REPORT ON SPM CHARACTERIZATION FOR HEAVY METALS CONCENTRATION

STUDY AREAS: RAIPUR & RAIGARH IN CHHATTISGARH STATE

2010-11

ZONAL OFFICE (CENTRAL)
CENTRAL POLLUTION CONTROL BOARD
BHOPAL

PRINCIPLE COORDINATOR:

- SH. S SURESH, ZONAL OFFICER

PROJECT COORDINATOR:

- SH. R D PATIL, SCIENTIST 'B'

MONITORING TEAM

- DR. Y K SAXENA, SSA
- DR. ANOOP CHATURVEDI, JSA
- SH. RAJEEV SHARMA, SR. TECH.
- SH. RAMESHWAR BANDEWAR, JLA
- SH. SUNIL KOLHATKAR, JLA
- SH. S K BHATIA, LAB ATTENDANT

HEAVY METALS ANALYZED BY

- SH. ANIL RAWAT, SSA
- MS. ANAMIKA SINGH, SSA

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INTRODUCTION:

Particulates, alternatively known to as particulate matter (PM) are tiny subdivisions of solid matter suspended in a gas or liquid. The particles and/or liquid droplets and the gas together are referred as aerosol. Suspended particulate matter (SPM) in air generally is a complex, multi-phase system of all airborne solid and low vapor pressure liquid particles having aerodynamic particle sizes from below 0.01-100 µg and larger sources of particulate matter can be manmade or natural. Some particulates occur naturally, originating from volcanoes, dust storms, forest & grassland fires, living vegetation, and sea spray. Human activities, such as the burning of fossil fuels in vehicles, power plants and various industrial processes also generate significant amounts of particulates. Averaged over the globe, *anthropogenic* aerosols—those made by human activities—currently account for about 10 percent of the total amount of aerosols in our atmosphere. Increased levels of fine particles in the air are linked to health hazards such as heart disease, altered lung function and lung cancer.

Anthropogenic sources (human activity) mostly related to burning different kinds of fuel

- "Stationary Sources" --- include stacks emissions of power plants, industries and waste incinerators, as well as furnaces and other types of fuel-burning heating devices etc.
- "Mobile Sources" --- include motor vehicles, marine vessels, aircraft and the effect of sound etc.
- Chemicals, dust and controlled burn practices in agriculture and forestry management --- Controlled or prescribed burning is a technique sometimes used in forest management, farming, prairie restoration or greenhouse gas abatement. Controlled burning stimulates the germination of some desirable forest trees, thus renewing the forest.

Natural sources

- Dust from natural sources, usually large areas of land with little or no vegetation.
- Radon gas from radioactive decay within the Earth's crust. Radon is a colorless, odorless, naturally occurring, radioactive noble gas that is formed from the decay of radium. It is considered to be a health hazard. Radon gas from natural sources can accumulate in buildings, especially in confined areas such as the basement and it is the second most frequent cause of lung cancer, after cigarette smoking.
- Smoke and carbon monoxide from wildfires.
- Vegetation, in some regions, emits environmentally significant amounts of VOCs on warmer days. These VOCs react with primary anthropogenic pollutants—specifically, NO_x, SO_2, and anthropogenic organic carbon

compounds—to produce a seasonal haze of secondary pollutants.
- Volcanic activity --- which produce sulfur, chlorine, and ash particulates

The capacity of particulate matter to produce adverse health effects in humans depends on its deposition in the respiratory tract. Particle size, shape, and density affect deposition rates. The most important characteristics influencing the deposition of particles in the respiratory system are size and aerodynamic properties (composition).

Characterization of SPM is mean by particle size distribution and composition of particulate matters.

Particle Size Categorization:

Among the most common categorizations imposed on particulates are those with respect to size, referred to as fractions. As particles are often non-spherical, there are many definitions of particle size. The most widely used definition is the aerodynamic diameter. PM diameters range from less than 10 nanometers to more than 10 micrometers. These dimensions represent the continuum from a few molecules up to the size where particles can no longer be carried by a gas. The notation PM_{10} is used to describe particles of 10 micrometers or less and $PM_{2.5}$ represents particles less than 2.5 micrometers in aerodynamic diameter. These are also sometimes referred to with other equivalent numeric values. Everything below 100 nm, down to the size of individual molecules is classified as **ultrafine particles (UFP or UP)**. PM_{10}-$PM_{2.5}$ is the difference of PM_{10} and $PM_{2.5}$, so that it only includes the coarse fraction of PM_{10}.

Fraction	**Size range**
PM_{10} (thoracic fraction)	<=10 µg
$PM_{2.5}$ (respirable fraction)	<=2.5 µg
PM_1	<=1 µg
Ultrafine (UFP or UP)	<=0.1 µg
PM_{10}-$PM_{2.5}$ (coarse fraction)	2.5 µg – 10 µg

Composition of SPM

The composition of SPM depends on their sources. Wind-blown mineral dust tends to be made of mineral oxides and other material blown from the Earth's crust; this aerosol is light-absorbing. Sea salt is considered the second-largest contributor in the global aerosol budget, and consists mainly of sodium chloride originated from sea spray; other constituents of atmospheric sea salt reflect the composition of sea water, and thus include magnesium, sulfate, calcium, potassium, etc. In addition, sea spray aerosols may contain organic compounds, which influence their chemistry.

Secondary particles derive from the oxidation of primary gases such as sulfur and nitrogen oxides into sulfuric acid (liquid) and nitric acid (gaseous). The SPM may have an anthropogenic origin (from fossil fuel combustion) and a natural biogenic origin. In the presence of ammonia, secondary aerosols often take the form of ammonium salts; i.e. ammonium sulfate and ammonium nitrate (both can be dry or in aqueous solution); in the absence of ammonia, secondary

compounds take an acidic form as sulfuric acid (liquid aerosol droplets) and nitric acid (atmospheric gas). Secondary sulfate and nitrate aerosols are strong light-scatters. This is mainly because the presence of sulfate and nitrate causes the aerosols to increase to a size that scatters light effectively.

Organic matter can be either primary or secondary, the latter part deriving from the oxidation of VOCs; organic material in the atmosphere may either be biogenic or anthropogenic. Organic matter influences the atmospheric radiation field by both scattering and absorption. Another important aerosol type is constituted of elemental carbon (also known as black carbon) this aerosol type includes strongly light-absorbing material. Organic matter and elemental carbon together constitute the carbonaceous fraction of aerosols.

The chemical composition of the aerosol directly affects how it interacts with solar radiation. The chemical constituents within the aerosol change the overall refractive index. The refractive index will determine how much light is scattered and absorbed.

OBJECTIVE OF STUDY:

Raipur and Raigarh in Chhattisgarh state have witnessed high industrial growth resulting into heavy air pollution in these cities. These areas have mainly sponge iron industries contributing particulate matters in the ambient air. Health related complaints have been lodged with state/central authorities. Many studies have been carried out to study the pollution being increased by industrial growth in these cities. For further study the impact of high industrialization the project is taken up to study the SPM composition. As these areas are witnessed high industrial growth specific in sponge iron sector, the study is targeted to evaluate heavy metal composition present in the SPM fractions. The study aimed only to find out percentage of heavy metals present in SPM.

STUDY AREAS:

A) Raipur

Raipur is the capital city of the state of Chhattisgarh and situated at 21.14°N-81.38°E latitudes. The city is the administrative headquarters of Raipur District. As per census of India, 2011 the population of the city is 7,00,113. Raipur is located near the center of a large plain at an elevation of 298.15 meters from MSL, sometimes referred as the "rice bowl of India", where hundreds of varieties of rice are grown. The Mahanadi River flows to the east of the city Raipur, and the southern side has dense forests. The Maikal Hills rise on the north-west of Raipur; on the north, the land rises and merges with the Chota Nagpur Plateau, which extends north-east across Jharkhand state. On the south of Raipur lies the Baster Plateau. Raipur has a tropical wet and dry climate, temperatures remain

moderate throughout the year, except from March to June, which can be extremely hot. The city receives about 1,300 millimeters (51 in) of rain, mostly in the monsoon season from late June to early October. Winters last from November to January and are mild, although lows can fall to 5 °C (41 °F).

It has mix climate where as more towards hotter side, summer are extremely hot and at times the mercury may rise to 47°C.

Traditionally, Raipur's economy has been based on agricultural-processing and saw-milling. The traditional face of city has changed with Raipur becoming an important regional commercial and industrial destination for the coal, power, steel and aluminium industries. Raipur is among the richest cities and India's biggest iron market; there are about 200 steel rolling mills, 500 agro-industries and more than 47 sponge iron plants. There are more than 800 rice milling plants, and all major and cement manufacturing industry located near the city.

The list of industries provided by CECB is enclosed at Annexure.

B) Raigarh

Raigarh city is the administrative headquarter of Raigarh district located at 21.9°N83.4°E. It has an average elevation of 215 meters (705 feet). As per census of India, 2011 the population of the city is 1,15,908. Kelo River flows through the city, which is one of the water sources to it. The minimum - maximum temperature range is 29.5 - 49 °C in summer and 8 - 25 ° C in winter.

Raigarh is famous for its 'kosa' or tasar (a kind of fine silk created by the silk worm feeding on mulberry fruit). Tendupatta collection is one of major source of economy for villagers; Raigarh District is one of major producer of rice. It has transformed into a growing industrial hub for the steel market. Presently 24 sponge iron plant are located in and around the city producing around 12,360 TPD of sponge iron. M/s Jindal Steel and Power Limited, world's one of the largest sponge iron and steel plant is also situated near the city. The list of industries around the city is enclosed at Annexure.

HEAVY METALS IN AMBIENT AIR

Pollutants introduced into the atmosphere by human activities include NO_x, SO_3, dioxins and heavy metals. Exposure to heavy metals can cause a range of human disorders and ecological damage. Arsenic, cadmium, nickel, lead and ferrous, for example, are known to be carcinogenic. Heavy metals enter the environment in a variety of ways, with airborne emissions being of particular concern. Once introduced into the atmosphere, pollutants are able to travel great distances from their original source, transferring contaminants to ecosystems far and wide.

