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ORIGINAL RESEARCH PAPER

Leachate characterization and identification of dominant pollutants using leachate pollution index for an uncontrolled landfill site

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ABSTRACT: Landfill leachates are potential threats for environmental degradation. This study was conducted to determine the leachate quality, to identify the dominant pollutants and to evaluate the leachate pollution potential of an active and closed dumping ground of an uncontrolled municipal solid waste (MSW) landfill site in Kolkata, India using leachate pollution index. The results of the physico-chemical and biological analyses of leachate indicated that landfill site was in its methanogenic phase. Among the analysed leachate pollutants, TDS, BOD_5, COD, TKN, NH_3-N, Cl^-, TCB, Pb, and Hg surpassed the leachate discharge standards for inland surface water as specified by the municipal solid waste (management and handling) rules, 2013 for both the dumping grounds. Moreover the concentrations of total Cr and Zn also exceeded the leachate disposal standards for the active dumping ground. The leachate pollution potentialities of both the active and closed dumping grounds were comparable as the overall LPI obtained 34.02 and 31.80 respectively. The overall LPI, LPI organic (LPI_{or}), LPI inorganic (LPI_{in}) and LPI heavy metals (LPI_{hm}) of both the dumping grounds largely exceeded the LPI and sub-LPI values for treated leachate before disposal to the inland surface water. In terms of the individual pollution rating, total coliform bacteria, TKN, NH_3-N and Hg were identified as the dominant pollutants and major contributing factors for the leachate pollution potential.

KEYWORDS: *Dominant pollutants; Kolkata; Leachate pollution index (LPI); Leachate pollution potential; Total coliform bacteria (TCB): Uncontrolled landfill site*

INTRODUCTION

Landfilling is one of the dominant options for solid waste disposal all over the world (Laner *et al*., 2012). Solid waste landfills are significant sources of wide range of pollutants of environmental concern (Eggen *et al*., 2010). Uncontrolled/open dumping of the municipal solid waste (MSW) is associated with adverse health impacts as a consequence of landfill gas emissions and generation of highly concentrated leachates which poses hazardous effects on the surrounding ecosystem polluting the adjacent soil, sub-soil, surface water bodies and groundwater aquifers (Kim *et al*., 2010; Matejczyk *et al*., 2011; Paoli *et al*., 2012). In developing countries like India, MSW is mostly disposed in an uncontrolled manner into the open dumps without any liner, leachate collection and treatment facilities. Leachate is a high strength toxic effluent with a complex matrix of organic and inorganic pollutants. Leachates are produced as a result of rainwater percolation through the waste layers; physical, chemical, biochemical and microbiological reactions of the organics within the waste mass and due to the inherent or interstitial water content of the waste (Li *et al*., 2010; Schiopu and Gavrilescu, 2010). Christensen *et al*. (1994) sub-grouped the leachate

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pollutants in four major catagories: dissolved organic matter, inorganic macro components, heavy metals and xenobiotic organic compounds. Among the different leachate pollutants, organic substances, ammoniacal nitrogen and heavy metals are of significant concern to the environment (Yusof *et al*., 2009). Dissolved organic matter imparts a significant effect on other pollutant's characteristics by redox reactions and hydrophobic/ hydrophilic sorption (Seo *et al*., 2007). Ammonia is one of the odorous substances which are emitted from the landfill sites (Fang *et al*., 2012). Heavy metals are toxic, persistant, capable to bioaccumulate (Nguyen *et al*., 2013) and able to pollute the surrounding water resoursces to a landfill site (Awaz, 2015). Heavy metal pollution also leads to ecological risk (Karbassi *et al*., 2015). Thus leachate has the potential of polluting the adjoining aquatic and lithospheric systems unless remedial measures are implemented. To prioritize the actions of the remediation works, Kumar and Alappat, (2003a) formulated a method to identify the leachate pollution potential of different landfills by using an index known as leachate pollution index (LPI) and the dominant group of pollutants are analyzed by calculating the sub-leachate pollution indices: LPI organic (LPI_{or}), LPI inorganic (LPI_{in}) and LPI heavy metals (LPI_{hm}) depending on the leachate characteristics (Kumar and Alappat, 2005b). In a study by Umar *et al*., 2010, LPI values of four landfills in Malaysia were investigated to identify the highly polluted landfill site so that immediate remediation works can be encouraged. In another study by Kale *et al*., 2010, seasonal variation of LPI values were analysed suggesting that landfill leachate have more pollution potential during pre-monsoon in comparison to post-monsoon.

Since the knowledge of leachate composition is essential to evaluate the leachate pollution potential of a landfill site, the aim of the study was to monitor leachate characteristics of both the active and closed dumping grounds of the uncontrolled landfill site in Kolkata, India. Moreover, LPI and sub-LPI had been applied to rank and identify the dominant pollutants of the uncontrolled landfill site in Kolkata on the basis of their leachate pollution potential. Very few published data are available on the leachate pollution potential of the concerned landfill site. Thus, the present study would be helpful to identify the dominant pollutants present in the Dhapa landfill site and to assess the probability of leachate induced groundwater pollution along with developing a proper leachate management and treatment programs for the identified landfill site. This study has been performed in Dhapa uncontrolled landfill site in Kolkata, India during 2014-2015.

