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Characterization of Leachate and Leachate Pollution Index from Dumping Sites in Lahore, Pakistan

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ABSTRACT

In Lahore solid waste is not managed properly and efficiently in terms of collection, transportation and dumping which has resulted in unsanitary conditions. The study was aimed at assessing the characteristics of municipal solid waste leachate and its contamination potential. The characteristics of leachate were analyzed and contamination potential was estimated through Leachate Pollution Index. Saggian (SG) and Mehmood Booti (MB) dumping sites had alkaline pH whereas Baggrian (BG) dumping site had acidic pH. All the three dumping sites had very low dissolved oxygen. Leachate at BG had highest turbidity, TSS, TDS, BOD_5, COD, SO_4^{-2}, NO_3^{-1} and Cl^- followed by MB and SG dumping sites. Significantly ($P<0.05$) high amount of turbidity, TSS, TDS, BOD_5,COD were present during summer season as compared to winters at all the three dumping sites in Lahore. At SG, MB and BG dumping site, pH, BOD_5, COD, PO_4^{-3}, NO_3^{-1} and Cl^- during both winter and summer season were significantly higher ($P<0.05$) than FEPA standard. The Leachate Pollution Index at SG dumping site was 13.7, at MB was 16.7 and at BG was 21.7. The leachate from the BG dumping site had the highest contamination potential followed by MB and SG dumping site.

KEYWORDS: solid waste, leachate, leachate pollution index, characterization

1- INTRODUCTION

Landfills are used for disposal of solid waste because they have capacity to accumulate large amounts of solid waste offering very low cost as compared to incineration [1]. For the disposal of waste landfill is the most cheap and common option [2-3]. The formation of the leachate occurs when the percolating water dissolves the soluble components out of the solid material. Further contaminants are added by depending on the type of solid waste and biodegradation stage [4]. If water percolates through any material, it will produce leachate. The leachate quality is dependent upon the solubility and composition of the constituents of the solid waste [5]. The estimation of quality of leachate generated is important for evaluating surface and ground water contamination and it is an indicator for the landfill degradation stage [6]. Biodegradable landfill produces leachate that contains significant ammonical nitrogen concentrations. Runoff water from landfill leachate containing suspended solids and ammonical nitrogen can be potential toxic to the aquatic organisms and threaten fish life [7].

Leachate is still a significant environmental threat even if the landfill contains non-hazardous waste [8]. The potential of leachate contamination from landfill site can be estimated through Leachate Pollution Index (LPI) [9] Mehmood Booti (MB), Saggian (SG) and Baggrian (BG) dumping sites are not recognized sanitary landfills as they have no systems for leachate collection or treatment and landfill gas collection [10]. MB and SG dumping sites are located near river Ravi and have potential to contaminate underground water. The Leachate Pollution Index value indicates the leachate contamination potential of a landfill site. It ranges from 5-100 and expresses the potential of contamination of leachate from a landfill site based on monitoring of parameters of leachate pollution [11]. A high Leachate Pollution Index value expresses a poor condition of surrounding environment [12]. The Leachate Pollution Index (LPI) value can be beneficial in many ways. It can be used to report the variation in the leachate pollution over time at a particular landfill site. The trend in LPI can be helpful for monitoring the pollution during the post closure of a landfill site. The trend of the leachate pollution at a specific site in an area can also facilitate the designing of another leachate treatment facility for another site in that same area [11]. The LPI value can also be exploited for the comparison of leachate pollution potential for landfill sites in a particular area or around the globe. Other applications include ranking of landfill sites based on their leachate pollution potential, allocation of the resources for the remediation of leachate pollution, scientific research and leachate standards enforcement [12]. The

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study was aimed at characterization of municipal solid waste leachate from different dumping sites in Lahore and estimation of leachate contamination potential by Leachate Pollution Index.

2- MATERIALS AND METHODS

Site description

Solid waste in Lahore is managed by open dumping at one official dumping site Mehmood Booti (MB) and two unofficial open dumping sites Saggian (SG) and Baggrian (BG). MB dumping site has been operated since 1997. It is located in northern Lahore about 1 km away from River Ravi. SG is located in Northwest region along River Ravi and has been operated since 1995. BG is located in South Lahore and its operation time is less than 5 years.