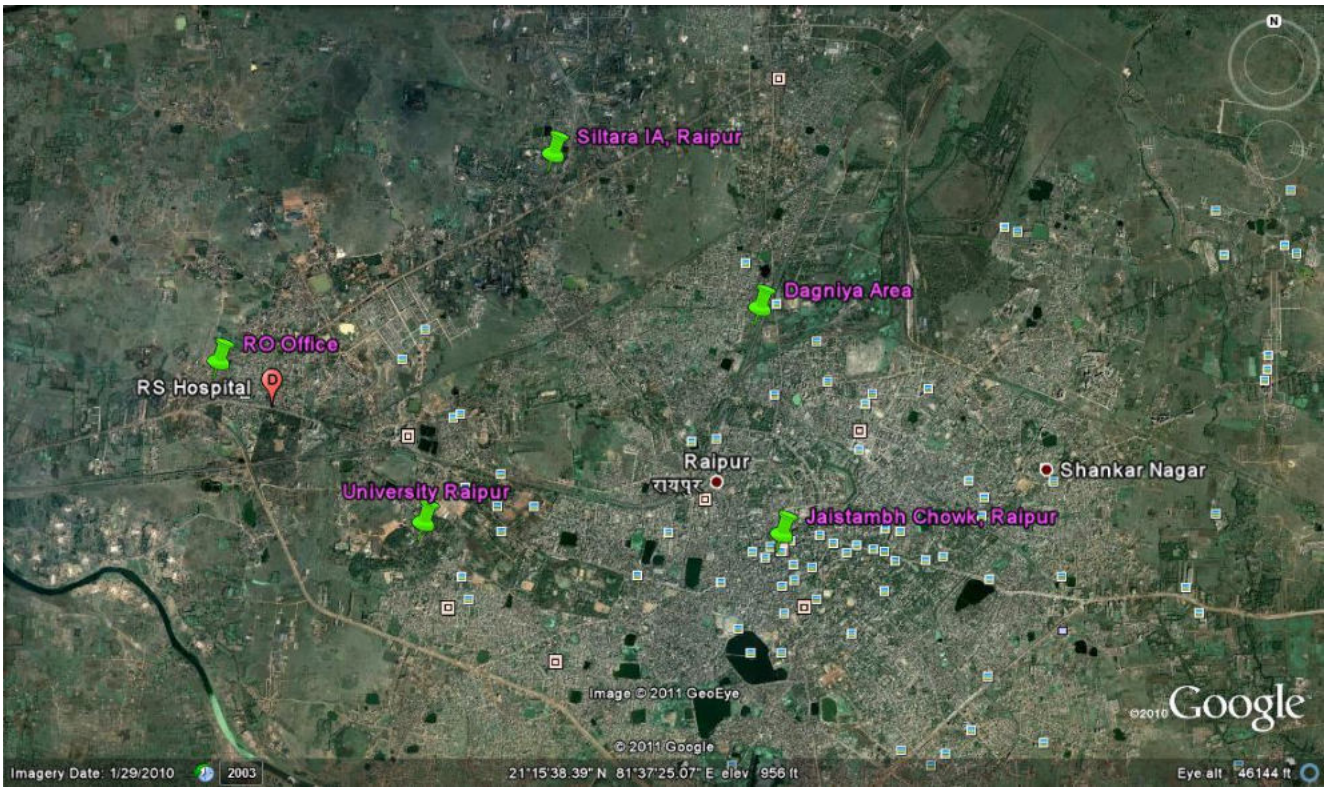
METHODOLOGY:

Sampling: Particulate sampling on filters are the most practical method currently available to characterize the sizes and chemical constituents of SPM and their sub-fractions. The SPM samples are collected on EPM – 2000 filter paper through High Volume samplers, from five different locations representing residential, industrial & commercial locations. The 24 hrs samples are collected by keeping sampler inlet at about 3mts above ground level so that emissions of low height local sources is captured but undue influence of larger size air borne local dust is avoided.

Sampling Locations: Five locations are selected in both the cities to study the presence of heavy metals in the Ambient Air.

A. Raipur

Five monitoring sites are selected. All the five locations are as shown in the picture.



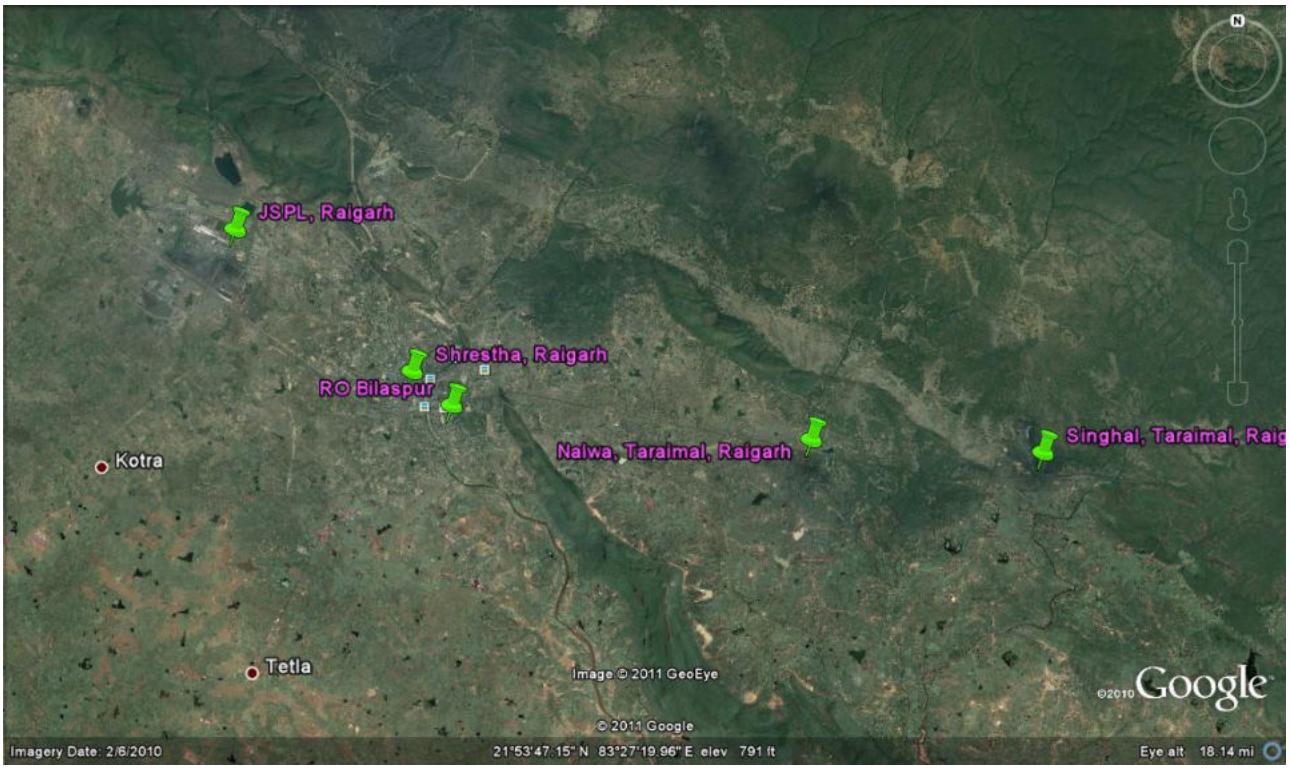
The sampler was placed near M/s Neco Jaiswal Ltd in Siltara industrial Area. The other four locations – RO Office (Tatibandh), University, Daganiya Area and Jaistambh Chowk is selected to study the impact of heavy metal emissions, if any from Siltara Industrial Area.

The 24 Hr samples were collected on October 10-11, 2010.

During the sampling period ambient temperature was in between 23 – 32^{0}C while the average wind speed was 1.1 Km/hr and the prominent wind direction was North-East.

B. Raigarh

The location selected to study the Heavy Metal emissions are as shown in the picture.

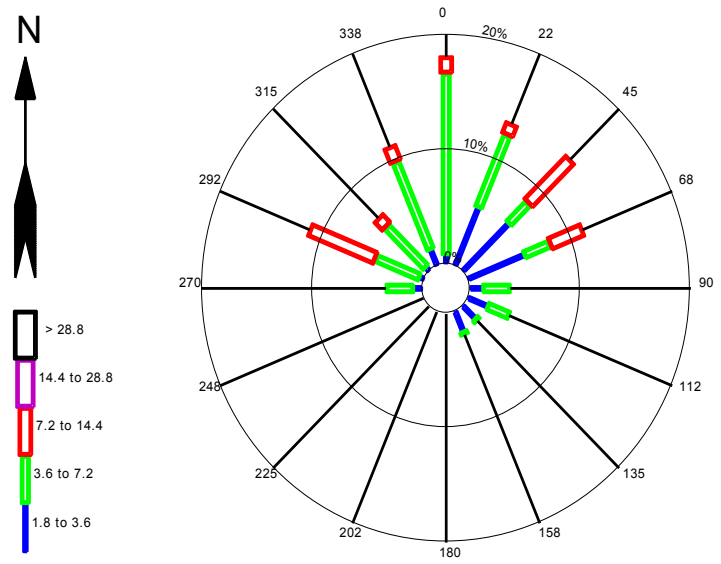


One sampler was set at M/s Jindal Steel and Power Ltd, situated in NW direction of Raigarh city. The other two samplers are placed near M/s Nalwa Steel Ltd in Taraimal Industrial Area and near M/s Singhal Steel in newly established O P Jindal industrial Park. Two HVS are set in city areas at T V Tower Road (RO Office) mainly residential area and near Hotel Shrestha representing commercial location.

As the city and industrial areas are placed horizontally from west to east these appropriate locations are finalized for sampling.

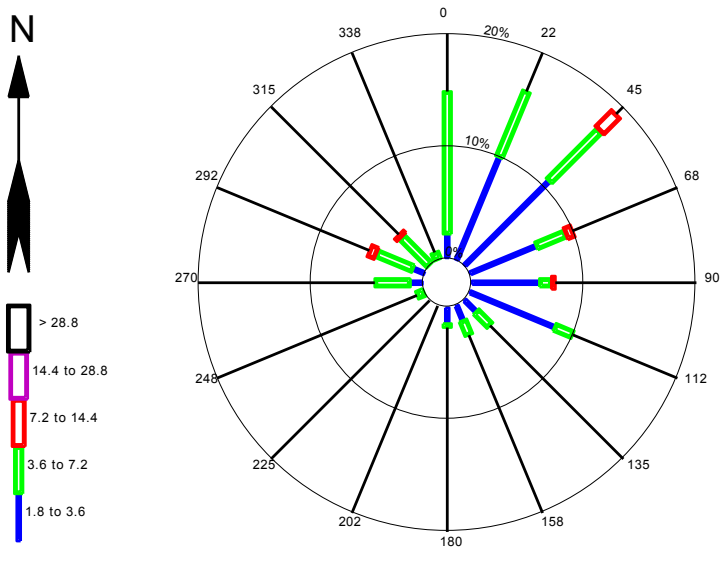
The samples are collected on February 01-02, 2011. During the monitoring days the ambient temperature was between 20.5 – 32.5 ^{0}C (01.02.2011) and 18.8-31.0^{0}C (02.02.2011) while the wind speed was in between 0.5-9.6 m/s on 01.02.2011 & 0.4-11.6 m/s on 02.02.2011. During the monitoring days NE is the prominent wind direction. The wind rose diagram on February 01 &02, 2011 is as given below

Wind rose diagram during 00.00 – 24:00 hrs on February 01, 2011



3.82% calm
100.0% Valid Data present.

Wind rose diagram during 00.00 – 24:00 hrs on February 02, 2011



1.74% calm
100.0% Valid Data present.