MATERIALS AND METHODS

Study area

Kolkata, a metropolitan city of India has a population of 8 million generates about 3000 MT of MSW per day (Chattopadhyay *et al*., 2007). Without any prior treatment, bulk of the generated solid waste is disposed on the open/uncontrolled landfill site at Dhapa, Kolkata. No source segregation is practiced, except the rag

Fig. 1: Location of active and closed dumping ground at Dhapa uncontrolled landfill in Kolkata, India (Source: Google Earth)

Table 1: Comparison of leachate characteristics of the active and closed dumping ground at Dhapa uncontrolled landfill site in Kolkata, India

Parameters (mg/L)[a]	Active dumping ground		Closed dumping ground		No. of samples	Leachate discharge standards[c]
	Mean ± SD[b]	Range	Mean ± SD[b]	Range		Inland surface water
pH	8.2 ± 0.15	7.8 – 8.4	8.2 ± 0.24	8.1 – 8.6	12	5.5 – 9
EC	26228 ± 10527	9557.14 – 41600	30775 ± 16976	12500 – 52600	12	–
TDS	10014 ± 3274	5660 – 15700	5987.50 ± 2875	2320 – 9240	12	2100
COD	5653 ± 3253	2000 – 13200	2775 ± 1939	1200 – 5600	12	250
BOD_5	2641.58 ± 1789	532 – 6440	1343.25 ± 1030	525 – 2800	12	30
Na^+	2196.42 ± 1094	869.57- 4347.83	2105.64 ± 1636	292.11 - 4000	12	-
K^+	1794.30 ± 824	561.22- 2960	1297.61 ± 1420	168.37 - 3375	12	-
Cl^-	4050.73 ± 1446	2103- 6735	3740.23 ± 1643	2223 – 6062	12	1000
HCO_3^-	51049.38 ± 53301	6100 - 127032	22073.46 ± 13093	5319 – 44072	12	–
PO_4^{3-}-P	18.88 ± 16	1.20 – 56.10	9.09 ± 8	3.70 – 20.99	12	–
TKN	5529.22 ± 3739	631 – 9139	2846 ± 1388	891 – 3961	12	100
NH_3-N	1681.67 ± 1451	168 – 4210	1341.28 ± 676	380 – 1865	12	50
As	0.03 ± 0.03	0.0045 – 0.07	0.22 ± 0.29	0.01 – 0.56	12	0.2
Total Cr	3.22 ± 3.78	0.31 – 10.43	1.19 ± 1.37	0.10 – 3.19	12	2.0
Cu	0.32 ± 0.17	0.14 – 0.68	0.27 ± 0.09	0.17 – 0.37	12	3.0
Total Fe	4.26 ± 3.41	0.80 – 11.25	3.16 ± 4.14	1.02 – 9.37	12	–
Hg	0.87 ± 1.06	0.21 – 2.65	1.20 ± 0.94	0.16 – 2.06	12	0.01
Ni	0.51 ± 0.19	0.23 – 0.77	0.43 ± 0.24	0.20 – 0.75	12	3.0
Pb	0.60 ± 0.22	0.37 – 1.06	0.69 ± 0.32	0.39 – 1.14	12	0.1
Zn	7.61 ± 7.77	1.18 – 25.14	3.26 ± 2.15	1.0 – 5.66	12	5.0
CN^-	0.03 ± .004	0.024 – 0.035	0.02 ± 0.008	0.01 – 0.03	12	0.2
Phenolic compounds	0.25 ± 0.06	0.16 – 0.34	0.18 ± 0.03	0.14 – 0.21	12	1.0
TCB	8×10^7± 2.30	4×10^7-11×10^7	7×10^6± 1.41	6×10^6-9×10^6	12	–

[a]Except pH and TCB (MPN/100 ml)
[b]Standard deviation
[c]Municipal solid waste (Management and handling) rules, 2013 (The gazette of India, 2013)

pickers who segregated the recyclable components in an unorganized, hazardous, and unhygienic way (Chattopadhyay *et al*., 2009).

Dhapa is located on the eastern part of Kolkata at latitude 22º 322 N and longitude 88º 262 E. Dhapa having around 24.71 ha of landfill area is situated on the western part of East Kolkata Wetlands (EKW) (Hazra and Goel, 2009). The landfill site is operational since 1981 and consists of an eastern dumping area i.e. "Eastern mound" (active) and a western dumping area i.e. "Western mound" (closed since 2009) (USEPA, 2010) (Fig. 1). The landfill site is non-engineered, unlined, open dump without any arrangements for leachate collection and treatment system with nominal daily cover. In Dhapa, MSW is disposed on the level ground whose permeability (10^{-5} to 10^{-6} cm/s) is less than the permeability of the dumped solid waste (10^{-3} cm/s) (KEIP, 2005). Moreover as the landfill site is without any leachate collection system and not confined by earthen embankments, major portion of the leachate flows out laterally from the waste heap. There are many groundwater zones and surface water bodies (jheels and bheris) around Dhapa landfill site which are habitually contaminated by landfill leachate. An area of about 800 ha adjacent to Dhapa landfill site are used for cultivation (Patra *et al*., 2001). Ground water along with surface water of this area is used for irrigation of the nearby agricultural fields. As a result, diseases such as hepatitis, diarrhoea, vomiting, abdominal pain, dysentery etc. have been frequently occurring in majority of the people of Makaltala, Durgapur, Khanaberia etc. villages around Dhapa landfill site.

Leachate sampling and analysis

To determine leachate characteristics and pollution potential of the Dhapa uncontrolled landfill site in Kolkata, leachate samples were collected every month from both the dumping grounds for a period of one year from May 2014 to April 2015. Six representative samples of leachate were collected from each of the active and closed mound of the landfill site in pre acid-washed high density polyethylene bottles of 1litre capacity from the leachate streams flowing out from the base of the waste dump and were mixed homogeneously to yield a composite sample representing each site. For the determination of heavy metals, 100 ml of the collected leachate samples were acidified with 5N nitric acid at pH <2. All the chemicals used were of analytical grade (AR) purchased from Merck Company.

