International Journal of
Environmental Health and Technology

Evaluation of Municipal Solid Waste Leachate Contamination Potential by using Leachate Pollution Index

Received date:11th August-2017, Accepted date: 20th October- 2017

ISSN: 2581-4516 ***(online)***

www.greenstrust.com/ijeht/

Lathamani R[1]*, Suresha S[2]

Abstract: Municipal solid waste landfills leachate can cause significantly adverse impacts on the environment and human health. The most commonly reported danger is the contamination of groundwater by leachate, produced from these landfills. To quantify the landfill leachate pollution, a technique has been developed known as leachate pollution index (LPI). LPI is a quantitative tool formulated based on the Delphi technique which reports leachate pollution data uniformly. In this study one leachate sample from the collection pond of compost unit, and another from the open landfill site were collected, analyzed and their LPI value were calculated. The LPI value of the compost unit collection pond leachate and open landfill leachate were 185.871 and 176.442 respectively. This shows the collection pond leachate is more polluted than open landfill leachate. Further, these LPI values show a 10 times higher value in comparison with treated leachate having 14.713 that can be disposed into land as per Indian standards. Based on the experimental results, it can be depicted that the LPI value for leachate is significantly high and proper treatment is necessary before discharge of leachate. 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; Environment; Human health; Leachate pollution index; Groundwater pollution.

1. Introduction

India is facing a great challenge in maintenance of solid waste specially generated in urban areas. Landfills are the primary means of municipal solid waste (MSW) disposal in most part of the country because they offer dumping high quantities of MSW at economical costs in comparison to other disposal methods such as incineration. Landfill leachate produced from MSW landfill sites is generally heavily contaminated and consist of complex wastewater that is very difficult to deal with [1-4]. The generation of leachate is a result of percolation of precipitation through open landfill or through cap of the completed site [5]. Leachate is characterized by high concentration of organic matter (biodegradable and non-biodegradable), ammonia nitrogen, heavy metals, and chlorinated organic and inorganic salts [6]. The characteristics of leachate are highly variable[7] depending on the waste composition, amount of precipitation, site hydrology, waste compaction, cover design, sampling procedures, and interaction of leachate with the environment, landfill design and operation[8]. 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 [9]. Leachate can contaminate groundwater where landfills are not provided with liners and surface water if it is not collected and treated prior to its discharge. The overall pollution potential of landfill leachate can be calculated in terms of leachate pollution index (LPI) as proposed by Kumar and Alappat [10]. LPI can be used as a mean to determine whether a landfill requires immediate attention in terms of introducing remediation measures.

[1]*Department of Environmental Science, Vidyavardhaka College, Mysuru, India.*
[2]*Department of Environmental Science, Yuvaraja college, University of Mysore, Mysuru-570005, India*
** Corresponding Email: lathamani17@rediffmail.com*

2. Methodology

2.1. Study area

Mysore city is located at 12.30°N 76.65°E by having an average altitude of 770 meters. Vidyaranyapuram Sewage farm is present in Mysore city by covering 287 Acres of land. Within the sewage farm Open landfill covers 8 acres and compost unit covers 5 acres of land area. Mysore city has around nine lakh inhabitants, spreading across an area of 128.42 km^2. Daily 402 metric tons of garbage is generated in Mysore city. 200 metric tons of waste is processed in Compost unit, 150 metric tons is dumped in open landfill and 50 metric tons is sent to zero waste management (Source: Mysore city corporation). As a consequence of population growth, Mysore Urban Development Authority (MUDA) is developing and constructing new layouts and roads. In addition to this, many private developers have created new layouts. In future quantity of waste predictably increases.

2.2. Leachate sampling

Two Leachate samples, one from collection tank of compost unit and the other one from open landfill site were collected. The compost unit occupies 5 acres of land with single leachate collection pond. Leachate sample from the open landfill site was collected from the base of solid waste heaps where the leachate is drained out by gravity. The samples were carefully collected from the landfill site, temperature and pH was measured onsite using a portable waterproof PCSTestr -35. The samples were then transferred to the laboratory in an ice cooler and stored in a cold room at 4^0 C. Prior to analysis, the samples were allowed to return to room temperature and measurements for leachate parameters were carried out using the following the standard methods found in the examination of water and wastewater [15]. The parameters measured for each leachate sample is given in Table 2. After laboratory analysis, the parameter results were used to calculate the Leachate pollution Index (LPI).