Leachate sampling and analysis

On site determination was carried out for pH, dissolved oxygen and turbidity. The measurement of leachate pH was carried out by pH meter (Inolab). Dissolved oxygen was measured using HANNA instrument HI 9145 DO meter. Leachate samples for other parameters were collected along the leachate surface flow path [13] in clean 5L polyethylene bottles following the standard operating procedures [14] and transported to laboratory. Biological oxygen demand (BOD_5), chemical oxygen demand (COD), total suspended solid (TSS), phosphate (PO_4^{-3}) and nitrate (NO_3^{-1}) were estimated within 6 hours of sampling according to methods described in(APHA 2005). [14]

Metal analysis

Leachate samples were preserved by acidifying the samples with conc. HNO_3 at pH less than 2. Samples were acid digested and filtered through 0.045µm membrane filter and analyzed by Atomic Absorption Spectrophotometer (AAS) Shimadzu AA-2000F.

Leachate Pollution Index

The leachate pollution index (LPI) provides an efficient method for evaluating the leachate contamination potential. It serves as a vital tool for policy makers and public about pollution threat from landfill. It is a quantitative and comparative measure for the leachate pollution potential. Then the LPI can be calculated by the equation

$$LPI = \sum_{i=1}^{n} Wi.pi / \sum_{i=1}^{n} Wi \quad [9]$$

3- RESULTS

Seasonal characterization of leachate at MG, SG and BGis presented in Table 1. Significantly ($P<0.05$) higher pH, turbidity, TSS, BOD_5 and COD were present in summer season as compared to winter seasoning all the dumping sites. pH values at these dumping sites ranged as 8.30-8.80, 7.20-8.10 and 5.10-6.30 respectively. The alkalinity of the leachate is representative of the maturity phase of dumping site [15]. All the three dumping sites had very low dissolved oxygen which ranged (mg L^{-1}) as 2.00-2.30, 2.00-2.60 and 2.20-3.10 respectively. Total suspended solid (mg L^{-1}) at SG ranged from 45.0 to 86.3 at MB 64.8 to 84.2 and at BG 74.1 to 115 while range of total dissolved solids (mg L^{-1}) was from16104 to 17483, 17818 to 18645 and 19679 to 20711 respectively.

High BOD_5 and COD of leachate indicate the presence of high organic matter [16]. The BOD_5(mg L^{-1}) at three dumping sites ranged as 445-941, 700-2250 and 1500-2891 at SG,MB and BG respectively while range of COD (mg L^{-1}) was 1550-2344, 1800-2890 and 1925-2386 respectively for these sites. High amount of anions in leachate are due to domestic waste [17]. The concentration range of sulfate (SO_4^{-2}) (mg L^{-1}) in leachate from SG was 39.3-78.1, MB 46.4-87.4 and BG 76.3-86.5. Range of phosphate (PO_4^{-3}) (mg L^{-1}) was 47.5-129, 56.8-119 and 68.2-114 respectively. Nitrate (NO_3^{-1}) concentrations ranged as 34.7-68.4, 25.3-80.4 and 58.2-70.8 respectively while the concentration range of Cl^- in leachate from SG was 215-318, MB 203-353 and BG 230-340.

Leachate characteristics at SG, MB and BG dumping sites in Lahore are presented in Table 2. Significantly ($P<0.05$) higher pH, turbidity, TSS, TDS, BOD_5, COD, SO_4^{-2}, PO_4^{-3} and NO_3^{-1} were present at BG followed by MB and SG dumping sites. Average concentration of metals in leachate from SG, MB and BG dumping sites is presented in Table 3.Leachate Pollution Index value of these dumping sites were 13.69, 16.69 and 21.68 respectively (Table 4).

Table 1 Seasonal variations in leachate characteristics at Saggian (SG), Mehmood Booti (MB) and Baggrian (BG) dumping sites in Lahore, Pakistan.

