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Assessment of Seasonal Variation of Landfill Leachate Quality and its Pollution Potential - A Dhapa MSW Landfill Site, Kolkata Case Study

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***Abstract**: Remediating the toxic effect of MSW landfill leachate is the prime task in front of all environmentalists around the globe. Dhapa is a solid waste disposal site situated in Kolkata, West Bengal, India. Numerous toxic chemicals are leaching through this landfill leading to generation of leachate. Consequently, adjacent surface water bodies and groundwater courses are getting contaminated by toxic pollutants. Leachate samples were collected from five different locations of the landfill site during pre-monsoon and post-monsoon seasons. Analysis was made for various parameters to evaluate the seasonal variation of leachate quality and extent of pollution that has occurred in the local water courses. Leachate Pollution Index (LPI) was also evaluated to examine the contamination potential of landfill site. The results showed that, the leachate generated was at a methanogenic state, which is indicated by the alkaline pH range (7.8-8.2) of the leachate sample. Lead concentration in the leachate samples was in the range of 0.32 mg/L to 0.43 mg/L in pre-monsoon season and 0.14 mg/L to 0.25 mg/L in post-monsoon season. Mercury concentration in the leachate samples were in the range of 0.21 mg/L to 1.09 mg/L in pre-monsoon season and 0.07 mg/L to 0.38 mg/L in post-monsoon season. The LPI values of leachate sample calculated for pre-monsoon and post-monsoon seasons for dumping ground were 28.903 and 18.09 respectively, well above the permissible limit. Higher LPI values of leachate samples indicate greater pollution potential. The study necessitates scientific disposal methodologies for the municipal solid waste of the city, Kolkata.*

***Keywords**- Dumping Sites; Leachate; Contamination Potential; Seasonal Variation; Leachate Pollution Index*

I. INTRODUCTION

India is the second highest inhabited country. The population of India, as per Census data 2011, was 1,210,193,422 and it is being reckoned as one of the fastest urbanizing countries in the planet. At present, India is facing a municipal solid waste impasse, for which all essentials of the society are to blame. The humanity sensitization and public consciousness is too low. There is no coordination between segregation of organic, inorganic and recyclable wastes at domestic level in India. In spite of a severe legislation in place, open dumping is the most well-known form of waste disposal. Consequently, leachate is being generated as a combination of rainwater percolation through the wastes, water formed from the biodegradation of wastes and the intrinsic water of the wastes themselves [1].The leachate generated from municipal solid waste is a mixture of organic, inorganic, dissolved and colloidal solids. Physical, chemical and biological processes stirring simultaneously at the municipal solid waste dumpsites bring about waste putrefaction as well as generation of leachate and landfill gas. Landfill leachate may be characterized as a water-based solution of dissolved organic matter, inorganic macro components, heavy metals and xenobiotic organic compounds [2].The leachate generated from open dumps and uncontrolled landfill sites can pose serious threat to environment (surface and ground water pollution) affecting human health. The Leachate Pollution Index (LPI) provides a significant method of evaluating the leachate contamination potential of different landfill sites at a particular time. It can serve as an important information tool for the policy makers and public about the leachate pollution threat from the landfills. The LPI can be used to conduct a comparative analysis so as to ascertain which disposal site needs instantaneous remedial actions and rectification using the accessible resources [3]. In the present study, a research work was undertaken to determine the composition of leachate generated from municipal solid waste land filling sites of Dhapa located at Eastern side of the Kolkata, West Bengal. Leachate samples were collected and analyzed for various physico-chemical parameters to examine its pollution potential and comparing the degree of pollution with seasonal variation.

II. STUDY AREA

The Dhapa Disposal Site is located in Kolkata, India in the state of West Bengal at 22.82°N and 88.20°E. The climate in Kolkata is tropical and rainy. The average temperature is 26.6°C. It is under the surveillance of the Kolkata Municipal Corporation (KMC). The disposal site has been operating as an open dump serving Kolkata since 1981 [4]. The Dhapa area is part of the wetlands (approximate area of 10000 ha), of which 24.71 ha are used for waste dumping [5]. This site neither has any bottom liner nor is outfitted with any leachate management system. The location of Dhapa dumping site is presented in Figure-1.