2.3. Concept of Leachate Pollution Index(LPI)

In an effort to develop a technique for comparing the leachate pollution potential of various landfill sites in a given geographical area, an index was formulated using Rand Corporation Delphi Technique. The formulation method and complete description on the development of the Leachate Pollution index, has been discussed elsewhere [16]. The mathematical method of the index includes multiple chemical and biological test results of the landfill leachate to give a single value result. LPI single value has a grade which expresses the overall leachate contamination potential of a landfill, based on several leachate pollution parameters at a given time, wherein a higher index value indicates a poorer environmental condition. To calculate LPI, eighteen leachate parameters (Variables) were selected, each parameter is assigned with calculated weights (Variable weights) based on the significance levels of the individual pollutants. The weight factor indicates the importance of each pollutant variable to the overall leachate pollution. **Table 1** gives the list of parameters and the weights assigned to them. To establish a relation between the leachate pollution and concentration of the parameter, the average sub index curves (variable curves) were plotted. The sub index curves are the curves that represent the relation between leachate pollution and the concentration of the parameter. The sub-index curves for all the pollutant variables are reported in [16]. The weighted sum linear aggregation function was used to sum up the behavior of all the leachate pollutant variables. The various possible aggregation functions were evaluated by [17] to select the best possible aggregation function.

Table 1 Weights of the pollutant parameters included in leachate pollution index (LPI)

S. No. Pollutant	Significance	Pollutant weight
pH	3.509	0.055
Total dissolved solids	3.196	0.050
BOD	3.902	0.061
COD	3.963	0.062
TKN	3.367	0.053
Ammonia Nitrogen	3.250	0.051
Total Iron	2.830	0.045
Copper	3.170	0.050
Nickel	3.321	0.052
Zinc	3.585	0.056
Lead	4.019	0.063
Total chromium	4.057	0.064
Mercury	3.923	0.062
Arsenic	3.885	0.061
Phenolic compounds	3.627	0.057
Chlorides	3.078	0.048
Cyanide	3.694	0.058
Total coliform bacteria	3.289	0.052
Total		1.000

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:

$$LPI = \sum_{i=1}^{n} wipi \qquad (1)$$

Where LPI= the weighted additive leachate pollution index,

wi= the weight for the i^{th} pollutant variable,

pi= the sub index value of the i^{th} leachate pollutant variable,

n= number of leachate pollutant variables used in calculating LPI

and $\sum_{i=1}^{n} wi = 1$

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 pollutants. In that case the LPI can be calculated by the equation:

$$LPI = \frac{\sum_{i=1}^{m} wipi}{\sum wi} \qquad (2)$$

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

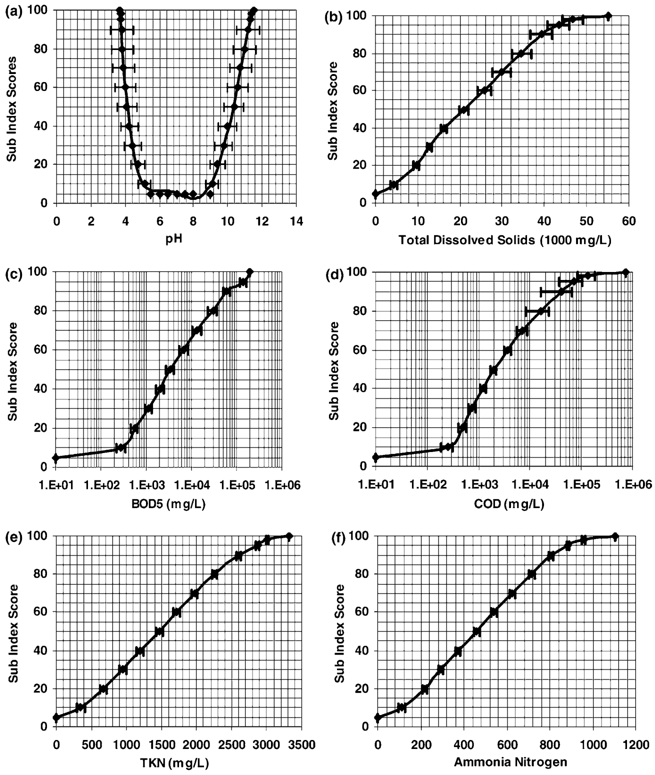
2.4. Procedure to calculate LPI

The stepwise procedure to calculate LPI is given below.

- Analysis of Leachate samples: Laboratory analysis was performed on leachate samples collected from the landfill site to calculate the concentration of the leachate pollutant variables.

- Calculation of sub-index values: To calculate the LPI, one must first compute the ‘p’ value of the parameters from the sub-index curves (Fig. 1) 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. In the present study some parameters like copper, zinc and lead showed very high concentration in both the leachate samples; hence sub index value for these three parameters were calculated mathematically based on the actual sub index curves.

- Aggregation of sub-index values: The ‘p’ values obtained for each of the parameters are multiplied with the respective weights (weight factors reported to in table 2). The weighted sum of all the parameters indicates the overall LPI. In this study, as the data for all the 18 parameters were not available, Eq. 2 is used to calculate LPI.