After collection, leachate samples were transferred shortly to the laboratory and stored under dark at 4°C. The selected parameters were subsequently analysed with three replicates. The physico-chemical and biological parameters were analysed according to the internationally accepted standard methods (APHA, AWWA, WPCF 20th edition). The various parameters determined in leachate includes: pH (using ECO Test pH 2, Eutech Instruments), electrical conductivity (EC) (using Deluxe conductivity meter- 601 from Electronics India), total dissolved solids (TDS) (Gravimetric method), sodium and potassium (flame photometric method), chloride(Cl^-) (Argentometric method), bicarbonate (HCO_3^-) (using titrimetric methods), cyanide (CN^-) (using nano-colorimeter 500D), phosphate (PO_4^{3-} - P) (stannous chloride method), ammoniacal-nitrogen (NH_3-N) (using Expandable ion analyzer EA940), total Kjeldahl nitrogen (TKN) (Semi-Micro-Kjeldahl Method), five days biochemical oxygen demand (BOD_5) (Azide modification of the Winkler method), chemical oxygen demand (COD) (open reflux digestion method), phenolic compounds (using UV-VIS spectrophotometer), total coliform bacteria (TCB) (Multiple tube fermentation technique) and the concentrations of arsenic, cadmium, total chromium, copper, total iron, mercury, manganese, nickel, Lead and Zinc were estimated using a graphite furnace (HGA Graphite Furnace) associated with Perkin Elmer Analyst 400 atomic absorption spectrometer (AAS) by electrothermal atomization.

After determining the leachate characteristics, LPI and Sub-LPI values for both the dumping grounds in Dhapa were calculated using the Eq. 1 (Kumar and Alappat, 2005a).

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

where LPI = the weighted additive leachate pollution index, w_i = the weight for the *i*th pollutant variable, p_i = the sub index score of the *i*th leachate pollutant variable, n = number of leachate pollutant variables used in calculating LPI and $\sum_{i=1}^{n} w_i = 1$

RESULTS AND DISCUSSION

Leachate characterization

The physical, chemical and biological characteristics of the leachate samples collected from both the dumping grounds at Dhapa uncontrolled landfill site are summarized in Table 1. The concentrations of the analysed parameters like TDS, COD, BOD_5, Cl^-, TKN, NH_3-N, Hg, Pb and TCB exceeded the permissible limits as specified by the Municipal solid waste (Management and handling) rules, 2013 (The gazette of India, 2013) notified by Ministry of Environment and Forests (MoEF) for both the leachate samples of the active and closed dumping ground at Dhapa to be disposed in inland surface water. Moreover, the concentrations of total Cr and Zn were also surpassed the standard discharge values in the leachate samples of the active dumping ground.

pH of the leachates varied in the range of 7.8 - 8.4 for the active dumping ground and 8.1 - 8.6 for the closed dumping ground at Dhapa landfill site. The leachate samples were in the alkaline range. According to Chian and De Walle (1976), pH of leachate becomes alkaline in nature as the free volatile fatty acids are used up by the methane producing bacteria. Although waste deposition continues in the landfill site, acidogenic leachates were not observed as the ratio of the old and stabilized waste to the newly deposited waste are high (Demirbilek *et al*., 2013). EC varied in the range of 9557.14 – 41600 mg/L with a mean value of 26228 mg/L for the active dumping ground and 12500 – 52600 mg/L with a mean value of 30775 mg/L for the closed dumping ground. Conductivity of the leachate samples is mainly due to the presence of the major ions like Calcium, magnesium, sodium and potassium (Johansen and Carlson, 1976). TDS varied in the range of 5660 - 15700 mg/L with a mean value of 10014 mg/L for the active dumping ground and 2320 - 9240 mg/L with a mean value of 5987.50 mg/L for the closed dumping ground. Leaching of ions may be responsible for the high values of TDS. Cl^- concentrations spanned between 2103 - 6735 mg/L for the active dumping ground and 2223 - 6062 mg/L for the closed dumping ground at Dhapa which were higher than the values as observed by Mandal, (2007). Chloride is one of the inorganic macro components whose sorption, complexation and precipitation reactions are negligible. Thus it can act as a conservative pollutant (Kjeldsen *et al*., 2002). Like Cl^-, Na^+ can also act as a conservative pollutant since Na^+ does not undergo complexation and precipitation

Table 2: Leachate pollution index (LPI) for the active and closed dumping ground at Dhapa, Kolkata

Parameters (1)	Weights, w_i (2)	Active dumping ground: Mean[a] values (mg/L) (3)	Active dumping ground: Individual pollution rating, p_i (4)	Active dumping ground: Overall pollution rating, $w_i p_i$ (5)	Closed dumping ground: Mean[a] values (mg/L) (6)	Closed dumping ground: Individual pollution rating, p_i (7)	Closed dumping ground: Overall pollution rating, $w_i p_i$ (8)
pH	0.055	8.2	5	0.28	8.2	5	0.28
TDS	0.050	10014.17	20	1.0	5987.50	13	0.65
BOD_5	0.061	2641.58	45	2.75	1343.25	32	1.95
COD	0.062	5653	66	4.09	2775	55	3.41
TKN	0.053	5529.22	100	5.30	2846	94	5.0
NH_3-N	0.051	1681.67	100	5.10	1341.28	100	5.10
Total Fe	0.045	4.26	5	0.23	3.16	5	0.23
Cu	0.050	0.32	6	0.30	0.27	6	0.30
Ni	0.052	0.51	6	0.31	0.43	6	0.31
Zn	0.056	7.61	7	0.39	3.26	6	0.34
Pb	0.063	0.60	7	0.44	0.69	8	0.50
Total Cr	0.064	3.22	17	1.09	1.19	7	0.45
Hg	0.062	0.87	81	5.02	1.20	92	5.70
As	0.061	0.03	5	0.31	0.22	5	0.31
Phenolic compounds	0.057	0.25	5	0.29	0.18	5	0.29
Cl^-	0.048	4050.73	34	1.63	3740.23	31	1.49
CN^-	0.058	0.03	5	0.29	0.02	5	0.29
TCB	0.052	8×10^7	100	5.2	7×10^6	100	5.2
Total				34.02			31.80
LPI value				34.02 (using Eq.1)			31.80 (using Eq.1)

