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Analysis of Leachate Contamination Potential of a Municipal Landfill Using Leachate Pollution Index

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Abstract: *The health hazards and environmental degradation from the uncontrolled and unlined landfills are well known facts. Leachate Pollution Index (LPI) is a quantitative tool by which the leachate pollution data of landfill sites can be reported uniformly. The LPI is an increasing scale index and has been formulated based on Delphi technique.In this paper, the concept of LPI is described in brief and LPI for active landfills in Mylai Balaji Nagar, Pallikkarani coming under Alandur Municipality and in Radha Nagar, Chromepet coming under Pallavaram Municipality is calculated based on the actual field datas.The LPI value for Pallikkaranai leachate and Periyaeri leachate was 37.006 and 15.325, respectively. This shows the Pallikkaranai leachate is more polluted than Peiyaeri leachate. Further, both leachates showed higher LPI value than that of 14.713 obtained for the treated leachate that can be disposed into land as per Indian standards.The study confirmed that Pallikkaranai landfill (Alandur Municiaplity) is highly polluted than the Periyaeri landfill (Pallavaram Municpality) based on LPI calculated. It is concluded that LPI value can be used as a tool to assess the leachate pollution potential from landfill sites particularly at places where there is a high risk of leachate migration and pollution of groundwater.*
Keywords: *landfill; leachate; leachate pollution index; groundwater contamination;*

I. Introduction

Landfills have been identified as on the major threats to the groundwater from the unlined and uncontrolled landfills exist in many parts of the worlds, particularly in the under-developed and developing countries where the hazardous industrial waste is also co-disposed with municipal waste and no provisions of separate secured hazardous landfills exists. Even if there are no hazardous wastes placed in municipal landfills, the leachate is still reported as a significant threat to the groundwater (Lee, 2002).

Waste placed in landfills or open dumps are subjected to either groundwater underflow or infiltration from precipitation. The dumped solid wastes gradually release its initial interstitial from precipitation. The dumped solid wastes gradually release its initial interstitial water and some of its decomposition by-products get into water moving through the waste deposit. Such liquid containing innumerable organic and inorganic compounds is called 'leachate'. This leachate accumulates at the bottom of the landfill and percolates through the soil.

Many factors influence the leachate composition including the types of wastes deposited in the landfill, composition of wastes, the particle size, the degree of compaction, the hydrology of the site, the climate, the age of the landfill and other site-specific conditions (Leckie et. al., 1979). The characteristics
of the leachate also depend on the pretreatment given to the solid waste such as segregation of recyclable materials (like plastics, paper, metals, glass, etc.), shredding and or bailing of the waste.

Areas near the landfills have a greater possibility of groundwater contamination because of the potential pollution source of leachate originating from the nearby site. Such contamination of groundwater resource poses a substantial risk to local resource user and to the natural environment. Contamination of groundwater by leachate makes the associated aquifer unreliable for domestic water supply and other uses (Jones Lee and Lee, 1993).

II. Need For The Study

The processes for leachate collection and treatment are complex and the cost are usually quite high (Youcai et al., 2000, Trabelsi et al., 2000, Tyrell et al., 2002). The remedial and preventive measures need to be taken up in a phased manner. Kumar and Alappat (2003a) developed a technique to evaluate the leachate contamination potential of different landfills on a comparative scale using an index known as Leachate Pollution Index (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.

The impact of landfill leachate on the surface and groundwater has given rise to a number of studies in recent years (Saarela, 2003; Abu-Rukah & Kofahi, 2001). It is necessary to ascertain the impact of concentration of leachate with groundwater and the suitability of groundwater for any purposes, the concentration of physical and chemical constituents in the water samples were compared with Bureau of Indian Standards (BIS) and World Health Organization (WHO) standard to know the suitability of water for drinking.

III. Objectives Of The Study

1. To determine the concentration of the leachate pollutant variable.2. To calculate the Leachate Pollution Index (LPI) and to compare the lechate contamination potential of the two landfill sites of Mylai Balaji Nagar – Pallikkaranai landfill (Alandur Municipality) and Chromepet Radha Nagar – Periyaeri landfill (Pallavaram Municipality). 3. To determine the characteristics of groundwater samples near the selected landfill sites.4. To compare the impact of concentration of leachate with groundwater and with standards.

IV. Scope Of The Study

1. The experiments will be conducted in laboratory using standard APHA methods.2. The leachate to be used in this study will be collected from Pallikkaranai landfill (Alandur Municipality) & Periyaeri landfill (Pallavaram Municipality) & characteristics of 18 Parameters is to be analyzed & LPI is to be calculated and to compared with LPI calculated for treated leachate standards.3. The groundwater to be used in this study will be collected from nearby Pallikkaranai landfill &Periyaeri landfill & characteristics of 6 Parameters are to be analyzed & compared with standards.

V. Concept Of Leachate Pollution Index

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 Leachate Pollution Index (LPI) was formulated using Rand Corporation Delphi Technique (Kumar and Alappat, 2003a). The formulation process and complete description on the development of the Leachate Pollution Index, has been discussed elsewhere (Kumar and Alappat, 2003a).

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 landfill in a given geographical area or around the world. The other potential applications of LPI include remediation, enforcement of leachate standards, scientific research and public information (Kumar& Alappat, 2003).

VI. Details Of Variables

Variable Selection:

Eighteen leachate parameters were selected for inclusion in LPI. They are pH, Total Dissolved Solids (TDS), Biochemical Oxygen Demand (5 day BOD), Chemical Oxygen Demand (COD), Total Kjeldahl Nitrogen (TKN), Ammonia Nitrogen, Total Iron, Copper, Nickel, Zinc, Lead, Chromium, Mercury, Arsenic, Phenolic Compounds, Chlorides, Cyanide, and Total Coliform Bacteria.

Variable Weights:

The weights for these eighteen parameters were calculated based on the significance levels of the individual pollutants. The weight factor indicates the importance of each pollutant variable to the overall leachate pollution. For example, the weight factor for chromium is 0.064, and so it is most important variable than the other pollutant variables, while total iron with a weight factor of 0.045 is least important Variable as compared to other pollutant variables included in LPI (Kumar and Alappat, 2003a). The weights for other pollutant variables are Total Dissolved Solids: 0.050; Biochemical Oxygen Demand: 0.061; Chemical Oxygen Demand: 0.062; Total Kjeldhal Nitrogen: 0.053; Ammonia Nitrogen: 0.051; Copper: 0.050; Nickel: 0.052; Zinc: 0.056; Lead: 0.063; Mercury: 0.062; Arsenic: 0.061; Phenolic Compounds: 0.057; Chlorides: 0.049; Cyanides: 0.058 and Total Coliform Bacteria: 0.052. The sum of the weights of all the eighteen parameters is one.

Variable Curves:

The averaged sub index curves for each parameter were drawn to establish a relation between the leachate pollution and strength or concentration of the parameter. The sub-index curves for all the pollutant variables are reported in Kumar and Alappat (2003a). The averaged sub index curves are the curves that represent the relation between leachate pollution and the strength or concentration of the parameter.

Variable Aggregations:

The weighted sum linear aggregation function was used to sum up the behaviors of all the leachate pollutant variables. The various possible aggregation functions were evaluated by Kumar and Alappat (2003b) to select the best possible aggregation function. The sensitivity analysis of the six short-listed aggregation function was performed to arrive at the best possible aggregation function. The Leachate Pollution Index can be calculated using the equation:

$$LPI = \sum_{i=1}^{n} w_i p_I \qquad (2.1)$$

Where LPI = the weighted additive leachate pollution index, w_i = the weight for the i^{th} pollutant variable, p_i =the sub index value of the i^{th} leachate pollutant variable, n = number of leachate pollutant variables used in calculating LPI. And

$$LPI=\sum_{i=1}^{m} w_i=1 \qquad (2.2)$$

However, when the data for all the leachate pollutant variables included in LPI is not available, the LPI can be calculated using the data set of the available leachate pollutants. In that case, the LPI can be calculated by the equation:

$$LPI=\sum_{i=1}^{n} w_i p_i / \sum_{i=1}^{m} w_i \qquad (2.3)$$

Where m is the number of leachate pollutant parameters for which data is available, but in that case, $18 < m$ and $\sum w_i < 1$

VII. Methods

Testing of Leachate Pollutants:

Analytical laboratory tests are to be performed on the leachate sample collected from the landfill leachate collection sump to find out the concentrations of the eighteen pollutants included in LPI. Alternatively, the data available for these pollutants can also be used. It should be noted that the LPI value would be representative of the leachate data used and will provide the Index value corresponding to the particular time for which the data is used.