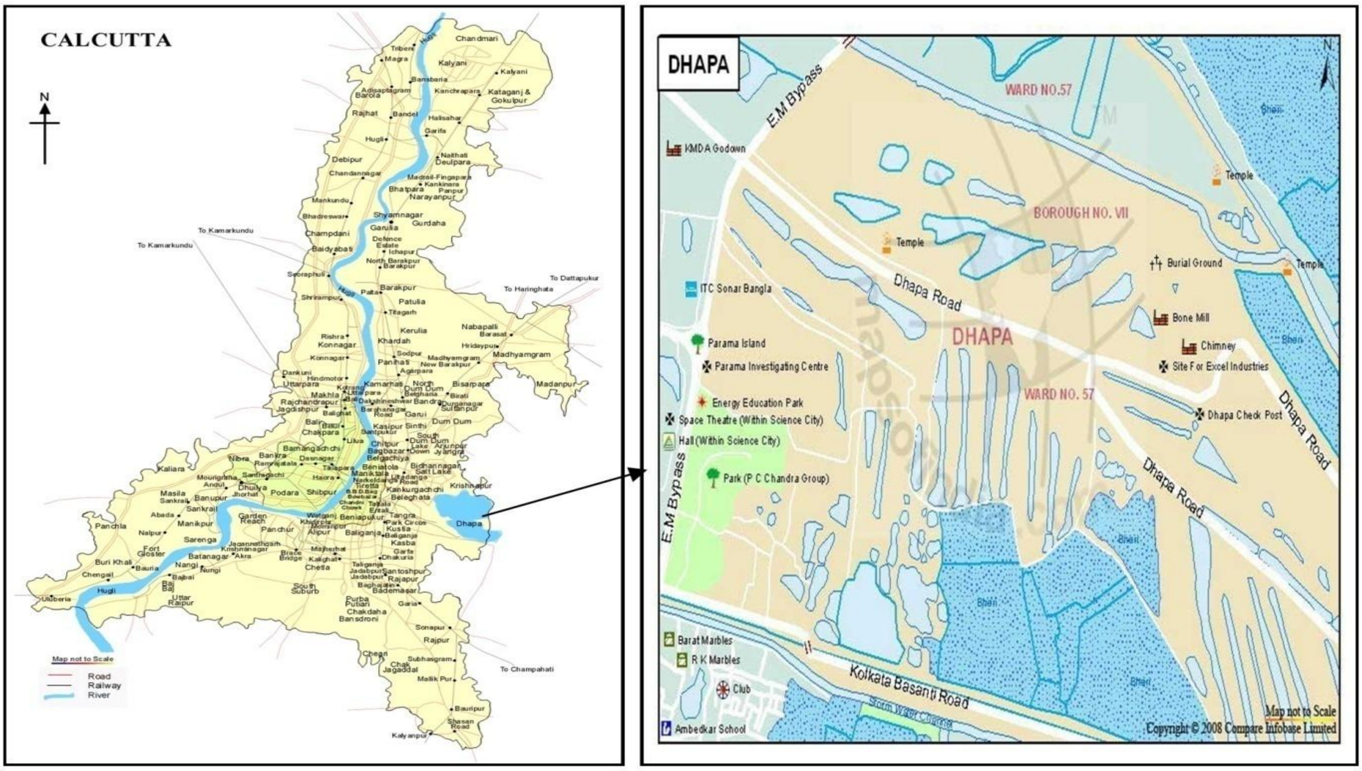

Fig-1. Map of Kolkata (Left) indicating Map of Dhapa disposal site (Right)

Fig-2: Leachate Collection Point of Dhapa disposal site (Source: Google Earth)

III. MATERIALS AND METHODS

A. Sample Collection:

Leachate samples were collected during 2012-2013 from five different leachate ponds surrounded by the landfill site of Dhapa to examine the quality of leachate. All the samples were collected in pre-cleaned polyethylene container of 5.0L capacity with proper labeling during pre-monsoon and post-monsoon seasons. Site specifications for sampling points are presented in Table-1 and Figure-2.

Table-1: Site Specification for Sampling

Sl. No.	Sampling locations	Latitude and Longitude	Type	Notation
1	LCP-1	22°31'54.9"N 88°25'44.8" E	Leachate	P1
2	LCP-2	22°32'03.9"N 88°25'43.0" E	Leachate	P2
3	LCP-3	22°32'16.6"N 88°25'37.0" E	Leachate	P3
4	LCP-4	22°32'19.4"N 88°25'33.8" E	Leachate	P4
5	LCP-5	22°32'03.9"N 88°25'35.1" E	Leachate	P5

B. Material Preservation: After returning to the laboratory the samples were stored in $4^{o}C$ in the incubator. Samples for heavy metals were preserved separately adding 1.0 ml of conc. nitric acid to avoid precipitation of the heavy metals.

