72	550, 250	98	-400, -400
7	45	550, 250	72	200, -350	97	-450, -200
8	45	-550, 100	72	-500, -050	96	-550, 100
9	43	-400, -400	71	-150, -850	90	550, 250
10	43	-250, -750	70	-250, -700	89	-250, -750
at Centre	8.4				13	

8. SSI-GTK: RD-PM10 (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC ($\mu g/m^3$)	Occurrence E, N (m)	GLC ($\mu g/m^3$)	Occurrence E, N (m)	GLC ($\mu g/m^3$)	Occurrence E, N (m)
1	158	-250, 600	225	-250, 600	251	-250, 600
2	115	550, -500	177	-250, 550	189	300, -200
3	112	-250, 550	166	300, -200	185	-250, 550
4	106	300, -200	156	550, -500	165	-150, 400
5	104	-200, 600	153	200, -050	163	800, -900
6	102	-150, 400	151	-150, 400	153	100, 050
7	101	450, -350	147	800, -900	149	550, -500
8	100	-100, 450	143	450, -400	149	-450, 500
9	96	800, -900	140	550, -550	148	200, -050
10	95	700, -700	140	450, -350	145	050, 150
at Centre	22		51		52	

9. Pitampura: RD-PM10 (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC ($\mu g/m^3$)	Occurrence E, N (m)	GLC ($\mu g/m^3$)	Occurrence E, N (m)	GLC ($\mu g/m^3$)	Occurrence E, N (m)
1	51	-500, 650	47	-700, 500	83	-700, 200
2	48	-700, 150	45	-600, 850	78	-550, 550
3	44	-850, -150	42	-600, 800	77	-650, 350
4	44	-450, 800	41	-650, 650	68	-500, 750
5	37	-750, 000	41	-700, 550	66	-750, 050
6	36	-450, 850	41	-600, 750	66	-600, 350
7	36	-500, 500	40	-1000, -100	63	-500, 700
8	34	-500, 700	40	-800, 250	63	-900, -200
9	34	-850, -100	40	-650, 600	63	-800, -050
10	33	-600, 300	40	-900, 050	60	-850, -100
at Centre	6.0		5.0		4.0	

10. Prahladpur: RD-PM10 (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC ($\mu g/m^3$)	Occurrence E, N (m)	GLC ($\mu g/m^3$)	Occurrence E, N (m)	GLC ($\mu g/m^3$)	Occurrence E, N (m)
1	24	350, 350	43	-400, 600	46	-400, 600
2	22	-250, 550	39	350, 350	45	350, 350
3	21	500, 300	37	-250, 550	39	-250, 550
4	21	-450, 650	36	-550, 750	36	-450, 650
5	20	1000, 100	35	-450, 650	36	500, 300
6	18	250, 400	32	500, 300	33	850, 150
7	18	-400, 600	32	-550, 700	32	1000, 100
8	17	-550, 750	29	1000, 100	32	-550, 700
9	16	750, 250	29	250, 400	31	000, 450
10	16	850, 150	29	850, 150	31	-550, 750
at Centre	1.2		3.0		3.8	

5.4.4 Modeling Results for 2 km x 2 km Study Zones: Cumulative Impact of All Sources

Table A5.4.8: Study Zone and Season-wise Predicted Highest Ten PM GLCs: Cumulative Impact of All the Sources

1. Ashram Chowk: PM (ES)

Rank	Summer			Post-Monsoon			Winter		
	GLC ($\mu g/m^3$)	Occurrence (m)		GLC ($\mu g/m^3$)	Occurrence (m)		GLC ($\mu g/m^3$)	Occurrence (m)	
		E	N		E	N		E	N
1	146	50	0	124	-150	250	201	100	-150
2	145	200	-300	123	-450	-400	193	200	-300
3	145	-250	450	115	300	-450	192	-150	250
4	142	200	300	115	100	-150	189	300	-500
5	142	100	-150	114	-100	250	187	50	0
6	140	-150	250	113	-50	-50	181	0	-50
7	140	300	-500	112	50	0	179	-250	450
8	137	-450	-400	110	50	50	177	0	100
9	135	500	-900	110	-50	100	177	500	-900
10	131	50	150	108	50	-150	169	750	800
At Centre	65	0	0	97	0	0	112	0	0

2. Dhaula Kuan: PM (ES)

Rank	Summer			Post-Monsoon			Winter		
	GLC ($\mu g/m^3$)	Occurrence (m)		GLC ($\mu g/m^3$)	Occurrence (m)		GLC ($\mu g/m^3$)	Occurrence (m)	
		E	N		E	N		E	N
1	155	250	-50	214	150	50	296	200	-100
2	144	250	-100	169	100	50	284	250	-100
3	137	250	0	130	50	200	254	300	-250
4	135	300	0	130	150	100	215	650	-900
5	113	300	-50	123	200	50	214	400	-400
6	111	350	50	121	100	200	213	250	-150
7	109	300	-100	119	200	100	206	300	0
8	108	350	0	118	100	100	205	250	-50
9	108	350	-200	117	250	-100	197	550	-700
10	106	250	50	117	200	-100	197	200	-150
At Centre	21	0	0	66	0	0	15	0	0