[a]Except pH and TCB (MPN/100 ml)

reactions (Erses *et al*., 2008). K^+ can also be used as a conservative pollutant and dilution indicator in the leachate system (Demirbilek *et al*., 2013). Thus high concentrations of Na^+ and K^+ were found in both the dumping grounds with mean values being 2196.42 mg/L and 1794.30 mg/L respectively for the active dumping ground and 2105.64 mg/L and 1297.61 mg/L respectively for the closed dumping ground. At the pH range of 7.0-8.6, HCO_3^- ions are mainly responsible for the alkalinity of the leachate samples (Clement *et al*., 1995). High values of bicarbonate concentrations were observed with the mean values being 51049.38 mg/L for the active dumping ground and 22073.46 mg/L for the closed dumping ground. PO_4^{3-} - P is mainly released into the leachate by the biological degradation of the organic matter containing phospholipids and phosphoproteins (Fatta *et al*., 1999). PO_4^{3-} - P concentrations varied in the range of 1.20 – 56.10 mg/L with the mean value being 18.88 mg/L for the active dumping ground and 3.70 – 20.99 mg/L with the mean value being 9.09 mg/L for the closed dumping ground. The concentration of COD for the active dumping ground (5653 mg/L) was slightly higher than the closed dumping ground (2775 mg/L). Similar results were also observed for BOD_5. Low concentrations of COD and BOD_5 indicated that the leachate were in their intermediate stage as BOD_5/COD ratio were in between 0.1 - 0.5 (Foo and Hameed, 2009). These intermediate biodegradability (BOD_5/COD) values were due to the continuous process of waste deposition. High concentrations of ammoniacal nitrogen were observed in both the active (1681.67 mg/L) and closed dumping grounds (1341.28 mg/L) at Dhapa. Decomposition of proteins may be responsible for the release of ammonia from the solid waste. Increase in oxygen demand and eutrophication of the aquatic resources are the notable consequences of nitrogen pollution by ammoniacal nitrogen (Gupta *et al*., 2015). TKN ranged between 631 – 9139 mg/L for the active dumping ground and 891 – 3961 mg/L for the closed dumping ground. TKN decreases during stabilization (Abd EI-Salam and Abu-Zuid, 2015) but in the current study high concentrations of TKN were attributed to the ongoing process of waste disposal. Very low concentrations of cyanide and phenol were observed in both of the dumping grounds with the mean values being 0.03 mg/L and 0.25 mg/L respectively for the active dumping ground; 0.02 mg/L and 0.18 mg/L respectively for the closed dumping ground as industrial wastes were not disposed in the concerned landfill site (Kale *et al*., 2010). TCB is one of the

Table 3: Sub-LPI for the active and closed dumping ground in Dhapa Kolkata

Index	Parameters	w_i	Pollutant conc. (Active dumping ground)[a]	p_i	$w_i\ p_i$ (Active dumping ground)	Pollutant conc. (Closed dumping ground)[a]	p_i	$w_i\ p_i$ (Closed dumping ground)	Leachate disposal standards (Inland surface water)	Treated leachate sub-index value p_i	Treated leachate w_ip_i
LPI organic LPI_{or}	COD	0.267	5653	66	17.62	2775	55	14.69	250	10	2.67
	BOD_5	0.263	2641.58	45	11.84	1343.25	32	8.42	30	6	1.58
	phenolic compounds	0.246	0.25	5	1.23	0.18	5	1.23	1.0	5	1.23
	TCB	0.224	8×10^7	100	22.40	7×10^6	100	22.40	-	-	-
	summation	1.000			53.09			46.74			5.48
	LPI_{or}				53.09			46.74			7.03
LPI inorganic LPI_{in}	pH	0.214	8.2	5	1.07	8.2	5	1.07	5.5 - 9.0	5	1.07
	TKN	0.206	5529.22	100	20.60	2846	94	19.36	100	6	1.24
	NH_3-N	0.198	1681.67	100	19.80	1341.28	100	19.80	50	7	1.39
	TDS	0.195	10014.17	20	3.90	5987.50	13	2.54	2100	7	1.37
	Cl^-	0.187	4050.73	34	6.36	3740.23	31	5.80	1000	8	1.50
	summation	1.000			51.73			48.57			6.57
	LPI_{in}				51.73			48.57			6.57
LPI heavy metals LPI_{hm}	Total Cr	0.125	3.22	17	2.13	1.19	7	0.88	2.0	9	1.13
	Pb	0.123	0.60	7	0.86	0.69	8	0.98	0.1	5	0.62
	Hg	0.121	0.87	81	9.80	1.20	92	11.13	0.01	6	0.73
	As	0.119	0.03	5	0.60	0.22	5	0.60	0.2	5	0.60
	CN^-	0.114	0.03	5	0.57	0.02	5	0.57	0.2	6	0.68
	Zn	0.110	7.61	7	0.77	3.26	6	0.66	5.0	6	0.66
	Ni	0.102	0.51	6	0.61	0.43	6	0.61	3.0	10	1.02
	Cu	0.098	0.32	6	0.59	0.27	6	0.59	3.0	18	1.76
	Total Fe	0.088	4.26	5	0.44	3.16	5	0.44	-	-	-
	summation	1.000			16.37			16.46			7.2
	LPI_{hm}				16.37			16.46			7.89

[a]All values are in mg/L except pH and TCB (MPN/100 ml)

indicators of organic pollution of water and wastewater quality (Matejczyk *et al*., 2011). As septic tank sludge were directly released on the Dhapa landfill site, very high concentrations of TCB were found in the range of 4×10^7 - 11×10^7 MPN/100 ml for the active dumping ground and 6×10^6 - 9×10^6 MPN/100 ml for the closed dumping ground.

