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Assessment of Impact of Leachate on Groundwater, in the Vicinity of the First Engineered Landfill Site in Delhi, India

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***Abstract* - The dumping of solid waste in sanitary landfills can cause significant impacts on the environment and human health. The main concern is focussed on the pollution potential due to movement of the leachate generated from these landfills into the groundwater, surface water or the sea. Hence, to decide whether the leachate is to be collected and treated, or may be allowed to discharge into the adjoining soil or public sewer or surface water body, it is essential to have the assessment of its composition, strength and its variation with time and space. In this paper, the experimental work carried out at the first engineered landfill site in New Delhi, India, to ascertain the composition of leachate, and its effect on the groundwater under the existing scenario, is presented. For asserting the contamination potential of the landfill site, a tool called Leachate Pollution Index (LPI) has been used. LPI is an increasing scale index, where a higher value indicates poor environmental condition, developed based on the Rand Corporation's Delphi Technique; which is an opinion based research technique to extract information from a group of panellists. LPI includes 18 parameters, out of which the leachate samples were analyzed for 16 parameters *viz.* pH, TDS, BOD_5, COD, TKN, Ammonia nitrogen, Total Iron, Copper, Nickel, Zinc, Lead, Total chromium, Mercury, Arsenic, Chlorides and Cyanide. The groundwater samples collected from the vicinity of the landfill were analyzed for 12 parameters *viz.* pH, TDS, Chlorides, Total iron, Arsenic, Cyanide, Lead, Zinc, Copper, Total chromium, Mercury and Nickel. In order to determine the factors which had higher detection rate and larger impact, the Pearson correlation matrix has been developed among the parameters tested of groundwater samples. Results clearly indicated that the likely contamination of groundwater due to leachate released from the landfill. Results are further compared with Bureau of Indian Standards and standards laid down by World Health Organisation (WHO), for drinking water. Presence of contaminants in groundwater particularly near the landfill sites warns its quality and thus renders the associated aquifer unreliable for domestic water supply and other uses.**

***Keywords:* Leachate Pollution Index, Groundwater characterisation, Narela-Bawana landfill, correlation matrix, Integrated Municipal Solid Waste Management Facility, Engineered landfill site**

I.INTRODUCTION

It has been estimated that urban India is generating approximately 1,88,500 tonnes of municipal solid waste per day (68.8 million tonnes per year). The capital of India, Delhi generates approximately 11,558 tonnes of municipal solid waste daily (Annepu, 2012). The generation rate is about 700 gm/person/day, which is almost five times the national average. The management of MSW is going through a critical phase, due to the unavailability of suitable facilities to treat and dispose off the larger amount of MSW generated daily in metropolitan cities. It involves activities associated with generation, storage, collection, transfer and transport, processing and disposal of solid wastes. But, in most cities, the MSWM system comprises only four activities, i.e., waste generation, collection, transportation, and disposal.

The disposal of solid waste currently relies principally on landfills. Landfill of MSW is the simplest, cheapest and most cost effective method of disposing of waste in both developed and developing nations of the world [Barrett and Lawlor, 1995; El-Fadel et al, 1997; Daskalopoulos et al, 1998; Jhamnani and Singh, 2009; Longe and Bologun, 2010]. In India, most landfills are usually open dumps/unlined landfills. Only a fraction can be regarded as engineered landfills, indicating that they were designed and constructed according to engineering specifications. Landfills are considered one of the major threats to groundwater [USEPA, 1984; Fatta et al, 1999]. The scale of this threat depends on the concentration and toxicity of contaminants in leachate, type and permeability of geological strata, depth of water table and the direction of groundwater flow [Al-Khaldi, 2006]. Modern sanitary landfills have been reported to leak leachate and pollute groundwater [Lee and Jones-Lee, 2004]. Wastes placed in landfills are subject to either groundwater underflow or infiltration from precipitation and as water percolates through the waste, it picks up a variety of inorganic and organic compounds, flowing out of the wastes to accumulate at the bottom of the landfill. The resulting contaminated water is termed leachate and can percolate through the soil [Mor et al, 2006]. Municipal landfill leachate is highly concentrated complex effluents which contain dissolved organic matters; inorganic compounds; heavy metals and xenobiotic substances [Lee and Jones-Lee, 1993,Christensen et al, 2001,Tengrui et al, 2007,Ogundiran and Afolabi, 2008]. The management of leachate is among the most important factors to be considered in planning, designing, operation, and long-term management of an MSW landfill [Halim et al, 2010]. The state regulatory authorities, in almost all the countries of the world, have framed regulations to safeguard against the contamination of groundwater sources from the leachate generated from the landfills. The processes for leachate collection and treatment are complex and the costs are usually quite high [Youcai et al, 2000]. Therefore the remedial and preventive measures cannot be undertaken at all the existing closed and the active landfill sites in one go because of the financial constraints. The remedial and preventive measures need to be taken up in a phased manner. The overall pollution potential of landfill leachate can be calculated in terms of Leachate Pollution Index (LPI) as proposed by Kumar and Alappat [Kumar and Alappat, 2003]. Because identification and quantification of pollutants in landfill leachate is the major limitation for its successful treatment [Trankler et al, 2005], LPI can be used as a mean to determine whether a landfill requires immediate attention in terms of introducing remediation measures.

