Impact of Plastic Waste Disposal on Soil and Water Quality at Lucknow Dumpsites

CENTRAL POLLUTION CONTROL BOARD
(Ministry of Environment & Forests)
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FOREWORD

The soil and groundwater has been contaminated due to indiscriminate littering and dumping of various wastes including plastic waste. The existing MSW landfill sites are mostly filled with different categories of plastic waste which persist in nature for several years specially due to its non-biodegradability. Plastic waste dumping on land causes several environmental issues like imparting infertility in soil, releasing toxic gases on burning, causing death on eating by cattle and most importantly, the additives and colours used during manufacturing processes have potential of leaching out heavy metals and other chemical compounds that may contaminate soil & ground-water quality. To study the effect of municipal and plastic waste dumping on soil and underground water, CPCB sponsored a project to Indian Institute of Toxicological Research (IITR), Lucknow to study "Impact of Plastic Waste Disposal on Soil and Water Quality at Lucknow Dumpsites". The soil and water quality data revealed that the heavy metals, chloride, phthalates etc. migrate from plastic waste into the surrounding medium because these are not chemically bound and remain present as mobile and leachable phase. The leachate can cause considerable pollution problems by contaminating the surrounding soil, ground or surface water.

I hope this report would be useful to the urban local bodies, State Pollution Control Boards and other agencies to understand the environmental issue due to improper dumping of MSW including Plastic waste. I would like to thank officials of IITR, Lucknow for completing the study. I would also like to appreciate sincere efforts made by Dr. S.K. Nigam, Additional Director, CPCB, Delhi for overall co-ordination of the study and Scientists of Zonal Office, Lucknow in assisting the field studies.

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Executive Summary

Solid waste management (SWM) is an integral part of the urban environment and planning of the urban infrastructure to ensure safe and healthy environment. While considering the promotion of sustainable economic growth, the rapid and unplanned industrialization, urbanization and population growth have resulted in proliferation of consumer articles vis a vis generation of waste.

Lucknow city is situated at the banks of river Gomti. Geographically, Lucknow city is situated at coordinates 26.85°N and 80.92°E having 2,528 km^2 area. As per 2001 census its population was approximately 27.50 lakhs generating more than 1200 tonnes per day of municipal solid waste. The purpose of the study was to assess the impact of plastic waste disposal on soil and ground water quality of Lucknow dumpsite. The following two dumpsite locations of Lucknow city: a) Ghaila, Hardoi Road and b) Dudauli, Sitapur Road have been under taken for the sampling and study.

Samples of soil and water were collected and analyzed in both pre monsoon and post monsoon seasons. It was found through the determination of Toxicity Characteristic Leaching Procedure (TCLP) that chemical moieties like heavy metals, chloride, phthalates etc. migrate from plastic waste to the surrounding medium. Since these plastic additives are not chemically bound with the polymeric chain and remain present as free and leachable phase, hence, they can migrate from plastic to the recipient medium during landfilled conditions due to physico-chemical exertion and microbial degradation. These leachates can cause considerable pollution problems by contaminating the surrounding soil, ground or surface waters.

1. Introduction

Plastics are petro-based polymer made-up of long chain of hydrocarbons and non-biodegradable. Plastics are widely used for storage and packaging of food stuffs and transportation. The usage includes disposable and reusable containers, plastic wraps, cutlery, water bottles and baby bottles. Plastic products can be easily found in human residential and occupational environments in high concentrations. After their service life, the plastic products may be landfilled where due to biotic and abiotic degradation, leaching of plastic additives i.e. heavy metals, plasticizers, stabilizers, unreacted monomers and harmful moieties of colorants occur which ultimately percolate in different segments of environment contaminates soil and water bodies.)

The toxicological effects of several plastic additives have been sporadically studied and there is a need for holistic study on impact of plastics waste disposal on soil and ground water. The aim of this study is to monitor and assess the impact of polymeric and plastic additives with special reference to heavy metals and phthalate esters on soil and water medium as they are landfilled along with municipal solid waste. An effect has been made to understand the toxicological implications due to leaching of plastic waste and to generate baseline data to draw recommendations for identifying the health risk due to the presence of heavy metals and phthalate esters migrating food chain through various polymeric and plastic additives used by plastic products manufacturing industries.

2. AIMS & OBJECTIVES

- To collect the soil and water samples from two identified dumpsite locations of Lucknow city (i.e. Dudauli and Ghaila sites) and compile the information regarding the commonly used practice for plastic waste disposal by municipal authorities and Consumers.
- To estimate the migration or leaching of heavy metals (Cd, Co, Cr, Cu, Pb, Mo, Ti and Zn) and phthalate esters in ground water and soil samples collected from landfill sites.

3. SCOPE OF THE STUDY

- To collect and identify different types of plastic products and waste from market and dumpsites such as colored plastic bags and containers and gift items, plastic crockery and multilayered plastic and find out leachability of plastic products and waste in laboratory through appropriate testing methods.
- To collect water and soil samples near the dumpsites at Lucknow.
- To **study the migrations of phthalate esters from dump sites.**
- To suggest remedial measures on use of additives in production of plastic products.

4. PLAN OF WORK

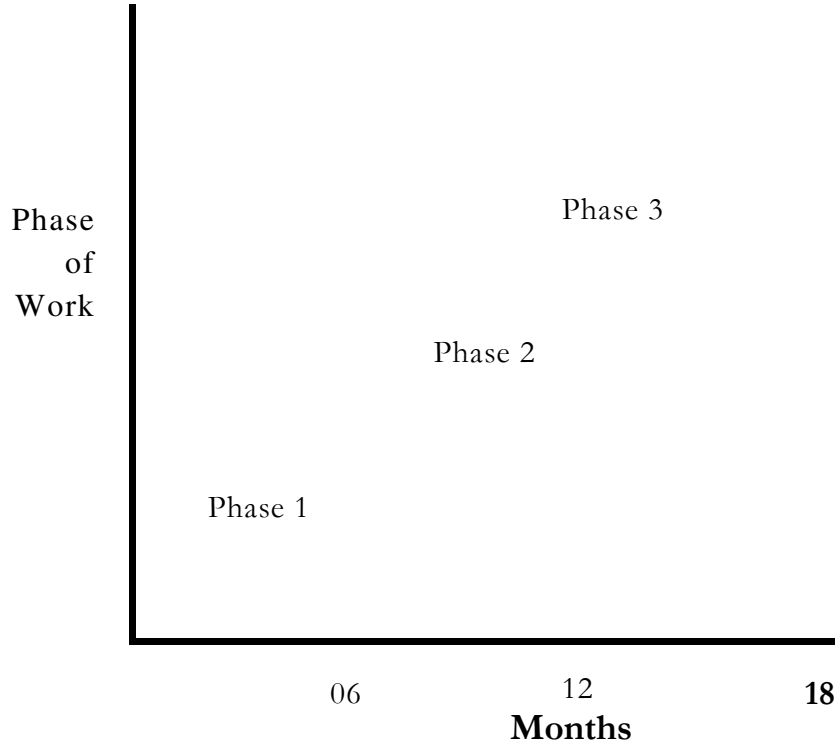


Table-1: Work Plan

Phases	Proposed Plan	Status
Phase 1:	Initiation of sample collection, procurement of chemicals and glassware, processing, preparation of reagents, standardization of method and appointment of staff.	• Control samples of and water had been analyzed during November, 08-January, 09. • Procurement of chemicals and glass wares, processing, preparation of reagents, standardization of method had been completed. • Project staff as envisaged in the project had been appointed. • Pre-monsoon sampling from Dudauli dumpsite was completed.
Phase 2:	Estimation of plastic additives viz. heavy metals and phthalates using standard procedure.	Analysis of pre-monsoon samples was done
Phase 3:	Continued the analysis of phthalates, metals etc, and interpretation of available data and compilation of report.	Post-monsoon sampling from Dudauli dumpsite was completed on September 28-30, 2009 and sampling on Ghaila dumpsite was completed on December 9-10, 2009.

5. METHODOLOGY

5.1 Sampling

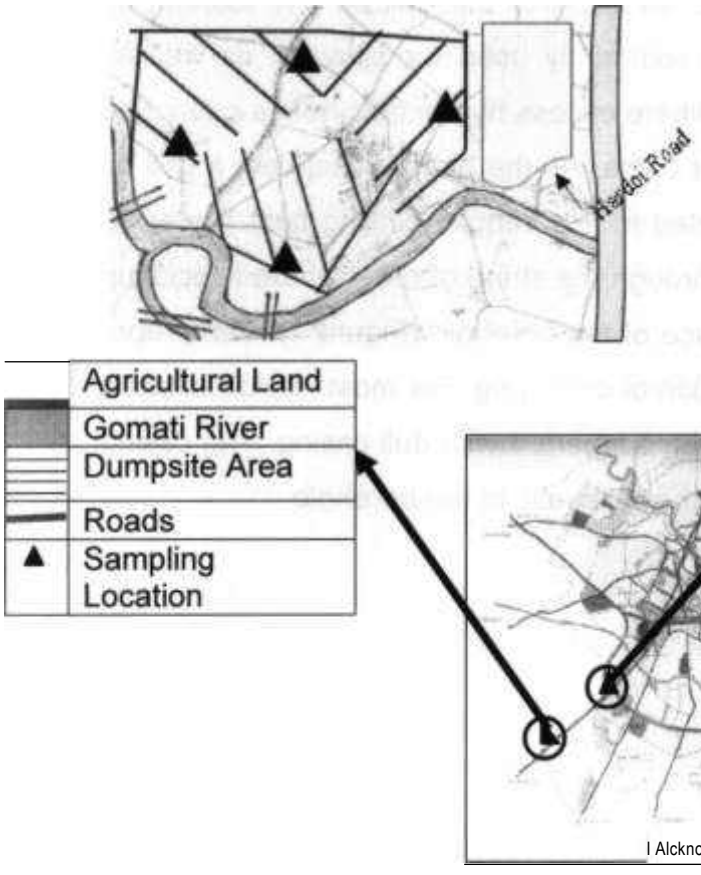
5.1.1 Identification of Sampling Location:

On the basis of field survey and data concerning to municipal and plastic waste dumping provided by Lucknow Nagar Nigem, relating to two dumpsite location i.e. (a) Ghaila, Hardoi Road and (b) Dudauli, Sitapur Road have been under taken for digging borewell of 30 meter deep at each locations. The samples were taken for soil and water quality testing using Standard Methods. Samples were taken at two locations on Ghaila dumpsite and four locations on Dudauli dumpsite in pre and post monsoon period. From each location respective siol samples were collected at the surface and further at regular intervals of 3 metes upto the depth of the constructed well. After construction of well first static water samples were drawn in triplicate at each location. Summary of the sample collection is presented in **Table 2.**

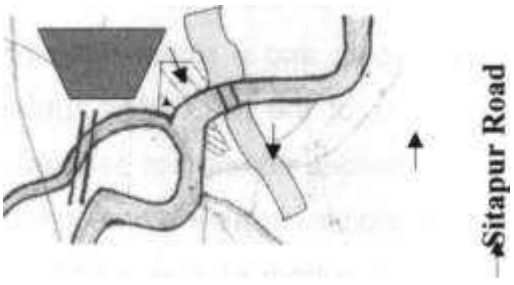
Table - 2

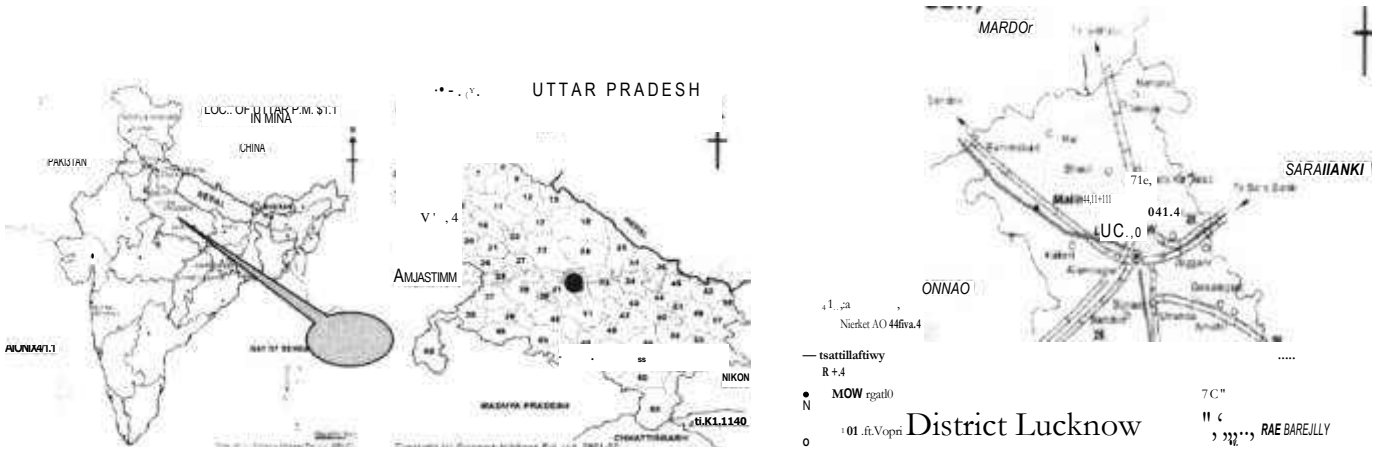
S. No.	Sample Site	No. of Samples			
		Pre-Monsoon Plan for Sampling		Post-Monsoon Plan for Sampling	
		Water	Soil	Water	Soil
1.	Municipal Solid Waste Dumpsite, **Ghaila,** Hardoi Road, Lucknow (2 **locations, 3 each)**	06	06	06	06
2.	Municipal Solid Waste Dumpsite, **Dudauli,** Sitapur Road, Lucknow (4 locations, 3 each)	12	12	12	12
	Total (72 Samples)	18	18	18	18
Total No. of construction of 30 meter deep test wells: 06 **Total No. of samples involving lysimetric method:** Water (36 samples) and Soil (36 samples)					

Ghaila Municipal Solid Waste Dumpsite, Hardoi Road, Lucknow



Dudauli Municipal Solid Waste Dumpsite, Sitapur Road, Lucknow





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5.1.2. Sampling Procedure:

Sampling was carried out through direct circulation system rotary (Mud Rotary Drilling) method using DC mini rig (suitable capacity 300 mm diameter and 120 meter depth in alluvial soil). This method and system includes a drill bit, a drill string having drill rods, and a rotary table or power swivel for bringing the drill bit into rotation by means of the rods. Mud rotary drilling is a commonly used for alluvium as well as overburden but cannot be used in situations where excess hydrostatic heads cannot be tolerated such as in some earth embankment dams. As the name describes, a drill bit on the bottom of a string of drill rods is rotated in a borehole. Drilling fluid (water) is circulated in the borehole by pumping down through the string of rods, where it picks up the drill cuttings and carries them to the surface of the borehole (Figure 1). The proper drilling fluid is essential for the proper installation of drilling rig. For most instrumentation installations the sides of the borehole should be supported with drill casing. The casing also prevents the drilling fluid from contacting the sidewalls of the borehole.