Calculating Sub-index Values:

To calculate the LPI, one first computes the 'p' values or sub-index values for all the eighteen parameters from the sub-index curves based on the concentration of the leachate pollutants obtained during the tests. The 'p' values are obtained by locating the concentration of the leachate pollutant on the horizontal axis of the sub index curve for that pollutant and noting the leachate pollution sub-index value where it intersects the curve.

Aggregation of Sub-index Values:

The 'p' values obtained above for all the parameters are multiplied with the respective weights assigned to each parameter (reported above). The equation (1) is used to calculate LPI if the concentrations of all the eighteen variables included in LPI are known. Otherwise, equation (2) is used. The true value of LPI is obtained when the concentrations of all the eighteen variables included in LPI are known. The concentrations of the various leachate pollutant variables has been determined in the laboratory using standard methods and reported in Table 4.3 Column 3 & 6. The LPI for the data set considered using the above procedure is calculated and reported in Table 4.3, Column 5 & 8.

Selection of sites (study area):

Pallikkarani (Mylai Balaji Nagar) Landfill (Alandur Municipality) and Periya eri (Chromepet-Radha Nagar) Landfill (Pallavaram Municipality) are selected for the study. Both are in active operation. Both dumpsites are located in low lying marshy lands and above the ground water table.

VIII. Methodology For Groundwater Quality Survey

Sampling:

Open wells closer to polluting sources (near the Pallikkaranai landfill and Periya eri landfill) is selected as sampling location.

Sampling collection, transported, preservation and analysis:

Groundwater samples were collected from selected open wells (total six samples, three in each sites) Water samples were collected 30 cm below the water level in open wells using water sampler. Water samples are collected in 1.

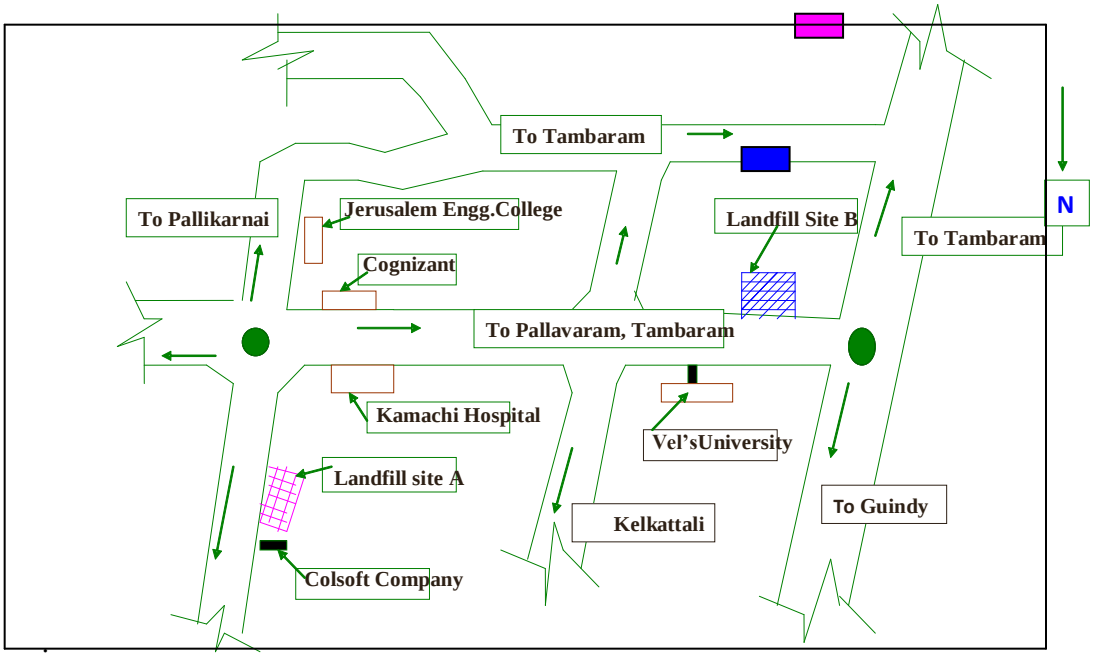

Fig 3.1 Sketch showing the study area

Site A – (Mylai Balagi Nagar - Pallikkarani Landfill) - Alandur Municpality
Site B - (Radha Nagar –Chromepet Landfill) - Pallavaram Municipality

litre plastic containers & the bottles were washed with non-ionic detergent and rinsed with de-ionized water prior to usage. Before the final water sampling was done; the bottles were rinsed three times with well water at the point of collection. Each bottle was rinsed three times with well water at the point of collection. Each bottle was labeled according to sampling location, while all the samples were preserved at 4 degree and transported to the laboratory.

IX. Field Sampling and Laboratory Analysis

In an effort of investigate the extent of groundwater contamination, three sampling points designated W_1 to W_3 were selected between 200m to 235m and 3m to 20m near the Pallikkaranai landfill (Alandur Municpality) and Periya eri landfill (Pallavaram Municipality) respectively. Details of sampling points are presented in Table 3.1 and Table 3.2 respectively.

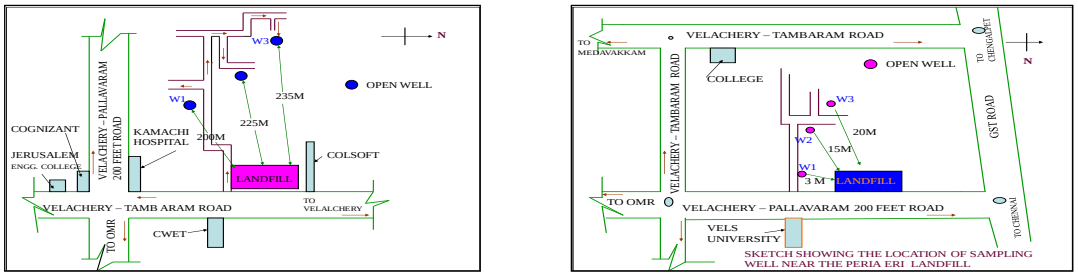

Fig. 3.3 Location of sampling wells near Periaeri landfill

Table 3.1 Description of groundwater sampling locations (Pallikkarani Landfill)

Sl. No	Sample	Location	Identification	Source	Distance from Landfill site (m)	Depth of water levels in wells (m)	Water Use	Land Use/ Specific Activity
1	W_1	Ram Nagar, 16th main road	Opp. To D.No.1530,	OW	200	1.500	Garden, washing the floor around the building	Residential
2	W_2	Plot No. 1514, B	Ram Nagar	OW	225	1.200	Garden, washing the floor around the building	Residential
3	W_3	1529, 14 th main road.	Near panchayat water tank	OW	235	1.800	Garden, washing the floor around the building	Residential

Table 3.2 Description of groundwater sampling locations (Peria eri Landfill)

Sl. No	Sample	Location	Identification	Source	Distance from Landfill site (m)	Depth of water levels in wells (m)	Water Use	Land Use/ Specific Activity
1	W_1	Ganapathypuram erikkarai road	OPP to Vels university	OW	3	4.000	Garden, washing the floor around the building	Residential
2	W_2	D.No.15	Vallalperumal theru	OW	15	4.500	Garden, washing the floor around the building	Residential
3	W_3	Vallalperumal cross street	Near cementry	OW	20	4.200	Garden, washing the floor around the building	Residential

Note: HP-Hand Pump, BW - Bore Well; OW - Open Well, TW-Tube Well

Table A.1 Description of groundwater sampling locations (Pallikkarani Landfill)