Kumar and Alappat [Kumar and Alappat, 2003] developed a technique to evaluate the leachate contamination potential of different landfills on a comparative scale using an index known as LPI. LPI has many applications including ranking of landfill sites, resource allocation for landfill remediation, trend analysis, and enforcement of standards, scientific research and public information. In an effort to develop a method for comparing the leachate pollution potential of various landfill sites in a given geographical area, an index known as LPI was formulated using Rand Corporation's Delphi Technique. The formulation process and complete description on the development of the LPI, has been discussed elsewhere [Kumar and Alappat, 2003]. The LPI represents the level of leachate contamination potential of a given landfill. It is a single number ranging from 5 to 100 (like a grade) that expresses the overall leachate contamination potential of a landfill based on several leachate pollution parameters at a given time. It is an increasing scale index, wherein a higher value indicates a poor environmental condition. The LPI can be used to report leachate pollution changes in a particular landfill over time.

The trend analysis so developed for the landfill can be used to assess the post closure monitoring periods. The leachate trend at a given landfill site can facilitate design of leachate treatment facilities for other landfills in the same region. The LPI can also be used to compare leachate contamination potential of different landfills in a given geographical area or around the world. The other potential application of LPI include ranking of landfill sites based on leachate contamination potential, resource allocations for landfill remediation, enforcement of leachate standards, scientific research and public information [Kumar and Alappat, 2003].

II.MATERIALS AND METHODS

Site Description

The Narela - Bawana Integrated Municipal Solid Waste Management Facility covers approximately 100 acre (40 Hectares) of land (between 28°57'39"N, 77°03'42"E and 28°48'21"N, 77°04'14"E) and is located in the Northern part of Delhi along Haryana border on Narela - Bawana road at a distance of about 5-6 kms from Bawana village, towards Narela Village. The site is bounded by Western Yamuna canal and high tension wire and electric substation on south, village Sanoth on north east and Narela - Bawana road on north. Sanoth village and Bawana settlements are located approximately 1.00 km and 2.70 km away from the proposed site, respectively. The site is accessible through Narela - Bawana road.

Western Yamuna Canal passes through the southern side and is around 550 m away from the boundary of the facility. Daryapur water body is on the eastern side and passes along the periphery of the site.

MSW site is being constructed in different phases. Currently second phase of construction is being under taken. Once fully functional, 4000 tonnes/day of waste would be dumped in the concerned landfill site. The site is being claimed to be efficiently installed with instrument which leads to effective management of waste produced and waste reduction and generation of electricity from waste. Out of the total 40 ha, material recovery facility, including Refuse Derived Fuel (RDF) recovery covers an area of 0.27 ha. Compost Plant and Recyclables storage area are said to be placed in 2.7 ha and 0.27 ha respectively. Power plant has an area of 13.1 ha and landfill occupy majority of land which is around 16.1 ha (Ramky Enviro Engineers Limited, 2010). It is claimed that the landfill is lined with two layers of clay and a High Density Polythene layer in between. Once the RDF plant becomes operational, there is a place to collect the harmful gases and flare it before releasing in the atmosphere which will be produced when RDF would be burned.