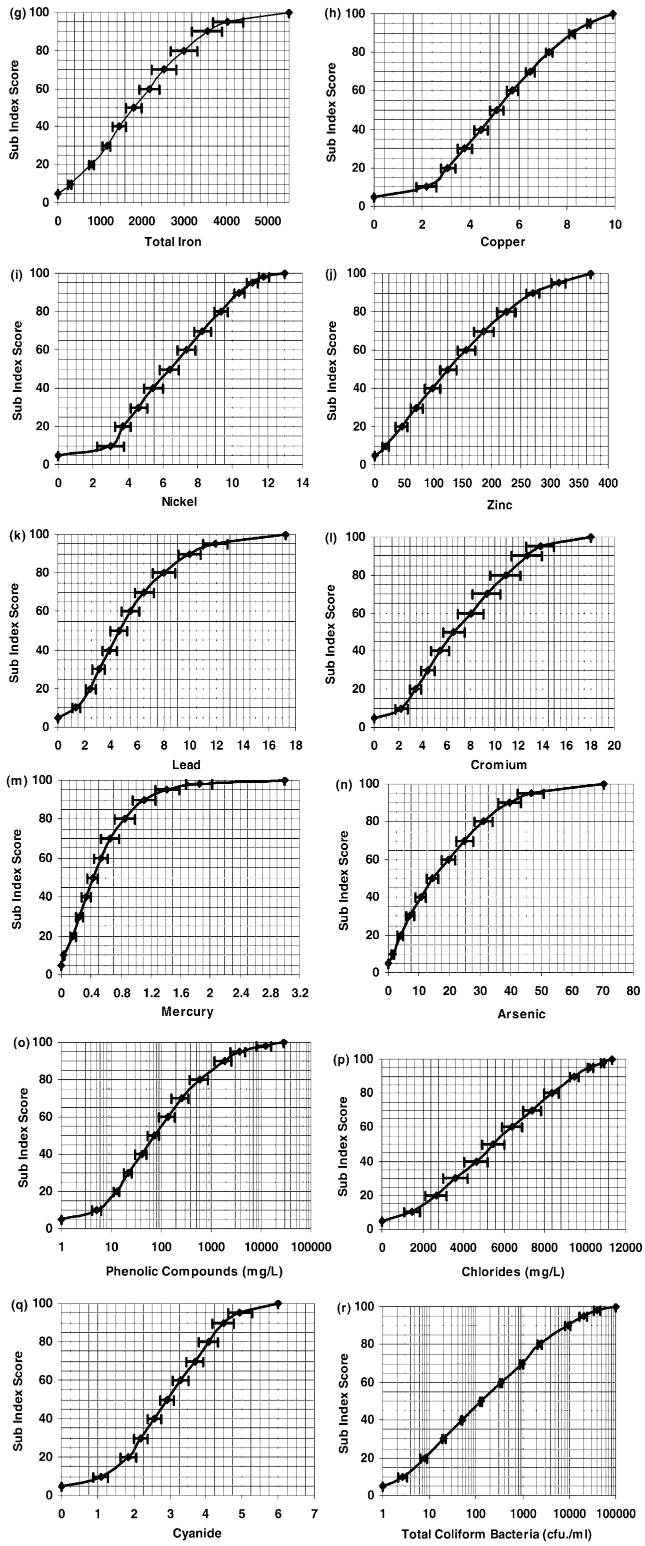


Figure 1 The averaged sub index curves of pollutant (a) pH (b) TDS (c) BOD5 (d) COD (e) TKN (f) ammonia nitrogen (g) iron (h) copper (i) nickel (j) zinc (k) lead (l) chromium (m) mercury (n) arsenic (o) phenol (p) chlorides (q) cyanide (r) TCB [16]

3. Results and Discussion

Table 2 shows the calculation for LPI values for Open landfill leachate (OLL) and Compost tank leachate (CTL). 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. Physico-chemical characteristics of the leachate depend primarily upon the waste composition and water content in total waste. The pH was 8.20 and 8.31 for OLL and CTL respectively. pH correspondingly becomes alkaline according to the increasing age of landfill similarly these changes also corresponds to the nature of precipitation and the quantity and quality of waste. The pH of young leachate is less than 6.5 while old landfill leachate has pH higher than 7.5 [18]. Initial low pH is due to high concentration of volatile fatty acids (VFAs) [19]. Stabilized leachate shows fairly constant pH with little variations and it may range between 7.5 and 9. According to this, the present samples show the stabilization status. TDS comprises mainly of inorganic salts and dissolved organics. TDS is one of the parameter taken into consideration for licensing discharge of landfill leachate in many countries such as the U.K [20]. The amount of TDS reflects the extent of mineralization and a higher TDS concentration can change the physical and chemical characteristics of the receiving water [21]. The increase in salinity due to increase in TDS concentration also increases toxicity by changing the ionic composition of water. TDS concentration was reported as 29,400mg/L and 38,980 mg/L for OLL and CTL respectively**.** BOD is a measure of biodegradable organic mass of leachate and indicates the maturity of the landfill which typically decreases with time[22]. Young landfill leachate is characterised by high BOD_5 (4000-13,000 mg/L) and COD (30,000-60,000 mg/L) [23]. A decrease in BOD_5 and COD is often reported with the increase in age of the landfill. For stabilized leachates, COD generally ranges between 5000-20,000 mg/L[24]. The BOD_5/COD ratio provides a good estimate of the state of the leachate and this ration for young leachate is generally between 0.4-0.5[25]. During the methanogenic phase, the organic strength of the leachate is reduced ny methanogenic bacteria such as *methanogenic archaea* and the concentration of VFSs also declines which results in a raio of BOD5/COD less than 0.1[25,26] . In the study for BOD and COD values ,OLL and CTL showed 2800mg/L and 9029 mg/L, CTL showed 2400mg/L and 10771mg/L respectively, this proves the landfill old age and stabilization stage.

Table 2 Leachate Characteristics of Open landfill leachate and Compost tank leachate, with Leachate Pollution Index (LPI).
(*OLL-Open landfill leachate : CTL-Compost tank leachate)