Parameters	Dumping sites					
	SG		MB		BG	
	Winter	Summer	Winter	Summer	Winter	Summer
pH	8.40 ±0.10[b] (8.50-8.80)	8.70 ± 0.10[a] (8.30-8.50)	7.60 ±0.60[b] (7.20-8.10)	8.00 ± 0.10[a] (7.81-8.11)	5.50 ± 0.70[b] (5.10-6.30)	5.90 ± 0.90[a] (5.30-6.80)
DO ($mg\ L^{-1}$)	2.20 ±0.10 (2.10-2.30)	2.10 ± 0.10 (2.00-2.20)	2.30 ±0.40 (2.00-2.60)	2.20 ±0.20 (2.00-2.40)	2.70 ± 0.30 (2.40-3.10)	2.40 ±0.20 (2.20-2.60)
Turbidity (NTU)	32.5±20.5[b] (18.0-47.0)	44.5 ± 3.6[a] (41.0-49.0)	67.0±2.80[b] (65.0-69.0)	68.0 ± 2.10[a] (63.0-70.0)	71.0± 12.0[b] (57.0-79.0)	73.0 ± 4.6[a] (62.0-79.0)
TSS ($mg\ L^{-1}$)	65.5±28.9[b] (45.0-86.3)	72.9 ± 8.4[a] (63.2-80.5)	68.0±5.60[b] (64.8-72.3)	78.5 ± 6.70[a] (52.8-84.2)	91.3±21.2[b] (74.1-115)	97.3 ± 12.4[a] (76.8-107)
TDS ($mg\ L^{-1}$)	16565 ± 462 (16104-17027)	17217 ± 266 (16951-17483)	18004 ± 186 (17818-18190)	18487 ± 159 (18328-18645)	19789 ±109 (19679-19898)	20504 ± 207 (20298-20711)
BOD_5 ($mg\ L^{-1}$)	875 ±35.0[b] (445 -516)	896 ± 45.0[a] (851-941)	1475±196[b] (700-2250)	1792 ±150[a] (896-1891)	1983 ±194[b] (1500-2700)	1991 ± 89.0[a] (1096-2891)
COD ($mg\ L^{-1}$)	1925 ±8.40[b] (1550-2150)	1942± 9.60[a] (1687-2344)	2275±13.4[b] (1800-2750)	2346 ± 15.6[a] (1916-2890)	2405±15.0[b] (1925-2275)	2416 ± 19.0[a] (1846-2386)
BOD_5/COD ratio	0.45	0.46	0.64	0.76	0.82	0.82
SO_4^{-2} ($mg\ L^{-1}$)	55.5±23.3 (39.3-72.9)	58.6 ± 15.4 (40.6-78.1)	62.0±2.00 (46.4-85.1)	66.7 ± 4.70 (48.9-87.4)	79.0±4.2 (76.3-82.0)	83.7 ± 5.6 (77.1-86.5)
PO_4^{-3} ($mg\ L^{-1}$)	78.5±44.5 (47.5-111)	80.2 ± 15.9 (50.6-128)	86.3±20.1 (65.3-106)	91.2 ± 24.7 (56.8-119)	80.0±16.9 (68.2-92.5)	84.7± 15.8 (70.6-114)
NO_3^{-1} ($mg\ L^{-1}$)	48.0±19.8 (34.7-62.2)	50.6 ± 14.8 (41.2-68.4)	48.6±26.9 (25.3-78.9)	50.9 ± 16.2 (33.5-80.4)	62.5±6.36 (58.2-67.4)	65.8 ± 4.58 (58.4-70.8)
Cl^- ($mg\ L^{-1}$)	232 ± 17.4 (215-250)	303 ± 14.2 (289-318)	233 ± 30.5 (203-264)	316 ± 36.7 (279-353)	260 ± 30.4 (230-290)	312 ± 28.4 (284-340)

Different letters (a, b) indicates significant difference (P<0.05)

Table 2 Leachate characteristics (mean ± SD) at Saggian (SG), Mehmood Booti (MB) and Baggrian (BG) dumping sites in Lahore, Pakistan and their comparison with standard values