Leachates of the Dhapa landfill site were in the methanogenic phase as relatively low concentrations of COD, slightly alkaline pH, intermediate biodegradability (BOD_5/COD) and high concentrations of NH_3-N were observed. Leachates in the methanogenic phase are also characterized by lower concentrations of heavy metals (Kjeldsen *et al*., 2002) as a result of sorption and precipitation reactions with the co-existing sulphides, carbonates and hydroxides (Lo, 1996). But some of the heavy metals were observed in the higher range in the leachate samples of the Dhapa landfill site as the concentrations of the sulphides, carbonates and hydroxides were low or insufficient for the adsorption or precipitation reactions. Thus high concentrations of Hg and Pb were found in both the dumping grounds at Dhapa with the mean values of 0.87 mg/L and 0.6 mg/L respectively for the active dumping ground; 1.20 mg/L and 0.69 mg/L respectively for the closed dumping ground. The occurence of Hg in leachate indicated the disposal of household batteries, fluorescent lamps, medical thermometers, thermostats etc. along with MSW. Anthropogenic sources like Pb batteries, Pb based paints and pipes may be attributed to the high levels of Pb in leachate (Mor *et al*., 2006). Leachate from the active dumping ground exhibited high mean values of total Cr (3.22 mg/L) and Zn (7.61 mg/L). The sources of Cr in the leachate samples may be attributed to the presence of Pb-Cr batteries, coloured polythene bags, discarded plastic materials and empty paint containers in the disposal site (Parth *et al*., 2011). Leather tanning and electroplating effluents are also a significant source of Cr (Aravind *et al*., 2015). Agro-chemicals like fertilizers and pesticides are the major sources of Zn (Parth *et al*., 2011). Total Cr and Zn were present with the mean values of 1.19 mg/L and 3.26 mg/L for the closed dumping ground. Leachates were very dark blackish brown in color which may due to the changes in the oxidation state of Fe^{+2} (ferrous ion) to Fe^{+3} (ferric ion). Fe^{+3} eventually form ferric hydroxide colloids and fulvic complexes attributing the blackish brown color of the leachate (Chu *et al*., 1994). Total Fe was found in the range of 0.80 – 11.25 mg/L for the active dumping ground and 1.02 – 9.37 mg/L for the closed dumping ground which may be due to the presence of Fe and steel based scrap (Mor *et al*., 2006). Other heavy metals which were examined and found to be below the permissible limit of leachate discharge standards as per the MoEF rules were As, Cu and Ni with the mean values being 0.03 mg/L, 0.32 mg/L and 0.51 mg/L respectively for the active dumping ground; 0.22 mg/L, 0.27 mg/L and 0.43 mg/L respectively for the closed dumping ground. The presence of heavy metals in leachate can be attributed to the disposal of unsegregated MSW in the landfill site.

LPI and Sub-LPI

The mean concentrations of the 18 leachate pollutants for calculating LPI for the active and closed dumping grounds are represented in column 3 and 6 respectively of Table 2. The sub-index scores of the i^{th} leachate pollutant i.e. p_i value, were obtained from the sub-index curves as described by Kumar and Alappat, 2005a. Thus on the basis of the p_i values, TCB and ammoniacal nitrogen scored the highest value of 100

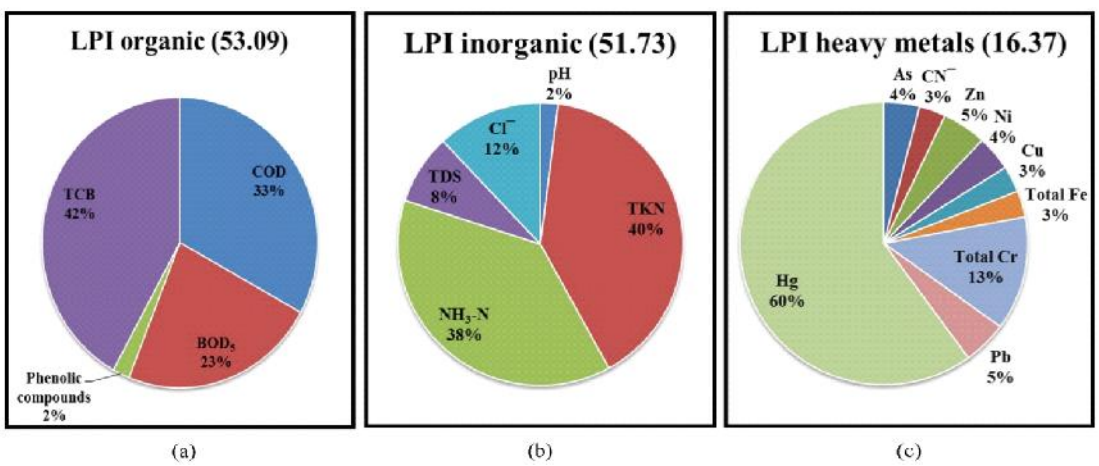

Fig. 2: Percentage distribution of the components of (a) LPI organic, (b) LPI inorganic and (c) LPI heavy metals for the active dumping ground at Dhapa, Kolkata