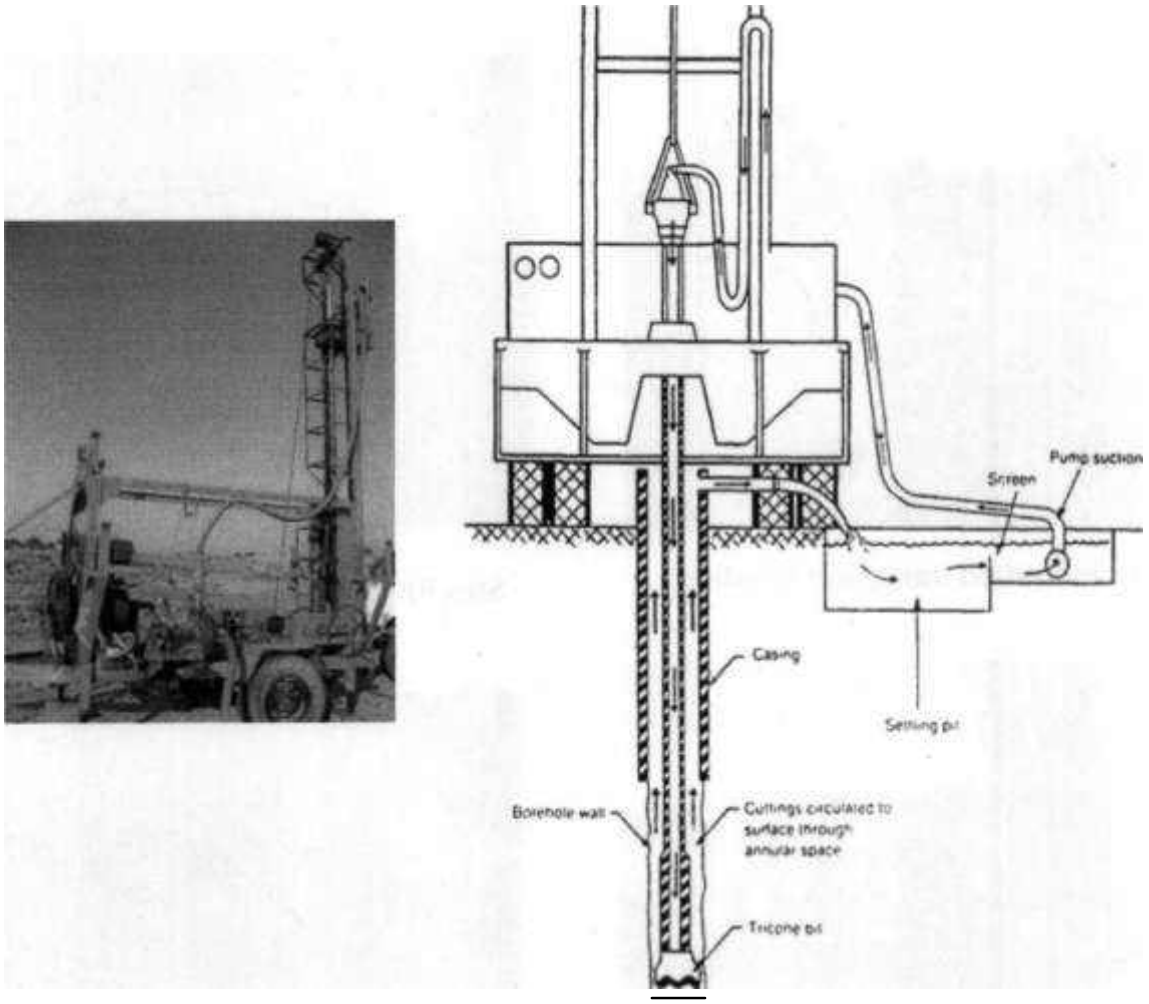
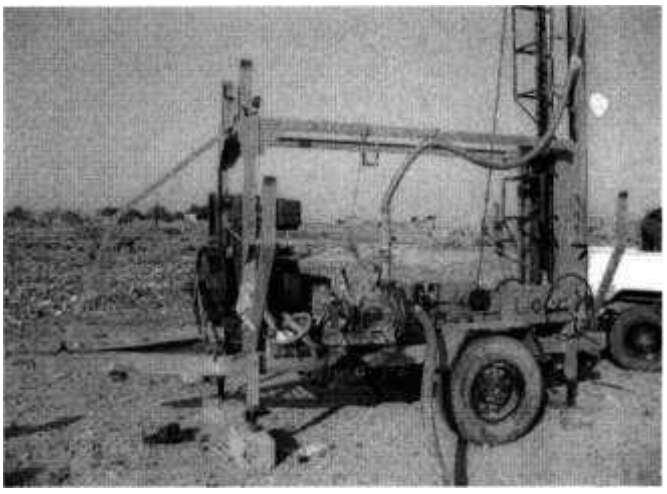


Fig 1: Direct Circulation System Rotary (Mud Rotary Drilling) method using DC mini rig

5.1.3. Step of Sampling:

Step i): Identified sampling location



Step ii): Installation of DC mini rig for drilling bottles

Step iii): Mode of drilling using Direct Circulation System Rotary (Mud Rotary Drilling) method

Step iv): Formation of recycled water micro well

Step v: Soil sample collection in cloth bag

Step vi: Drawing water samples by installation of submersible pump in constructed well

Step vii): Collection of water samples in glass bottles

Step viii): Sealing of construction well using concrete cement material

5.1.4. Preservation of Samples:

Soil samples were collected in cloth bag and glass bottles. Samples of water collected in 2 litre glass bottles and LDPE containers as per USEPA guidelines for waste and solid waste: SW 846. All samples were preserved at refrigerated conditions. During sampling and processing of the samples, precautions were taken to avoid external contamination. This is important since phthalates are ubiquitous chemicals in the indoor

environment. Therefore, use of plasticized plastic equipments were avoided during sampling and processing. For phthalate analysis, all glassware's were properly cleaned with Dichloromethane (DCM/HPLC grade) before use. Detergents were not used during washing of glassware's and all equipments were preconditioned and checked for blank levels of phthalates before analysis. The sample for analysis of heavy metals were preserved by adding 5 ml Nitric acid per liter of water sample.

5.2 ANALYSIS

Parameters of soil and water samples collected and analysed are given below **Table-3** :

S.No.	Sample	Parameters
i)	**Soil**	pH, Heavy metals (Cd, Co, Cr, Cu, Pb, Mo, Ti and Zn), Nitrogen, Phosphorous, Potassium, Phthalates.
ii)	**Water**	Heavy metals (Cd, Co, Cr, Cu, Pb, Mo, Ti and Zn) and Phthalates.
iii)	**Leachates**	TCLP for heavy metals (Cd, Co, Cr, Cu, Pb, Mo, Ti and Zn), *Carbon Black,* Nigrosine Dye, Chlorides, Phthalates.

5.2.1. Determination of Hazardous Characteristics of Wastes: Toxicity Characteristic Leaching Procedure (TCLP)

This method is based on USEPA Method 1311-Toxicity Characteristics Leaching Procedure (TCLP). This is applicable to the determination of mobility of metals and semi-volatile organic compound in solids. The principle involved in leaching procedure consists of 3 main steps:

Step I- Crushing/grinding: The solid sample has been passed through 9.5-mm sieve.

Step II- Determination of appropriate extraction fluid: Depending on the pH of the solid sample, one of two extraction fluids is used to extract the soil.

Step III- Extraction of solid sample: The solid sample is extracted (20:1 liquid to solid ratio) by shaking it end over end for 18 ± 2 hours at a controlled temperature at 30 rpm. The extract also known as the leachate is then filtered and analyzed for desired analytes. The moisture content of the solid sample is determined separately and reported alongwith the analytical results.

Preparation of Extraction Fluid No.1:

- 5.7 ml of glacial acetic acid added to 500 ml of double distilled water.
- Then 64.3 ml of 1 M NaOH added to above solution and diluted to 1 liter.
- The pH of this fluid maintained at 4.93 0.05.

Preparation of Extraction Fluid No.2:

- 5.7 ml of glacial acetic acid diluted to 1 liter.
- The pH of this fluid maintained 2.88 ± 0.05.

Note: The extraction fluids should be monitored frequently for impurities and the pH concentration and it may be discarded, if impurities found or pH is not within specifications.

Determination of Appropriate Extraction Fluid:

- 5.0 g (± 0.1 g) of the sample (<9.5 mm) transferred into a 500 ml beaker or Erlenmeyer flask. 96.5 ml of DDW added to the beaker and covered with a watch glass. It then stirred vigorously for 5 minutes using a magnetic stirrer.
- The pH solution measured and recorded.
- When the pH 5.0, extraction fluid No.1 used.
- When the pH > 5.0, added 3.5 ml 1 M HCl, covered with a watch glass, heated to 50°C±2 for 10 minutes. Solution allowed to cool at room temperature and then pH recorded. When the pH was 5, use extraction fluid No.1. Otherwise, use Extraction fluid No.2

Analysis of leachate:

The leachates have been prepared and analyzed as per standard guidelines.

5.2.2. Estimation of Heavy Metals:

200 ml of water sample or the TCLP extract of soil/plastic material were taken in conical flask, digested it for organic substances, if any, with 20 ml concentrated nitric acid in a fuming chamber. The digested samples were made upto 20 ml with 0.1 N HNO_3 and analyzed for Cd, Co, Cr, Cu, Pb, Mo, Ti and Zn with the help of Atomic Absorption Spectrophotometer (ZEEnit- 700) under following conditions are mentioned at **Table-4.**

Table:- 4

S. No	Metals	Lamp current (m A)	Wave length (nm)	Slit Width (nm)
1	Cd	6	228.8	0.2
2	Co	4	240.7	0.2
3	Cr	6	357.9	0.2
4	Cu	3	324.8	0.5
5	Pb	3	283.3	0.5
6	Mo	3	313.4	0.5
7	Ti	3	320.0	0.5
8	Zn	3	213.9	0.5

5.2.3. Estimation of Phthalates:

A 500 ml of water sample collected from each location or TCLP leachate was extracted three times using 30 ml of dichloromethane (HPLC grade) solvent in one litre separatory funnel each time. The micelle formation was suppressed by adding 10 ml of saturated sodium chloride solution during each operation. The organic layers were combined together and demoistered by passing through anhydrous granular sodium sulphate bed [EPA method-8060, Analysis of phthalate esters in water and waste water (1986); EPA method-3510, Separatory funnel liquid-liquid extraction (1986)]. Each sample was processed for column cleanup prior to analysis on HPLC. For proper cleanup, chromatographic column (300 mm length X 10 mm I.D.) was prepared by placing 10 g of activated Florisil on bed of Pyrex glass wool at the bottom. The column was tapped properly to settle the Florisil and further added 1 cm of anhydrous sodium sulfate to the top [EPA method-3620, Florisil column cleanup-1986]. Column was preluted with 40 ml n-Hexane (v/v). The compounds were eluted with 100 ml of 20% ethyl ether in hexane (v/v). The extract in hexane was concentrated under reduced pressure using rotary evaporator (Buchi, B 490). The exchange of solvent was done by replacing hexane with methanol (HPLC grade) and final volume was made up to 10 ml in volumetric flask.

The methodology was tested using water samples. Each sample was screened for 5 Phthalates viz. Di-methyl phthalate (DMP), Di-ethyl phthalate (DEP), Di-butyl phthalate (DBP), Di (2-ethylhexyl) phthalate (DEHP) and Di-octyl phthalate (DOP) by using HPLC under following conditions:

Equipment: HPLC, Water's make, pump-515; Column: RP, C-18; Temperature: 27° C.
Mobile phase: Methanol-water (90:10), Flow Rate 2 ml/rnin.
Detector: UV-VIS detector (Model 2487; Water's make), Wavelength: 254 nm.

To identify the chromatographic peaks, the five representative samples were analyzed on Gas chromatograph-Mass Spectrophotometer (GC-MS) using following conditions:

Equipment: GC-MS, Turbo Mass, Perkin Elmer, USA.
Column: DB-5ms low bleed (30X0.25 mm), Film thickness: 0.25 Om; Temperature programme: 1 min. hold at 70°C and raised the temperature up to 325°C @ 10^0 C/min.
Injector temperature: 250^0 C.
Mobile phase: Helium, Flow Rate 1.25 ml/min.
Ionization mode: El; Mass resolution (m/z): 30-550; Scan rate: 10/sec; Ionization energy: 70 eV; Detector: Mass; Source temperature: 280^0 C.

Schematic Flow-Diagram of Phthalate Extraction from Water Samples ITCLP Leachate

500 ml of sample was taken in a separating funnel

Add 20 ml of sodium chloride to the sample

Thenafter add 30 ml of dichloromethane to the sample

1.

Resulting sample was shaken vigorously for 5 min with periodic venting to release excess pressure

Stand and allowed the organic layer to separate from water phase for a minimum of 10 min.