C. Sample Analysis: Parameters monitored to examine the characteristics of landfill leachate, methods of their determination and major instruments involved are furnished in the Table-2 as per the Standard Methods (APHA, 17th Edition) [6]. The concentration of various physico-chemical parameters and trace metals in leachate samples are compared with the respective standards specified in "Municipal Solid Wastes (Management and Handling) Rules, 2000" for disposal of treated leachates [7]. The water quality parameters monitored under the purview of the present study and the methods of determination followed are furnished in Table-4. Radar plot showing physico-chemical parameters and level of trace elements of leachate samples are presented in Figure-3 and Figure-4.

Table-2: Details of Parameters Monitored, Methods of Analysis and Instrument used

Parameter	Method Adopted	Apparatus/Instrument Used
pH	Electrometric Method	Electronic pH meter
Electrical Conductivity (EC)	Laboratory Method	Deluxe conductivity meter
Total Dissolved Solid (TDS)	Gravimetric Method	_
Total Hardness	EDTA Titrimetric Method	_
Chemical Oxygen Demand (COD)	Open Reflux Method	Digestion vessels
Biochemical Oxygen Demand (BOD_5)	Winkler's Method	Air incubator
Chloride (Cl^-)	Argentometric method	_
Phosphate (PO_4^{3-})	Colorimetric Method	UV-Visible Spectrophotometer (Varian Make, Model-50 Bio)
Sulphate (SO_4^{2-})	Turbidimetric Method	UV-Visible Spectrophotometer (Varian Make, Model-50 Bio)
Ammoniacal nitrogen (NH_4^+-N), Nitrate nitrogen (NO_3^--N)	Ion Selective Electrode Method	Expandable Ion analyzer, EA 940 (Orion Research)
Total Kjeldahl Nitrogen (TKN)	Macro Kjeldahl Method	Digestion - Distillation Apparatus
Fluoride (F^-)	SPADNS Method	Expandable Ion analyzer, EA 940 (Orion Research)
Sodium (Na^+), Potassium (K^+)	Flame Photometric Method	PEI Flame Photometer
Iron (Fe), Cadmium (Cd), Chromium (Cr), Mercury (Hg), Lead (Pb), Zinc (Zn), Copper (Cu), Manganese (Mn),Nickel (Ni), Cobalt (Co)	Graphite Furnace Atomic absorption spectrometric Method	Atomic Absorption Spectrophotometer (AAnalyst 400, Perkin Elmer)

Precision and accuracy of the analytical data were maintained with spiked samples in triplicate. Frequent calibration of analytical instruments was carried out with working standard solutions. Seasonal variations and site specific variations in the leachate quality were evaluated using leachate pollution index calculated on the basis of the method developed by Kumar and Alappat (2005) [8].

D. Leachate Pollution Index (LPI)

LPI value indicates the level contamination potential of leachate emanating from a landfill. It is an increasing scale index, wherein a higher value indicates a poor environmental condition. 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, Total Chromium, Mercury, Arsenic, Phenolic Compounds, Chlorides, Cyanide, and Total Coliform Bacteria. The weights for these eighteen parameters were calculated based on the significance levels of the individual pollutants. The weights for pollutant variables are presented in Table-3. The sum of the weights of all the eighteen parameters is one [9].

Table-3: Pollutants and Weights of the pollutants in Leachate Pollution Index (LPI)

Pollutant	Pollutant Weight	Pollutant	Pollutant Weight
pH	0.055	Zinc	0.056
Total Dissolved Solids	0.050	Lead	0.063
Biochemical Oxygen Demand	0.061	Total Chromium	0.064
Chemical Oxygen Demand	0.062	Mercury	0.062
Total Kjeldhal Nitrogen	0.053	Arsenic	0.061
Ammonia Nitrogen	0.051	Phenolic Compounds	0.057
Total Iron	0.045	Chlorides	0.048
Copper	0.050	Cyanides	0.058
Nickel	0.052	Total Coliform	0.052

.The leachate pollution index (LPI) is an efficient tool to determine the detrimental effect that the leachate of the dumping site can produce if not treated properly. It is a quantitative measure of the leachate contamination potential and is calculated using the equation.