Analysis: One fourth portion of the filter paper is digested in concentrated nitric acid. The content was filtered through Whattman filter paper and final volume made up to 25 ml by Distilled water. The filtrate was examined for the concentration of Fe, Zn, Cu, Pb, Mn, Ni, Cd and Cr by GBC Avanta, AAS and procedure followed as per methodology described in APHA manual.

RESULTS AND DISCUSSION:

Only four heavy metals (Fe, Ni, Mn & Ni) are majorly detected in the Ambient Air. And remaining heavy metals are below the detectible range. All the values noted in the section are in $\mu g/m^3$ except the percentile numbers.

a. RAIPUR: The eight hourly SPM and Heavy Metal values are tabulated in Table – 01.

TABLE – 01

Location	Time	SPM	Fe	Ni	Mn	Zn	THM	%HM
RO Office, Raipur	06:00-14:00	72	1.47	0.098	0.09	0.038	1.70	2.36
	14:00-22:00	105	1.76	0.047	0.05	0.02	1.88	1.79
	22:00-06:00	103	1.31	0.037	0.03	0.008	1.39	1.34
University Raipur	06:00-14:00	128	2.92	0.05	0.11	0.017	3.10	2.42
	14:00-22:00	254	5.19	0.026	0.16	0.018	5.39	2.12
	22:00-06:00	391	4.12	0.011	0.18	0.016	4.33	1.11
Daganiya, Raipur	06:00-14:00	304	3.22	0.017	0.16	0.12	3.52	1.16
	14:00-22:00	282	3.27	0.028	0.15	0.16	3.61	1.28
	22:00-06:00	96	0.78	0.015	0.025	0.04	0.86	0.90
Siltara IA (NECO) Raipur	06:00-14:00	293	5.54	0.006	1.14	0.58	7.27	2.48
	14:00-22:00	310	2.56	0.005	0.063	0.08	2.71	0.87
	22:00-06:00	359	6.78	0.009	1.31	0.37	8.47	2.36
Jaistambh Chowk Raipur	06:00-14:00	97	1.1	0.003	0.03	0.02	1.15	1.19
	14:00-22:00	105	1.23	0.017	0.04	0.01	1.30	1.24
	22:00-06:00	104	1.89	0.003	0.04	0.013	1.95	1.87

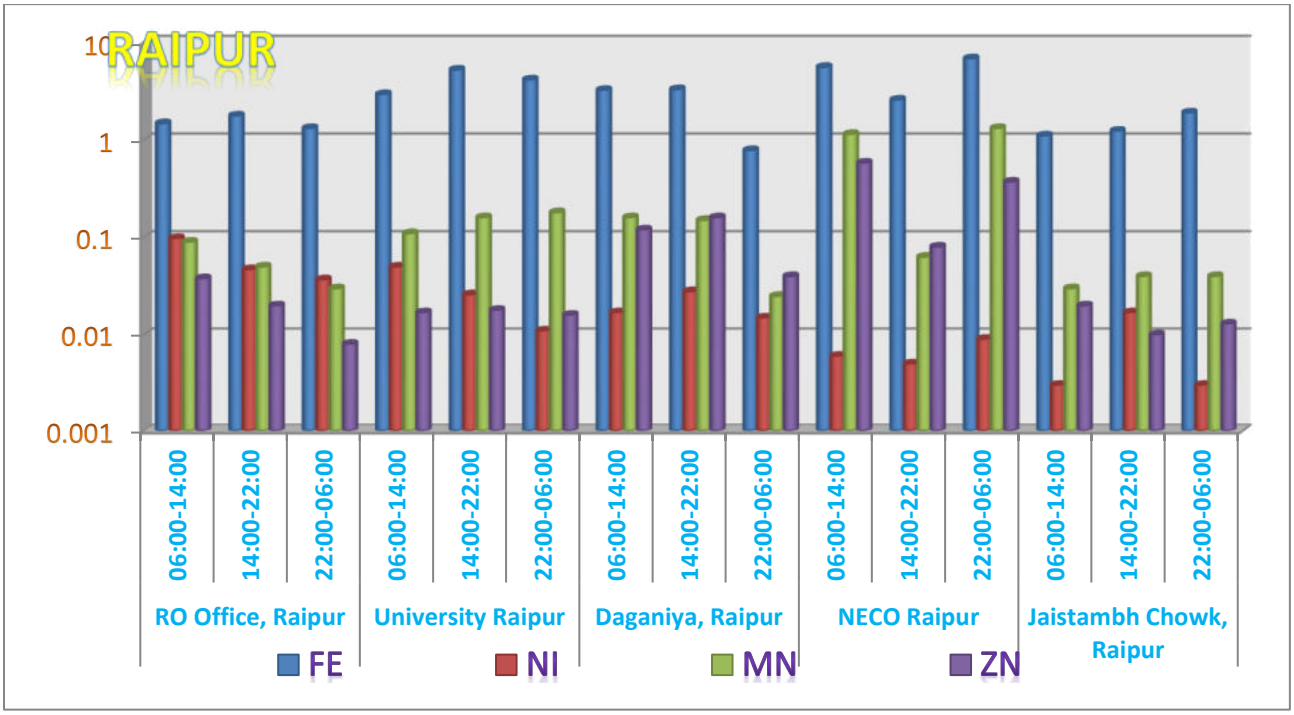
The table shows 8 hourly concentrations of SPM, Fe, Ni, Mn & Zn. The total concentrations off these heavy metals are tabulated in THM columns, while %HM represents percentage of heavy metal concentrations present in the SPM fraction.

The sampling was interrupted by intermediate rain. But as the study is not targeting to find out pollution load in the area. And only with limited objective to find out percentage of heavy metals in SPM, the objective was not much affected by it.

Iron is the major part of heavy metals present in the SPM. The heavy metals are in the range of 0.87-2.48 % of SPM, on eight hourly basis.

The graphical presentation of heavy metal concentrations is give in the Chart – 01.

CHART – 01



The relation between SPM and Heavy Metal on 24 hourly (average values) basis are presented in Table – 02.

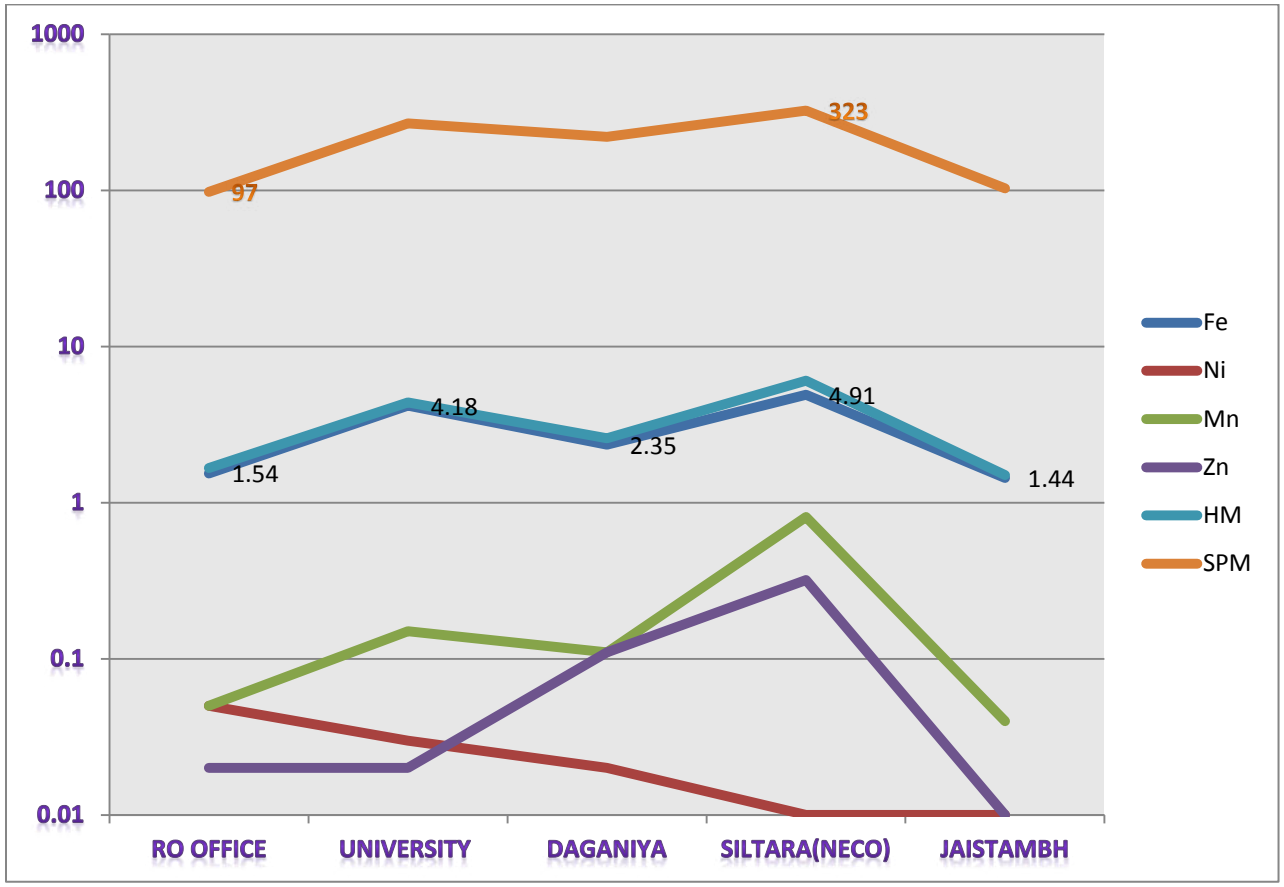
TABLE – 02

Locations	Fe	Ni	Mn	Zn	HM	SPM	% HM
RO Office, Raipur	1.54	0.05	0.05	0.02	1.67	97.73	1.71
University, Raipur	4.18	0.03	0.15	0.02	4.38	268.53	1.63
Daganiya, Raipur	2.35	0.02	0.11	0.11	2.58	220.36	1.17
NECO, Raipur	4.91	0.01	0.81	0.32	6.05	323.18	1.87
Jaistambh Chowk, Raipur	1.44	0.01	0.04	0.01	1.50	102.96	1.46

On 24 hourly average basis, heavy metals are in the range of 1.17-1.87 % of total SPM.

The co-relations between heavy metals detected and SPM is presented below in Chart – 02.