Leachate Sample Collection

Leachate samples were collected thrice in the months of February and March 2016 from the sump pond in the centre of the MSW landfill site. The samples were collected in High Density Polyethylene (HDPE) bottles, which were rinsed with distilled water in the laboratory, sterilized by heating at 180^0C together with their stoppers for some time and later, washed 2-3 times with the samples which were to be collected, on site. After collection, all samples were taken straight to the laboratory and stored in refrigerator at 4^0c temperature. The samples were properly labelled with details of the source, date of sampling, time of sampling.

Groundwater Sample Collection

In order to check the contamination due to leachate, samples of ground water were collected from nearby hand pumps at different locations, list of which has been provided in Table 1, along with their respective GPS coordinates and distance from landfill site.

TABLE I GROUNDWATER SAMPLING LOCATIONS.

Samples	**GPS Coordinates**		**Distance from the facility (Km)**
	Latitude	**Longitude**	
GW1	28°48'4.73"N	77° 4'10.17"E	0
GW2	28°48'11.83"N	77° 4'21.08"E	0.2
GW3	28°48'6.62"N	77° 3'48.77"E	0.46
GW4	28°47'36.16"N	77° 4'30.48"E	1.09
GW5	28°47'53.49"N	77° 5'5.81"E	1.53

Priority was kept to take sample nearest to landfill. Since the considered landfill is situated in an industrial area, precaution of not collecting sample nearby the industrial area was kept in mind. Landfill is also confined by Western Yamuna Canal on one side, thus it was kept in mind to not to collect samples beyond the canal. For ground water sample collection, 1 litre HDPE sampling bottles were used, which were rinsed with distilled water in the laboratory, sterilized by heating at 180^0C together with their stoppers for some time and later, washed 2-3 times with the samples which were to be collected, on site. After collection, all samples were taken straight to the laboratory and stored in refrigerator at 4^0c temperature. The samples were properly labelled with details of the source, date of sampling, time of sampling. The facility and the ground water collection locations have been shown in the image taken from the Google Earth (Fig. 10).

Fig.1 Location of DMSWSL and the groundwater sampling locations

Laboratory Analysis

The chemical analysis was done in accordance with the APHA methods (APHA, 1994). The pH and TDS were measured using conductivity meter; BOD_5 is based mainly on bio-assay and DO using Winkler's method; COD by open reflux method and titration; TKN and Ammonia Nitrogen by micro Kjeldahl's unit and Nesslerization method respectively; Chlorides by titration; Cyanide by ion-selective electrode; and heavy metals (Fe, Cu, Ni, Zn, Pb, Cr, As) using Atomic Absorption Spectrophotometer.

III.RESULTS

Leachate Characterization

The leachate samples taken from the dumping ground of Delhi Municipal Solid Waste Solutions Limited's Integrated Municipal Solid Waste Management Facility at Narela – Bawana, which is an engineered landfill with very little chances of dumping inert and other unacceptable material being disposed off.

All the experiments were carried out in triplicate and the results were found reproducible within 3%. Results for each parameter have been presented in Table 2.

TABLE II RESULTS OF LEACHATE SAMPLES

S. No.	Parameters	Units	Concentration
1	pH		8.22
2	TDS	mg/L	26392.66
3	BOD_5	mg/L	10209.52
4	COD	mg/L	32936.63
5	TKN	mg/L	337.68
6	Ammonia Nitrogen	mg/L	158.35
7	Total Iron	mg/L	22.819
8	Copper	mg/L	2.968
9	Nickel	mg/L	0.574
10	Zinc	mg/L	8.840
11	Lead	mg/L	0.065
12	Total Chromium	mg/L	0.868
13	Arsenic	mg/L	0.119
14	Chlorides	mg/L	4436.50
15	Cyanide	mg/L	2.542

Groundwater Analysis

The underground water of the studied area is used mainly for domestic and other purposes. Table shows the desired and maximum permissible limits recommended by Bureau of Indian Standards (BIS, 1991) and World Health Organization (WHO, 1997).

TABLE III DRINKING WATER QUALITY STANDARDS AS RECOMMENDED BY BIS AND WHO.