Sl. No.	Leachate characteristics	Value		Individual pollution rating (pi)		Weights (wi)	Overall Pollution Rating (piwi)	
		OLL	CTL	OLL	CTL		OLL	CTL
1	pH	8.20	8.31	5.5	5.5	0.055	0.302	0.302
2	TDS	29400	38980	70	95	0.050	3.5	4.75
3	BOD	2800	2400	30	25	0.061	1.83	1.525
4	COD	9029	10771	30	37	0.062	1.86	2.294
5	TKN	-	-	NA	-	-	-	-
6	Ammonia nitrogen	-	-	NA	-	-	-	-
7	Total iron	80.91	60.03	8	6	0.045	0.36	0.27
8	Copper	48.12	1.94	720	30	0.050	36	1.5
9	Nickel	-	-	NA	-	-	-	-
10	Zinc	627.2	576	1020	930	0.056	57	52
11	Lead	11.58	44.56	210	800	0.063	13.23	50.4
12	Total Chromium	0.86	3.90	9	40	0.064	0.576	2.56
13	Mercury	5.09	20.10	25	100	0.062	1.55	6.2
14	Arsenic	1.44	1.68	7	8	0.061	0.427	0.488
15	Phenolic compounds	-	-	NA	-	-	-	-
16	Chlorides	9194	11679	55	70	0.048	2.64	3.36
17	Cyanide	-	-	NA	-	-	-	-
18	Total Coliform bacteria	-	-	NA	-	-	-	-
	Total					0.677	119.275	125.649
	LPI value using Eq. 2						176.442	185.871

The concentration of iron as Fe in OLL is 80.91 and in CTL is 60.03 . A Lower value of iron content in the CTL shows the segregation process involved before putting the solid waste to compost unit. 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 oxidation of ferrous to ferric form and the formation of ferric hydroxide colloids and complexes with fulvic/humic substances [27]. In general, the concentration of heavy metals in landfill leachate is fairly low[28].

Concentration of heavy metals in a landfill is generally higher at earlier stages because of higher metal solubility as a result of low pH caused by production of organic acids[19, 20]. As a result of decreased pH at later stages, a decrease in metal solubility occurs resulting in rapid decrease in the concentration of heavy metals except lead because lead is known to produce very heavy complex with humic acids[29]. The analysis results of OLL and CTL for Copper, Lead, Chromium, Mercury and Arsenic are mentioned in Table 2. Zinc value for OLL and CTL was 627.2 mg/L and 576 mg/L respectively, very high values for Zinc in both the leachate samples shows the presence of Zinc oriented waste present in the dumpsite. However, the solubility and mobility of metals may increase in the presence of natural and synthetic complexing ligands such as EDTA and humic substances[30]. Further, colloids have great affinity for heavy metals and a significant but highly variable fraction of heavy metals is associated with colloidal matter [28,31]. According to Baun and Christensen [32] , less than 30%, typically less than 10% of the total metal concentration is present in free metal ion forms and the rest is present colloidal or organic complexes. Jensen and christensen[31] found that 10-60% of Ni, 30-100% Cu and 0-95% Zn were constituted in colloidal fractions. The solubility of metals can also increase because of the reducing condition of the leachate which changes the ionic state of the metals(i.e., Cr(VI)→ Cr(III), and As(V) → As(III)[30,33,34,35] .Chlorides are usually not attenuated by soil and are extremely mobile under all conditions, they have a special significance as the tracer element of leachate plume linking the groundwater[36] . 9,194 mg/L and 11,679 mg/L of chloride is present in OLL and CTL respectively. High concentration of chloride in both samples gives clear picture of groundwater contamination possibilities. Since the Open landfill is not having any liner system, concentrated leachate generated from it has the possibility to pollute groundwater, surface water and even soil structure. Although two to three borewells near to dumping site has banned using water for drinking purposes, concentrated leachate has the ability to infiltrate easily into the soil and has the chance to pollute more borewells.

4. Conclusion

The Compost tank leachate showed high LPI value (185.871) compared to the Open landfill leachate index value(176.442). The elevated value of compost tank leachate is by the addition of concentrated leachate on a daily basis to the tank from compost unit. The comparison of the leachate characteristics with the standards set for the disposal of treated leachate verified the fact that the leachate generated from the landfill is highly contaminated and the LPI value exceed the LPI value 14.713 of treated leachate. Since both leachate samples are highly contaminated , proper treatment will have to be ensured before discharging the leachate and immediate attention is required to avoid big pollution incident. The LPI is a good tool to examine pollution potential of landfill sites. The landfill sites requiring immediate attention can also be prioritized based on the value of LPI to avoid future pollution cases. Leachate pollution index can also be considered as hazard identification tool.