Location	Identification	Source	Distance from Landfill site (m)	Depth of water levels in wells (m)	Water Use	Land Use/ Specific Activity
Ram Nagar, 16th main road	Opp. To D.No.1530,	Open Well	200	1.500	Garden, washing the floor around the building	Residential
Plot No. 1514, B	Ram Nagar	Open Well	225	1.200	Garden, washing the floor around the building	Residential
1529, 14 th main road.	Near panchayat water tank	Open Well	235	1.800	Garden, washing the floor around the building	Residential

Table A.3 Concentration of Leachate pollution variable

Site A - (Mylai Balagi Nagar - Pallikkaranai Landfill) - Alandur Municipality								
Leachate Pollutant variable	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**	**Min. concentration**	**Max. concentration**	**Average of Min. & Max. conc.**	**Treated Leachate standards**
Ph	6·83	7·28	7·85	8·10	6·83	8·10	7·50	5.5 - 9.0
Total Dissollved Solids	19740	13116	17856	16097	13116	19740	16428	2100
BOD	8125	10100	1428	285	285	10100	5195	100
COD	24720	48960	3704	2990	2990	48960	25975	_
Total Kjeldhal Nitrogen as N	710	1150	364	530.2	364	1150	757	_
Ammonical Nitrogen as N	537	891	238	473	238	891	565	_
Iron as Fe	59.5	88.1	56	37.7	37.7	88.1	63	_
Copper as Cu	0.602	0.53	0.20	0.406	0·20	0.602	0.401	_
Nickel as Ni	0.79	0.86	1·20	0.420	0.420	1·20	0.812	_
Zinc as Zn	1·22	1·35	1·80	1·015	1·015	1·80	1·41	_
Lead as Pb	BDL (D.L. 0.05)				_	_	_	_
Total Chromium as Cr	0.66	0.62	0.8	0.481	0.48	0.8	0.64	_
Mercury as Hg	BDL (D.L. 0.05)				_	_	_	_
Arsenic as As	BDL (D.L. 0.05)				_	_	_	0.2
Phenolic Compounds as C6H5OH	12·3	BDL	3·35	BDL	12·3	3·35	7·83	200
Chlorides as Cl	4005	1771	4566	4735	1771	4735	3253	600
Cynaide as CN	BDL (D.L. 0.05)				_	_	_	0.2
Total coliforms MPN/100ml	>1600	>1600	>1600	>1600	>1600	>1600	>1600	_

Table A.5 Calculating LPI for Pallikkaranai Landfill(Alandur Municipality& Periaeri Landfill (Pallavaram Municipality)

Landfill	**Pallikkaranai Landfill**				**Periyaeri Landfill**			**Treated leachate standards**		
Leachate Pollutant variable (1)	**Variable weights**	**Pollutant Conc.**	**Pollutant Sub Index Value**	**Aggrega-tion**	**Pollutant Conc.**	**Pollutant Sub Index Value**	**Aggrega-tion**	**Pollutant Conc.**	**Pollutant Sub Index Value**	**Aggregation**
	wi	**c_i**	**pi**	**wi.pi**	**ci**	**pi**	**wi.pi**	**ci**	**pi**	**wi.pi**
	2	3	4	5	6	7	8	6	7	8
pH	0.055	7·50	5	0.275	8·08	4	0.220	5.5 - 9.0	5	0.275
Total Dissollved Solids, mg/l	0.050	16428	40	2.000	6341	10	0.500	2100	7	0.250
BOD, mg/l	0.061	5193	55	3.355	313	10	0.610	100	8.5	0.519
COD,mg/l	0.062	25975	90	5.580	1189	8	0.496	_	_	_
Total Kjeldhal Nitrogen (as N), mg/l	0.053	757	25	1.325	317	8	0.424	_	_	_
Ammonical Nitrogen (as N), mg.l	0.051	565	56	2.856	310	32	1.632	_	_	_
Iron (as Fe), mg/l	0.045	63	6	0.270	17.77	5	0.225	_	_	_
Copper (as Cu), mg/l	0.050	0.401	6	0.300	0.432	7	0.350	_	_	_
Nickel (as Ni), mg/l	0.052	0.812	6.5	0.338	0.449	5	0.260	_	_	_
Zinc (as Zn), mg/l	0.056	1·41	6.5	0.308	0·753	5	0.280	_	_	_
Lead (as Pb), mg/l	0.063	_	5	_	_	5	_	_	_	_
Total Chromium (as Cr), mg/l	0.064	0.64	6.5	4.160	0.549	6	0.384	_	_	_
Mercury (as Hg), mg/l	0.062	_	48	_	_	48	_	_	_	_
Arsenic (as As), mg/l	0.061	_	10	_	_	10	_	0.2	5	0.305
Phenolic	0.057	7·83	15	0.855	0·85	5	0.285	200	65	3.705

Compounds as C6H5OH										
Chlorides (as Cl), mg/l	0.048	3253	25	1.200	1987	15	0.720	600	7	0.336
Cynaide (as CN), mg/l	0.058	_	10	_	_	10	_	0.2	6	0.348
Total coliforms MPN/100ml	0.052	>1600	100	5.200	>1600	100	5.200	_	_	_
Total	**1.000**			**28.022**			**11.586**			**5.739**
LPI				**37.066**			**15.325**			**14.713**

Table A.6 Characteristics concentration of Groundwater near the Pallikkaranai Lar

Sample	Distance (M)	Parameter					
		pH	Total Dissolved Solids	BOD	COD	Phenolic Compounds (asC_6H_5OH)	Chlorides
			mg/l	mg/l	mg/l	mg/l	mg/l
BIS		6.5 - 8.5	500	NS	NS	0.001	250
WHO		6.5 - 8.5	1000	NS	NS	NS	250
W 1	200	8.090	18283	22	149	0.610	8020
W 2	225	8.120	19734	14	89	1.160	6248
W3	236	8.070	9079	11	45	1.030	3766

NS - Not specified

Table: A.7 Characteristics construction of Groundwater near the Periyaeri Landfill

Sample	Distance (M)	Parameter					
		pH	Total Dissolved Solids	BOD	COD	Phenolic Compounds (asC_6H_5OH)	Chlorides
BIS		6.5 - 8.5	500	NS	NS	0.001	250
WHO		6.5 - 8.5	1000	NS	NS	NS	250
W 1	3	7.250	1718	14	37	0.830	496
W 2	15	7.630	998	6	22	1.110	173
W 3	20	7.070	1718	6	15	0.600	292

X. Results And Discussion

LEACHATE:

Physico-chemical characteristics of the leachate depend primarily upon the waste composition and water content in total waste. The characteristics of Pallikkaranai landfill (Alandur Municipality) leachate and Periyaeri landfill (Pallavaram Municipality) leachate, i.e., 18 parameters analysed in the laboratory using standard methods are presented in Table A.3 and Table A.4.

The pH varied from 6.83 to 8.10 & 7.90 to 8.26 in leachate collected from Pallikkaranai landfill and Periyaeri landfill respectively shown in Fig.4.1. pH will tent to alkaline according to the increasing age of landfill, similarly these changes also connect to the nature of precipitation and the quantity and quality of industry waste. TDS concentration varied from 13000 to 20000mg/l & 2000 to 11000mg/l in leachate collected from Pallikkaranai landfill and Periyaeri landfill respectively shown in Fig.4.2.