Parameter	BIS Standards		WHO Standards
	Desirable	Maximum Permissible	
Colour	5	25	-
Odour	Unobjectionable	Unobjectionable	-
Taste	Agreeable	Agreeable	-
pH	6.5-8.5	6.5-8.5	6.5-9.2
Total Hardness	300	600	300
Total Alkalinity	200	600	
Total Dissolved Solids	300	1500	500
Chloride	250	1000	250
Sulphates	250	400	200
Nitrates	45	45	50
Fluoride	1	1.5	0.5
Calcium	75	200	100
Magnesium	30	100	150
Potassium	-	-	200
Sodium	-	-	200
Ammonium	-	-	1.5
Phenol	-	-	0
Boron	-	-	0.3
Iron	-	-	0.3

Groundwater samples were collected after the extraction of water either from hand pumps in the period February-March 2016. The water was left to run from the source for about 4minutes to stabilize the electrical conductivity. All the experiments were carried out in triplicate and the results were found reproducible within ±3%. Results for each parameter have been presented in Table 3.

TABLE IV GROUNDWATER RESULTS

S. No.	Parameters	GW1	GW2	GW3	GW4	GW5
1	pH	6.32	7.26	7.89	5.96	6.11
2	Total Dissolved Solids	2159.87	2115.5	2209.6	1538.72	1658.08
3	Chlorides	1702.21	1108.3	1574.6	1197.51	802.6
4	Total Iron	0.591	0.368	0.602	0.112	0.103
5	Arsenic	ND	ND	ND	ND	ND
6	Cyanide	ND	ND	ND	ND	ND
7	Lead	0.07	ND	ND	0.13	ND
8	Zinc	0.078	0.363	0.861	ND	ND
19	Copper	0.265	0.25	0.291	0.219	ND
10	Total Chromium	0.112	0.088	0.116	0.076	0.085
11	Mercury	ND	ND	ND	ND	ND
12	Nickel	0.31	ND	ND	0.44	ND

Correlation coefficient analysis

Pearson correlation is a descriptive method used to evaluate the degree of interrelation and association between two different variables. A correlation of positive sign indicates a perfect positive relationship between two variables. A correlation of negative sign indicates that one variable changes inversely with relation to the other. A correlation of zero indicates that there is no relationship between the two variables. Table 4 represents the correlation matrix table among fifteen ground water quality parameters of groundwater of the study area.

The results indicate a significant correlation among each of pH, Zn, TDS, Cl^-, Cr, Ni, Pb and Fe at the level of $p \leq 0.05$.

TABLE V PEARSON CORRELATION COEFFICIENTS AMONG VARIOUS GROUND WATER QUALITY PARAMETERS

Parameter	pH	TDS	Chlorides	Total Iron	Lead	Zinc	Copper	Chromium	Nickel
pH									
TDS	0.767								
Chlorides	0.361	0.68							
Total Iron	0.663	0.944 (0.016*)	0.902 (0.036*)						
Lead	-0.636	-0.49	0.227	-0.263					
Zinc	0.971 (0.006*)	0.69	0.427	0.655	-0.54				
Copper	0.551	0.655	0.817	0.733	0.218	0.55			
Chromium	0.59	0.845	0.817	0.943 (0.016*)	-0.329	0.632	0.519		
Nickel	-0.642	-0.401	0.316	-0.165	0.989 (0.001*)	-0.553	0.25	-0.229	

* Correlation is significant at $p \leq 0.05$

Figures in brackets indicate P-value at significance level = 0.05

Leachate Pollution Index

Using the results of leachate characterisation, the LPI of the landfill site under study has been established (Table 4).

TABLE VI LEACHATE POLLUTION INDEX

S.No.	Leachate Characteristics	Value	Individual pollution rating (p_i)	Weights (w_i)	Overall pollution rating ($p_i w_i$)
1	pH	8.22	5	0.055	0.275
2	TDS	26392.66	60	0.050	3.00
3	BOD5	10209.52	60	0.061	3.66
4	COD	32936.63	88	0.062	5.456
5	Total Kjeldahl Nitrogen	337.68	10	0.053	0.53
6	Ammonia Nitrogen	158.35	15	0.051	0.765
7	Total Iron	22.819	5	0.045	0.225
8	Copper	2.968	20	0.050	1.00
9	Nickel	0.574	5	0.052	0.26
10	Zinc	8.840	6	0.056	0.336
11	Lead	0.065	5	0.063	0.315
12	Total Chromium	0.868	6	0.064	0.384
13	Mercury	-	-	-	-
14	Arsenic	0.119	5	0.061	0.305
15	Phenolic compounds	-	-	-	-
16	Chlorides	4436.50	40	0.048	1.92
17	Cyanide	2.542	40	0.058	2.32
18	Total coliform bacteria	-	-	-	-
Total				**0.829**	**20.751**