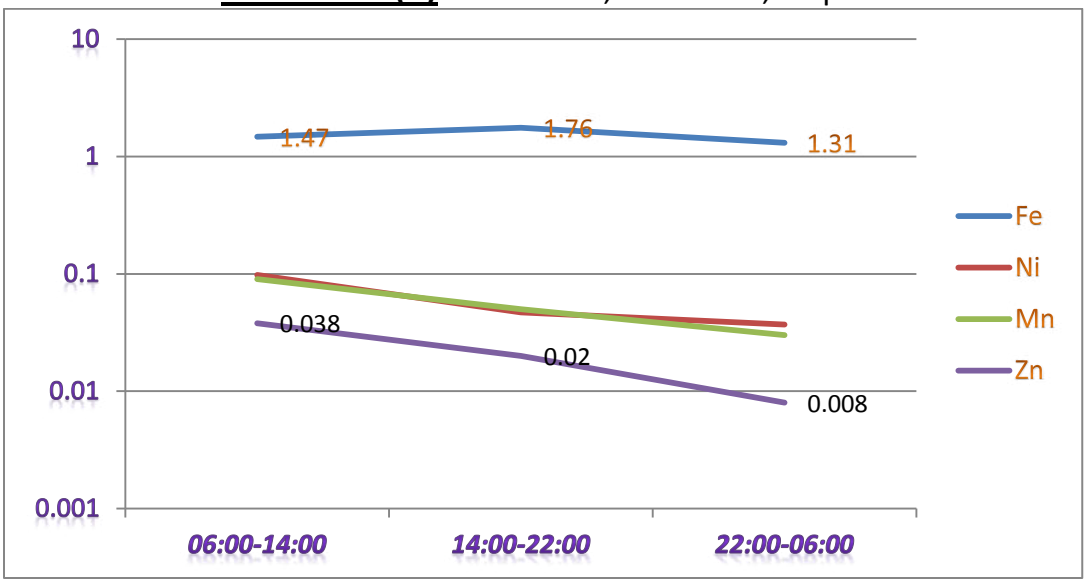
CHART – 02



In the light of value of SPM and mass of metals, it was observed that Siltara is the most polluted location and Jaistambh chowk receives least pollution. The pollution emitted from Siltara is dispersed in downwind directions. And least pollution receives at Jaistambh chowk with reference to Heavy Metals. Iron is the major part of heavy metals detected. The Fe may be possibly emitting from sponge iron units in Siltara area and dispersing in the ambient air.

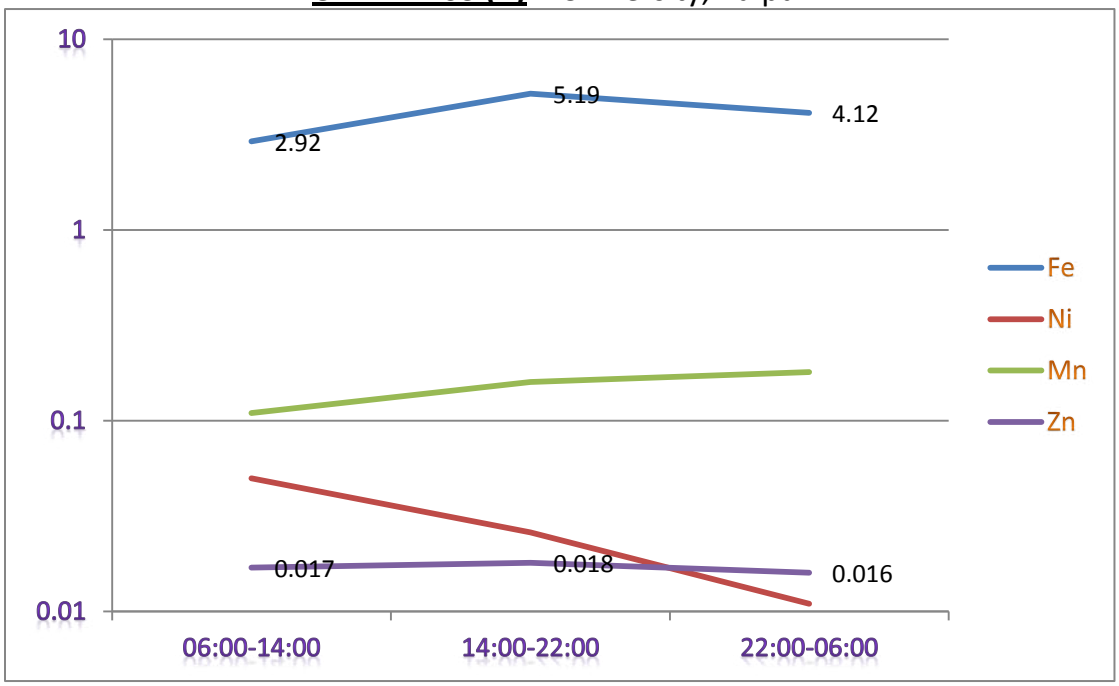
THE HEAVY METAL PATTERNS AT VARIOUS LOCATIONS WITH RESPECT TO TIME ARE PRESENTED IN CHARTS – 03 (A-E)

CHART – 03 (A) – RO Office, Tatibandh, Raipur



The behavior of heavy metal concentrations at Tatibandh Area is showing similar patterns. The heavy metal concentrations are higher during the morning period. The wind direction carrying pollution from industrial areas is the major cause for change in the concentrations. The station is on downwind side of Siltara industrial Area. The impact of pollution from Urla Industrial Area is also seen in the results.

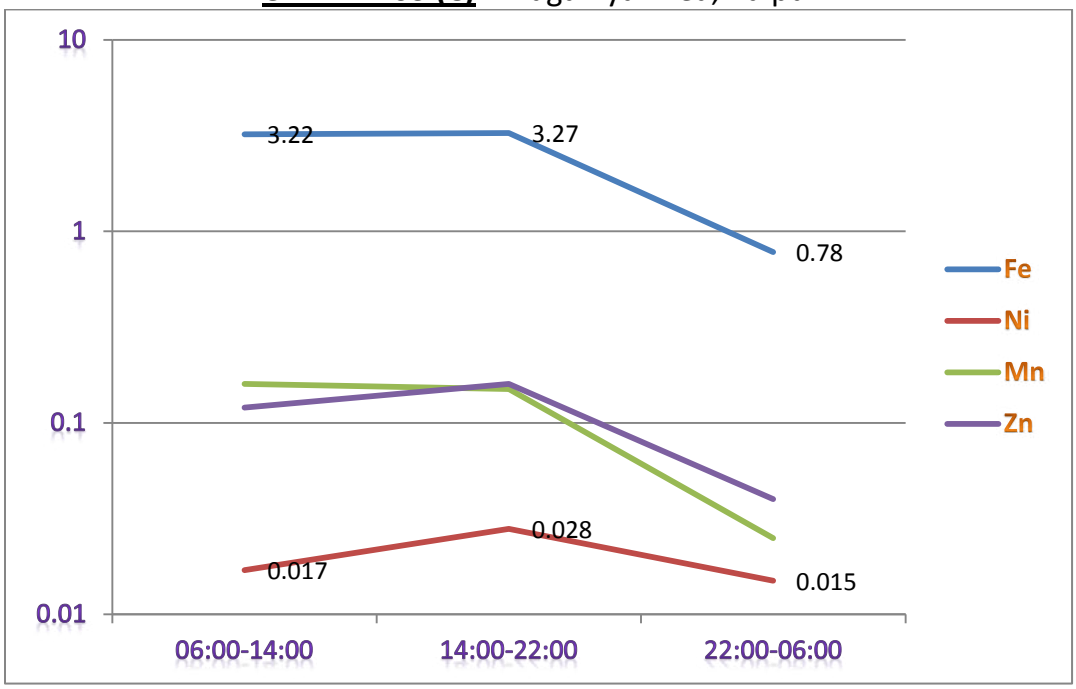
CHART – 03 (B) – University, Raipur



The heavy metal concentrations are higher in the evening. The Iron is the major part of heavy metal content touching 5.19 µg/m^3. The station is on downwind side of Siltara

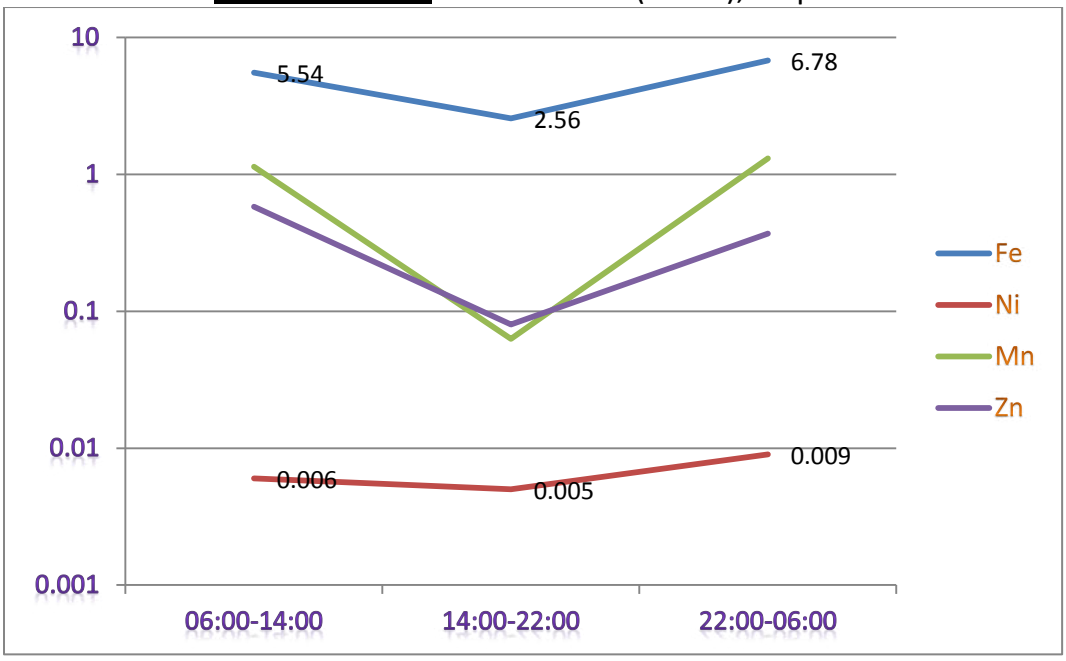
industrial Area and receives the dispersed pollution emitted from the industries. This station also receives pollution from Urla Industrial Area.