3. Mayapuri: PM (ES)

Rank	Summer			Post-Monsoon			Winter		
	GLC ($\mu g/m^3$)	Occurrence (m)		GLC ($\mu g/m^3$)	Occurrence (m)		GLC ($\mu g/m^3$)	Occurrence (m)	
		E	N		E	N		E	N
1	50	-50	-800	64	0	150	102	-50	-900
2	46	100	300	60	-200	-750	87	450	500
3	36	450	600	59	250	350	84	100	200
4	35	-250	-700	58	650	700	75	-250	-800
5	34	700	-950	56	0	200	70	-800	-550
6	33	750	900	55	50	200	69	0	100
7	31	650	750	55	0	-850	67	-800	950
8	31	-850	-450	54	250	400	64	650	650
9	30	600	650	52	150	250	64	-200	-800
10	30	0	200	51	-350	-700	60	-600	-600
At Centre	13	0	0	13	0	0	42	0	0

4. ISBT: PM (ES)

Rank	Summer			Post-Monsoon			Winter		
	GLC (µg/m^3)	Occurrence (m)		GLC (µg/m^3)	Occurrence (m)		GLC (µg/m^3)	Occurrence (m)	
		E	N		E	N		E	N
1	205	100	-400	363	50	-600	586	100	-550
2	194	100	-350	352	50	-700	549	300	-1000
3	193	200	-300	348	50	-650	523	150	-600
4	192	200	-500	347	0	-600	522	200	-700
5	190	200	-450	336	100	-800	490	200	-550
6	181	250	-850	327	50	-450	483	150	-650
7	178	250	-800	322	100	-700	470	200	-400
8	178	100	-300	312	150	-950	455	200	-600
9	173	150	-400	312	50	-800	451	200	-750
10	173	150	-550	311	0	-650	450	250	-950
At Centre	60	0	0	102	0	0	259	0	0

5. Loni Road: PM (ES)

Rank	Summer			Post-Monsoon			Winter		
	GLC (µg/m^3)	Occurrence (m)		GLC (µg/m^3)	Occurrence (m)		GLC (µg/m^3)	Occurrence (m)	
		E	N		E	N		E	N
1	175	-900	-400	234	-850	-400	383	50	300
2	168	50	350	216	50	-550	350	50	-50
3	148	50	200	197	0	600	336	-900	-500
4	148	50	-300	187	-900	-500	297	50	-550
5	136	-850	-300	186	50	-400	284	-850	-400
6	129	50	-450	182	50	-250	275	50	450
7	128	-800	-300	163	50	-50	270	50	100
8	125	50	50	158	50	-900	265	-950	-700
9	118	100	-800	149	50	100	263	100	-850
10	113	50	700	145	0	100	249	50	600
At Centre	34	0	0	25	0	0	14	0	0

6. Anand Vihar: PM (ES)

Rank	Summer			Post-Monsoon			Winter		
	GLC (µg/m^3)	Occurrence (m)		GLC (µg/m^3)	Occurrence (m)		GLC (µg/m^3)	Occurrence (m)	
		E	N		E	N		E	N
1	83	350	100	95	550	100	117	550	100
2	78	750	150	85	-900	-1000	116	-900	-1000
3	73	550	100	82	350	100	87	-850	-1000
4	71	-650	-950	77	750	150	86	300	50
5	64	550	150	74	700	100	84	-700	-1000
6	63	600	150	73	550	150	84	150	50
7	60	-900	-950	73	150	50	83	700	100
8	60	350	150	70	600	150	79	350	50
9	59	600	100	70	-650	-950	79	600	600
10	57	-850	-1000	69	300	50	75	550	50
At Centre	3	0	0	7	0	0	2	0	0

7. Naraina: PM (ES)

Rank	Summer			Post-Monsoon			Winter		
	GLC (µg/m^3)	Occurrence (m)		GLC (µg/m^3)	Occurrence (m)		GLC (µg/m^3)	Occurrence (m)	
		E	N		E	N		E	N
1	86	-200	-900	134	-250	-700	188	-200	-900
2	81	-250	-750	130	-150	-850	178	-350	-550
3	80	-400	-400	128	-300	-500	171	-400	-400
4	79	-350	-400	122	-200	-900	169	-250	-750
5	77	-300	-550	122	-350	-350	159	-300	-750
6	77	-250	-700	121	550	250	159	-450	-200
7	76	-200	-750	119	-300	-550	158	-300	-600
8	76	-300	-600	117	-400	-150	158	-300	-550
9	75	-400	-250	116	-150	-900	157	-350	-400
10	74	-150	-900	114	-600	350	150	-150	-900
At Centre	41	0	0	62	0	0	86	0	0