References

[1] Mohajeri S., Aziz H. A., Isa M. H., Zahed M. A., Adlan M. N., Statistical optimization of process parameters for landfill leachate treatment using electro-Fenton technique, *J of Haz Mat.*, **176(1–3)**, 749–758 **(2010).**

[2] Palaniandy P., Adlan M. N., Aziz H. A., Murshed M. F., Application of dissolved air flotation (DAF) in semi-aerobic leachate treatment, *Chemical Engineering Journal.*, (**2009**).

[3] Foul A.A., Aziz H.A.,. Isa M.H., Hung Y.T., Primary treatment of anaerobic landfill leachate using activated carbon and limestone: batch and column studies, *I.J of Envi and Waste Mana.*, **4(3-4)**, 282–298 **(2009).**

[4] Daud Z., Aziz H. A, Adlan M.N., Hung Y.T., Application of combined filtration and coagulation for semi-aerobic leachate treatment, *I. J of Envi and Waste Mana.,* **4(3-4),** 457–469 **(2009).**

[5] Aziz H.A., Alias S., Adlan M.N., Faridah F., Asaari A.H., Zahari M.S., Colour removal from landfill leachate by coagulation and flocculation processes, *Bioresource Technology.*, **98(1),** 218–220 **(2007).**

[6] Renou S., Givaudan J.G., Poulain S., Dirassouyan F., Moulin P., Landfill leachate treatment: review and opportunity, *J of Hazardous Materials.*, **150(3),** 468–493 **(2008).**

[7] Kulikowska D., Klimiuk E., The effect of landfill age on municipal leachate composition, *Bioresource Technology.*, **99(13),** 5981–5985 (**2008).**

[8] Reinhart D.R., Grosh C.J., Analysis of Florida MSW landfill leachate quality, Tech. Rep. Florida Center for Solid and Hazardous Waste Management, Gainesville, Fla, USA., **97-3**, **(1998).**

[9] Halim A.A., Aziz H.A., Johari M.A.M., Ariffin K.S. and Adlan M.N., Ammoniacal nitrogen and COD removal from semi-aerobic landfill leachate using a composite adsorbent: fixed bed column adsorption performance, *J of Hazardous Materials.*, **175(1–3),** 960–964 **(2010).**

[10] Kumar D., Alappat B.J., Evaluating leachate contamination potential of landfill sites using leachate pollution index, *Clean Technologies and Environmental Policy*., **7(3),** 190–197 **(2005).**

[11] Jorstad L.B., Jankowski J., Acworth R.L., Analysis of the distribution of inorganic constituents in a landfill leachate-contaminated aquifer Astrolabe park, Sydney, Australia, *Environ. Geology.*, **46,** 263-272 **(2004).**

[12] Aluko O.O., Sridhar M.K.C., Oluwande P.A., Characterization of leachates from a municipal solid waste landfill site in Ibadan, Nigeria, *J. Environ. Health Res.,* **2(1),** 32-37 **(2003).**

[13] El-Fadel M., Bou-Zeid E., Chahine W., Alayli B., Temporal variation of leachate quality from pre-sorted and baled municipal solid waste with high organic and moisture content, *Waste Mgt*., **22,** 269–282 **(2002).**

[14] Reinhart D.R., Grosh C.J., Analysis of Florida MSW landfill leachate quality, Florida center for solid and hazardous waste management, Report., 97-3, **(1998).**

[15] APHA, Standard methods for the examinations of water and wastewater, 20th edn. American Public Health Association. American Water Works Association, Water Environment Federation Publication, Washington, D.C. **(1998).**

[16] Kumar D., A Technique to Quantify Landfill Leachate Pollution, Ninth International Landfill Symposium, Caglia ri, Italy., **(2003).**

[17] Kumar D., Selection of the Appropriate Aggregation Function for Calculating Leachate Pollution Index, *ASCE Practice Periodicals of Hazardous, Radioactive and Toxic Wastes*., **(2003).**