CHART – 03 (C) – Daganiya Area, Raipur



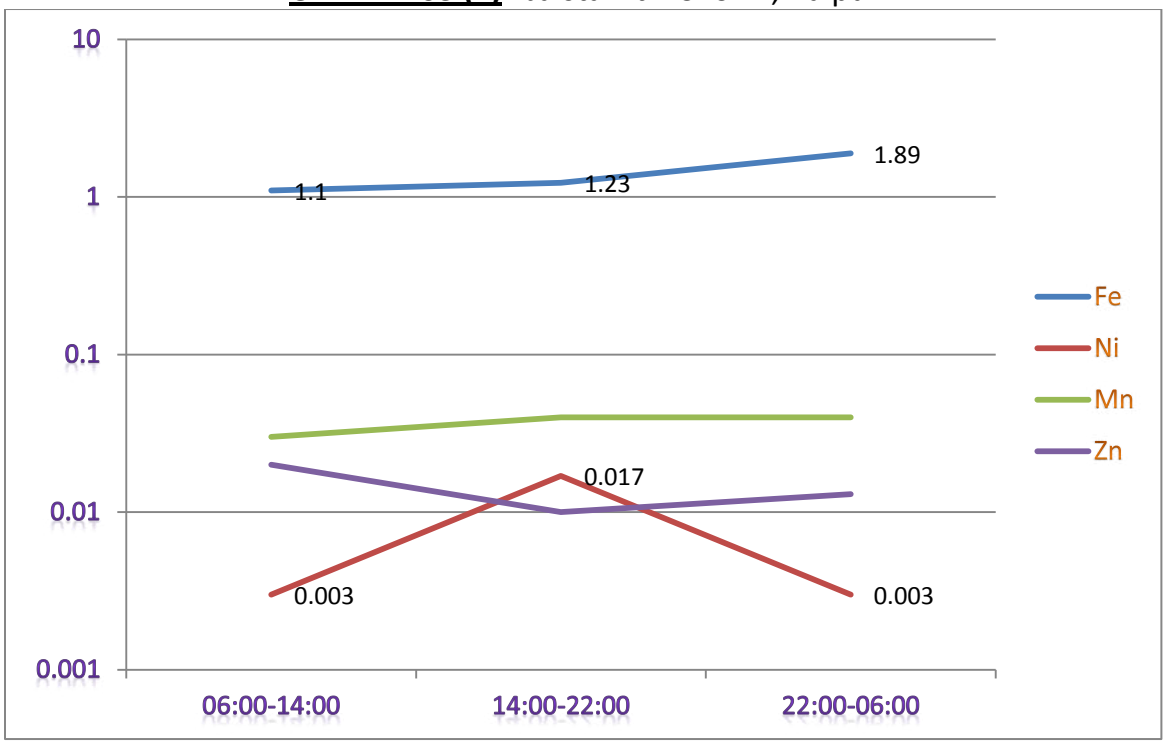
The station is at approximate same distance that of Tatibandh & University with respect to the Siltara Industrial Area. The concentrations of the heavy metals are higher in morning and evening time.

CHART – 03 (D) – Siltara Area (NECO), Raipur



The Silatara Industrial Area is the hub of sponge iron industries. The area is contributing most of the pollution load in Ambient Air. The station is considered as the pollution generator station. The concentrations of heavy metals are lesser during evening. The unstable environmental condition shall carrying the pollutants toward Tatibandh & University areas, and the ground level concentrations in this area during evening is comparatively less.

CHART – 03 (E) –Jaistambh Chowk, Raipur



The station is at highest distance in comparison with other stations from the Siltara Industrial Area. As the pollution are get diluted before travelling to this area, the station is comparatively least polluted with respect to the heavy metal concentrations. The heavy metal concentrations are higher at night during stable environmental conditions.

THE HEAVY METAL PATTERNS AT VARIOUS DURATIONSWITH RESPECT TO LOCATIONSARE PRESENTED IN CHARTS – 04 (A-C)

CHART – 04 (A) – Pattern of Heavy Metals concentrations during 06:00 AM – 02:00 PM

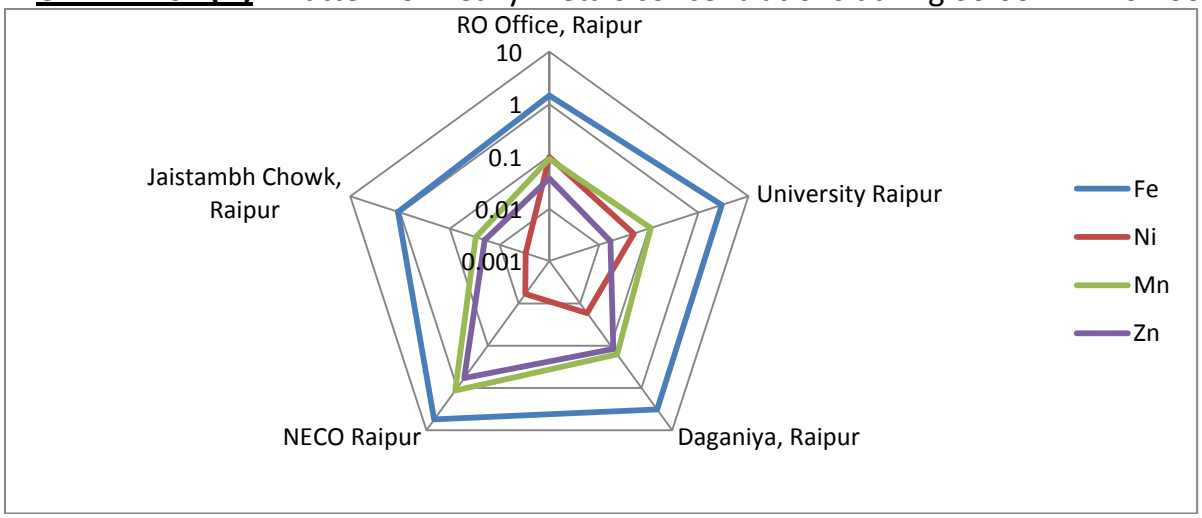


CHART – 04 (A) – Pattern of Heavy Metals concentrations during 02:00 PM – 10:00 PM

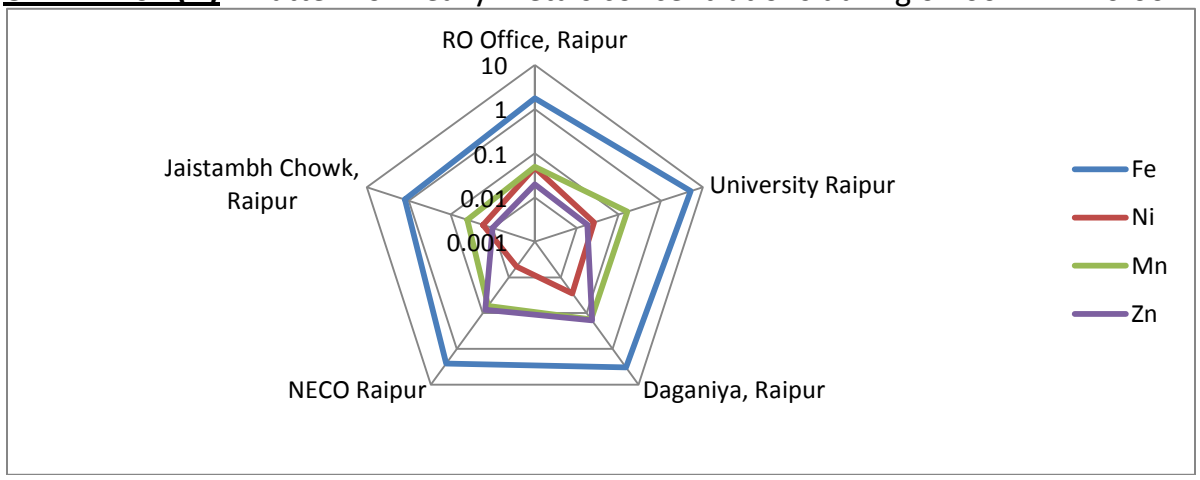
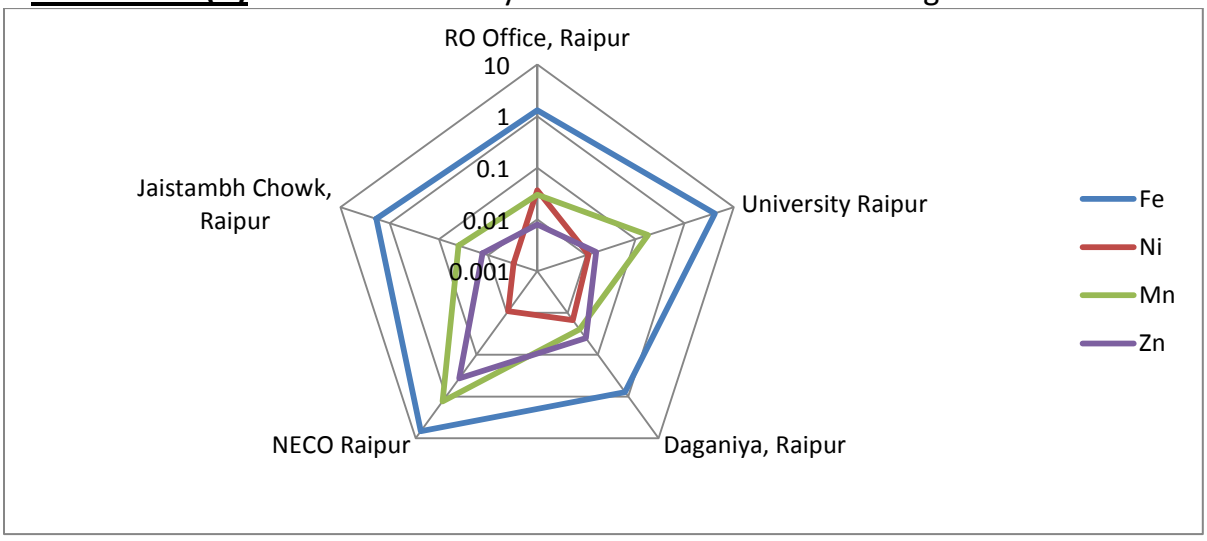


CHART – 04 (A) – Pattern of Heavy Metals concentrations during 10:00 PM – 06:00 AM



The pollution radar diagrams are showing the behavior of heavy metals at various time periods. At all the time the concentration of heavy metals at Siltara Industrial Area (NECO) is higher, the station is placed in the cluster of sponge iron industries. Based of wind directions the receptor stations receive pollution of different levels. The impact of iron content is significant in the city. The sponge iron industry is the major source of emissions of iron particles.

The Heavy Metal and SPM pattern clearly indicating that the ambient air quality in the Raipur City is getting degraded with respect to Heavy Metal (mainly Iron) concentration which is a major point of concern.

B. RAIGARH

The analysis results of the samples collected at five locations on eight hourly basis is tabulated at Table – 03. Only four heavy metals – Fe, Ni, Mn & Zn are detected in the SPM fractions collected from Raigarh city.