8. SSI-GTK: PM (ES)

Rank	Summer			Post-Monsoon			Winter		
	GLC (µg/m^3)	Occurrence (m)		GLC (µg/m^3)	Occurrence (m)		GLC (µg/m^3)	Occurrence (m)	
		E	N		E	N		E	N
1	502	-250	600	869	-250	600	862	-250	600
2	438	-200	600	791	-250	550	783	-250	550
3	435	-250	550	768	-350	750	715	-200	550
4	432	-350	750	745	-200	600	708	-200	600
5	410	-200	650	737	-400	700	705	-300	550
6	408	-300	800	736	-300	550	691	-100	650
7	405	-300	750	731	-300	750	686	-150	550
8	402	-250	650	728	-400	750	682	-150	650
9	402	-100	700	720	-200	550	677	-100	500
10	394	-200	550	706	-300	800	676	-100	550
At Centre	120	0	0	215	0	0	418	0	0

9. Pitampura: PM (ES)

Rank	Summer			Post-Monsoon			Winter		
	GLC (µg/m^3)	Occurrence (m)		GLC (µg/m^3)	Occurrence (m)		GLC (µg/m^3)	Occurrence (m)	
		E	N		E	N		E	N
1	61	-500	650	62	-700	500	103	-700	200
2	59	-700	150	55	-600	850	95	-650	350
3	53	-850	-150	55	-750	350	93	-550	550
4	52	-450	800	54	-800	250	85	-600	350
5	46	-750	0	54	-850	200	84	-750	50
6	44	-500	500	54	-800	300	79	-500	750
7	44	-450	850	54	-900	50	77	-900	-200
8	43	-600	300	53	-700	550	76	-800	-50
9	42	-500	700	53	-850	150	75	-650	200
10	42	-850	-100	52	-900	100	75	-600	400
At Centre	8	0	0	7	0	0	7	0	0

10. Prahladpur: PM (ES)

Rank	Summer			Post-Monsoon			Winter		
	GLC (µg/m^3)	Occurrence (m)		GLC (µg/m^3)	Occurrence (m)		GLC (µg/m^3)	Occurrence (m)	
		E	N		E	N		E	N
1	26	1700	1700	47	200	2200	50	200	2200
2	24	500	2100	42	1700	1700	48	1700	1700
3	23	2000	1600	40	500	2100	42	500	2100
4	23	100	2300	39	-100	2500	38	100	2300
5	21	3000	1200	38	100	2300	38	2000	1600
6	20	1500	1800	35	-100	2400	36	2700	1300
7	19	200	2200	34	2000	1600	34	3000	1200
8	18	-100	2500	31	1500	1800	34	-100	2400
9	18	2500	1500	31	3000	1200	34	1000	1900
10	18	2700	1300	31	2700	1300	33	-100	2500
At Centre	0	0	0	3	0	0	2	0	0

Table A5.4.9: Study Zone and Season-wise Predicted Highest Ten NOx GLCs: Cumulative Impact of All the Sources (Existing Scenario)

1. Ashram Chowk: NOx (ES)

Rank	Summer			Post-Monsoon			Winter		
	GLC (µg/m^3)	Occurrence (m)		GLC (µg/m^3)	Occurrence (m)		GLC (µg/m^3)	Occurrence (m)	
		E	N		E	N		E	N
1	233	50	0	212	-150	250	287	100	-150
2	230	200	-300	203	100	-150	280	50	0
3	229	-250	450	193	50	-150	276	200	-300
4	226	200	300	187	-50	-50	274	300	-500
5	226	100	-150	185	300	-500	268	-150	250
6	220	-150	250	179	0	-50	259	500	-900
7	219	300	-500	174	50	0	258	0	-50
8	215	500	-900	174	-250	450	257	-250	450
9	214	-450	-400	170	-450	-400	252	750	800
10	210	50	150	169	300	-550	251	0	100
At Centre	99	0	0	144	0	0	152	0	0

2. Dhaula Kuan: NOx (ES)

Rank	Summer			Post-Monsoon			Winter		
	GLC (µg/m^3)	Occurrence (m)		GLC (µg/m^3)	Occurrence (m)		GLC (µg/m^3)	Occurrence (m)	
		E	N		E	N		E	N
1	250	250	-100	294	150	50	408	200	-100
2	240	250	-50	247	200	-100	383	250	-100
3	207	300	0	233	100	50	343	300	-250
4	181	300	-100	226	250	-100	304	250	-50
5	177	300	-50	220	300	-250	293	300	0
6	177	250	0	195	200	-150	288	650	-900
7	176	350	-200	193	400	-400	287	250	-150
8	170	100	250	191	50	200	285	400	-400
9	168	350	0	183	100	200	273	200	-150
10	167	300	-250	177	500	-550	268	500	-550
At Centre	24	0	0	78	0	0	26	0	0