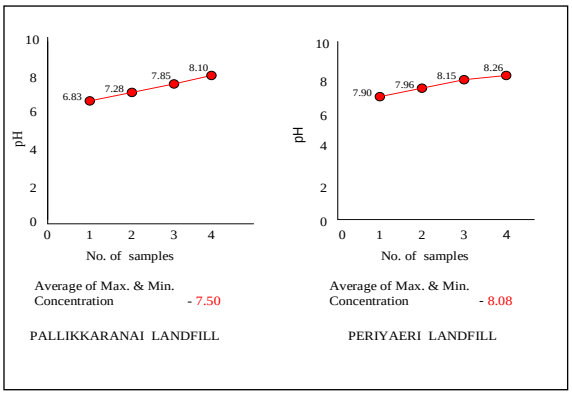

Fig 4.1 Variation in quality of leachate ($_{P}H$)

Fig.4.3 shows the variation of BOD & COD and it is varied from 300 to 10000mg/l & 3000 to 50000mg/l in

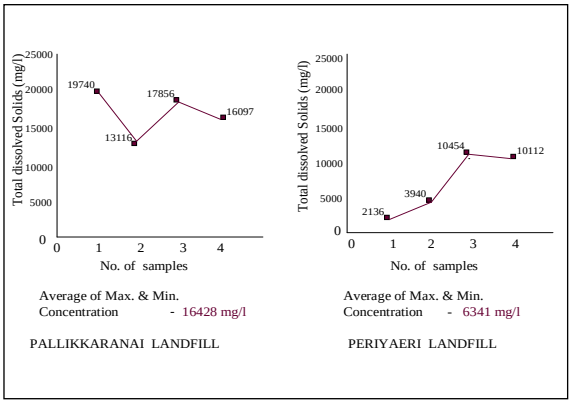

Fig 4.2 Variation in quality of leachate (TDS)

pallikkaranai landfill (Alandur Municipality) & in Periyaeri landfill (Pallavaram Municipality) leachate, BOD was between 50 to 600mg/l & COD between 230 to 2200 mg/l. The presence of high BOD and COD indicate the high organic strength.COD was very high in Pallikkaranai landfill because of high organic and oxidisable inorganic substances. Also high COD in pallikkarani landfill indicates that in addition to the Municipal solid waste, industrial solid waste has also been disposed there.

BOD is a measure of biodegradable organic mass of leachate and that indicates the maturity of the landfill which typically decreases with time. (S.Esakku, et. al. 2007). A BOD/COD ratio greater than 0.5 indicates a young landfill, when the ratio is less than 0.1 the landfill can be considered old and stable, whereas the ration 0.1 to 0.5 indicates partially stable leachate. (Jaffar Y.M. et. al. 2009).Therefore, in a given leachate, the values of BOD/COD ratio ranged from 0.1 to 0.21 in Pallikkaranai landfill and 0.23 to 0.27 in Periyaeri landfill, which indicates the partial stabilization of these leachates.

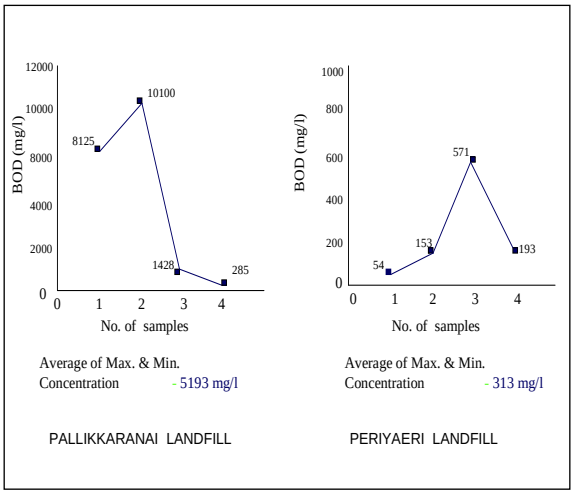

Fig 4.2 Variation in quality of leachate (BOD)

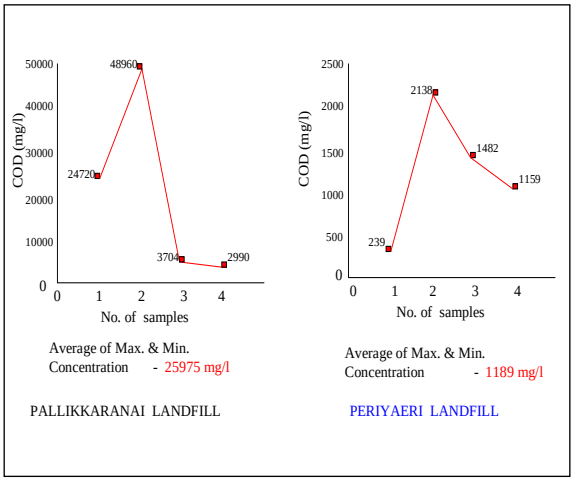

Fig 4.2 Variation in quality of leachate (COD)

The value of Total Kjeldhal Nitrogen and Ammonical-nitrogen is 757 mg/l & 565mg/l respectively in the leachate from Pallikkaranai landfill and 317 mg/l & 310mg/l in the leachate from Periyaeri landfill are shown in Fig.4.5. Ammonical Nitrogen is a common constituent of landfill leachate as a result of the biological degradation of amino acids and other nitrogenous organic matter (Jaffar Y.M. et. al. 2009).

The concentration of Iron as Fe in leachate collected from Palllikkaranai landfill is 63mg/l which is 3.7 times greater than the Periyaeri landfill (17.77mg/l) as shown in Fig.4.6. The high level of iron in the leachate sample indicates that iron and steel scrap are also dumped in the landfill. The dark brown colour of the leachate is mainly attributed to the oxidationof ferrous to ferric form and the formation of ferric hydroxide colloids and complexes with fulvic/humic substance (Chu, et. al., 1994).

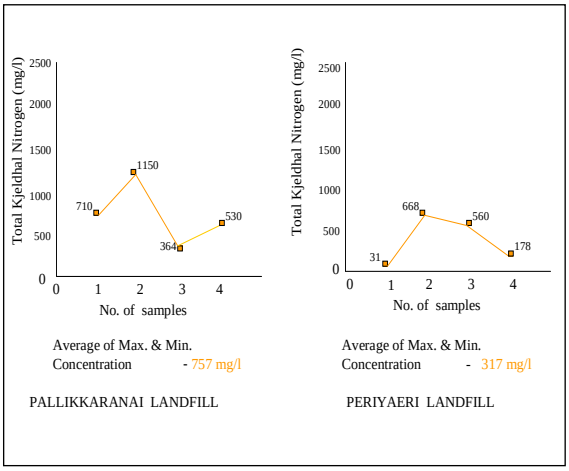

Fig 4.5 Variation in quality of leachate (TKN)

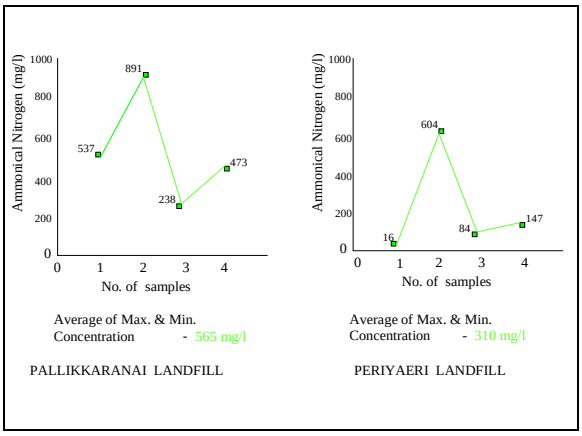

Fig 4.5 Variation in quality of leachate (NH_3 amm)

The presence of Nickel as Ni in Pallikkaranai landfill and Periyaeri landfill is 0.812 mg/l & 0.449 mg/l respectively are shown in Fig.4.8.