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

Where LPI = the weighted additive LPI, *Wi* = the weight for the i^{th} pollutant variable, Pi = sub- index score of the i^{th} leachate pollutant variable, *n* = number of leachate pollutant variables used in calculating LPI and

$$\sum_{i=1}^{n} Wi = 1.$$

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

$$LPI = \frac{\sum_{i=1}^{m} WiPi}{\sum_{i=1}^{m} Wi} \qquad (2)$$

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

$$\sum_{i=1}^{m} Wi < 1.$$

IV. RESULTS AND DISCUSSION

A. Seasonal Variations in Leachate Quality from Dumpsites

The variation in TDS, COD, BOD_5 and chloride level in the leachate emanating from Dhapa solid waste dumping ground was very high. The pH value of the collected leachate was considerably alkaline, which was corroborated by Fatta et al., 1999 [10]. High pH (>8.0) in leachate samples induces the formation of toxic trihalomethanes leading to the development of toxicity. Alkaline pH (Table-1) of all samples indicate that they were undergoing methanogenic phase in which the leachate became almost stabilized. TDS and EC values for leachate samples were very high for all samples collected in both pre and post-monsoon seasons, which was corroborated by Mor et al., 2006 [11]. Higher values of Chloride in leachate samples may have animal origin since night soil is also being disposed in Dhapa Landfill site. Higher sulphate concentration in leachate may be contributed by different inorganic waste materials present in the leachate. Phosphates might be contributed by a diversity of sources counting agricultural fertilizers, domestic wastes, detergents, industrial process wastes etc. Ammoniacal nitrogen concentration was obtained in high range in leachate samples, which was corroborated by Motling et al., 2013 [12]. Through aerobic and anaerobic decomposition of solid waste a part of nitrogen may be released along with leachate as ammoniacal compound**.** Most of the nitrogen in the leachate samples was present in ammoniacal form rather than nitrates which might be caused by the de-amination reaction occurring during the stabilization of leachates. Concentration of Total hardness (TH) in the leachate samples was also obtained in higher range may be primarily due to the presence of multivalent cations particularly calcium and magnesium. BOD_5 and COD in both pre and post-monsoon seasons exceeded the recommended standards for the disposal of leachate. The concentration of Biochemical oxygen demand (BOD_5) in the collected leachate was also observed to be high. High values of BOD_5 were also obtained by Kjeldsen et al., 2002 in leachate [13]. The biodegradability ratio BOD_5/COD (Table-4) is in the range of 0.5-0.76 for all leachate samples. According to Metcalf & Eddy BOD_5/COD ratio value of leachate indicates the biodegradability of the leachate. Among the heavy metals (Fe, Zn, Ni, Cu, Pb, Cr, Cd, Mn, Co and Hg), the lower Fe concentration was found in most of the samples during both pre and post-monsoon seasons as only segregated organic waste was used for composting. It might also be caused due to increase in pH values leading to lesser metal solubility as Fe^{2+} gets oxidized to Fe^{3+} which is insoluble in alkaline conditions. Other heavy metals like Zn, Ni, Cu, Cr, Co, Mn and Cd present in leachate samples were within the range stipulated by MoEF in the leachate disposal standard, 2000 except Pb and Hg, which were present at very high level in leachate samples. Higher concentration of Hg and Pb in leachate was also obtained by Kale et al., 2009 [14]. High concentration of Pb establishes that the wastes were mostly of municipal origin containing refused batteries, paint products, metallic items etc.**.** Mercury can be present in several products viz. fluorescent and other lights, batteries, electrical switches and relays, barometers, and thermometers etc., much of which ends up in municipal landfills.

Table-4: Physico-chemical characteristics and level of trace elements of leachate samples: pre-monsoon and post-monsoon, in mg/L, except pH and EC (µmho/cm)