TABLE – 03

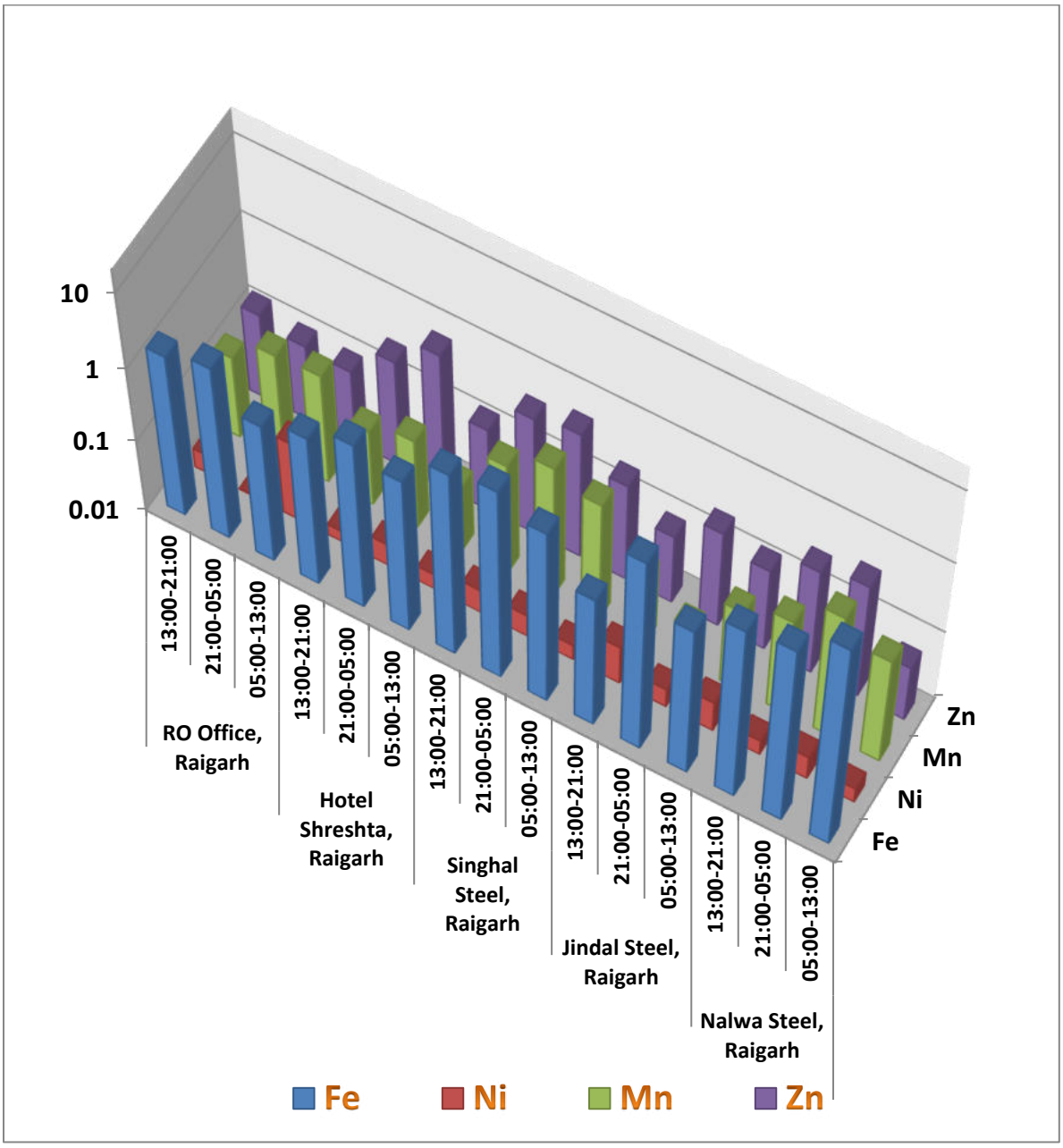
Location	Time	SPM	Fe	Ni	Mn	Zn	THM	%HM
RO Office, Raigarh	13:00-21:00	465	1.65	0.02	0.13	0.15	1.94	0.42
	21:00-05:00	516	2.37	0.01	0.29	0.11	2.78	0.54
	05:00-13:00	375	0.82	0.12	0.31	0.10	1.35	0.36
Hotel Shreshta, Raigarh	13:00-21:00	495	1.18	0.01	0.11	0.28	1.58	0.32
	21:00-05:00	601	2.03	0.02	0.17	0.72	2.94	0.49
	05:00-13:00	318	1.38	0.02	0.08	0.14	1.62	0.51
Industrial Park (Singhal Steel), Raigarh	13:00-21:00	862	3.67	0.02	0.35	0.42	4.46	0.52
	21:00-05:00	1123	4.69	0.02	0.68	0.54	5.93	0.53
	05:00-13:00	732	2.72	0.02	0.45	0.22	3.41	0.47
Jindal Steel, Raigarh	13:00-21:00	268	0.70	0.03	0.09	0.09	0.92	0.34
	21:00-05:00	298	5.24	0.02	0.04	0.22	5.51	1.85
	05:00-13:00	298	1.27	0.03	0.14	0.14	1.58	0.53
Taraimal IA, Nalwa Steel, Raigarh	13:00-21:00	556	2.94	0.02	0.23	0.30	3.49	0.63
	21:00-05:00	1109	3.51	0.02	0.60	0.41	4.54	0.41
	05:00-13:00	683	8.50	0.02	0.32	0.06	8.89	1.30

The 8 hourly concentrations of SPM, Fe, Ni, Mn & Zn are shown in the table. The total concentrations off these heavy metals are tabulated in THM columns, while %HM represents percentage of heavy metal concentrations present in the SPM fraction.

Iron is the major part of heavy metals present in the SPM. The total heavy metal content is in the range of 0.32-1.85 % of total SPM.

The graphical presentation of heavy metal concentrations is given in the Chart – 05.

CHART – 05



The heavy metals and SPM in the ambient air shows similar pattern. The iron is the major content of heavy metals present in SPM.

The 24 hourly average concentrations of SPM, Fe, Ni, Mn, & Zn are tabulated in Table – 04.

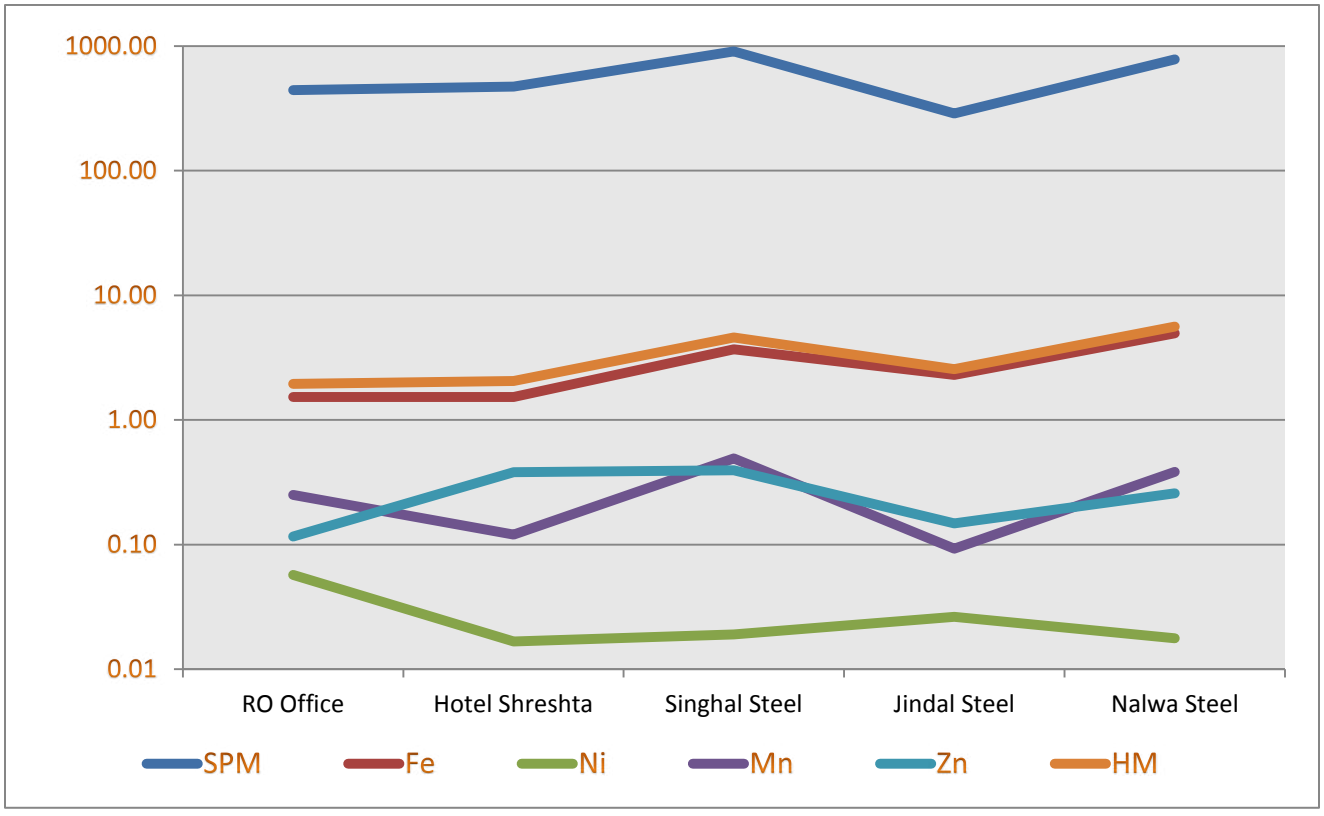
TABLE – 04

Locations	SPM	Fe	Ni	Mn	Zn	HM	% HM
RO Office	443.77	1.53	0.06	0.25	0.12	1.95	0.44
Hotel Shreshta	472.23	1.53	0.02	0.12	0.38	2.05	0.43
Singhal Steel	905.65	3.69	0.02	0.49	0.39	4.60	0.51
Jindal Steel	287.89	2.29	0.03	0.09	0.15	2.56	0.89
Nalwa Steel	783.27	4.96	0.02	0.38	0.26	5.62	0.72

Total percentile heavy metal presence in SPM on 24 hourly basis is in the range of 0.43-0.89 %. The heavy metal contents at industrial areas (Sl No 03-05) are higher than in commercial & residential areas.

The co-relation of heavy metals and SPM on the basis of 24 hourly average values are given in the Chart – 06.

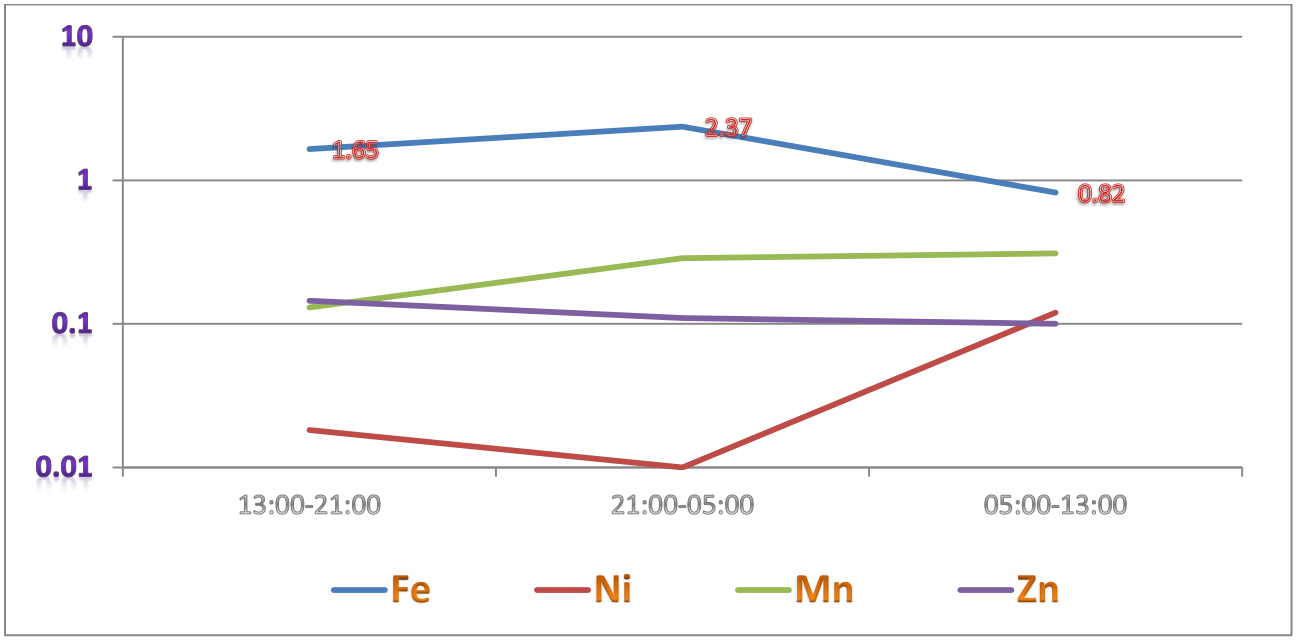
CHART – 06



The graph represents co-relation between SPM & heavy metals present in ambient air at Raigarh. The iron is the major part of heavy metals present in SPM. The behavior of SPM & total heavy metals shows similar patterns indicating the major part of SPM in ambient air is contributed by industrial pollution.