Collected organic layer and pool in a separate conical flask

Repeat the extraction two more times using fresh portions of solvent in the same manner

Combined three solvent extracts and process it for column cleanup

Concentrated the extract (eluate) up to dryness on rotavapour

Final volume was made up to 10 ml with filtered methanol solution

Estimation of Phthalate using HPLC

Source: EPA method-3510, Separatory funnel liquid-liquid extraction; 1986.
EPA method-3620, Florisil column cleanup; 1986.

Schematic Flow-Diagram of Phthalate Extraction from Soil Samples

5 gm of dry sample was taken

Extracted using Soxhlet apparatus with the help of 1:1 Acetone/n- Hexane mixture for approx. 18 hours

Collect the extract and process it for column cleanup

Concentrate the extract (eluate) upto dryness on rotavapour

Made up the final volume upto 10 ml with filtered methanol solution

Estimation of Phthalate using HPLC

Source: EPA method-8060, Analysis of phthalate esters in water and waste water; 1986.

5.2.4. Estimation of Chloride in leachates

In the leachate (each 20 ml), add 3 drops of $K_2Cr_20_7$, stirred well and titrated against 0.014 $AgNO_3$. The formula used is as follows:

$$Cl\ mg/L = \frac{S-B) \times 0.5}{\text{ml of sample}} \times 1000$$

5.3 Sampling Conditions

5.3.1 Pre-monsoon Sampling

First phase of pre-monsoon sampling was conducted at four identified locations of Municipal Solid Waste Dumpsite, Dudauli, Sitapur Road, Lucknow during April 12, 2009 to April 15, 2009 while second phase of pre-monsoon sampling was conducted at two identified locations of Municipal Solid Waste Dumpsite, Dudauli, Ghaila, Hardoi Road, Lucknow during May 04, 2009 to May 05, 2009. Conditions during sampling are given below.

Location I: Municipal Solid Waste Dumpsite, Dudauli, Sitapur Road, Lucknow

Date	**Time**	**Site**	**Location of Drilling**	**Temperature**
12.04.09	6: 00 pm — 10: 30 pm	Municipal Solid Waste Dumpsite, Dudauli, Sitapur Road, Lucknow	Point I	**36°±2** C
13.04.09	1:30 pm — 5:45 pm	Municipal Solid Waste Dumpsite, Dudauli, Sitapur Road, Lucknow	Point II	**41° ±2** C
14.04.09	10:15 am — 12:15 pm	Municipal Solid Waste Dumpsite, Dudauli, Sitapur Road, Lucknow	Point III	**42°** ±2 C
15.04.09	3:30 pm — 6: 45 pm	Municipal Solid Waste Dumpsite, Dudauli, Sitapur Road, Lucknow	Point IV	**39°±2C**

Location II: Municipal Solid Waste Dumpsite, Ghaila, Hardoi Road, Lucknow

Date	**Time**	**Site**	**Location of Drilling**	**Temperature**
04.05.09	9: 00 am — 5: 00 pm	Municipal Solid Waste Dumpsite, Ghaila, Hardoi Road, Lucknow	Point I	**35°±2** C
05.05.09	8:30 am — 4:45 pm	Municipal Solid Waste Dumpsite, Ghaila, Hardoi Road, Lucknow	Point II	39°±2 C

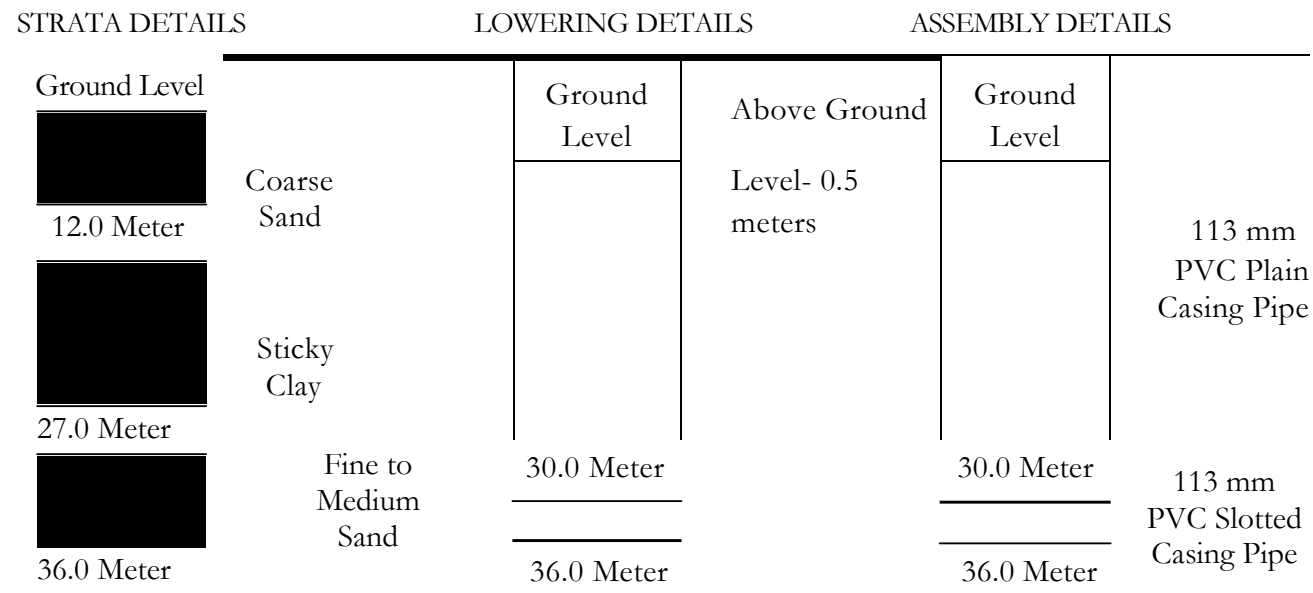
5.3.2 Post-monsoon Sampling

The proposed post-monsoon sampling was delayed for three months due to late monsoon conditions and prolonged water logging after heavy rains at Ghaila Municipal Solid Waste Dumpsite, Hardoi Road, Lucknow. Post-monsoon sampling was conducted at one identified location of Municipal Solid Waste Dumpsite, Dudauli, Sitapur Road, Lucknow during September 28-30, 2009 while last phase of post-monsoon sampling was also conducted at one identified location of Municipal Solid Waste Dumpsite, Ghaila, Hardoi Road, Lucknow during December 9-10, 2009. Conditions during sampling are charted below.

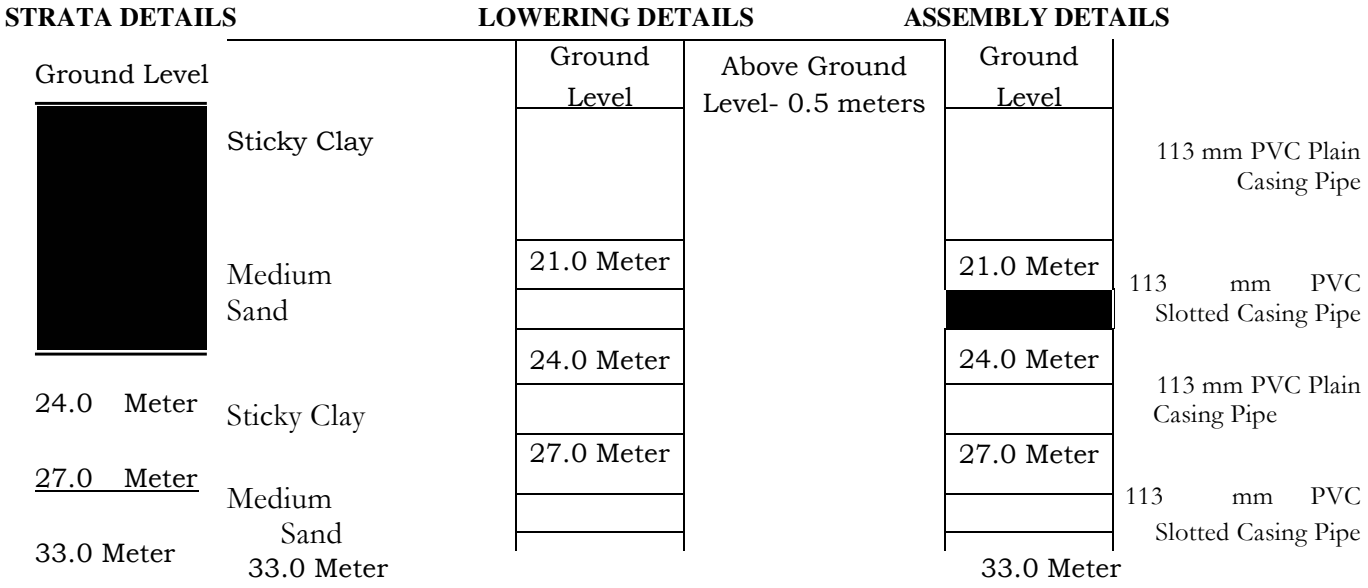
	Date	Time	Site	Location of Drilling	Temperature
Location I	29.10.09	10:00 am — 05: 30 pm	Municipal Solid Waste Dumpsite, Dudauli, Sitapur Road, Lucknow	Point I	29°±2C
Location II	09.12.09	9:30 am — 5:30 pm	Municipal Solid Waste Dumpsite, Ghaila, Hardoi Road , Lucknow	Point II	26°±2C

5.4 Geo-physical and Drilling Features of Dumpsite Area:

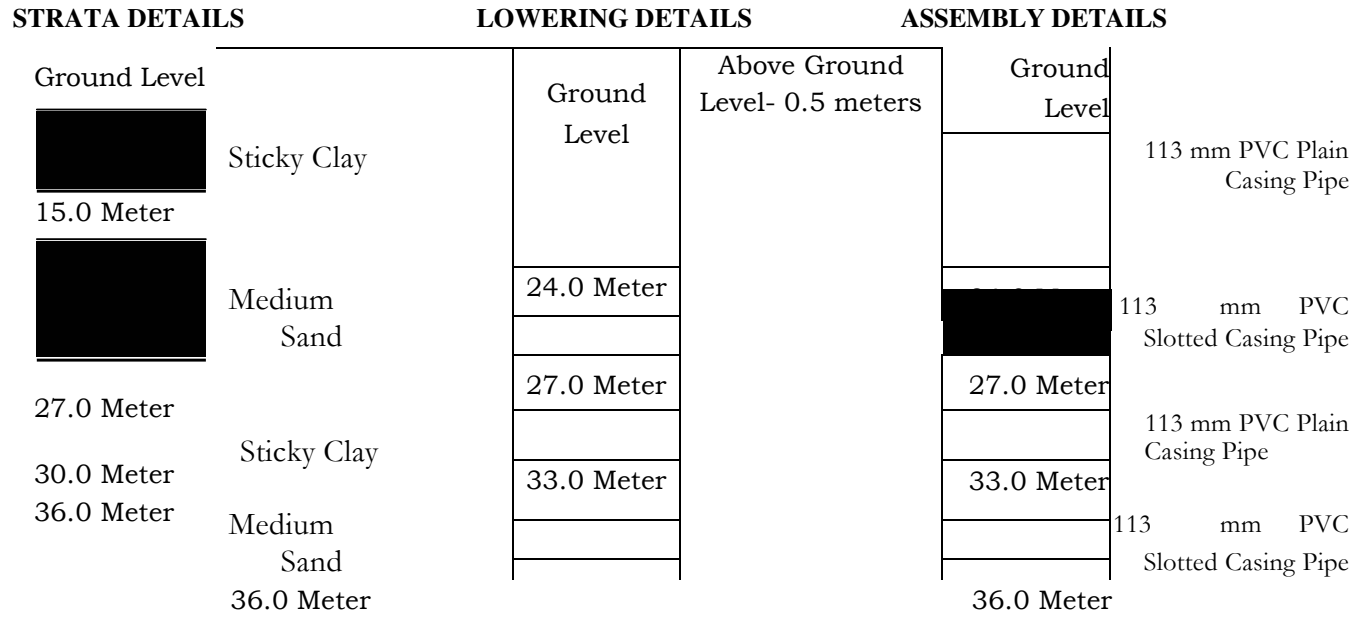
Strata Chart: Municipal Solid Waste Dumpsite, Dudauli, Sitapur Road, Lucknow
Test Well No. 1 Static Water Level: 13.7 meter



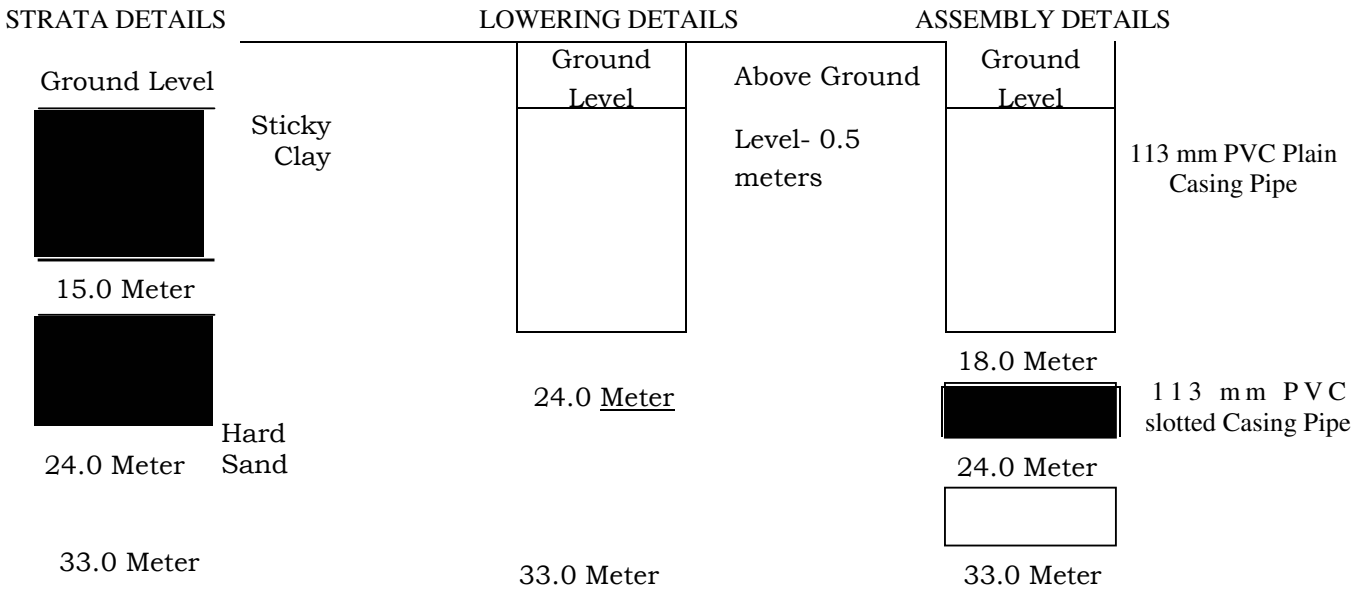
Strata Chart: Municipal Solid Waste Dumpsite, Dudauli, Sitapur Road, Lucknow
Test Well No. 2 Static Water Level: 10.70 meter