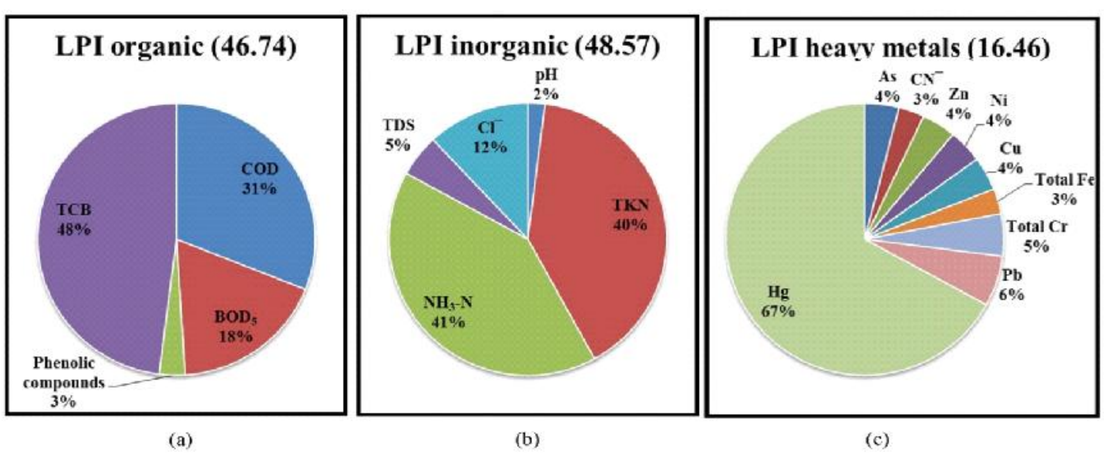

Fig. 3: Percentage distribution of the components of (a) LPI organic, (b) LPI inorganic and (c) LPI heavy metals for the closed dumping ground at Dhapa, Kolkata

indicating the maximum pollution potentiality in both the dumping ground at Dhapa. TKN scored a pollution rating of 100 and 94 for active and closed dumping ground respectively. Mercury had the p_i value of 81 (active dumping ground) and 92 (closed dumping ground) which implies that it was one of the dominant leachate pollutants present in the Dhapa landfill site. COD, BOD_5 and Cl^- had moderate p_i values of 66, 45 and 34 for the active dumping ground; 55, 32 and 31 for the closed dumping ground respectively. TDS and total Cr had the p_i value of 20 and 17 respectively for the active dumping ground. The p_i values of all other parameters for the active dumping ground (50% of the parameters) remained within 8 and for the closed dumping ground (77% of the parameters) remained within 13 indicating least pollution potentiality.

The calculated LPI values for the active and closed dumping grounds were 34.02 and 31.80 respectively. These LPI values were much higher than the standard LPI value for the treated leachate disposal limit for inland surface water, 7.378 (Kumar and Alaappat, 2003b). These high LPI values signify that the dumping grounds were highly contaminated and the leachate should be properly treated before discharging it into the inland surface water. LPI of the closed dumping ground is still high since it was active till 2009 and any kind of post closure reclamation works had not been performed on the closed dumping ground.

The sub-LPI scores for the active and closed dumping ground as well as for the treated leachate disposal standards for inland surface water are represented in Table 3. For the active dumping ground, the values of LPI_{or}, LPI_{in}, and LPI_{hm} were 53.09, 51.73 and 16.37 respectively and for the closed dumping ground, were 46.74; 48.57 and 16.46 respectively. The three sub-LPI values for both the dumping grounds were much higher than the sub-indices values of the standards for treated leachate (LPI_{or}, 7.03; LPI_{in}, 6.57 and LPI_{hm}, 7.89) before disposal to the inland surface water.

TCB was the major pollutant in LPI_{or} contributing about 42% in active dumping ground (Fig. 2a) and 48% in closed dumping ground (Fig. 3a). The major pollutants for the LPI_{in} were TKN and NH_3-N which contributed about 40% and 38% respectively in active dumping ground (Fig. 2b) and 40% and 41% respectively in closed dumping ground (Fig. 3b). Among the heavy metals, Hg was the dominant pollutant in LPI_{hm} which contributed about 60% in active dumping ground (Fig. 2c) and 67% in closed dumping ground (Fig. 3c).

CONCLUSION

Leachate generated from the Dhapa MSW uncontrolled landfill site demonstrated that it was in its methanogenic phase with intermediate biodegradability, slightly alkaline pH with high concentrations of NH_3-N and heavy metals. As LPI is a very useful method to identify the leachate pollution potential of different landfills, LPI value of 34.02 for the active dumping ground and 31.80 for the closed dumping ground at Dhapa, Kolkata implies that the dumping grounds were highly unstabilized and hazardous largely exceeding the LPI value for the leachate disposal standards (7.378) for the inland surface water. The sub-LPI scores of the active dumping ground, LPI_{or}, 53.09; LPI_{in}, 51.73 and LPI_{hm}, 16.37 and closed dumping ground, LPI_{or}, 46.74; LPI_{in}, 48.57 and LPI_{hm}, 16.46 indicated that the values are much higher than the leachate disposal standard values of 7.03, 6.57 and 7.89 respectively for inland surface water. As per the individual pollution rating, the major pollutants identified in the Dhapa active and closed dumping grounds were TCB, TKN, NH_3-N and Hg. High values of LPI_{or} were majorly due to the abundance of TCB which indicated sanitary and epidemiological hazard. High LPI_{in} values were due to the high concentrations of TKN and NH_3-N which showed the vulnerability of the surrounding groundwater aquifers and the moderate values of LPI_{hm} were mainly due to the presence of Hg, one of the priority hazardous substances which undergoes bio-accumulation and bio-magnification.