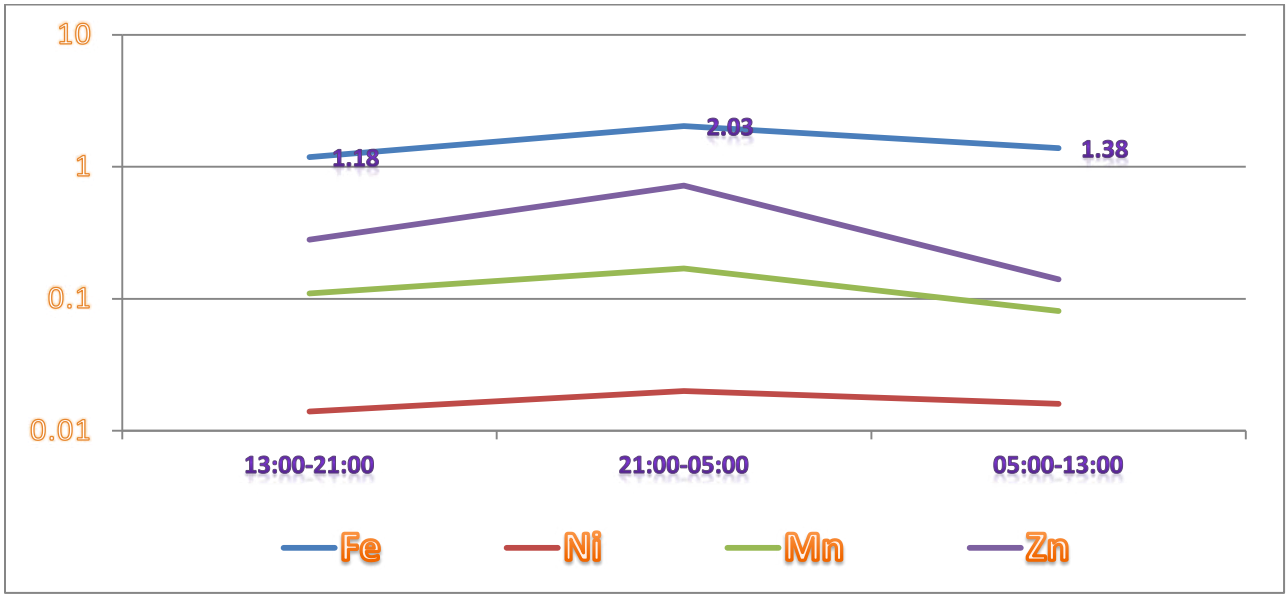
THE HEAVY METAL PATTERNS AT VARIOUS LOCATIONS WITH RESPECT TO TIME ARE PRESENTED IN CHARTS – 07 (A-E)

CHART – 07 (A)–RO Office, TV Tower Road, Raigarh



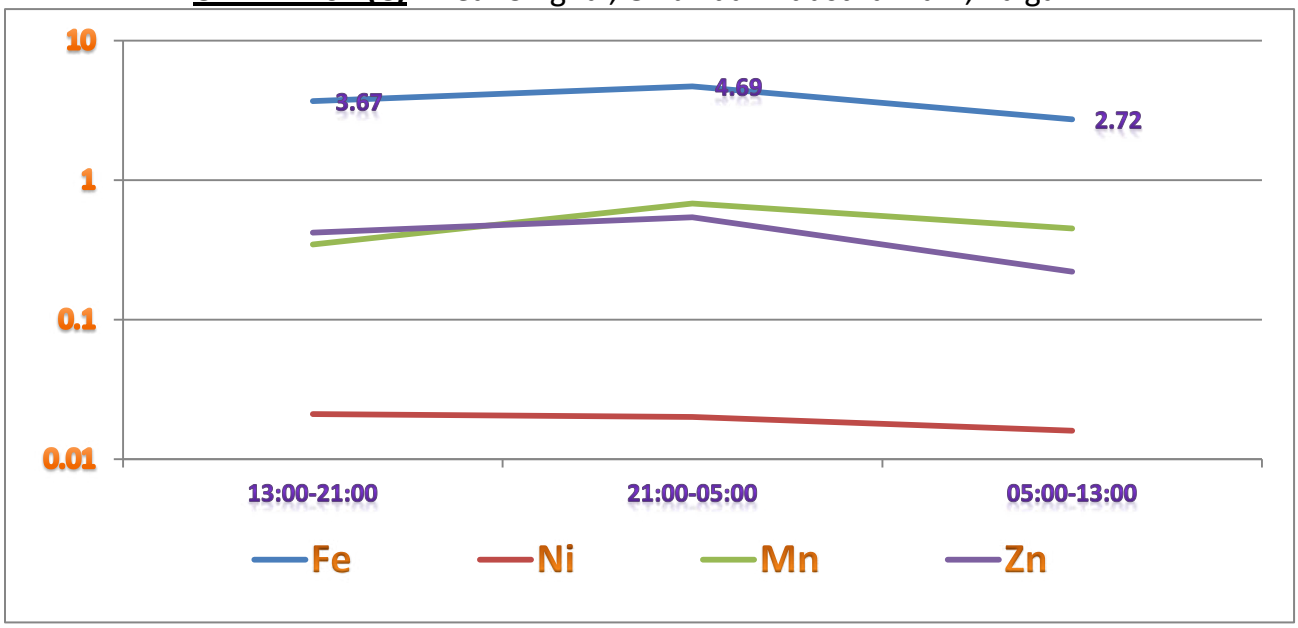
The station is located in the mid-city area and representing residential locality. The iron is the major heavy metal and found its concentration up to 2.37 µg/m^3 during night time.

CHART – 07 (B) –Near Hotel Shreshta, Raigarh



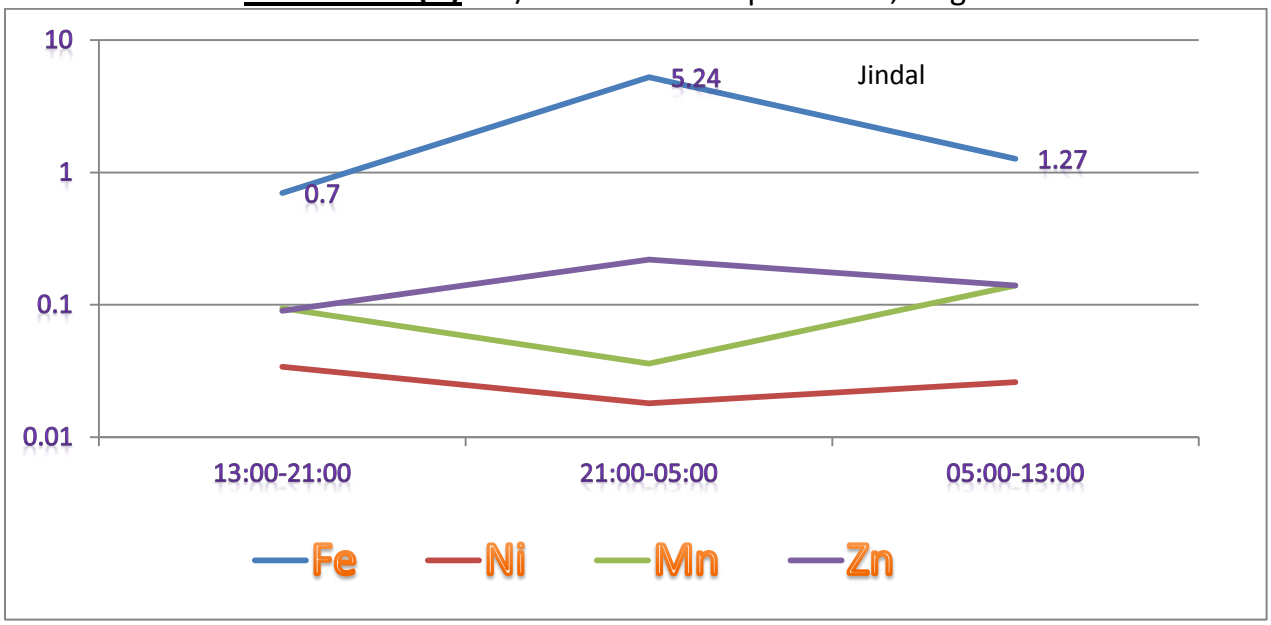
The station is representing commercial locality. The heavy metal concentrations at this stations is shown similar patterns over the time. The iron concentrations are higher during the night up to 2.03 µg/m^3.

CHART – 07 (C) –Near Singhal, OP Jindal Industrial Park, Raigarh



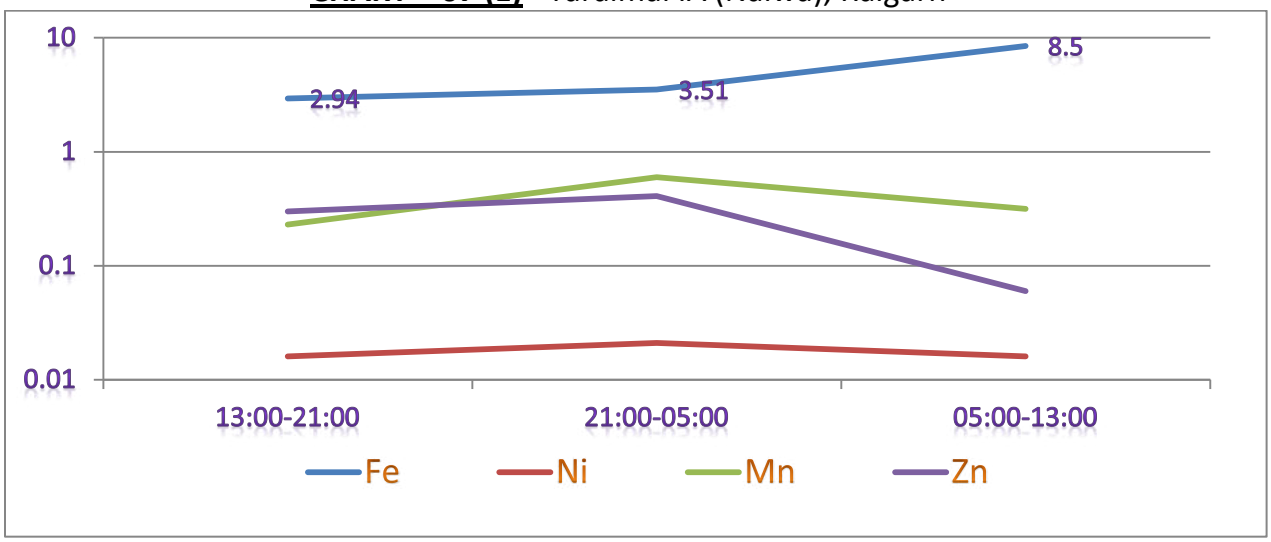
The station is located near the established Industrial Park. As sponge iron units are located in this area, the iron concentrations in SPM are higher with respect to concentration at Raigarh city. 4.69 µg/m^3 is the highest concentration found during night time.