$$\text{Leachate Pollution Index} = \frac{20.751}{0.829} = 25.03$$

IV.DISCUSSION

Leachate

1. The Leachate Pollution Index value of the standards given under Municipal Solid Waste (Management and Handling) Rules 2000, Government of India (MSW, 2000) for the disposal of leachate to inland surface water is 7.378. In the present study, LPI value of the leachate was found to be 25.03, indicating need for treatment before disposal.
2. Physicochemical characteristics of the leachate depend primarily upon the waste composition and water content of total waste. High value of pH obtained for leachate sample indicates the phase of decomposition of waste characterized by the production of volatile fatty acids and carbon dioxide (Kjeldsen et al, 2002).
3. High value of Total Dissolved Solids of the order of 26392.66 mg/l is observed, which indicates the presence of inorganic material in the samples.
4. Value of BOD_5 in leachate is observed around 10209.52 mg/l which tends to indicate the maturity of the landfill and shows that microbial activity in the decomposing leachate is yet to attain stability.
5. Value of COD and BOD observed are 32936.63 and 10209.52 mg/l respectively, thus ratio of BOD_5:COD comes out to be around 0.31. COD is an important parameter for its usefulness in determining the relative degree of solid waste decomposition, leachate treatment technique, detection of contaminant migration, and organic contamination (Stephen et al, 1977).
6. Value of Chlorides observed was quiet high, of the order 4436.50mg/l.
7. Heavy metals contents of the leachate samples include Iron, Copper, Nickel, Zinc, Lead, Chromium and Arsenic. Iron has the highest concentration of all the heavy metals present in the leachate followed by Zn, Cu, Cr, Ni, As and Pb.
8. The high concentration of Total Iron (22.819 mg/l), in the leachate samples is evidence of dumping of iron and steel scraps wastes in the landfill, which is justified as there is a huge industrial area - Bawana industrial area, in the proximity of landfill, although it is a MSW site.

9. On the other hand, the concentration of Zinc which is about 8.84 mg/L depicts dumping of batteries and fluorescent lamps in the landfill could be a possible source of it.
10. Concentration of Copper observed was 2.968 mg/l and potential source of Cu is thought to have originated from the dumping of waste related to cement like bags in the dumpsite.
11. The presence of Cr (0.868 mg/l) in the leachate samples may have originated from the emission of automobile exhaust of diesel tanker vehicles that are often seen in the vicinity of the dumpsite, possible reason of which could be their frequent maintenance visit to the garage located nearby and also due to other vehicle which ply on the road that leads to oil refinery in the city.
12. The different heavy metals detected are indication that the Narela-Bawana landfill site receives variety of wastes from both industrial and residential sources.