3. Mayapuri: NOx (ES)

Rank	Summer			Post-Monsoon			Winter		
	GLC (µg/m^3)	Occurrence (m)		GLC (µg/m^3)	Occurrence (m)		GLC (µg/m^3)	Occurrence (m)	
		E	N		E	N		E	N
1	106	900	350	145	1000	50	90	-50	-900
2	106	950	350	143	1000	100	85	100	200
3	105	900	400	141	1000	0	79	450	500
4	105	950	400	140	1000	150	74	-250	-800
5	105	900	300	140	950	50	73	0	100
6	104	950	300	138	950	100	69	850	100
7	104	850	350	136	950	0	69	850	150
8	104	900	450	136	1000	200	69	900	100
9	104	850	400	135	950	150	69	800	150
10	103	950	450	133	900	50	69	800	100
At Centre	13	0	0	16	0	0	58	0	0

4. ISBT: NOx (ES)

Rank	Summer			Post-Monsoon			Winter		
	GLC (µg/m^3)	Occurrence (m)		GLC (µg/m^3)	Occurrence (m)		GLC (µg/m^3)	Occurrence (m)	
		E	N		E	N		E	N
1	265	100	-400	421	50	-600	687	100	-550
2	263	200	-450	411	50	-700	645	300	-1000
3	257	200	-300	405	0	-600	616	200	-700
4	248	200	-500	401	50	-650	611	150	-600
5	242	100	-350	391	50	-450	584	200	-550
6	240	250	-850	378	100	-800	571	150	-650
7	240	250	-800	374	100	-700	559	200	-400
8	239	200	-600	364	50	-800	540	200	-600
9	236	200	-550	364	0	-650	534	200	-750
10	234	200	-400	363	100	-600	530	50	-450
At Centre	98	0	0	159	0	0	320	0	0

5. Loni Road: NOx (ES)

Rank	Summer			Post-Monsoon			Winter		
	GLC (µg/m^3)	Occurrence (m)		GLC (µg/m^3)	Occurrence (m)		GLC (µg/m^3)	Occurrence (m)	
		E	N		E	N		E	N
1	55	50	-50	97	200	-200	164	550	-250
2	53	350	-100	89	550	-250	141	200	-200
3	50	700	-150	83	-800	-100	140	850	-300
4	48	-600	-100	80	-300	-150	135	50	-150
5	48	100	-200	80	50	-200	130	-300	-150
6	47	250	-200	80	-600	-100	120	-450	-100
7	46	-600	0	79	50	-250	118	900	-300
8	45	-100	-100	78	-450	-100	118	100	-200
9	45	400	-200	73	-950	-100	115	700	-300
10	45	-300	-50	73	350	-250	115	350	-250
At Centre	27	0	0	25	0	0	14	0	0

6. Anand Vihar: NOx (ES)

Rank	Summer			Post-Monsoon			Winter		
	GLC (µg/m^3)	Occurrence (m)		GLC (µg/m^3)	Occurrence (m)		GLC (µg/m^3)	Occurrence (m)	
		E	N		E	N		E	N
1	24	-1000	-1000	188	-700	-1000	178	-650	-850
2	33	-950	-1000	186	-650	-950	178	-650	-900
3	46	-900	-1000	179	-650	-1000	178	-700	-850
4	86	-850	-1000	163	-450	-1000	178	-650	-800
5	69	-800	-1000	161	-150	-900	177	-700	-900
6	51	-750	-1000	161	-400	-950	177	-700	-800
7	99	-700	-1000	153	-50	-550	176	-650	-750
8	98	-650	-1000	150	-600	-950	175	-600	-850
9	70	-600	-1000	148	-600	-1000	175	-700	-750
10	53	-550	-1000	148	-250	-950	175	-600	-800
At Centre	28	0	0	16	0	0	20	0	0

7. Naraina: NOx (ES)

Rank	Summer			Post-Monsoon			Winter		
	GLC (µg/m^3)	Occurrence (m)		GLC (µg/m^3)	Occurrence (m)		GLC (µg/m^3)	Occurrence (m)	
		E	N		E	N		E	N
1	128	-650	450	190	-600	350	240	-650	450
2	120	-400	-250	181	-300	-500	227	-500	-50
3	118	-500	-50	178	-600	400	226	-200	-900
4	115	-350	-400	178	-650	450	224	-400	-400
5	113	-300	-600	171	-350	-350	219	-400	-250
6	113	-250	-750	169	-600	300	217	-250	-750
7	111	-550	100	165	-400	-150	213	-350	-400
8	111	-400	-400	165	-350	-400	212	-300	-600
9	108	-200	-900	164	-350	-300	212	-450	-200
10	107	-450	-50	163	-500	-50	212	-550	100
At Centre	38	0	0	68	0	0	57	0	0