Pre-Monsoon						**Post-Monsoon**						**Standards (Mode of Disposal: In Inland Surface Water)**
Parameter	**P1**	**P2**	**P3**	**P4**	**P5**	Parameter	**P1**	**P2**	**P3**	**P4**	**P5**	
pH	8.1	8.0	8.0	8.0	8.0	pH	8.2	7.8	8.1	8.1	8.0	5.5- 9.0
TDS	15700	42600	19100	23460	19690	TDS	8980	7460	6690	8455	7334	2100
EC	22428	60857	13000	33514	28128	EC	12828	10657	9557	12078	10477	-
TSS	2460	8940	680	3660	5682	TSS	160	320	180	270	470	-
Cl^-	4708	4484	7000	10697	7645	Cl^-	2197	2103	4330	6500	4578	1000
SO_4^{2-}	1127	2280	990	2614	1333	$SO4^{2-}$	1022	1927	876	1280	920	-
PO_4^{3-}	30	156	18.6	197	123	$PO4^{3-}$	17.05	117	5.3	95.7	67.7	-
NO_3^--N	77.6	110	105	27.6	121.5	NO^{3-}	59.2	29.8	15.1	19.5	18.3	-
TKN	997	702	958	638	777.4	TKN	883	381.2	687	481.2	653	100
NH_4^+-N	760	490	670	350	535	NH_4^+-N	660	220	568	312	421	50
Na^+	9734	1435	1435	1947	1738	Na^+	1460	1217	1335	1721	1415	-
K^+	4889	1186	1246	1713	1455	K^+	1350	727	1068	1063	1051	-
Total Hardness	1850	1560	900	1750	1050	Total Hardness	870	920	500	1200	970	-
BOD_5	5493	3220	2479	4611	5678	BOD_5	3745	2891	2250	2400	2245	30
COD	9128	4226	4636	7862	10833	COD	7041	4070	4500	3745	3775	250
BOD_5/ COD	0.6	0.76	0.53	0.58	0.52	BOD_5/ COD	0.53	0.71	0.5	0.64	0.59	-
Alkalinity	21000	29500	22000	23004	18104	Alkalinity	4360	8702	6390	20000	15255	-
F^-	0.27	0.15	0.17	0.2	0.23	F^-	0.2	0.1	0.15	0.15	0.18	2
Fe	10.15	15.11	1.31	1.37	9.43	Fe	2.34	0.915	1.03	0.75	7.55	-
Zn	0.56	0.38	0.29	0.85	0.25	Zn	0.25	0.19	0.1	0.09	0.15	5
Ni	0.04	0.045	0.05	0.035	0.04	Ni	0.03	0.025	0.01	0.02	0.01	3
Cu	0.09	0.08	0.07	0.08	0.04	Cu	0.02	0.025	0.05	0.045	0.03	3
Pb	0.42	0.43	0.33	0.32	0.37	Pb	0.24	0.24	0.14	0.25	0.22	0.1
Cr	0.04	0.318	0.21	0.23	0.15	Cr	0.02	0.03	0.12	0.15	0.02	2
Cd	0.05	0.074	0.06	0.07	0.025	Cd	0.01	0.025	0.01	0.02	0.015	2
Mn	0.08	0.09	0.055	0.09	0.075	Mn	0.03	0.05	0.04	0.03	0.025	-
Co	0.04	0.04	0.03	0.055	0.02	Co	0.01	0.02	0.015	0.02	0.01	-
Hg	1.09	0.80	0.21	0.31	0.75	Hg	0.25	0.38	0.35	0.12	0.07	0.01