Parameters	Dumping Sites			FEPA standard (Ojoawo et al. 2012)
	(SG)	(MB)	(BG)	
pH	8.05 ± 1.90[a]	7.80 ± 1.69[b]	5.70 ± 0.28[c]	5.00
DO ($mg\ L^{-1}$)	2.15 ± 0.07	2.25 ± 0.07	2.55 ± 0.21	5.00
Turbidity (NTU)	38.5 ± 8.48[c]	67.5 ± 0.70[b]	72.0 ±1.41[a]	-
TSS ($mg\ L^{-1}$)	69.2 ± 5.23[c]	73.2 ± 7.40[b]	94.3 ± 4.24[a]	500.00
TDS ($mg\ L^{-1}$)	16891 ± 326[c]	18245 ± 241[b]	20147 ± 358[a]	-
BOD_5($mg\ L^{-1}$)	886 ± 14.8[c]	1634 ± 224[b]	1987 ± 5.65[a]	30.00
COD ($mg\ L^{-1}$)	1933 ± 12.0[c]	2310 ± 50.2[b]	2411 ± 7.77[a]	75.00
BOD_5/COD ratio	0.45	0.70	0.82	0.40
SO_4^{-2}($mg\ L^{-1}$)	57.1 ± 2.19[c]	64.3 ± 3.30[b]	81.4 ± 3.32[a]	100.00
PO_4^{-3}($mg\ L^{-1}$)	79.4 ± 1.20[c]	88.7 ± 3.4[b]	92.4 ± 3.32[a]	50.00
NO_3^{-1}($mg\ L^{-1}$)	49.3 ± 1.83[b]	49.7 ± 1.62[b]	64.2 ± 2.33[a]	20.00
Cl^- ($mg\ L^{-1}$)	268 ± 35.4	275 ± 41.3	286 ± 25.8	100.00

Different letters (a, b, c) in a row indicates significant difference (P<0.05)

Table 3 Concentrations of metals ($mg\ L^{-1}$) in leachate from different dumping sites in Lahore

Metals	Dumping Sites			FEPA standard (Ojoawo et al. 2012)
	(SG)	(MB)	(BG)	
Ni	0.005 ± 0.001	<0.001	1.08 ± 0.001	0.01
Pb	0.52 ± 0.01	0.74 ± 0.31	2.57 ± 2.48	0.05
Cr	1.41 ± 0.65	2.17 ± 1.16	3.76 ± 1.30	0.20
Cu	0.30 ± 0.01	1.13 ± 0.01	1.90 ± 1.88	5.00
Cd	0.176 ± 0.001	<0.001	<0.001	0.01
Mn	18.9 ± 0.01	29.1 ± 9.38	54.3 ± 0.02	0.05

Table 4 Leachate Pollution Index at Saggian (SG), Mehmood Booti (MB) and Baggrian (BG) dumping site in Lahore, Pakistan

Leachate Pollutant variable	Variable Weights (wi)	SG		MB		BG		SG	MB	BG
		(c_i)	(p_i)	(c_i)	(p_i)	(c_i)	(p_i)	(w_i p_i)	(w_i p_i)	(w_i p_i)
pH	0.055	8.05	5	7.8	5	5.7	5	0.275	0.275	0.275
TDS	0.050	16891	40	18245	42	20146	50	2	2.1	2.5
BOD	0.061	885.5	25	1633	32	1987	43	1.525	1.952	2.623
COD	0.062	1933.5	25	2310	35	2410	37	1.55	2.17	2.294
Ni	0.052	0.005	5	0.001	5	1.080	7	0.26	0.26	0.364
Pb	0.063	0.524	6	0.742	8	2.57	20	0.378	0.504	1.26
Cr	0.064	1.415	7	2.173	10	3.76	15	0.448	0.64	0.96
Cu	0.050	0.303	5	1.13	6	1.901	9	0.25	0.3	0.45
Cl	0.049	268	5	274.6	5	286.2	5	0.245	0.245	0.245
Total	0.506							6.931	8.446	10.971
LPI								**13.69**	**16.69**	**21.68**