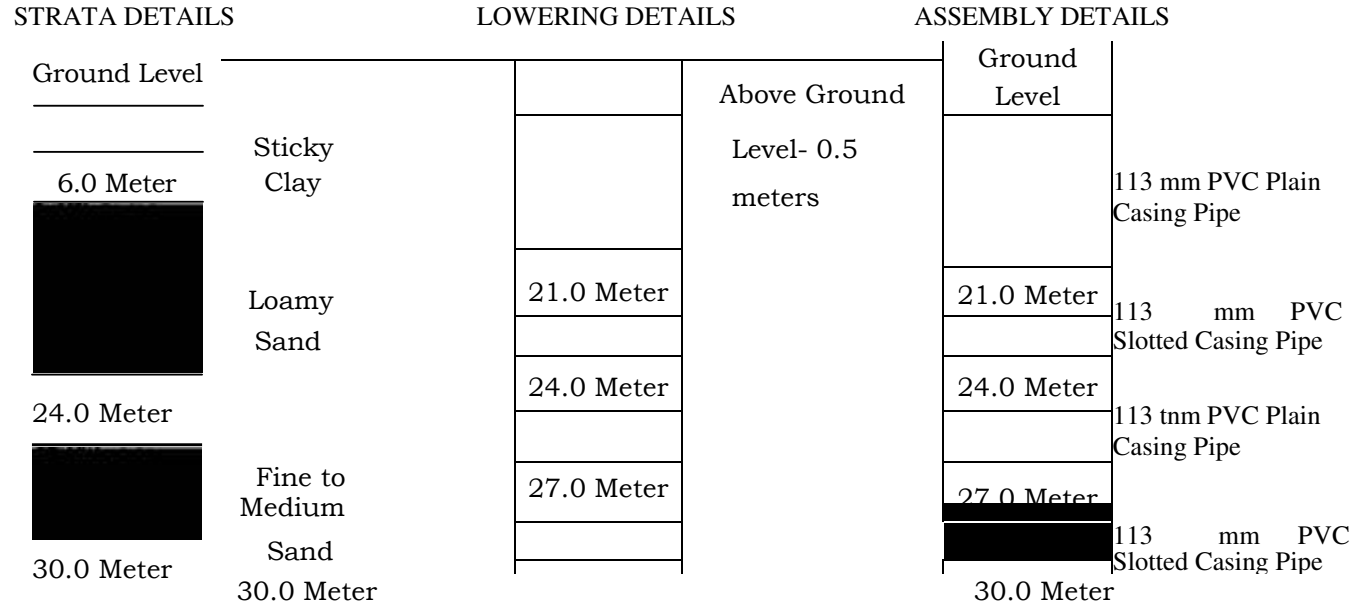
Strata Chart: Municipal Solid Waste Dumpsite, Dudauli, Sitapur Road, Lucknow
Test Well No. 3 Static Water Level: 13.7 meter



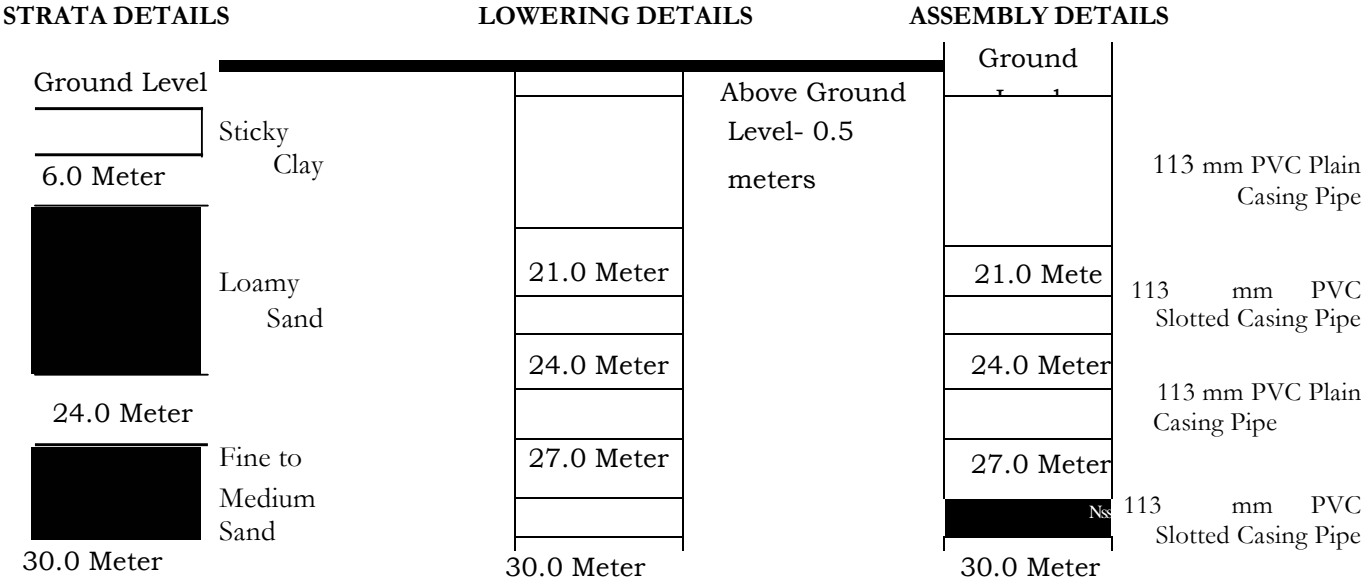
Strata Chart: Municipal Solid Waste Dumpsite, Dudauli, Sitapur Road, Lucknow
Test Well No. 4 Static Water Level: 12.70 meter



Strata Chart: Municipal Solid Waste Dumpsite, Ghaila, Hardoi Road, Lucknow
Test Well No. **1** Static Water Level: 10.70 meter



Strata Chart: Municipal Solid Waste Dumpsite, Ghaila, Hardoi Road, Lucknow
Test Well No. 2 Static Water Level: 10.70 meter



6. Sampling Details

6.1 List of Soil Samples

Sample Code	IITR Code No.	Texture	Depth	Sample Container	Date of Sampling	Remarks, if any
Point I,	**Municipal Solid Waste Dumpsite, Dudauli, Sitapur Road Lucknow (6: 00 pm — 10: 30**					
1.	AS 01/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Medium sand	3.4 meter	Cloth	12.04.09	Pre-monsoon [Experimental]
2.	AS 021D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Sticky clay	6.45 meter (3.05 meter)	Cloth	12.04.09	Pre-monsoon [Experimental]
3.	AS 03/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Clay + Gravel	9.50 meter (3.05 meter)	Cloth	12.04.09	Pre-monsoon [Experimental]
4.	AS 04/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Sticky clay + Gravel	12.50 meter (3.0 meter)	Cloth	12.04.09	Pre-monsoon [Experimental]
5.	AS 05/D/Soil/ IITR Dudauli, Sitapur Road, Lucknovt	Sticky clay + Gravel	15.50 meter (3.0 meter)	Cloth	12.04.09	Pre-monsoon [Experimental]

6.	AS 06/0/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Loamy clay + Gravel	18.50 meter (3.0 meter)	Cloth	12.04.09	Pre-monsoon [Experimental]
7.	AS 07/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Loamy clay + Gravel+ Sand	21.50 meter (3.0 meter)	Cloth	12.04.09	Pre-monsoon [Experimental]
8.	AS 08/D/So1l/ IITR Dudauli, Sitapur Road, Lucknow	Loamy clay + Gravel	24.50 meter (3.0 meter)	Plastic	12.04.09	Pre-monsoon [Experimental]
9.	AS 09/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Loamy clay + Gravel	27.50 meter (3.0 meter)	Plastic	12.04.09	Pre-monsoon [Experimental]
10.	AS 10/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Loamy clay + Gravel	30.50 meter (3.0 meter)	Plastic	12.04.09	Pre-monsoon [Experimental]
11.	AS 11/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Clay + Sand	33.50 meter (3.0 meter)	Cloth	12.04.09	Pre-monsoon [Experimental]
12.	AS 12/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Sand	36.50 meter (3.0 meter)	Cloth	12.04.09	Pre-monsoon [Experimental]
Point II, Municipal Solid Waste Dumpsite, Dudauli, Sitapur Road, Lucknow (1:30 pm - 5:45 pm)						
13.	AS 13/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Sticky clay+ small gravels	3.4 meter	Cloth	13.04.09	Pre-monsoon [Experimental]
14.	AS 14/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Sticky clay+ small gravels	6.45 meter (3.05 meter)	Cloth	13.04.09	Pre-monsoon [Experimental]
15.	AS 15/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Sticky clay	9.50 meter (3.05 meter)	Cloth	13.04.09	Pre-monsoon [Experimental]
16.	AS 16/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Sticky clay	12.50 meter (3.0 meter)	Cloth	13.04.09	Pre-monsoon [Experimental]

17.	AS 17/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Sticky clay	15.50 meter (3.0 meter)	Cloth	13.04.09	Pre-monsoon [Experimental]
18.	AS 18/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Sand + Gravel	18.50 meter (3.0 meter)	Cloth	13.04.09	Pre-monsoon [Experimental]
19.	AS 19/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Loamy Sand	21.50 meter (3.0 meter)	Cloth	13.04.09	Pre-monsoon [Experimental]
20.	AS 20/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Loamy Sand	24.50 meter (3.0 meter)	Cloth	13.04.09	Pre-monsoon [Experimental]
21.	AS 21/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Loamy Sand	27.50 meter (3.0 meter)	Cloth	13.04.09	Pre-monsoon [Experimental]
22.	AS 22/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Sand	30.50 meter (3.0 meter)	Cloth	13.04.09	Pre-monsoon [Experimental]
23.	AS 23/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Sand	33.50 meter (3.0 meter)	Cloth	13.04.09	Pre-monsoon [Experimental]
Point II, Municipal Solid Waste Dumpsite, Dudauli, Sitapur Road, Lucknow (10:15 am - 12:15 Pm)						
24.	AS 24/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Loamy Sand	3.4 meter	Cloth	14.04.09	Pre-mansoon [Experimental]
25.	AS 25/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Loamy Sand + gravel	6.45 meter (3.05 meter)	Cloth	14.04.09	Pre-mansoon [Experimental]
26.	AS 26/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Clay + garvel	9.50 meter (3.05 m)	Cloth	14.04.09	Pre-monsoon [Experimental]
27.	AS 27/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Clay + garvel	12.50 meter (3.0 meter)	Cloth	14.04.09	Pre-monsoon [Experimental]

28.	AS 28/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Clay + garvel	15.50 meter (3.0 meter)	Cloth	14.04.09	Pre-monsoon [Experimental]
29.	AS 29/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Clay + garvel	18.50 meter (3.0 meter)	Cloth	14.04.09	Pre-monsoon [Experimental]
30.	AS 30/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Loamy Sand	21.50 meter (3.0 meter)	Cloth	14.04.09	Pre-monsoon [Experimental]
31.	AS 31/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Loamy Sand	24.50 meter (3.0 meter)	Cloth	14.04.09	Pre-monsoon [Experimental]
32.	AS 32/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Loamy Sand	27.50 meter (3.0 meter)	Cloth	14.04.09	Pre-monsoon [Experimental]
33.	AS 33/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Loamy Sand	30.50 meter (3.0 meter)	Cloth	14.04.09	Pre-monsoon [Experimental]
34.	AS 34/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Sand	33.50 meter (3.0 meter)	Cloth	14.04.09	Pre-monsoon [Experimental]
35.	AS 35/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Sand	36.50 meter (3.0 meter)	Cloth	14.04.09	Pre-monsoon [Experimental]
Point IV, Municipal Solid Waste Dumpsite, Dudaul", Sitapur Road, Lucknow (3:30 pm- 6: 45 pm)						
36.	AS 36/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Clay + Mud	3.4 meter	Cloth	14.04.09	Pre-monsoon [Experimental]
37.	AS 37/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Clay + Mud	6.45 meter (3.05 meter)	Cloth	14.04.09	Pre-monsoon [Experimental]
38.	AS 38/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Clay + Gravel	9.50 meter (3.05 meter)	Cloth	14.04.09	Pre-monsoon [Experimental]