Groundwater

1. The ground water of the study area is used for domestic and agricultural purposes. The results show the concentration of various parameters present in the groundwater samples from which the quality of groundwater can be understood, as it is compared with the acceptable limit of BIS and WHO standards, which state that there should be no variation in the concentration of the constituents of water under normal circumstances, and on the contrary, variation in the ionic concentration of groundwater is expected in the direction of groundwater flow specifically nearby landfill site.
2. The pH value for groundwater samples is slightly-acidic to slightly-basic, in which the range is from 5.96-7.89. These values are exceeding WHO limits and the B.I.S standards permissible limit for portable drinking water. The pH value of water has no obvious effects on the consumers, but gives an indication that water is slightly acidic for GW1, GW4 and GW5 and slightly basic for GW2 and GW3.
3. Higher values for TDS were observed for GW1, GW2 and GW3, which is a strong indication of contaminant through landfill site. The concentration of TDS in water gives assistance in knowing the nature of quality or its salinity. The obtained concentrations of TDS in GW in the study area vary between 1538.72- 2209.6 mg/l. A high value of 2209.6 mg/l is measured for GW3, followed by GW1 with a value of 2159.87 mg/l and least value is observed of 1538.72 mg/l for GW4. These TDS values tend to decrease with distance of groundwater wells from the refuse dumpsite, along groundwater flow paths in down gradient direction. According to WHO, high level of TDS may be responsible for reduction in the palatability of water, inflict gastro-intestinal inconveniences in human and may also cause laxative effect particularly upon transits. In addition, the work of (Olaniya et al, 1977) has established measurable high level of TDS concentration as an indication of contamination of groundwater near refused dumpsite. High concentrations of dissolved solids increases the density of water, affects regulation of fresh water organism, and reduces solubility of gases like oxygen and utility of water for drinking, irrigational and industrial purposes. As per the classification of (Rabinove et al., 1958) based on TDS, all the samples were found to be slightly saline.
4. The concentration of Chloride is in the range of 802.6 – 1702.21 mg/l and significant proportion was found in GW1 and GW3 sampling location. High quantity of Chloride concentrations in water is indicator for pollution and as tracer for groundwater contamination (Loizidou et al, 1993). Domestic effluents, fertilizers, septic tank and natural sources such as rainfall and dissolution of fluid inclusion are some of the sources that may contribute to high Chloride concentration in groundwater and thus causing pollution, other than leaching from landfill and high concentration of Chloride is detrimental to people with heart diseases and kidney problems (WHO, 1997).
5. Among the heavy metals analyzed, Iron has the maximum concentration of 0.602 mg/l. The obtained value for GW1, GW2 and GW3 are evidently higher than the 0.3mg/l standard requirement for portable drinking water but GW4 and GW5 fall within the standard stipulated by the B.I.S and WHO standards. The colour of ground water samples at all locations was colourless, which however doesn't conform to (Rowe et al, 1995) findings, that a change in colour is often expected in groundwater which contains Fe^{2+}.
6. Total chromium present, varied from 0.076 - 0.116mg/l and concentration in groundwater is above permissible limit at all locations, being highest at GW3. Heavy doses of chromium salts even though are rapidly eliminated from human body, could corrode the intestinal tract (BIS, 1991).
7. There are minute concentrations of the following heavy metals that were detected in the groundwater samples and were below the required standard for portable drinking water of B.I.S and WHO. This includes Copper with a concentration of 0.291 mg/l for GW3 and went undetected for GW5, at all location is well under limits. Consumption of high levels of copper can cause nausea, vomiting, diarrhoea, gastric complaints and headaches. Long term exposure over many months and years can cause liver damage and deaths.
8. Zinc was detected at only 1st, 2nd and 3rd locations and is 0.078, 0.363 and 0.861mg/l respectively. These are in the minute

concentrations and assumption has been made that they have come from the underground soil stratum.

9. Arsenic, Lead, Cadmium, Mercury and Nickel were not detected at any locations nearby landfill, which is acceptable as their very low or no concentrations achieved in leachate also.
10. The groundwater samples analyzed indicated a trend of reducing contaminant concentration at increasing radial distances away from the landfill site for all contaminants studied but variation in concentrations is totally justified as the concerned area is confined by various industries of plastic, metals, textiles, etc.

V.CONCLUSION

The study primarily indicated that the Narela - Bawana integrated facility cumulatively generates significant amount of leachate which contains higher concentration of heavy metals and physico-chemical parameters. The groundwater samples around the facility is also contaminated containing heavy metals and physico-chemical parameters, more than that recommended by BIS and WHO standards for drinking water. The spatial distribution of all these heavy metals indicates possible leaching of contaminants from the landfill. The analyzed groundwater samples obtained from the vicinity of the facility's dumpsite did not evidently reflect water quality that is affected by the leachate collected from the refuse landfill site. Nevertheless the elevated values of TDS, chloride, iron, copper and chromium obtained, strongly depict the influence of leachate on the groundwater quality and may pose serious threat to groundwater quality in the distant future. The groundwater sample analysis result clearly indicated the trend of reducing contaminant concentration at increasing radial distances away from the landfill site for all parameters studied.

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