RECOMMENDATIONS

Necessary remedial action should be taken to meet the discharge standards before leachate is being properly disposed in the Dhapa landfill site. Immediate attention is required as leachate pose threat to the sorrounding ecosystems and human health. Regular monitoring is essential to avoid the contamination of the sub-surface and adjacent aquatic environment. Leachate treatment processes should also be encouraged to mitigate furthur environmental problems. Moreover an engineered sustainable sanitary landfill site should be designed for solid waste dumping as the life span of the existing uncontrolled landfill site at Dhapa is almost exhausted.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

REFERENCES

Abd EI-Salam, M.M.; Abu-Zuid, G.I., (2015). Impact of landfill leachate on the groundwater quality: A case study in Egypt. J. Adv. Res., 6(4): 579–586 **(8 pages)**.

APHA, AWWA, WPCF, (1999). Standard methods for the examination of water and wastewater, 20th Ed., Washington DC, USA.

Aravind, J.; Sudha, G.; Kanmani, P.; Devisri, A.J.; Dhivyalakshmi, S.; Raghavprasad, M., (2015). Equilibrium and kinetic study on chromium (VI) removal from simulated waste water using gooseberry seeds as a novel biosorbent. Global J. Environ. Sci. Manage., 1(3): 233–244 **(12 pages)**.

Awaz, B.M., (2015). Leachate and groundwater assessment at Kirkuk sanitary landfill site in ZindanaVillage, Iraq Int. J. Environ. Res., 9(2): 457-466 **(10 pages).**

Chattopadhyay, S.; Dutta, A.; Ray, S., (2007). Existing municipal solid waste management of Kolkata, Deficiencies and its solutions. J. Indian Assoc. Environ. Manage., 34 (3): 161–167 **(7 pages)**.

Chattopadhyay, S.; Dutta, A.; Ray, S., (2009). Municipal solid waste management in Kolkata, India: A review. Waste Manage., 29: 1449–1458 **(10 pages)**.

Chian, E.S.K.; De Wallee, F.B., (1976). Sanitary landfill leachates and their treatment. J. Env. Eng. Div., 102: 411–431 **(21 pages)**.

Christensen, T.H.; Kjeldsen, P.; Albrechtsen, H.J.; Heron, G.; Nielson, P.H.; Bjerg, P.L.; Holm, P.E., (1994). Attenuation of landfill leachate pollutants in aquifers. Crit. Rev. Environ. Sci. Technol., 24; 119 202 **(84 pages)**.

Chu, L.M.; Cheung, K.C.; Wong, M.H., (1994). Variations in the chemical properties of landfill leachate. Environ. Manage., 18(1); 105–117 **(13 pages)**.

Clement, B.; Merlin, G., (1995). The contribution of ammonia and alkalinity to landfill leachate toxicity to duckweed, Sci. Total Environ., 170: 71 79 **(9 pages)**.

Demirbilek, D.; Onal, A.O.; Demir, V.; Uslu, G.; Arslanoglu-Isýk. H., (2013). Characterization and pollution potential assessment of Tunceli, Turkey municipal solid waste open dumping site leachates. Environ. Monit. Assess., 185: 9435–9449 **(15 pages)**.

Eggen, T.; Moeder, M.; Arukwe, A., (2010). Municipal landfill leachates: a significant source for new and emerging pollutants. Sci. Total Environ., 408(21): 5147–5157 **(11 pages)**.

Erses, A.S.; Onay, T.T.; Yenigün, O., (2008). Comparison of aerobic and anaerobic degradation of municipal solid waste in bioreactor landfills. Bioresource Technol., 99: 5418–5426 **(9 pages)**.

Fang, J.J.; Yang, N.; Cen, D. Y.; Shao, L. M.; He, P. J., (2012). Odor compounds from different sources of landfill: characterization and source identification. Waste Manage., 32(7): 1401–1410 **(10 pages)**.

Fatta, D.; Papadopoulos, A.; Loizidou, M., (1999) A study on the landfill leachate and its impact on the groundwater quality of the greater area, Environ. Geochem. Health. 21 (2): 175-190 **(16 pages)**.

Foo, K.Y.; Hameed, B.H., (2009). An overview of landfill leachate treatment via activated carbon adsorption process. J. Hazard. Mater., 171: 54–60 **(7 pages)**.

Gupta, V.K.; Sadegh, H.; Yari, M.; Shahryari Ghoshekandi, R.; Maazinejad, B.; Chahardori, M., (2015). Removal of ammonium ions from wastewater. A short review in development of efficient methods. Global J. Environ. Sci. Manage., 1(2): 149–158 **(10 pages)**.

Hazra, T.; Goel, S., (2009). Solid waste management in Kolkata, India: Practices and challenges. Waste Manage., 29: 470–478 **(9 pages)**.

Johansen, O. J.; Carlson, D. A., (1976). Characterization of sanitary landfill leachates. Water Res., 10: 1129–1134 **(6 pages)**.

Kale, S.S.; Kadam, A.K.; Kumar, S., (2010). Evaluating pollution potential of leachate from landfill site, from the Pune metropolitan city and its impact on shallow basaltic aquifers. Environ. Monit. Assess., 162: 327–346 **(20 pages)**.

Karbassi, A.R.; Tajziehchi, S.; Afshar, S., (2015). An investigation on heavy metals in soils around oil field area. Global J. Environ. Sci. Manage., 1(4): 275–282 **(8 pages)**.