39.	AS 39/D/Soil/IITR Dudauli, Sitapur Road, Lucknow	Clay + Gravel	12.50 meter (3.0 meter)	Cloth	14.04.09	Pre-monsoon [Experimental]
40.	AS 40/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Clay + Gravel	15.50 meter (3.0 meter)	Cloth		Pre-monsoon [Experimental]
41.	AS 41/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Loamy Sand	18.50 meter (3.0 meter)	Cloth	14.04.09	Pre-monsoon [Experimental]
42.	AS 42/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Loamy Sand	21.50 meter (3.0 meter)	Cloth	14.04.09	Pre-monsoon [Experimental]
43.	AS 43/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Sticky Clay	24.50 meter (3.0 meter)	Cloth	14.04.09	Pre-monsoon [Experimental]
44.	AS 44/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Clay + sand + Gravel	27.50 meter (3.0 meter)	Cloth	14.04.09	Pre-monsoon [Experimental]
45.	AS 45/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Sand	30.50 meter (3.0 meter)	Cloth	14.04.09	Pre-monsoon [Experimental]
46.	AS 46/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Sand	33.50 meter (3.0 meter)	Cloth	14.04.09	Pre-monsoon [Experimental]
Point I, Municipal Solid Waste Dumpsite, Ghaila, Hardoi Road, Lucknow (10:30 am- 4: 45 pm)						
47.	AS 47/G/Soil/ IITR, Ghaila, Hardoi Road, Lucknow	Sticky clay	3.4 meter	Cloth	04.05.09	Pre-monsoon [Experimental]
48.	AS 48/G/Soil/ IITR, Ghaila, Hardoi Road, Lucknow	Loamy Sand	6.45 meter (3.05 meter)	Cloth	04.05.09	Pre-monsoon [Experimental]
49.	AS 49/G/Soil/ IITR, Ghaila, Hardoi Road, Lucknow	Loamy Sand	9.50 meter (3.05 meter)	Cloth	04.05.09	Pre-monsoon [Experimental]

50.	AS 50/G/Soil/IITR, Ghaila, Hardoi Road, Lucknow	Lomy Sand	12.50 meter (3.0 meter)	Cloth	04.05.09	Pre-monsoon [Experimental]
51.	AS 51/G/Soil/ IITR, Ghaila, Hardoi Road, Lucknow	Loamy Sand	15.50 meter (3.0 meter)	Cloth	04.05.09	Pre-monsoon [Experimental
52.	AS 52/G/Soil/ IITR, Ghaila, Hardoi Road, Luthnow	Loamy Sand	18.50 meter (3.0 meter)	Cloth	04.05.09	Pre-monsoon [Experimental]
53.	AS 53/G/Soil/ IITR, Ghaila, Hardoi Road, Lucknow	Loamy Sand	21.50 meter (3.0 meter)	Cloth	04.05.09	Pre-monsoon [Experimental]
54.	AS 54/G/Soil/ IITR, Ghaila, Hardoi Road, Lucknow	Loamy Sand	24.50 meter (3.0 meter)	Cloth	04.05.09	Pre-monsoon [Experimental]]
55.	AS 55/G/Soil/ IITR, Ghaila, Hardoi Road, Lucknow	Sand	27.50 meter (3.0 meter)	Cloth	04.05.09	Pre-monsoon [Experimental]
56.	AS 56/G/Soil/ IITR, Ghaila, Hardoi Road, Lucknow	Sand	30.50 meter (3.0 meter)	Cloth	04.05.09	Pre-monsoon [Experimental]
Point II, Municipal Solid Waste Dumpsite, Ghila, Hardoi Road, Lucknow (8:30 am- 11:30am)						
57.	AS 57/G/Soil/ IITR, Ghaila, Hardoi Road, Lucknow	Sticky clay	3.4 meter	Cloth	05.05.09	Pre-monsoon [Experimental]
58.	AS 58/G/Soil/ IITR, Ghaila, Hardoi Road, Lucknow	Sticky clay	6.45 meter (3.05 meter)	Cloth	05.05.09	Pre-monsoon [Experimental]
59.	AS 59/G/Soil/ IITR, Ghaila, Hardoi Road, Lucknow	Loamy Sand	9.50 meter (3.05 meter)	Cloth	05.05.09	Pre-monsoon [Experimental]
60.	AS 60/G/Soil/ IITR, Ghaila, Hardoi Road, Lucknow	Loamy Sand	12.50 meter (3.0 meter)	Cloth	05.05.09	Pre-monsoon [Experimental]
61.	AS 61/G/Soil/ IITR, Ghaila, Hardoi Road, Lucknow	Loamy Sand	15.50 meter (3.0 meter)	Cloth	05.05.09	Pre-monsoon [Experimental]
62.	AS 62/G/Soil/ IITR, Ghaila, Hardoi Road, Lucknow	Loamy Sand	18.50 meter (3.0 meter)	Cloth	05.05.09	Pre-monsoon [Experimental]

63.	AS 63/G/Soil/ IITR, Ghaila, Hardoi Road, Lucknow	Loamy Sand	21.50 meter (3.0 meter)	Cloth	05.05.09	Pre-monsoon [Experimental]
64.	AS 641G/Soil/ IITR, Ghaila, Hardoi Road, Lucknow	Loamy Sand	24.50 meter (3.0 meter)	Cloth	05.05.09	Pre-monsoon [Experimental]
65.	AS 65/G/Soil/ IITR, Ghaila, Hardoi Road, Lucknow	Sand	27.50 meter (3.0 meter)	Cloth	05.05.09	Pre-monsoon [Experimental]
66.	AS 66/0/Soil/ IITR, Ghaila, Hardoi Road, Lucknow	Sand	30.50 meter (3.0 meter)	Cloth	04.05.09	Pre-monsoon [Experimental]
67.	AS 67/C/Soil/ IITR, Sitapur Road (FaizullaGanj, near old Kisan Mandi), Lucknow	Clay + gravel	5 cm below from upper layer	Cloth	07.08.08	Pre-monsoon [Control]
68.	AS 68/ C /Soil/ IITR, Ghaila, Hardoi Road, Lucknow	Loamy clay	5 cm below from upper layer	Cloth	07.08.08	Pre-monsoon [Control]
69.	AS 69/ C /Soil/ IITR, Ghaila, Hardoi Road (Near temple, opposite to dumpsite), Lucknow	Rough clay	5 cm below from upper layer	Cloth	07.08.08	Pre-monsoon [Control]
70.	AS 70/ C /Soil/ IITR, Jiamau, Lucknow	Rough clay	5 cm below from upper layer	Cloth	07.08.08	Pre-monsoon [Control]
71.	AS 71/ C /Soil/ IITR, Jiamau, Lucknow	Loamy clay	5 cm below from upper layer	Cloth	07.08.08	Pre-monsoon [Control]
72.	AS 72/ C /Soil/ IITR, Manas Nagar, Jiamau, Lucknow	Rough clay	5 cm below from upper layer	Cloth	06.11.08	Pre-monsoon [Control]
73.	AS 73/ C /Soil/ IITR, RamaBai Sthali, Ashiana Lucknow	Rough clay	5 cm below from upper layer	Cloth	06.11.08	Pre-monsoon [Control]
74.	AS 74/ C /Soil/ IITR, Kila Mohannmadi Nagar, Smriti Park, Ashiana, Lucknow	Rough clay	5 cm below from upper layer	Cloth	06.11.08	Pre-monsoon [Control]
75.	AS 75/ C /Soil/ IITR, B Block, Indira Nagar, Lucknow	Rough clay	5 cm below from upper layer	Cloth	06.11.08	Pre-monsoon [Control]
76.	AS 76/ C /Soil/ IITR, C Block, Lucknow	Rough clay	5 cm below from upper layer	Cloth	06.11.08	Pre-monsoon [Control]
77.	AS 77/ C /Soil/ IITR, Gheru Soil, Lucknow	Rough clay	5 cm below from upper layer	Cloth	3.12.08	Pre-monsoon [Control]

78.	AS 78/C /Soil/ IITR, Alambagh, Lucknow	Rough clay	5 cm below from upper layer	Cloth	3.12.08	Pre-monsoon [Control]
79.	AS 79/ C /Soil/ IITR, IITR Gate, Lucknow	Rough clay	5 cm below from upper layer	Cloth	06.01.09	Pre-monsoon [Control]
80.	AS 80/ C /Soil/ IITR, IITR Gate, Lucknow	Rough clay	5 cm below from upper layer	Cloth	06.08.09	Pre-monsoon [Control]
81.	AS 81/ C /Soil/ IITR, Sitapur Road (FaizullaGanj, near old Kisan Mandi), Lucknow	Rough clay	5 cm below from upper layer	Cloth	29.10.09	Post-monsoon [Control]
82.	AS 82/ C /Soil/ IITR, Kila Mall Ghaila, Lucknow	Rough clay	5 cm below from upper layer	Cloth	29.10.09	Post-monsoon [Control]
83.	AS 83/ C /Soil/ IITR, Ghaila, Hardoi Road (Near temple, opposite to dumpsite), Lucknow	Rough clay	5 cm below from upper layer	Cloth	29.10.09	Post-monsoon [Control]
84.	AS 84/ C /SoiV IITR, Jiamau, Lucknow	Rough clay	5 cm below from upper layer	Cloth	30.10.09	Post-monsoon [Control]
85.	AS 85/ C /Soil/ IITR, Jiamau, Lucknow	Rough clay	5 cm below from upper layer	Cloth	30.10.09	Post-monsoon [Control]
86.	AS 86/ C /Soil/ IITR, Manas Nagar, Lucknow	Rough clay	5 cm below from upper layer	Cloth	30.10.09	Post-monsoon [Control]
87.	AS 87/ C /Soil/ IITR, RamaBai Sthali, Ashiana	Rough clay	5 cm below from upper layer	Cloth	30.10.09	Post-monsoon [Control]
88.	AS 88/ C /Soil/ IITR, IITR Gate, Lucknow	Rough clay	5 cm below from upper layer	Cloth	30.10.09	Post-monsoon [Control]

Sample Code	IITR Code No.	Texture	Depth	Sample Container	Date of Sampling	Remarks, if any
Point I – Municipal Solid Waste Dumpsite Dudauli, Sitapur Road, Lucknow (9:00 am -12:00 pm)						
	AS 89/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Medium sand	3.4 meter	Cloth	29.10.09	Post-monsoon [Experimental]
90.	AS 901D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Sticky clay	6.45 meter (3.05 meter)	Cloth	29.10.09	Post-monsoon [Experimental]
91.	AS 91/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Clay + Gravel	9.50 meter (3.05 meter)	Cloth	29.10.09	Post-monsoon [Experimental]
92.	AS 92/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Sticky clay + Gravel	12.50 meter (3.0 meter)	Cloth	29.10.09	Post-monsoon [Experimental]
93.	AS 93/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Sticky clay + Gravel	15.50 meter (3.0 meter)	Cloth	29.10.09	Post-monsoon [Experimental]
94.	AS 94/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Loamy clay + Gravel	18.50 meter (3.0 meter)	Cloth	29.10.09	Post-monsoon [Experimental]
95.	AS 951D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Loamy clay + Gravel+ Sand	21.50 meter (3.0 meter)	Cloth	29.10.09	Post-monsoon [Experimental]
96.	AS 96/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Loamy clay + Gravel	24.50 meter (3.0 meter)	Cloth	29.10.09	Post-monsoon [Experimental]
97.	AS 97/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Loamy clay + Gravel	27.50 meter (3.0 meter)	Cloth	29.10.09	Post-monsoon [Experimental]
98.	AS 98/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Loamy clay + Gravel	30.50 meter (3.0 meter)	Cloth	29.10.09	Post-monsoon [Experimental]
99.	AS 991D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Clay + Sand	33.50 meter (3.0 meter)	Cloth	29.10.09	Post-monsoon [Experimental]
100.	AS 100/D/Soil/ IITR Dudauli, Sitapur Road, Lucknow	Sand	36.50 meter (3.0 meter)	Cloth	29.10.09	Post-monsoon [Experimental]

Sample code	IITR Code No.	Texture	Depth	Sample Container	Date of Sampling	Remarks, if any
Point I Municipal Solid Waste Dumpsite, Ghaila, Hardoi, Lucknow (9:00 am -5:00 pm)						
101.	AS 101/0/Soil/ IITR Ghaila, Hardoi Road , Lucknow	Sticky Clay	3.4 meter	Cloth	09.12.09	Postmonsoon [Experiment]
102.	AS 102/0/Soil/ IITR Ghaila, Hardoi Road , Lucknow	Loamy Sand	6.45 meter (3.05 meter)	Cloth	09.12.09	Postmonsoon [Experiment]
103.	AS 103/ G /Soil/ IITR Ghaila, Hardoi Road, Lucknow	Loamy Sand	9.50 meter (3.05 meter)	Cloth	09.12.09	Postmonsoon [Experimental]
104.	AS 104/C /Soil/ IITR Ghaila, Hardoi Road, Lucknow	Loamy Sand	12.50 meter (3.0 meter)	Cloth	09.12.09	Postmonsoon [Experimental]
105.	AS 105/ G /Soil/ IITR Ghaila, Hardoi Road, Lucknow	Loamy Sand	15.50 meter (3.0 meter)	Cloth	09.12.09	Postmonsoon [Experimental]
106.	AS 106/ G /Soil/ IITR Ghaila, Hardoi Road, Lucknow	Loamy Sand	18.50 meter (3.0 meter)	Cloth	09.12.09	Postmonsoon [Experimental]
107.	AS 107/ G /Soil/ IITR Ghaila, Hardoi Road, Lucknow	Loamy Sand	21.50 meter (3.0 meter)	Cloth	09.12.09	Postmonsoon [Experimental]
108.	AS 108/ G /Soil/ IITR Ghaila, Hardoi Road, Lucknow	Loamy Sand	24.50 meter (3.0 Meter)	Cloth	09.12.09	Postmonsoon [Experimental]
109.	AS 109/C /Soil/ IITR Ghaila, Hardoi Road, Lucknow	Sand	27.50 meter (3.0 meter)	Cloth	90.12.09	Postmonsoon [experimental]
110.	AS 110/ G /Soil/ IITR Ghaila, Hardoi Road, Lucknow	Sand	30.50 meter (3.0 meter)	Cloth	09.12.09	Postmonsoon [Experimental]