8. SSI-GTK: NOx (ES)

Rank	Summer			Post-Monsoon			Winter		
	GLC (µg/m^3)	Occurrence (m)		GLC (µg/m^3)	Occurrence (m)		GLC (µg/m^3)	Occurrence (m)	
		E	N		E	N		E	N
1	237	-250	600	325	-250	600	364	-250	600
2	230	550	-500	315	300	-200	322	300	-200
3	212	300	-200	307	550	-500	282	500	-550
4	211	450	-400	297	550	-550	282	800	-900
5	210	450	-350	291	450	-400	281	550	-550
6	202	550	-550	283	550	-600	276	550	-500
7	193	700	-700	278	450	-350	264	-250	550
8	192	350	-200	275	800	-900	262	650	-750
9	191	700	-750	271	200	-50	261	450	-350
10	186	800	-900	271	700	-750	260	400	-400
At Centre	45	0	0	102	0	0	89	0	0

9. Pitampura: NOx (ES)

Rank	Summer			Post-Monsoon			Winter		
	GLC ($\mu g/m^3$)	Occurrence (m)		GLC ($\mu g/m^3$)	Occurrence (m)		GLC ($\mu g/m^3$)	Occurrence (m)	
		E	N		E	N		E	N
1	68	-500	650	82	-700	500	109	-700	200
2	65	-700	150	76	-750	350	100	-550	550
3	62	-450	800	73	-600	850	99	-650	350
4	60	-850	-150	73	-700	550	98	-600	350
5	56	-450	850	71	-900	50	95	-900	-200
6	53	-500	700	70	-850	200	94	-750	50
7	53	-500	500	70	-650	650	88	-800	-50
8	53	-750	0	69	-650	600	87	-500	750
9	52	-850	-100	69	-800	300	86	-650	200
10	51	-600	300	68	-600	750	86	-600	400
At Centre	10	0	0	14	0	0	15	0	0

10. Prahladpur: NOx (ES)

Rank	Summer			Post-Monsoon			Winter		
	GLC ($\mu g/m^3$)	Occurrence (m)		GLC ($\mu g/m^3$)	Occurrence (m)		GLC ($\mu g/m^3$)	Occurrence (m)	
		E	N		E	N		E	N
1	15	1700	1700	29	-100	2400	34	200	2200
2	14	500	2100	25	200	2200	33	1700	1700
3	13	2000	1600	23	1700	1700	29	500	2100
4	13	100	2300	23	300	2200	27	100	2300
5	12	3000	1200	23	500	2100	26	2000	1600
6	11	1500	1800	23	-100	2500	25	-100	2400
7	11	200	2200	22	1500	1800	24	2700	1300
8	11	2500	1500	21	1800	1700	23	-100	2500
9	11	-100	2500	20	100	2300	23	3000	1200
10	10	2700	1300	19	2500	1500	22	1000	1900
At Centre	1	0	0	5	0	0	4	0	0

Annexure 5.5: Modeling Results – Predicted First 10 Highest GLC for Delhi – Existing Scenario

5.5.1 Modeling Results for Delhi: Area Sources (Existing Scenario)

Table A5.5.1: Season-wise Predicted Highest Ten PM GLCs in Delhi: Area Sources (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC ($\mu g/m^3$)	Occurrence E, N (km)	GLC ($\mu g/m^3$)	Occurrence E, N (km)	GLC ($\mu g/m^3$)	Occurrence E, N (km)
1	102	12.0, 27.5	132	24.0, 18.5	144	14.0, 26.0
2	102	12.0, 28.0	132	24.0, 19.0	139	14.0, 26.5
3	99	12.0, 27.0	128	24.0, 19.5	138	24.0, 18.0
4	97	12.5, 27.5	127	23.5, 18.5	135	24.0, 18.5
5	96	12.5, 28.0	127	14.0, 26.5	135	13.5, 26.0
6	95	12.5, 27.0	125	23.5, 19.0	133	23.5, 18.0
7	92	12.0, 26.5	122	23.5, 19.5	133	13.5, 26.5
8	90	13.0, 27.5	122	23.0,18.5	131	24.0, 19.0
9	90	13.0, 27.0	122	13.5, 26.5	130	14.0, 27.0
10	90	12.5, 26.5	121	14.0, 27.0	129	24.0 ,19.5

Table A5.5.2: Season-wise Predicted Highest Ten NOx GLCs in Delhi: Area Sources (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC ($\mu g/m^3$)	Occurrence E, N (km)	GLC ($\mu g/m^3$)	Occurrence E, N (km)	GLC ($\mu g/m^3$)	Occurrence E, N (km)
1	27	4.0, 24.0	49	20.0, 18.5	56	20.0, 18.0
2	27	4.5, 24.0	49	19.5, 18.5	54	19.5, 18.0
3	27	4.0, 23.5	48	20.0, 19.0	54	20.0, 18.5
4	27	5.0, 24.0	48	19.5, 19.0	53	19.5, 18.5
5	26	4.5, 23.5	48	19.0, 18.5	52	19.0, 18.0
6	26	5.0, 23.5	47	19.0, 19.0	52	19.0, 18.5
7	26	5.5, 24.0	45	20.0, 19.5	51	19.0, 19.0
8	25	5.5, 23.5	45	19.5, 19.5	51	20.0, 19.0
9	25	4.0, 23.0	45	19.0, 19.5	51	19.5, 19.0
10	25	4.5, 23.0	45	18.5, 19.0	49	18.5,18.0