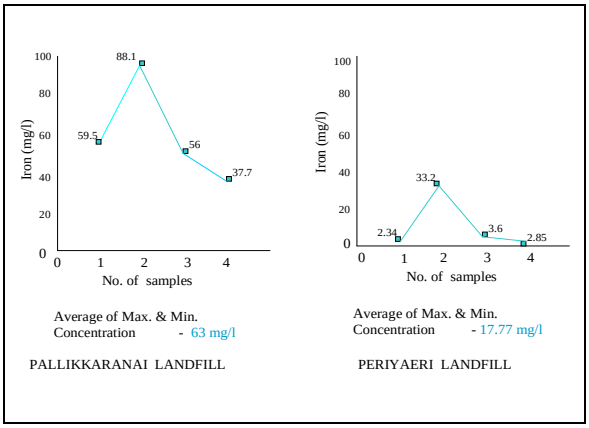

Fig 4.6 Variation in quality of leachate (Iron as Fe)

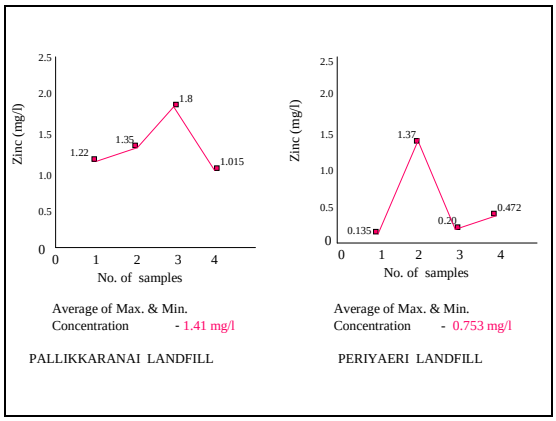

Fig 4.6 Variation in quality of leachate (zinc)

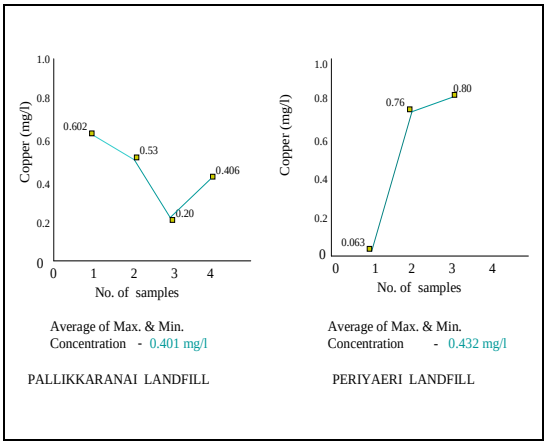

Fig 4.7 Variation in quality of leachate (Copper)

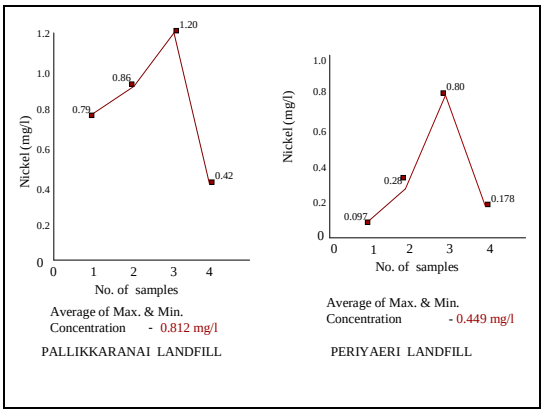

Fig 4.7 Variation in quality of leachate (Nickel)

Fig.4.9 shows the variation of concentration of Phenolic Compounds i.e., 7.83mg/l & 0.85mg/l in the leachate collected from Pallikkaranai landfill & Periyaeri landfill respectively, is less than treated leachate standards i.e. 200mg/l. There is no Lead concentration in the leachate samples collected in both the landfills, indicates there is no disposal of Pb batteries, chemicals for photograph processing, Pb-based paints and pipes at the landfill site (Moturi et al., 2004: Mor et al., 2005).

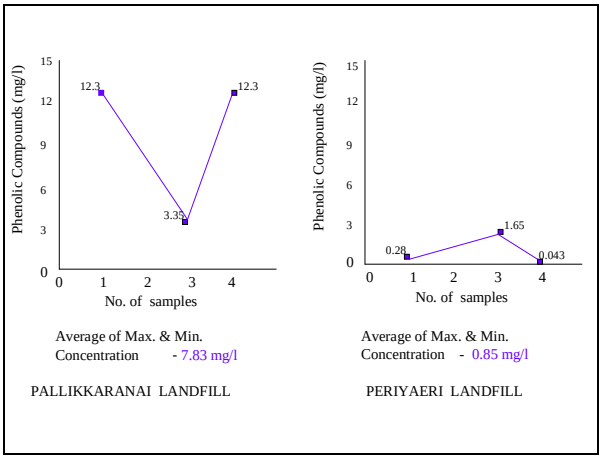

Fig.4.9 Variation in quality of leachate (phenolic compounds)

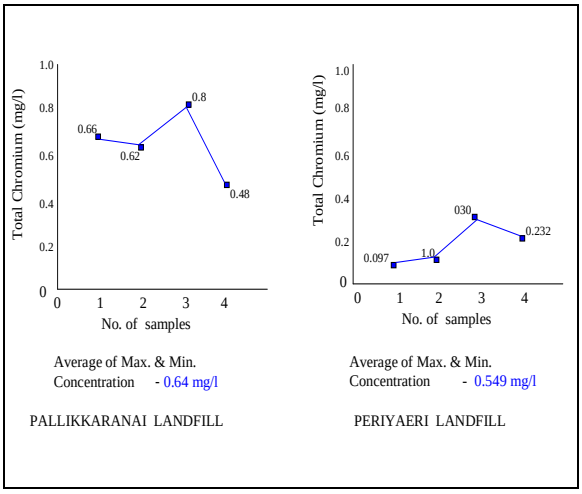

Fig.4.9 Variation in quality of leachate (Total Chromium)

The concentration of Lead, Mercury, Arsenic and Cyanide in the leachate collected from both Pallikkaranai landfill and Periyaeri landfill are below detectable level (detectable level is 0.05). Chlorides concentrations are 3253mg/l & 1987mg/l in leachate collected from Pallikkaranai landfill & Periyaeri landfill respectively are shown in Fig.4.10.

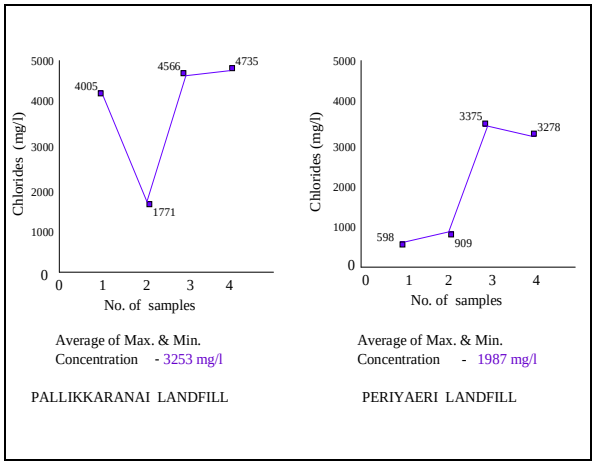

Fig 4.10 Variation in quality of leachate (Chlorides)

Table A.5 shows the calculations for LPI values for the two active landfill sites, Pallikkaranai landfill (Alandur Municipality) and Periyaeri landfill (Pallavaram Municapality). Since, the data for all the parameters included in LPI are not available; the LPI has been calculated on the basis of the available data. The comparison of LPI values of two landfill sites is shown in Fig. 4.11.

It can be seen that the LPI value for the Pallikkaranai landfill is the highest while the LPI value for the Periyaeri landfill is found to be the lowest. The high LPI value (37.066) of Pallikkaranai landfill (Alandur Municipality) further indicates that the waste deposited has not yet stabilized. This is also evident from the high BOD and COD values reported by Lo (1996). The LPI value of the the treated leachate standards is also calculated and reported in Column 8, Table A.5 and also shown in Fig. A.1. the LPI value of the treated leachate shall not exceed 14.713.

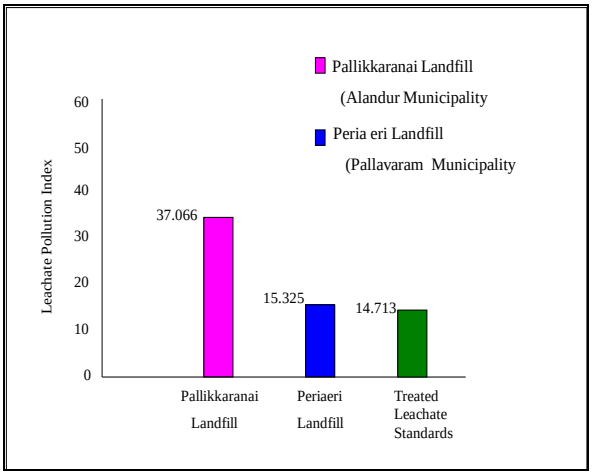

Fig 4.11 Comparison of leachate contamination Potential of the two Landfill sites under study

XI. Groundwater

The groundwater of the studied area is used for domestic and other purposes. Table A.5 shows the desirable and maximum permissible limit recommended by Bureau of Indian Standard (BIS, 1991) and world Health Organization (WHO, 1997). The pH of all the groundwater samples was about neutral, the range being 8.07 to 8.12 & 7.07 to 7.63 as shown in (Fig.4.12) near Pallikkaranai landfill and Periyaeri landfill respectively, which is also within the WHO and BIS standards.