6.2 List of Water Samples

Sample Code	IITR Code No.	Depth	Sample Container	Date of Sampling	Remarks, if any
Pre-monsoon Experimental Water Samples (collected from MSW dumpsite)					
Point I, Municipal Solid Waste Dumpsite, Dudauli, Sitapur Road, Lucknow (6:30 am— 7:45 am)					
1.	AS 01/D/Water/ IITR Dudauli, Sitapur Road, Lucknow	36.50 meter	Glass Bottle	17.04.09	Premonsoon [Experiment all
2.	AS 02/D/ Water / IITR Dudauli, Sitapur Road, Lucknow	36.50 meter	Glass Bottle	17.04.09	Premonsoon [Experiment all
3.	AS 03/D/ Water / IITR Dudauli, Sitapur Road, Lucknow	36.50 meter	Glass Bottle	17.04.09	Premonsoon [Experiment al]
Point II, Municipal Solid Waste Dumpsite, Dudauli, Sitapur Road, Lucknow (3:00 pm-4:45pm)					
4.	AS 04/D/ Water / IITR Dudauli, Sitapur Road, Lucknow	33.50 meter	Glass Bottle	15.04.09	Premonsoon [Experiment al]
5.	AS 05/D/ Water / IITR Dudauli, Sitapur Road, Lucknow	33.50 meter	Glass Bottle	15.04.09	Premonsoon [Experiment al]
6.	AS 06/D/ Water / IITR Dudauli, Sitapur Road, Lucknow	33.50 meter	Glass Bottle	15.04.09	Premonsoon [Experiment al]
Point III, Municipal Solid Waste Dumpsite, Dudauli, Sitapur Road, Lucknow (11:00am-1:45pm)					
7.	AS 07/D/ Water / IITR Dudauli, Sitapur Road, Lucknow	36.50 meter	Glass Bottle	15.04.09	Premonsoon [Experiment all

8.	AS 08/D/ Water / IITR Dudauli, Sitapur Road, Lucknow	36.50 meter	Glass Bottle	15.04.09	Premonsoon [Experiment all
9.	AS 09/D/ Water / IITR Dudauli, Sitapur Road, Lucknow	36.50 meter	Glass Bottle	15.04.09	Premonsoon [Experiment al]
Point IV, Municipal Solid Waste Dumpsite, Dudauli, Sitapur Road, Lucknow (8:30 am- 10: 15 am)					
10.	AS 10/D/ Water / IITR Dudauli, Sitapur Road, Lucknow	33.50 meter	Glass Bottle	17.04.09	Premonsoon [Experiment al]
11.	AS 11/D/ Water / IITR Dudauli, Sitapur Road, Lucknow	33.50 meter	Glass Bottle	17.04.09	Premonsoon [Experiment al]
12.	AS 12/D/ Water / IITR Dudauli, Sitapur Road, Lucknow	33.50 meter	Glass Bottle	17.04.09	Premonsoon [Experiment al]

Sample Code	**IITR Code No.**	**Depth**	**Sample Container**	**Date of Sampling**	**Remarks, if any**
Point V, Municipal Solid Waste Dumpsite, Ghaila Hardoi Road, Lucknow (10:30 am—3: 30 pm)					
13.	AS 13/GNVater/ IITR Ghaila, Hardoi Road, Lucknow	30.85 meter	Glass Bottle	04.05.09	Premonsoon [Experiment al]
14.	AS 14/G/ Water / IITR Ghaila, Hardoi Road, Lucknow	30.85 meter	Glass Bottle	04.05.09	Premonsoon [Experiment al]
15.	AS 15/G/ Water / IITR Ghaila, Hardoi Road, Lucknow	30.85 meter	Glass Bottle	04.05.09	Premonsoon [Experiment al]

Point VI, Municipal Solid Waste Dumpsite, Ghaila, Hardoi Road, Lucknow (8:00am-11:45am)					
16.	AS 16/G/ Water / IITR Ghaila, Hardoi Road, Lucknow	30.85 meter	Glass Bottle	06.05.09	Premonsoon [Experiment al]
17.	AS 17/G/ Water / IITR Ghaila, Hardoi Road, Lucknow	30.85 meter	Glass Bottle	06.05.09	Premonsoon [Experiment al]
18.	AS 18/G/ Water / I ITR Ghaila, Hardoi Road, Lucknow	30.85 meter	Glass Bottle	06.05.09	Premonsoon [Experiment al]
Pre-monsoon Control Water Samples					
19.	AS 19/C/Water/ IITR HP Water, Dudauli, Sitapur Road, Lucknow	Hand Pump	Glass Bottle	04.05.09	Pre- monsoon [Control]
20.	AS 20/C/ Water / IITR Ghaila, Hardoi Road, Lucknow	Hand Pump	Glass Bottle	07.08.08	Premonsoon [Control]
21.	AS 21/C/ Water / IITR IITR, Main Campus, Lucknow	Tap Water	Glass Bottle	10.01.09	Premonsoon [Control]
22.	AS 22/C/ Ghaila Tube well water,, Hardoi Road, Lko	Tube well water	Glass Bottle	04.05.09	Pre- monsoon [Control]
23.	AS 23/C/ Water / IITR Ghaila Pond water,, Hardoi Road, Lko	Pond Water	Glass Bottle	05.05.09	Premonsoon [Control]
24.	AS 24/C/ Water / IITR Dudauli Tube well water, Sitapur Road, Lko	Tube well water	Glass Bottle	21.04.09	Premonsoon [Control]

Sample Code	IITR Code No.	Depth	Sample Container	Date of Sampling	Remarks, if any
Post-monsoon Experimental Water Samples (collected from MSW dumpsite)					
Point I, Municipal Solid Waste Dumpsite, Dudauli, Sitapur Road, Lucknow (6:30 am— 7: 45 am)					
25.	AS 25/D/Water/ IITR Dudauli, Sitapur Road, Lucknow	36.50 meter	Glass Bottle	30.10.09	Post-monsoon [Experimental]
26.	AS 26/D/ Water / IITR Dudauli, Sitapur Road, Lucknow	36.50 meter	Glass Bottle	30.10.09	Post-monsoon [Experimental]
27.	AS 27/D/ Water / IITR Dudauli, Sitapur Road, Lucknow	36.50 meter	Glass Bottle	30.10.09	Post-monsoon [Experimental]

Point II Municipal Solid Waste Dumpsite Dudauli, Sitapur Road, Lucknow (3:00 pm— 4: 45 pm)					
28.	AS 28D/ Water / IITR Dudauli, Sitapur Road, Lucknow	33.50 meter	Glass Bottle	30.10.09	Post-monsoon [Experimental]
29.	AS 29/D/ Water / IITR Dudauli, Sitapur Road, Lucknow	33.50 meter	Glass Bottle	30.10.09	Post-monsoon [Experimental]
30.	AS 30/D/ Water! I ITR Dudauli, Sitapur Road, Lucknow	33.50 meter	Glass Bottle	30.10.09	Post-monsoon [Experimental]
Point III, Municipal Solid Waste Dumpsite, Dudauli, Sitapur Road, Lucknow (11:00 am— 1: 45 pm)					
31.	AS 31/D/ Water / I ITR Dudauli, Sitapur Road, Lucknow	36.50 meter	Glass Bottle	30.10.09	Post-monsoon [Experimental]
32.	AS 32/D/ Water! I ITR Dudauli, Sitapur Road, Lucknow	36.50 meter	Glass Bottle	30.10.09	Post-monsoon [Experimental]
33.	AS 33/D/ Water / I ITR Dudauli, Sitapur Road, Lucknow	36.50 meter	Glass Bottle	30.10.09	Post-monsoon [Experimental]
Point IV, Municipal Solid Waste Dumpsite, Dudauli, Sitapur Road, Lucknow (8:30 am— 10: 15 am)					
34.	AS 34D/ Water! IITR Dudauli, Sitapur Road, Lucknow	33.50 meter	Glass Bottle	30.10.09	Post-monsoon [Experimental]
35.	AS 35/D/ Water / I ITR Dudauli, Sitapur Road, Lucknow	33.50 meter	Glass Bottle	30.10.09	Post-monsoon [Experimental]
36.	AS 36/D/ Water! I ITR Dudauli, Sitapur Road, Lucknow	33.50 meter	Glass Bottle	30.10.09	Post-monsoon [Experimental]
Sample Code	IITR Code **No.**	Depth	Sample Container	Date of Sampling	Remarks, if any
Point V Municipal Solid Waste Dumpsite Ghaila, Hardoi Road, Lucknow (10:30 am— 3: 30 pm)					
37.	AS 37/G/VVater/ IITR Ghaila, Hardoi Road, Lucknow	30.85 meter	Glass Bottle	10.12.09	Post-monsoon [Experimental]
38.	AS 38/G/ Water / IITR Ghaila, Hardoi Road, Lucknow	30. 85 meter	Glass Bottle	10.12.09	Post-monsoon [ExRerimental]

39.	AS 39/G/ Water / IITR Ghaila, Hardoi Road, Lucknow	30.85 meter	Glass Bottle	10.12.09	Post-monsoon [Experimental]
Point VI, Municipal Solid Waste Dumpsite, Ghaila, Hardoi Road, Lucknow (9:00am-10:45am)					
40.	AS 40/G/ Water / I ITR Ghaila, Hardoi Road, Lucknow	30.85 meter	Glass Bottle	10.12.09	Post-monsoon [Experimental]
41.	AS 41/G/ Water / IITR Ghaila, Hardoi Road, Lucknow	30.85 meter	Glass Bottle	10.12.09	Post-monsoon [Experimental]
42.	AS 42/G/ Water / IITR Ghaila, Hardoi Road, Lucknow	30.85 meter	Glass Bottle	10.12.09	Post-monsoon [Experimental]
Post-monsoon Control Water Samples					
43.	AS 43/C/VVater/ IITR HP Water, Dudauli, Sitapur Road, Lucknow	Hand Pump	Glass Bottle	30.10.09	Post-monsoon [Control]
44.	AS 44/C/ Water / I ITR Ghaila, Hardoi Road, Lucknow	Hand Pump	Glass Bottle	30.10.09	Post-monsoon [Control]
45.	AS 45/C/ Water / I ITR IITR, Main Campus, Lucknow	Tap Water	Glass Bottle	30.10.09	Post-monsoon [Control]
46.	AS 46/C/ Ghaila Tube well water, Hardoi Road, Lko	Tube well water	Glass Bottle	30.10.09	Post-monsoon [Control]
47.	AS 47/C/ Water / I ITR Ghaila Pond water,, Hardoi Road, Lko	Pond Water	Glass Bottle	30.10.09	Post-monsoon [Control]
48.	AS 48/C/ Water / I ITR Dudauli Tube well water, Sitapur Road, Lko	Tube well water	Glass Bottle	30.10.09	Post-monsoon [Control]

7. Analysis of soil & water samples:

7.1 Physio-chemical Parameters of Soil;

(Soil pH is a measurement of the soil acidity (pH<7) or soil alkalinity (pH>7). Soil solutions were extracted from the dumpsite as well as control soil by **lysimetric method** for determination of pH. The data obtained are presented in Figure 1. Observations reveaied that **the pH of dumpsite soil samples** collected in **post monsoon season was comparatively more basic than the pre monsoon** sampleThe similar trend was also observed in control soil samples. All the samples have pH>7 indicating occurrence of alkaline soil. It may be due to poor soil texture of sampling point 1-4, and upper soil portion of sampling point 5-6 which have thick hard calcareous (kankar) layers of low infiltration capacity in their soil profile. Such soil becomes alkaline due to presence of carbonates and bicarbonates of calcium, magnesium, sodium, and potassium held by soil colloids. During post-monsoon season, high rainfall occurred at both sampling location at **dumped waste containing high plastic contents** as well **as hard soil profile of low infiltration capacity caused water logging** at Ghaila dumpsite area. The irrigated water contained lime which might precipitated in the upper regions of dumpsite area nearest the water delivery inlets and in the water flow path. Due to prolonged water logging it has resulted into higher alkalinity of soil and pH levels rising to 7.0 and above until equilibrium is reached with atmospheric carbon dioxide levels. Such increase in soil pH occurs more rapidly on coarse and medium-textured soils than on clays which are more highly buffered. Higher pH values of soil may be due to above factors at Dudauli dumpsite and Locations 5 and 6 of Ghaila dumpsite area.

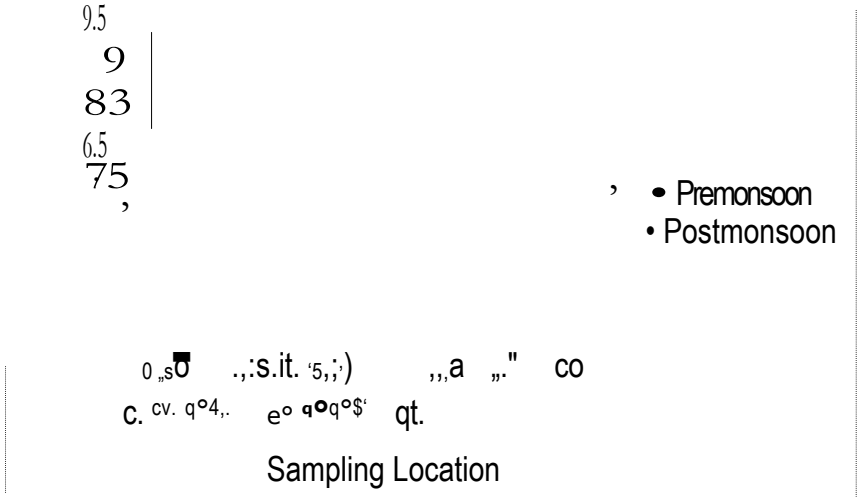


Fig. 1: Mean pH of collected soil samples of each sampling location in different monsoon seasons

7.2 Chemical Property of Soil Samples

Assessment of soil quality with respect to its chemical composition was also done by evaluating essential mineral level viz, available phosphorous as phosphate (in kg/ha), available potassium (in kg/ha), available nitrogen (in kg/ha) and chloride level (mg/kg). The data obtained are presented in **figure 2-5** revealed that control and dumpsite soil samples collected after rainfall (post monsoon samples) were comparatively found to be more enriched with essential minerals/ions. Availability of phosphorous and potassium was found to be higher in control soil samples than dumpsite samples indicating the depletion of nutritional quality of dumpsite soil due to dumping of municipal solid was, However, higher concentration of nitrogen and chloride ion was found throughout the soil profile of dumpsite area. The probable reason may be decomposition of landfilled/dumped waste under environmental conditions leading to formation of different characteristic chemical moieties viz, nitrogen, methane, chloride, phosphate etc. Such species were prominently found in higher concentration at Dudauli Municipal Solid Waste dumpsite area in comparison to Ghaila Municipal Solid Waste dumpsite because of high load of dumped waste in larger area at Dudauli dumpsite. It is worth to mention that significant amount of analytes were found throughout different soil layers and levels were comparatively higher in post monsoon season, specially in case of Ghaila dumpsite samples, indicating constant percolation of such analytes in the soil profile.