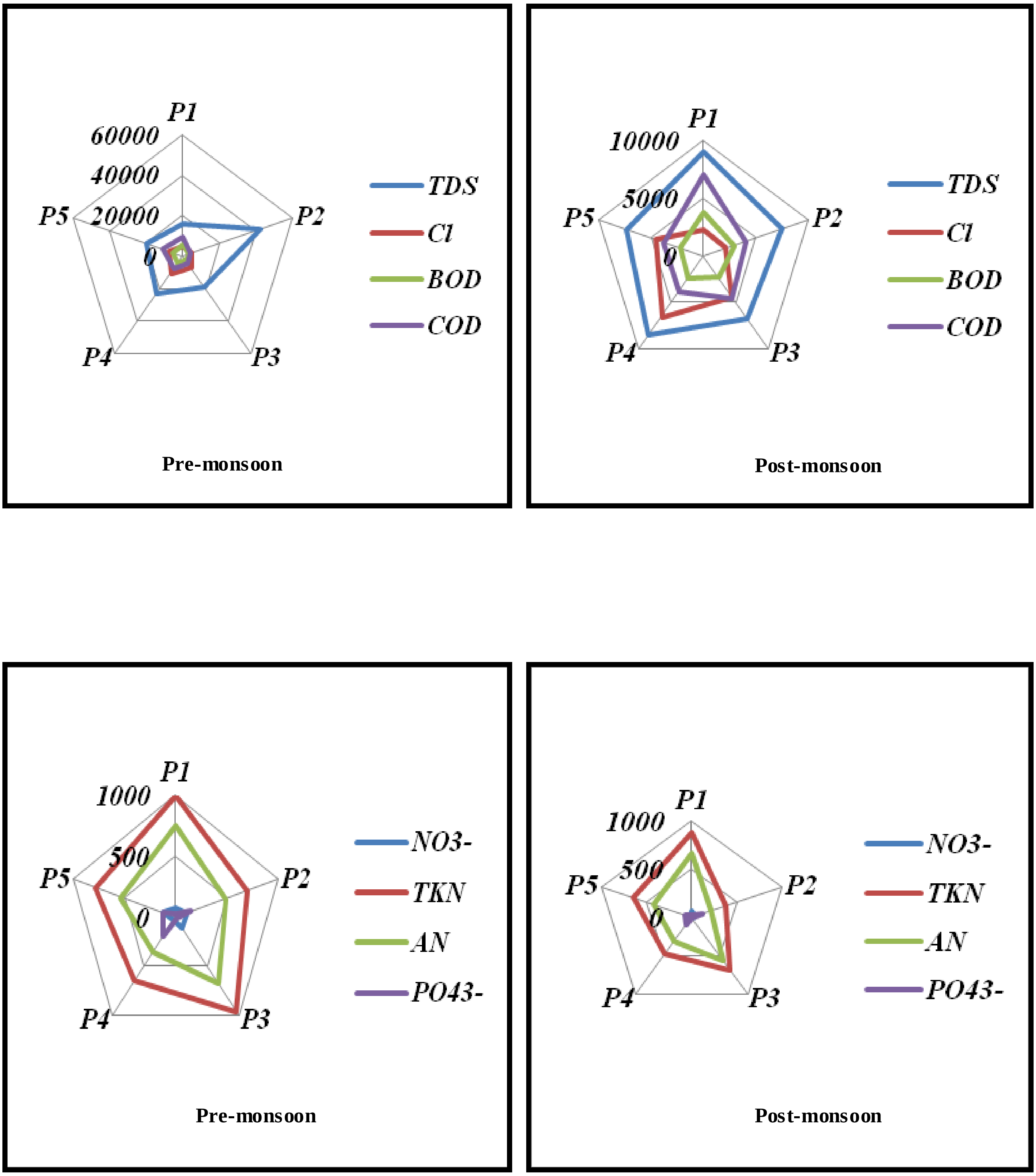

Fig-3: Radar plot showing physico-chemical parameters of leachate samples

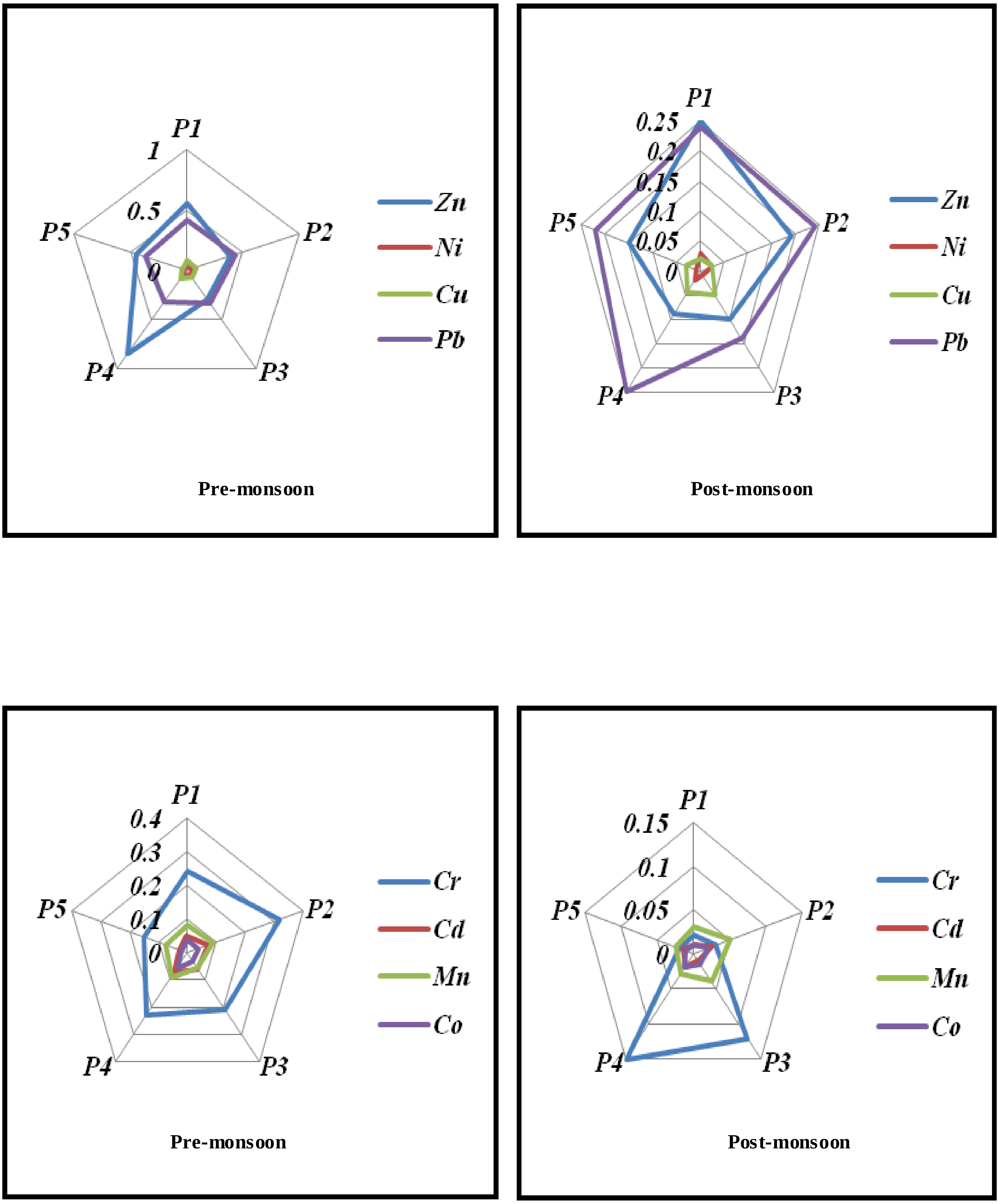

Fig-4: Radar plot showing level of trace elements of leachate samples

B. Leachate Pollution Index:

LPI is calculated based on average value of various parameters. LPI is presented in Table-5.

Table-5: Leachate pollution index (LPI) for the Dhapa landfill sites

Sl. No.	Leachate Characteristics	Average Value		Individual pollution rating		Pollutant Weight (w_i)		Overall pollution rating (p_i w_i)	
		Pre-Monsoon	Post-Monsoon	Pre-Monsoon	Post-Monsoon	Pre-Monsoon	Post-Monsoon	Pre-Monsoon	Post-Monsoon
1	pH	8.0	8.0	2.5	2.5	0.055	0.055	0.1375	0.1375
2	TDS	24110	7783.8	56	15	0.050	0.050	2.8	0.75
3	Cl^-	6906.8	3941.6	65	33	0.048	0.048	3.12	1.584
4	NH_3-N	561	436.2	58	46	0.051	0.051	2.958	2.346
5	BOD_5	4296.2	2706.2	52	43	0.061	0.061	3.172	2.623
6	COD	7337	4626.2	68	58	0.062	0.062	4.216	3.596
7	TKN	814.48	617.08	24	17	0.053	0.053	1.272	0.901
8	Cr	0.19	0.068	5	5	0.064	0.064	0.32	0.32
9	Cu	0.072	0.032	6	5	0.050	0.050	0.3	0.25
10	Fe	7.474	2.517	5	5	0.045	0.045	0.225	0.225
11	Ni	0.042	0.019	5	5	0.052	0.052	0.26	0.26
12	Pb	0.374	0.218	6	5	0.063	0.063	0.378	0.315
13	Zn	0.466	0.156	7	6	0.056	0.056	0.392	0.336
14	Hg	0.632	0.234	73	23	0.062	0.062	4.526	1.426
Total						0.833	0.833	24.0765	15.0695
Final LPI value by dividing Total Overall pollution rating by total W_i								28.903	18.09

The calculated LPI values over **pre-monsoon and post-monsoon** seasons for dumping ground are **28.903 and 18.09** respectively. The LPI value of the standards***** for the treated leachate is **7.378** [15]. Hence, all the LPI values are found to be well above the standard value. The LPI values suggest that pre-monsoon leachate had greater pollution potential than that corresponding to post-monsoon seasons.
*** The standards for the disposal of treated leachate to inland surface water as per Municipal Solid Waste (Management and Handling) Rules, 2000 (The Gazette of India, 2000).**