The TDS indicates the general nature of water quality or salinity. The range of TDS falls in between 9079mg/l to 19735 mg/l & 998mg/l to 1718mg/l as shown in (Fig 4.12) in the samples collected nearby Pallikkaranai landfill & Periyaeri landfill respectively. The TDS concentration was found to be remarkably high at both the sites. Table 3.3 shows the classification of groundwater samples on the bases of TDS Concentration. As per the classification, one sample is moderately saline (W_3) and two samples were very saline (W_1 & W_2) and Table A.6, one sample is Brackish water (W_3) and two samples were saline water (W1 & W_2) from the samples collected nearby Pallikkaranai landfill.

The samples collected nearby Periyaeri landfill has, one sample is Non-saline (W_2) and two samples were slightly saline (W_1 & W_3) Table A.6 and one sample is Fresh water (W_2) and two samples were Brackish water (W_1 & W_3) Table A.9. This high value of TDS may be due to the leaching of various pollutants into the groundwater. Olaniya and Saxena (1977) also reported the groundwater pollution from refuse in the vicinity of the dumping sites detectable through increased TDS concentration of water.

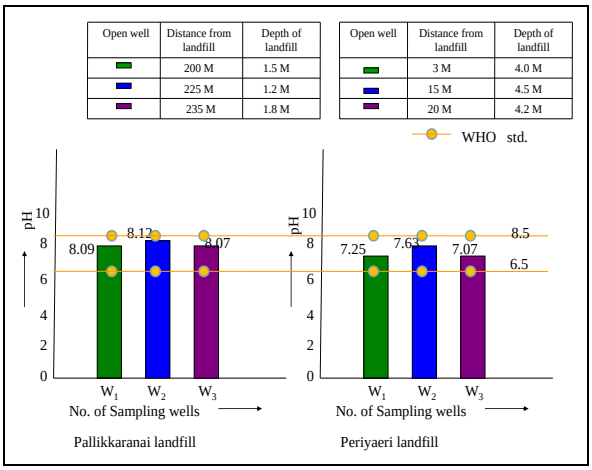

Fig 4.12 Concentration of pH in groundwater samples

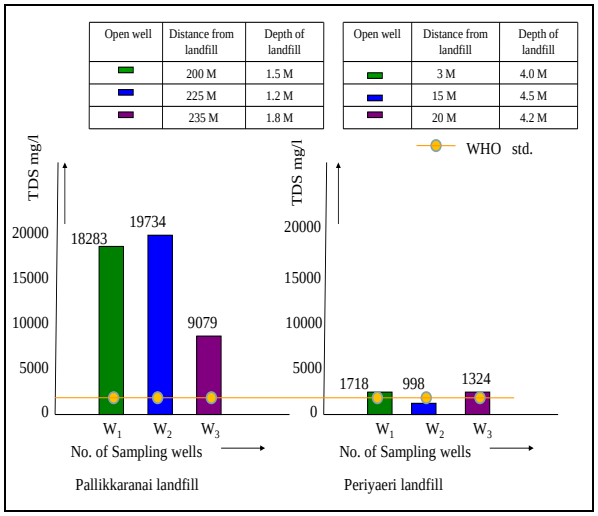

Fig 4.12 Concentration of TDS in groundwater samples

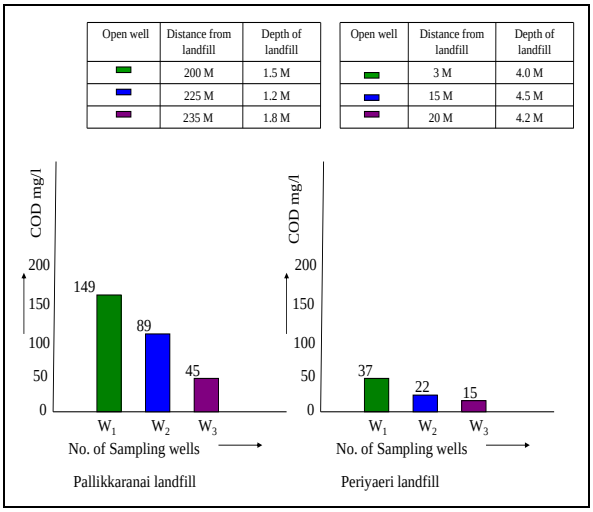

Fig 4.13 Concentration of COD in groundwater samples

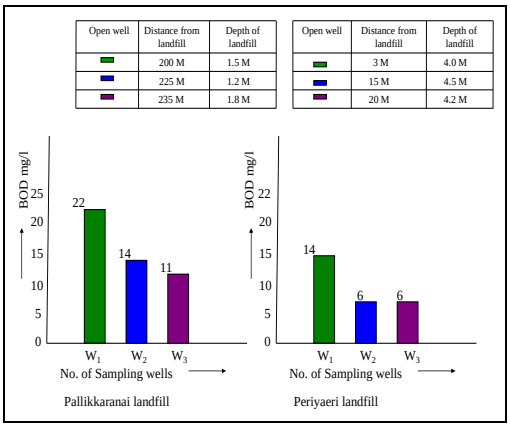

Fig 4.13 Concentration of BODin groundwater samples

Fig.4.13 shows the variation of BOD level in the groundwater samples collected from the nearby Pallikkaranai landfill and Periyaeri landfill varied from 11mg/l to 22mg/l & 6mg/l to 14 mg/l respectively.An excess of Cl^- in water is usually taken as an index of pollution and considered as tracer for groundwater contamination (Loizidou and Kapetanios, 1993). The concentration of Cl^- the groundwater samples collected from the nearby Pallikkaranai landfill and Periyaeri landfill ranged between 3766mg/l to 8020mg/l & 173mg/l to 496mg/l respectively shown in Fig. 4.15. High Cl^- content of groundwater is likely to originate from pollution sources such as domestic effluents, fertilizers, and septic tanks, and from natural sources such as rainfall, the dissolution of fluid inclusions. Increase in Cl^- level is injurious to people suffering from diseases of heart or kidney (WHO, 1997).

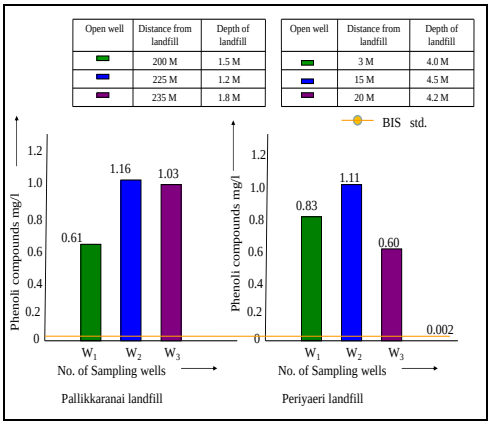

Fig 4.15 Concentration of Phenolic compound

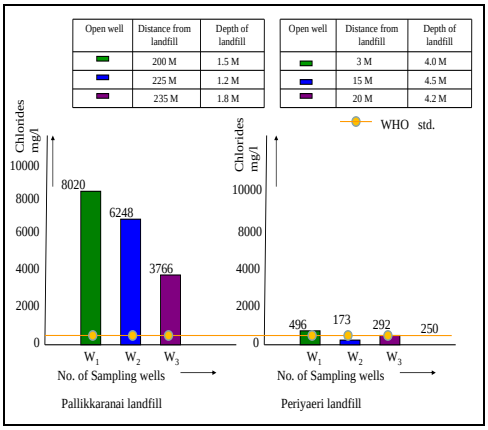

Fig 4.15 Concentration of Chlorides in groundwater samples

XII. Conclusion

1. The LPI value of 37.006 for the Pallikkaranai landfill (Alandur Municipality) site indicates that the leachate generated from this landfill is highly contaminated than the LPI value of 15.325 for Peiya eri landfill (Pallavaram Municipality) and proper treatment will have to be ensuring before discharging the leachate.
2. On comparing with the LPI value of 14.713 (treated leachate standards), the Pallikkaranai landfill site requiring immediate attention in order to avoid big pollution incident.
3. The TDS value of groundwater sample taken near the Pallikkaranai landfill sites is very high i.e., 13,681 mg/l (avg.) which indicates the presence of soluble salts in groundwater, which has to treat before using it for drinking.
4. The presence of chlorides, BOD, COD, and phenolic compounds indicates that leachate has significant impact on groundwater quality near the area of landfill sites because of dumping of MSW in non-engineered landfills.
5. Recommended action for Pallikkaranai landfill is rehabilitate the dumpsite into sustainable landfill in a phase manner and for periyaeri landfill is potential site for future landfill.