Table A5.5.3: Season-wise Predicted Highest Ten SO_2 GLCs in Delhi: Area Sources (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC ($\mu g/m^3$)	Occurrence E, N (km)	GLC ($\mu g/m^3$)	Occurrence E, N (km)	GLC ($\mu g/m^3$)	Occurrence E, N (km)
1	4.1	18.0, 20.0	8.1	19.5,18.5	9.1	20.0,18.0
2	4.1	18.0, 19.5	8.1	20.0,18.5	8.8	19.5,18.0
3	4.0	18.5,19.5	7.9	19.0,18.5	8.7	20.0,18.5
4	4.0	18.5, 20.0	7.8	19.5,19.0	8.6	19.5,18.5
5	3.9	18.0, 19.0	7.8	19.0,19.0	8.4	19.0,18.0
6	3.9	19.0, 19.5	7.8	20.0,19.0	8.3	19.0,18.5
7	3.8	18.5, 19.0	7.5	20.0,18.0	8.2	20.0,19.0
8	3.8	19.0, 20.0	7.5	18.5,18.5	8.2	19.5,19.0
9	3.8	22.0, 23.5	7.5	19.5,18.0	8.2	19.0,19.0
10	3.8	22.0, 24.0	7.4	18.5,19.0	7.8	18.5,18.0

5.5.2 Modeling Results for Delhi: Industrial Sources (Existing Scenario)

Table A5.5.4: Season-wise Predicted Highest Ten PM GLCs in Delhi: Industrial Sources (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m^3)	Occurrence E, N (km)	GLC (µg/m^3)	Occurrence E, N (km)	GLC (µg/m^3)	Occurrence E, N (km)
1	38.3	19.0, 18.5	37.1	24.5, 13.0	71.7	24.5, 13.0
2	37.7	19.5, 18.0	36.9	25.0, 12.5	71.0	25.0, 12.5
3	37.3	18.5, 19.0	36.0	25.5, 12.0	70.2	24.0, 13.5
4	35.7	18.0, 19.5	36.0	24.0, 13.5	69.1	25.5, 12.0
5	34.3	20.0, 17.5	34.8	26.0, 11.5	66.7	26.0, 11.5
6	33.5	17.5, 20.0	33.4	26.5, 11.0	64.3	23.5, 14.0
7	31.2	17.5, 20.5	32.3	23.5, 14.0	64.1	26.5, 11.0
8	29.2	16.5, 21.0	32.1	27.0, 10.5	61.5	27.0, 10.5
9	27.9	15.5, 22.0	30.7	27.5, 10.0	58.9	27.5, 10.0
10	27.5	16.0, 21.5	29.5	28.0, 9.5	56.5	28.0, 9.5

Table A5.5.5: Season-wise Predicted Highest Ten NOx GLCs in Delhi: Industrial Sources (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m^3)	Occurrence E, N (km)	GLC (µg/m^3)	Occurrence E, N (km)	GLC (µg/m^3)	Occurrence E, N (km)
1	618	19.0, 18.5	605	24.5, 13.0	1153	24.5, 13.0
2	613	18.5, 19.0	604	25.0, 12.5	1144	25.0, 12.5
3	593	18.0, 19.5	592	25.5, 12.0	1127	24.0, 13.5
4	591	19.5, 18.0	586	24.0, 13.5	1118	25.5, 12.0
5	563	17.5, 20.0	574	26.0, 11.5	1082	26.0, 11.5
6	531	17.0, 20.5	554	26.5, 11.0	1043	26.5, 11.0
7	513	20.0, 17.5	534	27.0, 10.5	1040	23.5, 14.0
8	500	16.5, 21.0	531	23.5, 14.0	1003	27.0, 10.5
9	472	16.0, 21.5	513	27.5, 10.0	964	27.5, 10.0
10	449	15.5, 22.0	493	28.0, 9.5	926	28.0, 9.5