CHART – 07 (D) –M/s Jindal Steel & power Ltd, Raigarh



The station is placed near M/s Jindal Steel & Power Ltd, India's one of the largest integrated steel plant. The higher concentration of iron is found at night time, touching up to 5.24 µg/m^3.

CHART – 07 (E) –Taraimal IA (Nalwa), Raigarh



The heavy metal concentrations in Taraimal Industrial Area are higher with respect to all other stations in Raigarh city. The iron concentrations are higher up to 8.5 µg/m^3 and the higher value of Fe is found during morning period. Heavy vehicular movement carrying raw materials are seen during morning period, and may be one of the reason for higher concentration of Fe. The concentration of other detected metals is higher during night period.

THE HEAVY METAL PATTERNS AT VARIOUS DURATIONSWITH RESPECT TO LOCATIONS ARE PRESENTED IN CHARTS – 08 (A-C)

CHART – 08 (A) Pattern of Heavy Metals concentrations during 01:00 PM – 09:00 PM

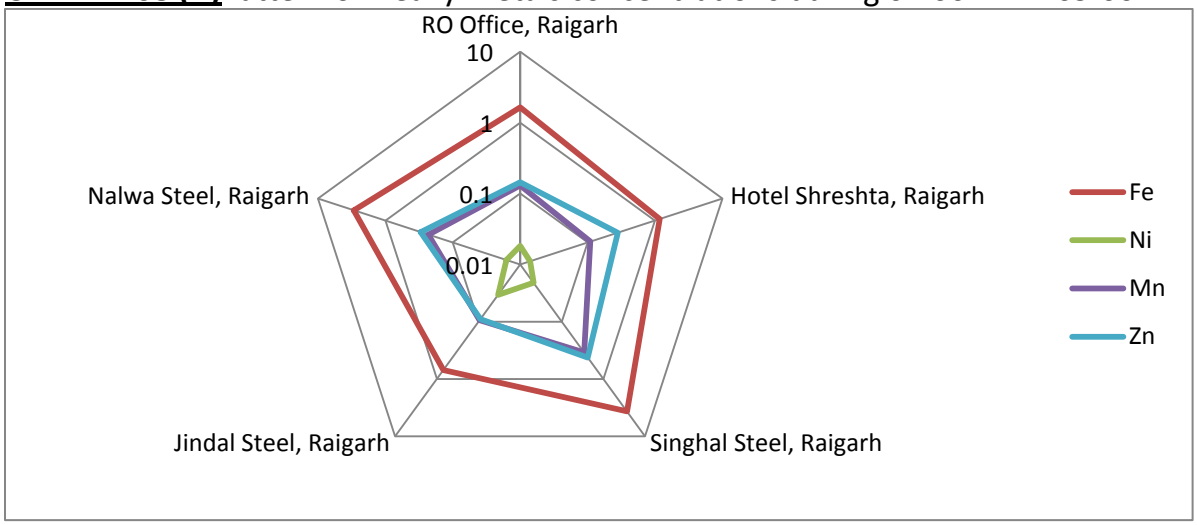


CHART – 08 (B) Pattern of Heavy Metals concentrations during 09:00 PM – 05:00 AM

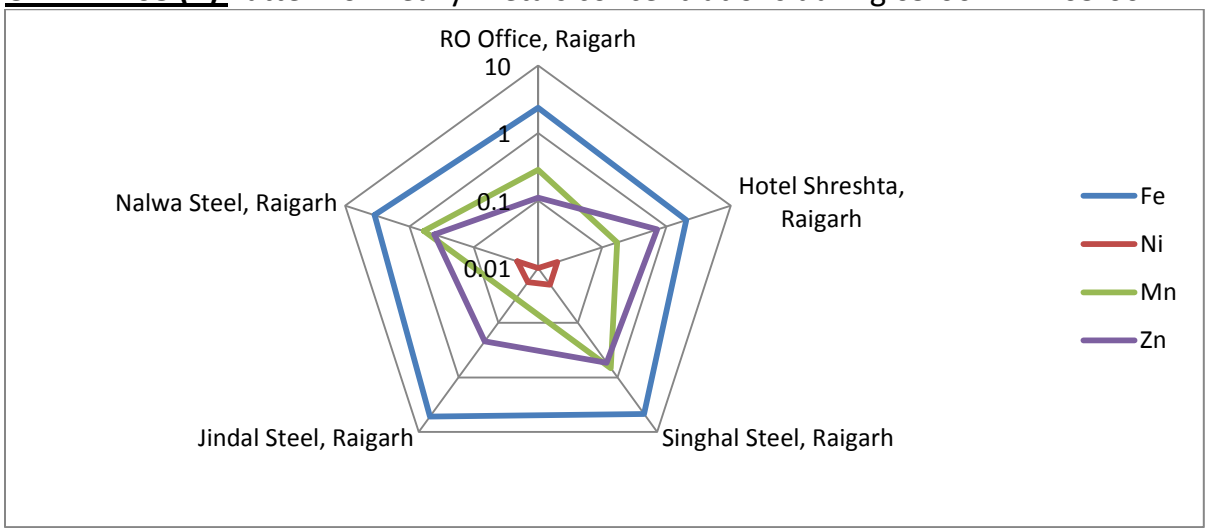
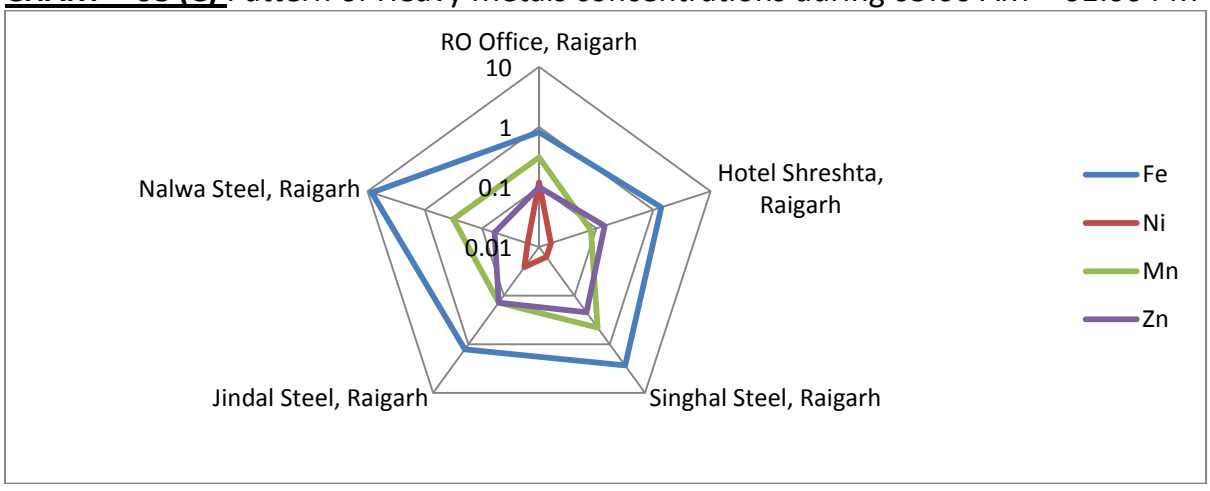


CHART – 08 (C) Pattern of Heavy Metals concentrations during 05:00 AM – 01:00 PM



The radar diagram shows the pattern of heavy metals during morning, evening and night time. The heavy metal concentrations are found higher during the night time. In general, the stable environmental condition allows environmental dust to settle down at ground level is one of the reason for higher pollution values during night. But in the case of Raigarh city the topography is the main reason for higher concentrations of pollutants during night time. The city and Industrial area is spread in NW to SE directions and having hills (forests) with height more than 30-50 m in SE direction. The pollution emitted during day time dispersed in the ambient air and carried towards hilly area in SE direction. The pollution got trapped due to height of the hills. During night, in a stable environmental conditions wind flows at lower levels towards hill and diverted back towards city areas. The reverse wind carries the trapped pollutants. This phenomenon is the major cause for increase in pollution levels during night time.

C. CONCLUSION

The study was carried out to find out the percentage of heavy metals in SPM at Raipur and Raigarh city in Chhattisgarh state.

- In Raipur city, the heavy metals were found in the range of **0.90-6.52%** of SPM, on eight hourly basis and **1.17-2.32 %** of SPM on 24 hourly average basis.
- In Raigarh city, the heavy metals are found in the range of **0.32-1.85 %** of SPM, on eight hourly basis and **0.43-0.89 %** of SPM on 24 hourly average basis.
- The heavy metals are mainly showing similar patterns with SPM and among the heavy metals. It indicates the source of emissions is same. The heavy metals and SPM are mostly emitted in to ambient air from industries. The higher values of Fe are confirming the sponge iron industries are the main contributor of ambient air pollution.
- In Raipur City, the trend shows that the pollution is generated from industries in Siltara industrial area and getting dispersed. The impact is seen in downstream towards prominent wind direction.
- In Raigarh City, topography plays major role in dispersion of pollutants. The heavy metals getting trapped near hilly areas and brought back towards the city along with reverse wind flow, causing higher metal concentrations during night time.
- The higher concentration of Fe is the matter of concern. The carrying capacity of ambient air is likely to be affected in future, if cautious steps are not initiated at this stage.

FURTHER SCOPE OF STUDIES

As the study was conducted with limited objective to study the percentage of heavy metals present in the SPM fractions, following are the areas that may requires to consider for further study:

- Detailed study of composition of SPM including cations, anions and heavy metal concentrations.
- Detailed study of particle size distribution.
- Behavior of heavy metal patterns in SPM during various seasons.
- Study of heavy metal concentrations with respect to reference and impact stations.
- Periodic study (after every 1-2 years) to asses increase/decrease of heavy metal concentrations in ambient air.