A planning index, specifically for decision making may be further generated for planning waste reatment projects. The proposed planning index may take into account, the current area population, downstream affected population, investments for the financial years and leachate pollution index.

Table A.1 Description of groundwater sampling locations (Pallikkarani Landfill)

Sl. No	Sample	Location	Identification	Source	Distance from Landfill site (m)	Depth of water levels in wells (m)	Water Use	Land Use/ Specific Activity
1	W_1	Ram Nagar, 16th main road	Opp. To D.No.1 530,	Open Well	200	1.500	Garden, washing the floor around the building	Residential
2	W_2	Plot No. 1514, B	Ram Nagar	Open Well	225	1.200	Garden, washing the floor around the building	Residential
3	W_3	1529, 14 th main road.	Near panchayat water tank	Open Well	235	1.800	Garden, washing the floor around the building	Residential

Table A.2 Description of groundwater sampling locations (Periaeri Landfill)

Sl. No	Sample	Location	Identification	Source	Distance from Landfill site (m)	Depth of water levels in wells (m)	Water Use	Land Use/ Specific Activity
1	W_1	Ganapathypuram erikkarai road	OPP to Vels university	Open Well	3	4.000	Garden, washing the floor around the building	Residential
2	W_2	D.No.15	Vallalperumal theru	Open Well	15	4.500	Garden, washing the floor around the building	Residential

3	W_3	Vallalperumal cross street	Near cementry	Open Well	20	4.200	Garden, washing the floor around the building	Residential

Table A.3 Concentration of Leachate pollution variable

Site A - (Mylai Balagi Nagar - Pallikkaranai Landfill) - Alandur Municipality								
Leachate Pollutant variable	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**	**Min. concentration**	**Max. concentration**	**Average of Min. & Max. conc.**	**Treated Leachate standards**
Ph	6·83	7·28	7·85	8·10	6·83	8·10	7·50	5.5 - 9.0
Total Dissollved Solids	19740	13116	17856	16097	13116	19740	16428	2100
BOD	8125	10100	1428	285	285	10100	5195	100
COD	24720	48960	3704	2990	2990	48960	25975	_
Total Kjeldhal Nitrogen as N	710	1150	364	530.2	364	1150	757	_
Ammonical Nitrogen as N	537	891	238	473	238	891	565	_
Iron as Fe	59.5	88.1	56	37.7	37.7	88.1	63	_
Copper as Cu	0.602	0.53	0.20	0.406	0·20	0.602	0.401	_
Nickel as Ni	0.79	0.86	1·20	0.420	0.420	1·20	0.812	_
Zinc as Zn	1·22	1·35	1·80	1·015	1·015	1·80	1·41	_
Lead as Pb	BDL (D.L. 0.05)				_	_	_	_
Total Chromium as Cr	0.66	0.62	0.8	0.481	0.48	0.8	0.64	_
Mercury as Hg	BDL (D.L. 0.05)				_	_	_	_
Arsenic as As	BDL (D.L. 0.05)				_	_	_	0.2
Phenolic Compounds as C6H5OH	12·3	BDL	3·35	BDL	12·3	3·35	7·83	200
Chlorides as Cl	4005	1771	4566	4735	1771	4735	3253	600
Cynaide as CN	BDL (D.L. 0.05)				_	_	_	0.2
Total coliforms MPN/100ml	>1600	>1600	>1600	>1600	>1600	>1600	>1600	_

Table A.4 Concentration of Leachate pollution variable

Site B - (Chromepet Radha Nagar - Periyaeri Landfill) - Pallavaram Municipality								
Leachate Pollutant variable	Sample 1	Sample 2	Sample 3	Sample 4	Min. concentration	Max.. concentration	Average of Min. & Max. conc.	Treated Leachate standards
pH	7·90	7·96	8·15	8·26	7·90	8·26	8·08	5.5 - 9.0
Total Dissollved Solids	2136	3940	10545	10112	2136	10545	6341	2100
BOD	54	153	571	193	54	571	313	100
COD	239	2138	1482	1159	239	2138	1189	_
Total Kjeldhal Nitrogen as N	30·7	668	560	178	30·7	668	317	_
Ammonical Nitrogen as N	16·1	604	84	147	16·1	604	310	_
Iron as Fe	2·34	33.2	3·6	2·847	2·34	33.2	17.77	_
Copper as Cu	0.063	0.76	0.80	BDL	0.063	0.80	0.432	_
Nickel as Ni	0.097	0.28	0.80	0.178	0.097	0.8	0.449	_
Zinc as Zn	0·135	1·37	0·20	0·472	0·135	1·37	0·753	_
Lead as Pb	BDL (D.L. 0.05)				_	_	_	_
Total Chromium as Cr	0.097	1.00	0.30	0.232	0.097	1.0	0.549	_
Mercury as Hg	BDL (D.L. 0.05)				_	_	_	_
Arsenic as As	BDL (D.L. 0.05)				_	_	_	0.2
Phenolic Compounds as C6H5OH	0·28	BDL	1·65	0·043	0·043	1·65	0·85	200
Chlorides as Cl	598	909	3375	3278	598	3375	1987	600
Cynaide as CN	BDL (D.L. 0.05)				_	_	_	0.2
Total coliform bacteria MPN/100ml	>1600	>1600	>1600	>1600	>1600	>1600	>1600	_

Table A.5 Calculating LPI for Pallikkaranai Landfill(Alandur Municipality& Periaeri Landfill (Pallavaram Municipality)

Landfill	**Pallikkaranai Landfill**				**Periyaeri Landfill**			**Treated leachate standards**		
Leachate Pollutant variable (1)	**Variable weights** **wi**	**Pollutant Conc.** **c_i**	**Pollutant Sub Index Value** **pi**	**Aggrega-tion** **wi.pi**	**Pollutant Conc.** **ci**	**Pollutant Sub Index Value** **pi**	**Aggrega-tion** **wi.pi**	**Pollutant Conc.** **ci**	**Pollutant Sub Index Value** **pi**	**Aggregation** **wi.pi**
	2	3	4	5	6	7	8	6	7	8
pH	0.055	7·50	5	0.275	8·08	4	0.220	5.5 - 9.0	5	0.275
Total Dissollved Solids, mg/l	0.050	16428	40	2.000	6341	10	0.500	2100	7	0.250
BOD, mg/l	0.061	5193	55	3.355	313	10	0.610	100	8.5	0.519
COD,mg/l	0.062	25975	90	5.580	1189	8	0.496	_	_	_
Total Kjeldhal Nitrogen (as N), mg/l	0.053	757	25	1.325	317	8	0.424	_	_	_
Ammonical Nitrogen (as N), mg.l	0.051	565	56	2.856	310	32	1.632	_	_	_
Iron (as Fe), mg/l	0.045	63	6	0.270	17.77	5	0.225	_	_	_
Copper (as Cu), mg/l	0.050	0.401	6	0.300	0.432	7	0.350	_	_	_
Nickel (as Ni), mg/l	0.052	0.812	6.5	0.338	0.449	5	0.260	_	_	_
Zinc (as Zn), mg/l	0.056	1·41	6.5	0.308	0·753	5	0.280	_	_	_
Lead (as Pb), mg/l	0.063	_	5	_	_	5	_	_	_	_
Total Chromium (as Cr), mg/l	0.064	0.64	6.5	4.160	0.549	6	0.384	_	_	_
Mercury (as Hg), mg/l	0.062	_	48	_	_	48	_	_	_	_
Arsenic (as As), mg/l	0.061	_	10	_	_	10	_	0.2	5	0.305
Phenolic Compounds as C6H5OH	0.057	7·83	15	0.855	0·85	5	0.285	200	65	3.705