Table A5.5.6: Season-wise Predicted Highest Ten SO_2 GLCs in Delhi: Industrial Sources (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m^3)	Occurrence E, N (km)	GLC (µg/m^3)	Occurrence E, N (km)	GLC (µg/m^3)	Occurrence E, N (km)
1	360	25.0, 15.5	292	26.5,14.0	510	24.0, 13.5
2	306	19.5, 18.0	258	24.0, 13.5	506	24.5, 13.0
3	303	19.0, 18.5	257	24.5,13.0	486	25.0,12.5
4	288	18.5, 19.0	255	26.0,14.5	481	23.5, 14.0
5	286	20.0, 17.5	247	25.0, 12.5	459	25.5, 12.0
6	270	18.0, 19.5	247	27.0, 13.5	436	26.5, 14.0
7	248	17.5, 20.0	240	23.5, 14.0	430	26.0, 11.5
8	226	17.0, 20.5	234	25.5, 12.0	421	26.0, 14.5
9	224	20.5, 17.0	219	26.0,11.5	401	26.5, 11.0
10	207	16.5, 21.0	204	26.5, 11.0	396	23.0, 14.5

5.5.3 Modeling Results for Delhi: Vehicular Sources (Existing Scenario)

Table A5.5.7: Season-wise Predicted Highest Ten PM GLCs in Delhi: Vehicular Sources (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC ($\mu g/m^3$)	Occurrence E, N (km)	GLC ($\mu g/m^3$)	Occurrence E, N (km)	GLC ($\mu g/m^3$)	Occurrence E, N (km)
1	28	18.0, 16.0	40	20.0, 14.5	46	20.0, 14.0
2	27	18.0, 15.5	40	20.0, 15.0	45	20.0, 14.5
3	26	18.5, 16.0	39	20.0, 14.0	43	20.0, 15.0
4	26	18.0, 15.0	39	19.5, 14.5	43	19.5, 14.0
5	26	18.5, 15.5	38	19.5, 15.0	43	19.5, 14.5
6	25	18.5, 15.0	38	20.0, 15.5	41	19.5, 15.0
7	25	19.0, 15.5	38	19.5, 14.0	41	20.0, 15.5
8	25	19.0, 16.0	37	19.0, 14.5	40	19.0, 14.0
9	24	18.0, 14.5	37	19.5, 15.5	40	19.0, 14.5
10	24	19.0, 15.0	36	19.0, 15.0	40	19.0, 15.0

Table A5.5.8: Season-wise Predicted Highest Ten NOx GLCs in Delhi: Vehicular Sources (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC ($\mu g/m^3$)	Occurrence E, N (km)	GLC ($\mu g/m^3$)	Occurrence E, N (km)	GLC ($\mu g/m^3$)	Occurrence E, N (km)
1	215	18.0, 16.0	315	20.0, 14.5	355	20.0, 14.0
2	213	18.0, 15.5	310	20.0, 14.0	347	20.0, 14.5
3	207	18.0, 15.0	307	20.0, 15.0	337	19.5, 14.0
4	205	18.5, 15.5	303	19.5, 14.5	336	20.0, 15.0
5	204	18.5, 16.0	297	19.5, 14.0	333	19.5, 14.5
6	200	18.5, 15.0	296	19.5, 15.0	322	19.5, 15.0
7	195	18.0, 14.5	294	20.0, 15.5	319	19.0, 14.0
8	193	19.0, 15.5	289	19.0, 14.5	317	20.0, 15.5
9	192	19.0, 15.0	285	19.5, 15.5	316	19.0, 14.5
10	192	19.0, 16.0	284	19.0, 15.0	311	19.0, 15.0

Table A5.5.9: Season-wise Predicted Highest Ten SO_2 GLCs in Delhi: Vehicular Sources (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC ($\mu g/m^3$)	Occurrence E, N (km)	GLC ($\mu g/m^3$)	Occurrence E, N (km)	GLC ($\mu g/m^3$)	Occurrence E, N (km)
1	2.1	18.0, 16.0	3.2	20.0, 14.5	3.6	20.0, 14.0
2	2.1	18.0, 15.5	3.1	20.0, 15.0	3.5	20.0, 14.5
3	2.0	18.5, 16.0	3.1	20.0, 14.0	3.4	20.0, 15.0
4	2.0	18.5, 15.5	3.0	19.5, 14.5	3.4	19.5, 14.0
5	2.0	18.0, 15.0	3.0	20.0, 15.5	3.3	19.5, 14.5
6	2.0	18.5, 15.0	3.0	19.5, 15.0	3.3	19.5, 15.0
7	1.9	19.0, 15.5	2.9	19.5, 14.0	3.2	20.0, 15.5
8	1.9	19.0, 16.0	2.9	19.5, 15.5	3.1	19.0, 14.0
9	1.9	19.0, 15.0	2.9	19.0, 14.5	3.1	19.0, 14.5
10	1.9	18.0, 14.5	2.8	19.0, 15.0	3.1	19.5, 15.5