4- DISCUSSION

The age of SG, MB and BG dumping sites is 18 years, 16 years and <5 years respectively. Average pH at SG and MB was alkaline whereas at BG was acidic which was due to the fact that SG and MB are old dumping sites but BG is a new dumping site and is in acidogenic phase and alkaline pH is indicator of dumping site maturity [15]. Low dissolved oxygen was a characteristic of all dumping sites leachate. All the other physicochemical parameters were significantly higher ($P<0.05$) at BG followed by MB and SG dumping sites. High biological and chemical oxygen demands are indicative of high organic matter content in leachate [16]. High level of total dissolved solids in leachate was due to the presence of large amount of anions and cations indicating presence of inorganic material [18] and represents the extent of mineralization of leachate [19]. Nitrate is present in leachate due to combustion process happening in dumping site that releases nitrogen oxide [20]. Presence of phosphate in leachate was due to organic waste degradation containing phospho-proteins and phospholipids [21]. BOD/COD ratio is the organic matter biodegradability measurement and indicates the leachate and landfill maturity [22]. The BOD/COD ratio at SG, MB and BG dumping site was 0.45, 0.70 and 0.82 respectively. Leachates from older waste dumping sites had lower BOD/COD ratio as compared to the leachates from young waste dumping sites in which BOD/COD ratio is higher [23]. This value is comparable to the BOD/COD ratio of mature landfill site (age 15 years) in Toronto where it ranged from 0.05 to 0.57 [24].

Significantly ($P<0.05$) high values of turbidity, total suspended solid (TSS), total dissolved solid (TDS), biological oxygen demand (BOD_5), chemical oxygen demand (COD) were found during summer season as compared to winters at all the three dumping sites in Lahore due to high evaporation rate in summers which concentrates pollutants in leachate. At SG, MB and BG dumping site, pH, BOD_5, COD, PO_4^{-3}, NO_3^{-1} and Cl^- during both winter and summer season were significantly higher ($P<0.05$) than FEPA standard [20]. Ni concentration at SG and MB was within it's permitted limit whereas at BG was 108 times higher than the FEPA standard of 0.01 mg L^{-1}. Pbconcentration at SG was 10.5, MB 14.8 and BG 51.4 times in excess than the FEPA standard of 0.01mgL^{-1}. Cr at SG, MB and BG was 7.1, 10.9 and 18.8 times greater than FEPA limit of 0.20 mg L^{-1}. Cu concentration at all the three dumping sites was in accordance with the FEPA standard of 5.00 mg L^{-1}. Cd concentration at SG was 17.6 times greater whereas at MB and BG was within the FEPA limit of 0.01 mg L^{-1}. Mn at SG, MB and BG was 380, 582 and 1088 times higher than FEPA standard of 0.05 mg L^{-1}. High concentrations of Ni, Pb and Cd in leachate indicates that waste has municipal origin containing fluorescents lamps, paint products, refused batteries and metallic items [17, 25]. Presence of Cr may be due to paint products, wood preservatives and high value of Mn suggests the presence of reducing environment in the dumping site [16]. High concentration of metals in leachate from Baggrian dumping site was due to its acidic pH because metals are more soluble at low pH [21].

The contamination potential of leachate is effectively presented through Leachate Pollution Index(LPI). The LPI at SG dumping site was 13.7, at MB was 16.7 and at BG was 21.7. The leachate from the BG dumping site had the highest contamination potential followed by MB and SG dumping sites. The calculated LPI value of these sites is comparable to the dumping sites in other metropolitan areas round the globe. LPI value at landfill in Pune City was 21.8 [16] in Nagu Chi Wan landfill site 15.9 [9] and in unscientific landfill in Banglore was 17.1 [18]. The age of the landfill influences the LPI value. The higher value of LPI indicates that the dumping site leachate has not been stabilized [11]. The LPI value at all three dumping sites in Lahore was higher than its standard value of 7.4 [21] which was 1.9 timeshigher at SG, 2.3 times at MB and2.9 times higher at BG than its permitted limit value.

CONCLUSION

The leachate from the Baggrian dumping site had high contamination potential followed by Mehmood Booti and Saggian dumping sites. The Leachate Pollution index value at all three dumping sites in Lahore was two to three folds higher than its standard value. The higher value of Leachate Pollution Index indicates that the dumping site leachate had not been stabilized.

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