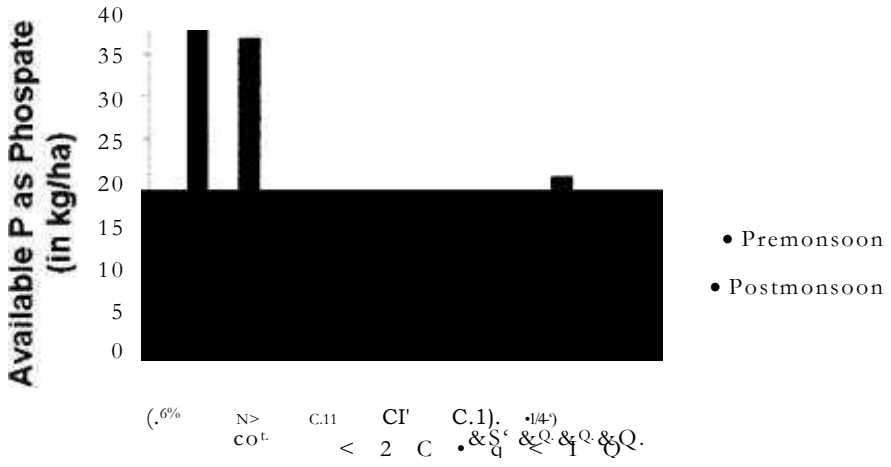


Fig 2: Mean Concentration of Available Phosphorous (P) as Phosphate in Collected Soil Samples of each Sampling location in different Monsoon Seasons

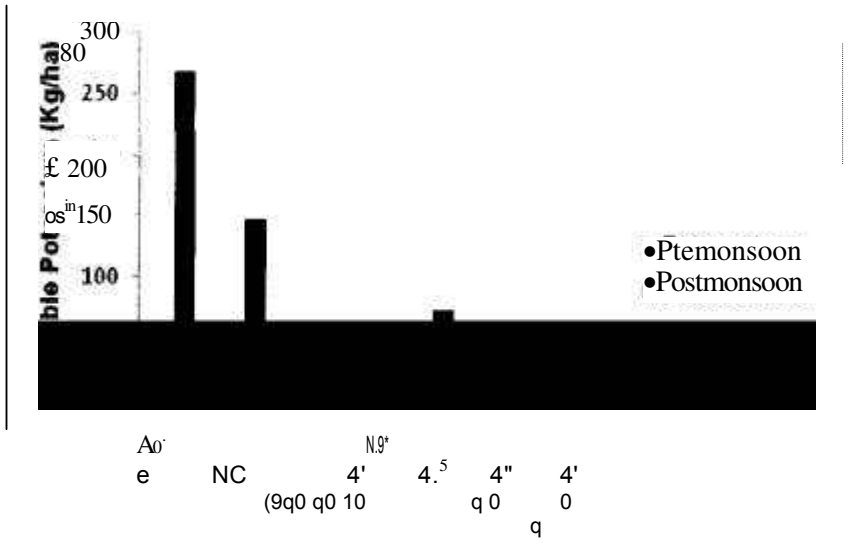


Fig 3: Mean concentration of available potassium in collected soil samples of each sampling location in different monsoon seasons

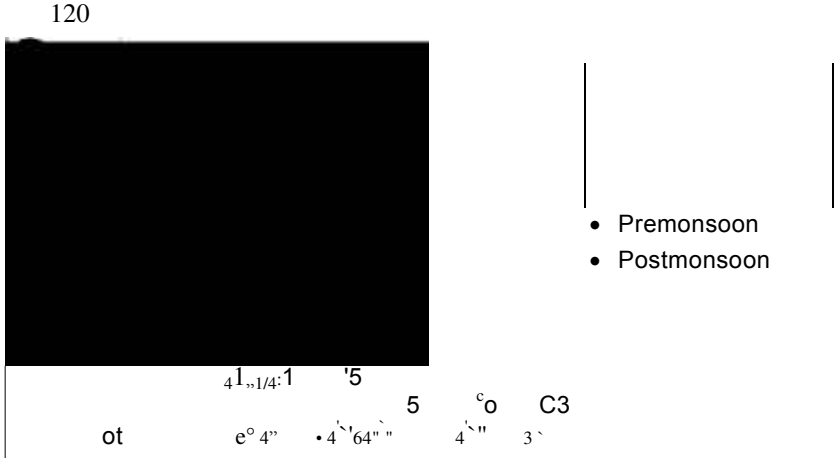


Fig 4: Mean values of available nitrogen in collected soil samples of each sampling location in different monsoon seasons

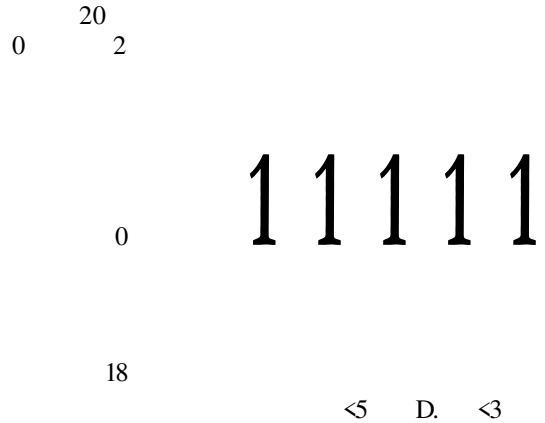


Fig 5: Samples of each sampling location in different monsoon seasons

7.3 Heavy Metals and Organic Contaminants in Soil Samples:

Heavy metals viz Cd,Co,Cr, Cu, Pb, Mo, Ti and Zn were analyzed in all control soil (22 nos.) samples (14 pre monsoon + 08 post monsoon) and experimental/dumpsite soil (88 nos.) samples (66 pre-monsoon + 22 Post monsoon). In addition level of phthalates viz. Di-methyl phthalate (DMP), Diethylphthalate (DEP), Di-butyl phthalate (DBP), Di (2-ethylhexyl) phthalate (DEHP) and Di-octyl phthalate (DOP) were also determined in leachates (TCLP) of soil samples. Data revealed that Ghaila Landfill site having coarse or sandy texture of soil have greater contamination of inorganic and organic moieties throughout soil profile and in deep aquifers because rain water leachates containing pool of contaminants may easily percolate throughi)On the other hand, impact of pollutants appeared more on upper strata soil and side streams at Dudauli waste dumpsite having clay, gravels or rocky soil texture. In addition, seasonal fluctuations also dominates on the quality and quantity of landfill leachate produced. During the wet season period (post monsoon), low-strength leachate may suppose to generate, while during the dry season period (pre monsoon), reduced percolation and enhanced evaporation increase the leachate strength.

Soils have property to bind various chemicals and it depends on the form in which they exist in the environment. It consists of mineral particles, organic matter and organic-mineral particles. They play important role in giving the soil's ability to absorb exchange, oxidize, reduce, catalyze and precipitate chemical and metal ions in particular. The inorganic colloidal fraction of soil is the most responsible for absorption by its mineral particles. Its large surface area and porosity makes it good absorber of organic and inorganic materials. Organic and inorganic moieties physically adsorb on soil surface instead of being chemically absorb. Due to variation in pH, temperature, weathering or flow of water from refusal tips such contaminants may migrate and percolates into lower soil strata or underground water profile. The period of waste dumping was also found to be an important parameter to characterize the leachate and to predict the environmental implications of waste dumping. Age of the landfill corresponding to stabilization stage has a significant effect on characteristic composition of leachate, as found at Dudauli dumpsite where dumping is continued since last five years and Ghaila dumpsite which is active since last three years. The observed value revealed that the quantity of leachate produced may be regarded as proportional to the volume of water percolating through the landfilled waste. Reduction of the quantity of water entering the tip is of great importance in reducing the rate of leachate generation. Leachate production has been found to be higher when the disposed refuse is less compacted since compaction was found to reduce the filtration rate.

7.3 Heavy Metals in Water Samples :

Heavy metals viz. Cd, Co, Cr, Cu, Pb, Mo, Ti and Zn were analyzed in all control water (12 nos.) samples (06 pre monsoon + 06 post monsoon) and experimental/dumpsite water (36 nos.) samples (18 pre monsoon + 18 post monsoon). The analytical data as presented in **table 5** revealed that Cd, Co and Ti were found below detection limit (BDL) in all 48 samples. However, Cu and Zn are present in significant concentration in all samples. Further, levels of Pb, Mo and Cr were found in traces and the concentration above permissible limit was found only in few samples of first strata water. There was no significant difference in level of heavy metals in pre-monsoon and post-monsoon water samples as seen in case of soil samples. This may be due to dilution factor because of rainfall. However, presence of heavy metals in traces in first strata in the underground water of d psite area, may occur due to percolation of such heavy metals from dumping of municipal solid waste including plastic waste. The effect of percolation was more at Ghaila dumpsite area having sandy soil texture than Dudauli dumpsite area with hard clay and gravels in soil profile. The concentration of Heavy Metals is mentioned at **Table-5.**

Table- 5: Concentration of Heavy Metals in Water Samples

CADMIUM (Cd)	Pre-monsoon Samples	Post-monsoon Samples
Concentration (mg/l)	Control	Control
Total	0	0
Average	0	0
Standard Deviation	0	0
Maximum value	0	0
Minimum value	0	0
	Experimental	Experimental
Total	0	0
Average	0	0
Standard Deviation	-	-
Maximum value	-	-
Minimum value	-	-

COBALT (Co)	Pre-monsoon *Samples*	Post-monsoon *Samples*
Concentration (mg/l)	Control	Control
Total	0	0
Average	0	0
Standard Deviation	0	0
Maximum value	0	0
Minimum value	0	0
	Experimental	Experimental
Total	0	0
Average	0	0
Standard Deviation	-	-
Maximum value	-	-
Minimum value	-	-

CHROMIUM (Cr)	Pre-monsoon *Samples*	Post-monsoon *Samples*
Concentration (mg/I)	Control	Control
Total	0	0
Average	0	0
Standard Deviation	0	0
Maximum value	0	
Minimum value	0	0
	Experimental	Experimental
Total	1.108	0.080
Average	0.061	0.004
Standard Deviation	0.058	0.018
Maximum value	0.196	0.080
Minimum value	0	

COPPER (Cu)	Pre-monsoon *Samples*	Post-monsoon *Samples*
Concentration (mg/I)	Control	Controi
Total	0.509	1.465
Average	0.084	0.244
Standard Deviation	0.085	0.324
Maximum value	0.213	0.900
Minimum value	0	0
	Experimental	Experimental
Total	0.857	1.129
Average	0.047	0.062
Standard Deviation	0.100	0.049
Maximum value	0.420	0.180
Minimum value	0	0

LEAD (Pb)	Pre-monsoon Samples	Post-monsoon Samples
Concentration (mg/I)	Control	Control
Total	0	0
Average	0	0
Standard Deviation	0	0
Maximum value	0	0
Minimum value	0	0
	Experimental	Experimental
Total	0.040	0
Average	0.002	0
Standard Deviation	0.022	0
Maximum value	0	0
Minimum value	0.040	0

MOLYBDENUM (Mo)	Pre-monsoon Samples	Post-monsoon Samples
Concentration (mg/I)	Control	Control
Total	0	0
Average	0	0
Standard Deviation	0	0
Maximum value	0	0
Minimum value	0	0
	Experimental _	Experimental
Total		
Average	0.105444	0
Standard Deviation	0.160629	0
Maximum value	0.417	0
Minimum value	0	0

Titenium (Ti)	Pre-monsoon Samples	Post-monsoon Samples
Concentrati on (mg/I)	Control	Control
Total	0	0
Average	0	0
Standard Deviation	0	0
Maximum value	0	0
Minimum value	0	0
	Experimental	Experimental
Total	0	0
Average	0	0
Standard Deviation	–	–
Maximum value	–	–
Minimum value	–	–

ZINC (Zn)	Pre-monsoon Samples	Post-monsoon Samples
Concentration (mg/I)	Control	Control
Total	4.197	3.120
Average	0.699	0.624
Standard Deviation	0.379	0.306
Maximum value	1.066	0.820
Minimum value	0	0
	Experimental	Experimental
Total	25.435	14.300
Average	1.413	0.841
Standard Deviation	1.279	0.648
Maximum value	4.410	2.500
Minimum value	0.006	0.100

7.5 Phthalates in Water Samples

The quality of water collected from dumpsite area was assessed with respect to phthalates. This was conducted to estimate the concentration level of phthalates viz. Di-methyl phthalate (DMP), Di-ethyl phthalate (DEP), Di-butyl phthalate (DBP), Di (2-ethylhexyl) phthalate (DEHP) and Di-octyl phthalate (DOP). The levels of different type of phthalates in the dumpsite water as well as control water samples at selected identified locations are presented in Table 4. During conducting experiment, Limit of Quantification (LOQ) and Limit of Detection (LOD) and recovery were determined by spiked sample method. The data analysed are presented at **Table 6.**

Table - 6

Compound	Spiked Level in water (Ogil)	Mean Recovery	LOQ (0g/1)	LOD (DWl)
DMP	10	70%	1.67	0.55
DEP	10	90%	0.28	0.09
DBP	10	76%	0.34	0.11
DEHP	10	85%	0.83	0.27
DOP	10	75%	0.40	0.13

The processed samples were analyzed using High Performance/Pressure Liquid Chromatography (HPLC). One representative chromatograph of Standard and a sample is presented in **Fig.6.** The five representative samples were analyzed on Gas Chromatography-Mass Spectrophotometer (GC-MS) to get confirmation of the respective chromatographic peaks of phthalates. The identification of the phthalates found in the samples was confirmed on GC-MS by comparing the RT and fragmentation patterns of the compound in the standard and samples.