V. CONCLUSIONS

The physico-chemical parameters for the leachate samples derived from the Dhapa municipal dumping ground demonstrated remarkably high values. The concentration of all parameters was higher in pre-monsoon season compared to post-monsoon season. All heavy metals, except lead and mercury were present at the levels below their respective permissible limits, prescribed in the disposal standards of leachate. The LPI values calculated for leachate generating from the dumping ground over pre-monsoon and post-monsoon seasons also indicated the magnitude of leachate contamination potential of a given landfill since all the LPI values were well above from their standard value. The LPI values also suggested that in pre-monsoon season the leachate was more polluted than that generated in post-monsoon season. The study emphasizes on the requirement of suitable management of leachate at the dumping site prior to its final disposal.

VI. REFERENCES

[1] Q. Zhang, B. Tian, X. Zhang, A. Ghulam, C. Fang and R. He, "Investigation on Characteristics of leachate and concentrated leachate in three landfill leachate treatment plants," waste management 33, 2013, pp 2277-2286.
[2] P. Kjeldsen, M.A. Barlaz, A.P.Rooker, A.Baun, A. Ledin and T.H.Christensen, "Present and Long-Term Composition of MSW Landfill Leachate: A Review," Critical Reviews in Environmental Science and Technology, 2002, pp 297-336.

[3] P. D'Souza and R. K. Somashekar, "Assessment of Stabilization, Temporal Variation and Leachate Contamination Potential of Municipal Solid Waste Dumpsites in Bangalore," International Journal of Environmental Protection, Jan. 2013, Vol. 3 Issue. 1, pp 28-35.

[4] Assessment report, Dhapa disposal site Kolkata, India prepared by SCS Engineers, File no. 02205942.00, April 2010

[5] T.Hazra and S Goel, " Solid waste management in Kolkata, India: Practices and Challenges," waste management 29 (2009), pp 470-478.

[6] Standard Methods for the Examination of Water and Wastewater (APHA), 1989, 17th Edition.

[7] The standards for the disposal of treated leachate to inland surface water as per Municipal Solid Waste (Management and Handling) Rules, 2000 (The Gazette of India, 2000).

[8] D. Kumar and B. J. Alappat, "Evaluating leachate contamination potential of landfill sites using leachate pollution index," Clean Techn Environ Policy (2005) 7 pp 190–197.

[9] Dinesh Kumar and Babu J. Alappat, "Errors Involved in the Estimation of Leachate Pollution Index," Practice Periodical of Hazardous, Toxic, and Radioactive Waste Management. 2005.9 pp 103-111.

[10] D. Fatta, A. Papadopoulos and M. Loizidou, 1999. A study on the landfill leachate impact on the groundwater quality
of the greater area. Received 17 November 1998; accepted in revised form 22 March 1999. Environmental Geochemistry and Health 21, 1999 pp 175–190.

[11] S. Mor, K. Ravindra, R. P. Dahiya and A. Chandra, "Leachate Characterization and Assesment of Groundwater pollution near Municipal Solid Waste Landfill site," Environmental Monitoring and Assessment.118, 2006, pp 435–456.

[12] S. Motling, S.N.Mukherjee, A. Dutta, 2013. "Leachate characteristics of municipal solid waste landfill site in Kolkata" Published in Indian Journal of Public Health Engineering, Volume 2013-14, Number 3, October 2013.

[13] P. Kjeldsen, B. A. M. Barlaz , P. A. Rooker, A. Baun, L. Anna, H. T. Christensen, 2002. Present and Long-Term Composition of MSW Landfill Leachate: A Review. Critical Reviews in Environmental Science and Technology, 32(4), pp.297-336.

[14] S.S.Kale, A.K .Kadam and S. Kumar, "Evaluating pollution potential of leachate from landfill site, from the Pune metropolitan city and its impact on shallow basaltic aquifers,".Environ Monit Assess, 162, 2010, PP 327-346.

[15] D.Kumar and B. J. Alappat, "Analysis of Leachate Contamination Potential of a Municipal Landfill using Leachate Pollution Index," Proceedings of the Workshop on Sustainable Landfill Management 3–5 December, 2003; Chennai, India, pp.147-153.