Chlorides (as Cl), mg/l	0.048	3253	25	1.200	1987	15	0.720	600	7	0.336
Cynaide (as CN), mg/l	0.058	_	10	_	_	10	_	0.2	6	0.348
Total coliforms MPN/100ml	0.052	>1600	100	5.200	>1600	100	5.200	_	_	_
Total	**1.000**			**28.022**			**11.586**			**5.739**
LPI				**37.066**			**15.325**			**14.713**

Table A.6 Characteristics concentration of Groundwater near the Pallil

Sample	Distance (M)	Parameter					
		pH	Total Dissolved Solids	BOD	COD	Phenolic Compounds (asC_6H_5OH)	Chlorides
			mg/l	mg/l	mg/l	mg/l	mg/l
BIS		6.5 - 8.5	500	NS	NS	0.001	250
WHO		6.5 - 8.5	1000	NS	NS	NS	250
W 1	200	8.090	18283	22	149	0.610	8020
W 2	225	8.120	19734	14	89	1.160	6248
W3	236	8.070	9079	11	45	1.030	3766

NS - Not specified

Table: A.7 Characteristics construction of Groundwater near the Periyaeri Landfill

Sample	Distance (M)	Parameter					
		pH	Total Dissolved Solids	BOD	COD	Phenolic Compounds (asC_6H_5OH)	Chlorides
BIS		6.5 - 8.5	500	NS	NS	0.001	250
WHO		6.5 - 8.5	1000	NS	NS	NS	250
W 1	3	7.250	1718	14	37	0.830	496
W 2	15	7.630	998	6	22	1.110	173
W 3	20	7.070	1718	6	15	0.600	292

Table A.8 Classification of groundwater samples on the basis of TDS Concentration

Nature of water	TDS (mg/l)	Samples	
		Pallikkaranai landfill	Periyaeri landfill
Non-saline	<1000	Nil	W2
Slightly Saline	1000-3000	Nil	W1 & W3
Moderately saline	3000 - 10,000	W3	Nil
Very saline	<10,000	W1 & W2	Nil

Source: Suman Mor et.al. 2010

Table A.9 Nature of groundwater in study area based on TDS values

Nature of water	TDS (mg/l)	Samples	
		Pallikkaranai landfill	Periyaeri landfill
Fresh water	<1000	Nil	W2
Brackish water	1000-10,000	W3	W1 & W3
Saline water	10,000- 1,00,000	W1 & W2	Nil
Brine water	<1,00,000	Nil	Nil

Source: .Rajkumar et. al., 2010

Table A.11 Comparison of concentration of landfill leachate and groundwater with standards

Pollutant variable	Treated leachate Standards	Pallikkaranai landfill	Periyaeri Landfill	BIS/WHO drinking water quality Standard	Pallikkaranai landfill	Periyaeri Landfill
		Leachate			Groundwater	
		Average of Min. & Max. conc.	Average of Min. & Max. conc.		Samples Conc. Range	Samples Conc. Range
LPI	14.713	37.066	15.325	_	_	_
pH	5.5 - 9.0	7·50	8·08	6.5 - 8.5	8.07 - 8.12	7.07 - 7.63
TDS	2100	16428	6341	500/1000	9079 - 18283	998 - 1718
BOD	100	5195	313	NS	11 to 22	6 to 14
COD	_	25975	1189	NS	45 to 149	15 to 37
Phenolic Compoundsas C6H5OH	200	7·83	0·85	0.001	0.61 - 1.16	0.60 - 1.11
Chlorides as Cl	600	3253	1987	250	3766 - 8020	173 - 496

NS - Not Specified, Except pH, All values are mg/l.

Table A.11 Comparison of concentration of landfill leachate and groundwater with standards

Pollutant variable	Treated leachate Standards	Pallikkaranai landfill Leachate	Periyaeri Landfill Leachate	BIS/WHO drinking water quality Standard	Pallikkaranai landfill Groundwater	Periyaeri Landfill Groundwater
		Average of Min. & Max. conc.	Average of Min. & Max. conc.		Samples Conc. Range	Samples Conc. Range
LPI	**14.713**	37.066	15.325	_	_	_
pH	**5.5 - 9.0**	7·50	8·08	**6.5 - 8.5**	8.07 - 8.12	7.07 - 7.63
TDS	**2100**	16428	6341	**500/1000**	9079 - 18283	998 - 1718
BOD	**100**	5195	313	**NS**	11 to 22	6 to 14
COD	_	25975	1189	**NS**	45 to 149	15 to 37
Phenolic Compounds as C6H5OH	**200**	7·83	0·85	**0.001**	0.61 - 1.16	0.60 - 1.11
Chlorides as Cl	**600**	3253	1987	**250**	3766 - 8020	173 - 496

NS - Not Specified, Except pH, All values are mg/l.

Leachate Pollutant variable	Treated leachate Standards	Pallikkaranai landfill Leachate	Periyaeri Landfill Leachate	Remarks
		Average of Min. & Max. conc.	Average of Min. & Max. conc.	
LPI	**14.713**	37.066	15.325	
pH	**5.5 - 9.0**	7·50	8·08	pH value is within the standards.
Total Dissolved Solids	**2100**	16428	6341	The high concentration of TDS decreases the palatability and may cause gastro-intestinal irritation in human and may also have laxative effect particularly upon transits (WHO, 1997).
BOD	**100**	5195	313	Used as an indicator of water quality. High value of BOD and COD indicates the high concentration of metals. BOD/COD ratio greater than 0.5 indicator of young landfill and less than 0.1 is the old and stable landfill and between 0.1 to 0.5 indicated partially stable leachate
COD	_	25975	1189	
TKN as N	_	757	317	
Ammonical Nitrogen as N	_	565	310	The high concentration of ammonia nitrogen brings unbalance of scale for the nutrition elements of microorganism.
Iron as Fe	_	63	17.77	High concentration of Fe may causes dental fluorosis (tooth mottling) and more seriously skeletal fluorosis) Ravindra and Garg. 2005).
Table A.10 Contn..				
Copper as Cu		0.401	0.432	Excessive intake of copper by man leads to sever mucosal irritation, widespread capillary damage hepatic and renal damage central nervous problems followed by depression, irritation and possible necrotic charges in the liver and kidney (Kalavathy et. al. 2005).

Nickel as Ni	_	0.812	0.449	Exposure to nickel, cause cancer, Heart disorders, Respiratory failure, Birth defects, Asthma and chronic bronchitis.
Zinc as Zn	_	1-41	0-753	Zinc is not biodegradable and travels through the food chain via bioaccumulation.
Lead as Pb	_	_	_	Exposure of heavy metals may cause blood and bone disorders, kidney damage and decreased mental capacity and neurological damage. Landfill leachates are less polluted with heavy metal due high pH values.
Total Chromium as Cr	_	0.64	0.549	
Mercury as Hg	_	_	_	
Arsenic as As	**0.2**	_	_	_
Phenolic Compounds as 6H5OH	**200**	7-83	0-85	The concentration of Phenolic compounds is too less the standards.
Chlorides as Cl	**600**	3253	1987	Increase in chlorides level is injurious to people suffering from diseases of Heart or Kidney (WHO, 1997),(Chloride is a Mobil constituent, which is often used as an indicator of contamination).
Cyanide as CN	**0.2**	_	_	_
Total coli forms MPN/100ml		>1600	>1600	Presence of coli form bacteria is an indicator of the sanitary quality of water.

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