5.5.4 Modeling Results for Delhi: Road Dust Re-suspension (Existing Scenario)

Table A5.5.10: Season-wise Predicted Highest Ten PM10 GLCs in Delhi: Road Dust Re-suspension (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m^3)	Occurrence E, N (km)	GLC (µg/m^3)	Occurrence E, N (km)	GLC (µg/m^3)	Occurrence E, N (km)
1	214	18.0, 16.0	325	20.0, 14.5	365	20.0, 14.0
2	212	18.0, 15.5	320	20.0, 15.0	362	20.0, 14.5
3	106	18.0, 15.0	313	20.0, 14.0	354	20.0, 15.0
4	205	18.5, 16.0	313	19.5, 14.5	347	19.5, 14.0
5	205	18.5, 15.5	309	19.5, 15.0	346	19.5, 14.5
6	200	18.5, 15.0	307	20.0, 15.5	340	19.5, 15.0
7	194	19.0, 15.5	301	19.5, 14.0	336	20.0, 15.5
8	193	19.0, 16.0	299	19.5, 15.5	326	19.5, 15.5
9	193	18.0, 14.5	296	19.0, 14.5	325	19.0, 14.0
10	192	19.0, 15.0	294	19.0, 15.0	325	19.0, 14.5

5.5.5 Modeling Results for Delhi: Cumulative Impact of All the Sources (Existing Scenario)

Table A5.5.11: Season-wise Predicted Highest Ten PM10 GLCs in Delhi: Cumulative Impact of All the Sources (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m^3)	**Occurrence E, N (km)**	**GLC (µg/m^3)**	**Occurrence E, N (km)**	**GLC (µg/m^3)**	**Occurrence E, N (km)**
1	260	18.0, 16.0	387	20.0, 14.5	438	20.0, 14.0
2	256	18.0, 15.5	384	20.0, 15.0	437	20.0, 14.5
3	251	18.5, 16.0	372	19.5, 14.5	431	20.0, 15.0
4	249	18.5, 15.5	372	20.0, 14.0	417	19.5, 14.5
5	248	18.0, 15.0	372	20.0, 15.5	415	19.5, 14.0
6	242	18.5, 15.0	370	19.5, 15.0	413	19.5, 15.0
7	240	19.0, 16.0	361	19.5, 15.5	412	20.0, 15.5
8	239	19.0, 15.5	357	19.5, 14.0	400	19.5, 15.5
9	235	19.0, 15.0	352	19.0, 14.5	392	19.0, 15.0
10	234	18.0, 14.5	352	19.0, 15.0	391	19.0, 14.5

Table A5.5.12: Season-wise Predicted Highest Ten NOx GLCs in Delhi: Cumulative Impact of All the Sources (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m^3)	**Occurrence E, N (km)**	**GLC (µg/m^3)**	**Occurrence E, N (km)**	**GLC (µg/m^3)**	**Occurrence E, N (km)**
1	735.0	19.0, 18.5	732.5	24.0, 13.5	1296.7	24.5, 13.0
2	730.4	18.5, 19.0	728.6	24.5, 13.0	1293.4	24.0, 13.5
3	729.7	19.5, 18.0	722.9	26.5, 11.0	1283.3	25.0, 12.5
4	712.9	18.0, 19.5	721.8	25.0, 12.5	1252.8	25.5, 12.0
5	693.1	17.5, 20.0	711.5	27.0, 10.5	1238.4	26.5, 11.0
6	649.6	17.0, 20.5	705.8	25.5, 12.0	1225.0	26.0, 11.5
7	642.6	20.0, 17.5	694.2	26.0, 11.5	1209.7	27.0, 10.5
8	621.1	16.5, 21.0	688.1	27.5, 10.0	1177.3	27.5, 10.0
9	596.0	16.0, 21.5	655.1	23.5, 14.0	1176.8	23.5, 14.0
10	565.4	15.5, 22.0	638.8	28.5, 9.0	1085.4	28.5, 9.0

Table A5.5.13: Season-wise Predicted Highest Ten SO_2 GLCs in Delhi: Cumulative Impact of All the Sources (ES)

Rank	Summer		Post-Monsoon		Winter	
	GLC (µg/m^3)	Occurrence E, N (km)	GLC (µg/m^3)	Occurrence E, N (km)	GLC (µg/m^3)	Occurrence E, N (km)
1	361.1	25.0, 15.5	295.3	26.5, 14.0	514.3	24.0, 13.5
2	309.4	19.5, 18.0	261.0	24.0, 13.5	510.0	24.5, 13.0
3	307.7	19.0, 18.5	259.9	24.5, 13.0	489.9	25.0, 12.5
4	293.3	18.5, 19.0	259.1	26.0, 14.5	485.7	23.5, 14.0
5	288.3	20.0, 17.5	250.0	25.0, 12.5	462.8	25.5, 12.0
6	275.2	18.0, 19.5	249.7	27.0, 13.5	439.8	26.5, 14.0
7	252.4	17.5, 20.0	243.0	23.5, 14.0	433.6	26.0, 11.5
8	230.5	17.0, 20.5	236.6	25.5, 12.0	426.0	26.0, 14.5
9	226.2	20.5, 17.0	222.0	26.0, 11.5	404.8	26.5, 11.0
10	211.5	16.5, 21.0	207.2	26.5, 11.0	400.0	23.0, 14.5