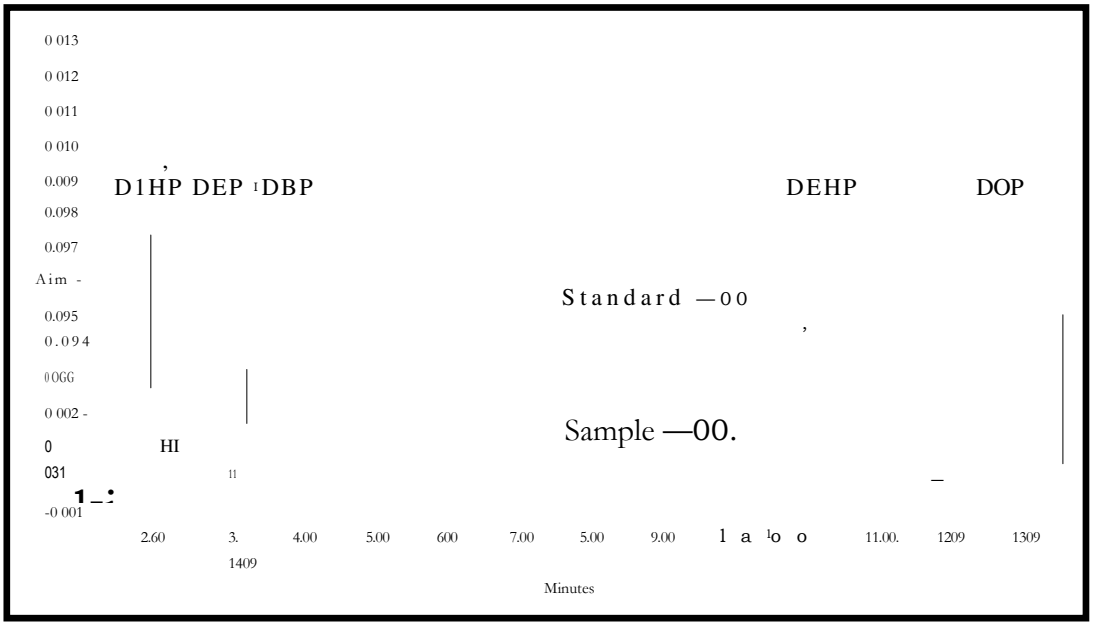
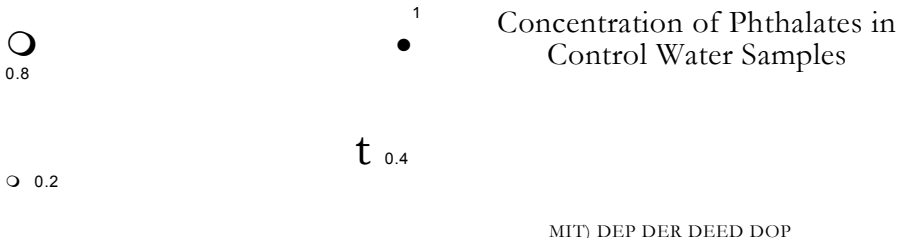


Fig-6: HPLC Chromatograph of representative Phthalate(s)

It is evident from the data of control water samples of all six locations that the values of phthalates are in traces **(Table 7)**. In **pre-monsoon control** water samples the mean values of individual phthalates are BDL, 0.958 mg/l, 0.747 mg/l, 1.005 mg/l and 0.462 mg/l for DMP, DEP, DBP, DEHP and DOP, respectively. These values revealed that DEHP were found to be present in 52.0% of the total phthalate concentration, while the DMP was the least detected phthalate. Detected phthalate concentration was found in the order DEHP>DEP>DBP>DOP»DMP, hence, it found in lesser quantity as compared to DEHP, DEP and DBP. **Data obtained from** the analysis **of post-monsoon control** water samples revealed the occurrence of **phthalates concentration is** comparatively higher than the **pre-monsoon samples (Fig. 7 and Fig. 8).** Mean values of individual phthalates concentration in post-monsoon control water samples are BDL, 1.033 mg/l, 0.832 mg/l, 1.358 mg/l and 0.517 mg/l for DMP, DEP, DBP, DEHP and DOP, respectively. Detected phthalate level was found to follow the same occurrence trend as pre-monsoon samples: DEHP> DEP>DBP>DOP>>DMP. Out of six control water samples, five samples were collected near (within 200 meters residential area) Dudauli and Ghaila Municipal waste dumpsite area from tube well or hand pump, which was used by local people. The presence of traces of phthalates in water samples of the dumpsite areas indicate the effect of dumping of municipal and plastic waste on the surroundings.

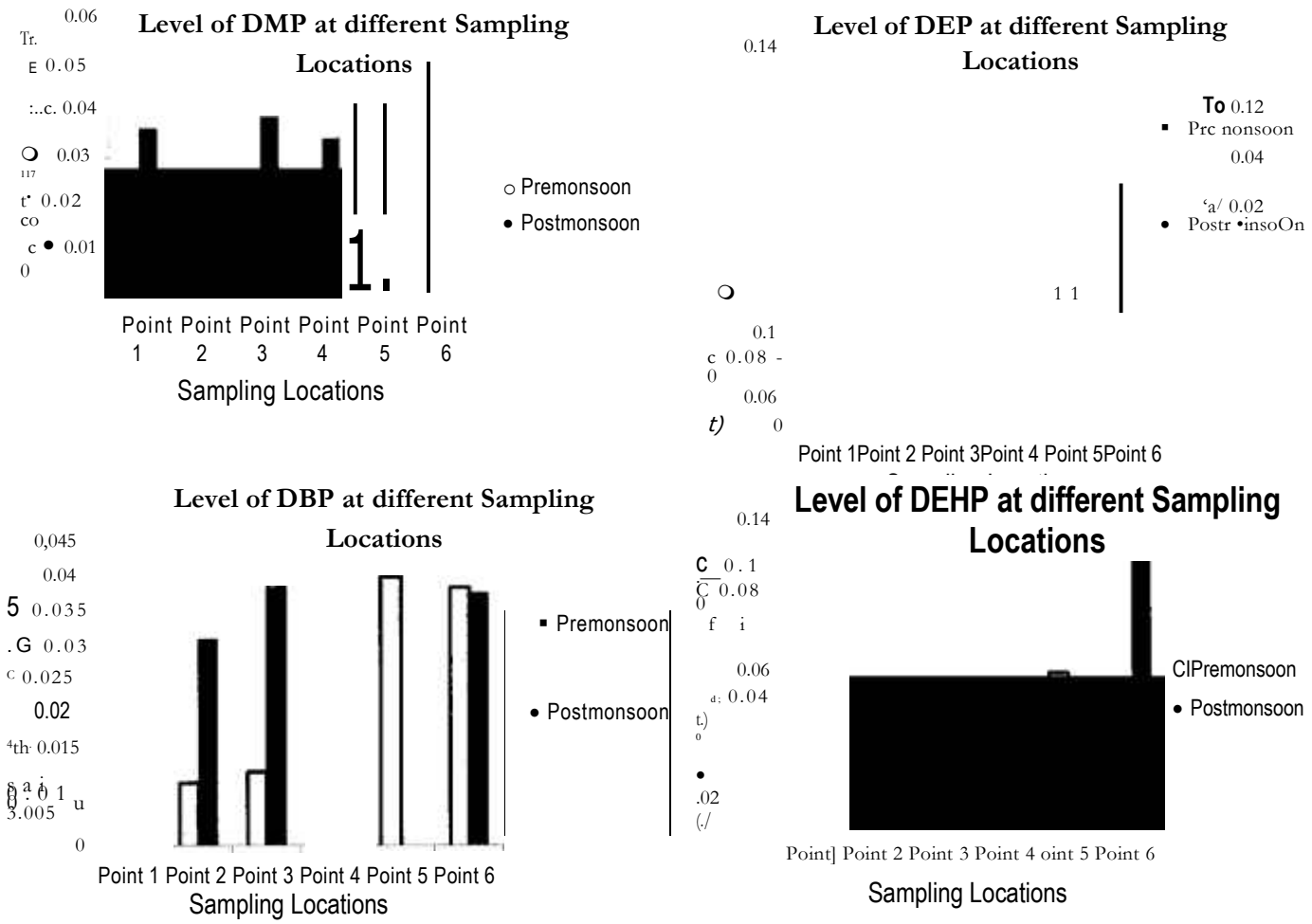
Fig 7: Mean Concentration of Phthalates (mg/l) in Control Water Samples



Control Water **Samples**	Mean Concentrat'on **(±SD)** of **Phthalates (mg/l)**				
	DMP	DEP	DBP	DEHP	DOP
Pre-monsoon	BDL	0.958 ±2.76	0.747 ±2.12	1.005 ±2.46	0.462 ±1.35
Post-monsoon	BDL	1.033 ±2.95	0.832 t2.37	1.358 ±3.45	0.517 ±1.51

Table 7: **Concentration of Phthalates in Experimental Water Samples**

Sampling Location	**Season**	**Mean** Concentration (±SD) **of Phthalates** (in **mg/l)**				
		DMP	DEP	**DBP**	**DEHP**	DOP
Point 1	Pre-monsoon	0.014 ±0.005	0.073 ±0.014	0.003 ±0.005	0.003 ±0.002	0.002 ±0.002
	Post-monsoon	0.036 ±0.012	0.081 ±0.010	0.017 ±0.029	0.012 ±0.013	BDL
Point 2	Pre-monsoon	0.009 ±0.001	0.105 ±0.013	0.009 ±0.005	0.009 ±0.001	BDL
	Post-monsoon	0.021 ±0.010	0.131 ±0.013	0.030 ±0.010	0.053 ±0.033	BDL
Point 3	Pre-monsoon	0.027 ±0.006	0.084 ±0.012	0.011 ±0.004	0.011 ±0.004	0.003 ±0.003
	Post-monsoon	0.038 ±0.007	0.121 ±0.024	0.038 ±0.005	0.007 ±0.005	BDL
Point 4	Pre-monsoon	0.016 ±0.006	0.058 ±0.053	0.006 ±0.002	0.009 ±0.001	BDL
	Post-monsoon	0.034 ±0.008	0.076 ±0.064	BDL	0.031 ±0.010	BDL
Point 5	Pre-monsoon	0.041 ±0. 006	0.085 ±0.015	0.040 ±0.005	0.069 ±0.019	0.003 ±0.005
	Post-monsoon	0.017 ±0.028	0.036 ±0.063	BDL	0.038 ±0.040	BDL
Point 6	Pre-monsoon	0.050 ±0.005	0.0683 ±0.010	0.038 ±0.008	0.067 ±0.007	0.006 ±0.010
	Post-monsoon	0.045 ±0.039	0.079 ±0.071	0.037 ±0.032	0.121 ±0.022	BDL



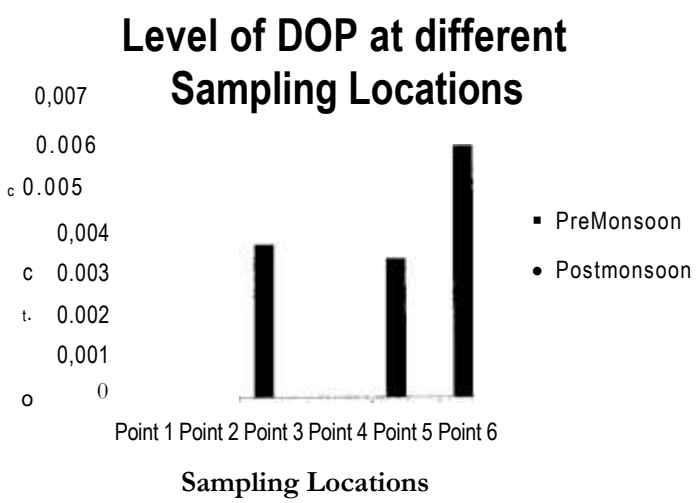


Fig 8: Mean Concentration of Phthalates (mg/I) in Experimental Water Samples

Conclusion:

- Characterization of dumpsite samples could be a yard-stick for the measurement of extent of pollution in surrounding environment. The biotic and abiotic transformation processes of different wastes give rise to pools of organic and inorganic compounds in the gaseous and liquid phases. During landfill operation, leachates are produced, mainly due to the infiltration of rainwater through the refuse tips. Such compounds may percolate through soil and contaminate groundwater basins in the drainage area of the landfill.
- The period of waste dumping (age of landfill site), geological and seasonal factors are important parameters to characterize the leachate and predict the environmental implications of waste dumping.
- The pH of dumpsite soil samples collected in post-monsoon season was found to be comparatively more basic than the pre-monsoon samples. Accumulated dumped waste containing high plastic contents as well as hard soil profile of low infiltration capacity caused water logging. This irrigated water contained much of the lime which might precipitate in the upper regions of dumpsite area and resulted into increase in the alkalinity of the soil.
- Availability of phosphorous and potassium was found to be higher in control soil samples than dumpsite samples indicating the depletion of nutritional quality of dumpsite soil due to dumping and degradation of plastics waste for more than 10 years.
- Decomposition of landfilled/dumped waste under environmental conditions caused higher concentration of nitrogen and chloride ions throughout the soil profile of dumpsite area.
- Presence of heavy metals and phthalates in first strata of underground water of umpsite area is due to migration and percolation of dumping of municipal and plastic waste.
- Data obtained from Toxicity Characteristic Leaching Procedure (TCLP) of dumpsite samples also contained significant amount of analytes indicating migration of chemical moieties from plastic waste.

Recommendation:

It has been observed that dumping of plastic waste may deteriorates soil and underground water quality due to leaching of additives, colours, stabilizes and fillers present in the different categories of plastic products. It is therefore recommended that plastic dumping should not be allowed to preserve the soil and water quality vis-as-vis Environment.