[18] Abbas A., Jingsong G., Ping L.Z., Ya P.Y., AlRekabi W.S., Review on landfill leachate treatments, J of Applied Sciences Research., **5(5),** 534–545 **(2009).**

[19] Bohdziewicz J., Kwarciak A., The application of hybrid system UASB reactor-RO in landfill leachate treatment, *Desalination*., **222(1–3),** 128–134 **(2008).**

[20] Koshy L., Jones T., BeruBe K., Bioreactivity of municipal solid waste landfill leachates-Hormesis and DNA damage, *Water Research*., **42(8-9),** 2177–2183 **(2008).**

[21] Al-Yaqout A.F., Hamoda M.F., Evaluation of landfill leachate in arid climate—a case study, *Environment International*., **29(5),** 593–600 **(2003).**

[22] Esakku S., et. al., Seasonal Variations in Leachate Characteristics from Municipal Solid Waste Dumpsites in India and Srilanka, *Proceedings of the International Conference on Sustainable, Chennai, India*., 341 – 347 **(2007).**

[23] Foo K.Y., Hameed B.H., An overview of landfill leachate treatment via activated carbon adsorption process, *J of Hazardous Materials*., **171(1–3),** 54–60 **(2009).**

[24] Li X.Z., Zhao Q.L., Map precipitation from landfill leachate and seawater bittern waste, *Environmental Technology*., **23(9),** 989–1000 **(2002).**

[25] Kurniawan T.A.,.Lo W.H., Chan G.Y.S., Physicochemical treatments for removal of recalcitrant contaminants from landfill leachate, *Journal of Hazardous Materials B*., **129(1–3),** 80–100 **(2006).**

[26] Ri vas F.J., Bel t ran F., Carvalho F., Acedo B., Gimeno O., Stabilized leachates: sequential coagulation-flocculation +chemical oxidation process, *J of Hazardous Materials*., **116(1-2),** 95–102 **(2004).**

[27] Jones-Lee A., Groundwater Pollution by Municipal Landfills: Leachate Composition, Detection and Water Quality Significance, Proceedings Sardinia, IV International Landfill Symposium, Sardinia, Italy., 1093-1103 **(1993).**

[28] Christensen T.H., Kjeldsen P., Bjerg P.L. et al., Biogeochemistry of landfill leachate plumes, *Applied Geochemistry*., **16(7-8),** 659–718 **(2001).**

[29] Harmsen J., Identification of organic compounds in leachate from a waste tip, *Water Research*., **17(6),** 699–705 **(1983).**

[30] Jones D.L., Williamson K.L., Owen A.G., Phytoremediation of landfill leachate, *Waste Management*., **26(8),** 825–837 **(2006).**

[31] Jensen D.L., Christensen T.H., Colloidal and dissolved metals in leachates fromfour Danish landfills, *Water Research*., **33(9),** 2139–2147 **(1999).**

[32] Baun D.L. and Christensen T.H., Speciation of heavy metals in landfill leachate: a review, *Waste Management and Research*., **22(1),** 3–23 **(2004).**

[33] Sierra-Alvarez R., Field J. A., Cortinas I. et al., Anaerobic microbial mobilization and biotransformation of arsenate adsorbed onto activated alumina, *Water Research.*, **39(1),** 199–209 **(2005).**

[34] Halim C.E., Scott J.A., Natawardaya H., Amal R., Beydoun D., Low G., Comparison between acetic acid and landfill leachates for the leaching of Ph(II), Cd(II), As(V), and Cr(VI) from clementitious wastes, *Environmental Science and Technology.*, **38(14),** 3977–3983 **(2004).**

[35] Li Y., Low G.K.C., Scott J.A., Amal R., Microbial reduction of hexavalent chromium by landfill leachate, *Journal of Hazardous Materials.*, **142(1-2),** 153–159 **(2007).**

[36] Kumar D., Alappat B. J., Analysis of leachate pollution index and formulation of sub-leachate pollution indices, *Waste Management and Research.*, **23(3),** 230–239 **(2005).**