KEIP, (2005). Rapid environmental impact assessment report and environmental management plan of engineered landfill at Dhapa. Kolkata environmental improvement project. Kolkata Municipal Corporation, India.

Kim, K.R.; Owens, G., (2010). Potential for enhanced phytoremediation of landfills using biosolids–a review. J. Environ. Manage., 91(4): 791–797 **(7 pages)**.

Kjeldsen, P.; Barlaz, M. A.; Rooker, A. P.; Baun, A.; Ledin, A.; Christensen, T.H., (2002). Present and long term composition of MSW landfill leachate: A Review. Crit. Rev. Environ. Sci. Tech., 32 (4): 297 336 **(40 pages)**.

Kumar, D.; Alappat, B.J., (2003a). A technique to quantify landfill leachate pollution. Proceedings of the ninth international landfill symposium, Cagliari, Italy, October, Paper No. 400.

Kumar, D.; Alappat, B.J., (2003b). Analysis of leachate contamination potential of a municipal landfill using leachate pollution index. Proceedings of the workshop on sustainable landfill management, Chennai, India, 3–5 December, pp. 147–153 **(7 pages)**.

Kumar, D.; Alappat, B.J., (2005a). Evaluating leachate contamination potential of landfill sites using leachate pollution index. Clean Tech. Environ. Pollot., 7: 190 197 **(8 pages)**.

Kumar, D.; Alappat, B.J., (2005b). Analysis of leachate polltion index and formulation of sub-leachate pollution indices. Waste Manage. Res., 23: 230 239 **(10 pages)**.

Laner, D.; Crest, M.; Scharff, H.; Morris, J. W.; Barlaz, M. A., (2012). A review of approaches for the long-term management of municipal solid waste landfills. Waste Manage., 32(3): 498–512 **(15 pages)**.

Li, W.; Hua, T.; Zhou, Q.; Zhang, S.; Li, F., (2010). Treatment of stabilized landfill leachate by the combined process of coagulation/flocculation and powder activated carbon adsorption. Desalination, 264: 56-62 **(7 pages)**.

Lo, I.M.C., (1996). Characteristics and treatment of leachates from domestic landfills. Environ. Int., 22(4): 433–442 **(10 pages)**.

Mandal, M., (2007). Leachate from municipal solid waste generation, characteristics and effects. MSc. Thesis, Bengal Engineering and Science University, Shibpur, Howrah, India.

Matejczyk, M.; P³aza, G.A.; Na³êcz-Jawecki, G.; Ulfig, K.; Markowska-Szczupak, A., (2011). Estimation of the environmental risk posed by landfills using chemical, microbiological and ecotoxicological testing of leachates. Chemosphere, 82(7): 1017–1023 **(7 pages)**.

MoEF, (2013). Municipal solid waste management and handling rules. New Delhi: Ministry of Environment and Forests, Government of India.

Mor, S.; Ravindra, K.; Dahiya. R.; Chandra. A., (2006). Leachate characterization and assessment of groundwater pollution near municipal solid waste landfill site. Environ. Monit. Assess., 118: 435–456 **(22 pages)**.

Nguyen, T.A.H.; Ngo, H.H.; Guo, W.S.; Zhang, J.; Liang, S.; Yue, Q.Y.; Li, Q.; Nguyen, T.V., (2013). Applicability of agricultural waste and by-products for adsorptive removal of heavy metals from wastewater. Bioresource Tech., 148: 574–585 **(12 pages)**.

Paoli, L.; Corsini, A.; Bigagli, V.; Vannini, J.; Bruscoli, C.; Loppi, S., (2012). Long-term biological monitoring of environmental quality around a solid waste landfill assessed with lichens. Environ. Pollut., 161: 70–75 **(6 pages)**.

Parth, V.; Murthy, N.N.; Saxena, P.R., (2011). Assessment of heavy metal contamination in soil around hazardous waste disposal sites in Hyderabad city, India: Natural and anthropogenic implications. E3 J. Environ. Res. Manage., 2(2): 27–34 **(8 pages)**.

Patra, U.; Gupta, S.; Talapatra, S.N.; Giri, A.K., (2001). Genotoxic effects after in vivo exposure of vegetable extracts containing heavy metals from the Dhapa area of Calcutta, India. I. Effects of cauliflower, spinach and radish. Food Chem. Toxicol., 39(1): 67 72 **(6 pages)**.

Schiopu, A.M.; Gavrilescu, M., (2010). Options for the treatment and management of municipal landfill leachate: common and specific issues. CLEAN, 38(12): 1101–1110 **(10 pages)**.

Seo, D.J.; Kim, Y. J.; Ham, S. Y.; Lee, D. H., (2007). Characterization of dissolved organic matter in leachate discharged from final disposal sites which contained municipal solid waste incineration residues. J. Hazard. Mater., 148(3): 679–692 **(14 pages)**.

USEPA, (2010). Landfill methane outreach program (LMOP). Methane to markets. United State Environmental Protection Agency. https://www.globalmethane.org/data/1128_dhapa.assessment.report.4-27-10.pdf.

Umar, M.; Aziz, H.A.; Yusoff, M.S., (2010). Variability of parameters involved in Leachate Pollution Index and determination of LPI from four landfills in Malaysia. Int. J. Chem. Eng., Article ID 747953. doi:10.1155/2010/747953 **(6 pages)**.

Yusof, N.; Haraguchi, A.; Hassan, M.A.; Othman, M.R.; Wakisaka, M.; Shirai, Y., (2009). Measuring organic carbon, nutrients and heavy metals in rivers receiving leachate from controlled and uncontrolled municipal solid waste (MSW) landfills. Waste Manage., 29: 2666–2680 **(15 pages)**.

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