Assessment of possible pollution of leachate from the MSW disposal site and its impact on groundwater quality, Hubli Town environs, India

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Abstract: Landfill leachate produced from open MSW dumping area can changes affect groundwater pollution. To appraise the leachate pollution index (LPI), the quantification of leachate to know the potential contamination using the LPI had been developed near MSW dumping yard caused by the dumping site. The municipal solid waste dumping site lies latitude of 15°19‘28.22N and longitude of 75°6‘34.61E.The aggregation of LPI sub-indices gives the total LPI of the dumping site. The leachate samples are collected from 10 different locations near the dumping sit and ground water samples. The leachate and ground water samples are characterized for BOD, COD, TDS, Chlorides, Zinc, Cadmium and Lead. LPI organic, LPI inorganic, LPI heavy metals are 1.125, 4.4766 and 1.7616 correspondingly. The overall LPI is found to be 7.3677, which can be reduced by taking some control measures to safeguard surrounding ecological system of the dumping site.

Keywords: Groundwater. MSW dump area, Landfill leachate, Pollutant, leachate pollution index

1 Introduction

Municipal solid waste management system is one of the basic environmental concerns around the world. [1]. The surprising things in increasing in population also increased in quantity of municipal solid waste [2]. The chief challenge in solid waste disposal and management [3,4]. These type of activities also in metropolitan cities have succeeded in management of solid waste diposal and collection using novel technological and using high power vehicles for collection of solid waste and disposal methods [5,6]. In most of in India open dumping of solid waste is practicing. This type of practices are threatens the ecological system. The dumping of waste in open land is creates a lot of problems, changes in the weather also generation black colour liquid waste is called Leachate [7,8]. The discharged leachate is contains highly organic and inorganic pollutants in the form of compounds in dissolved form along with heavy metals. [9,10,11]. These leachate percolated into the ground where the solid waste dumped site then contaminated the ground water and surface water considerably [12,13,14]. Another major issue related to leachate percolation is the causing the pathogens to ground water surface water sources; hence this is a major threats to living organisms [15]. The intensity of causes due to leachate is hazard changes with toxic conditions of pollutants, location of water table and ground water. [16,17]. This contamination due to black liquid is also changes in geotechnical properties of soils found noticed in the dumping site [18,19,20]. Earlier studies reported the occurrence of trace metals in plat tissues due to translocation of the black liquid [21,22].

2 Materials and Methodology

2.1 Site Details

Hubli-Dharwad also known as twin city and is the second largest city in the state of Karnataka. It is known as commercial and business hub center of North Karnataka. According to 2011 census the population of Hubli-Dharwad city is 9,43,788. Anchatgeri dumping yard is located at a distance of 4km from Hubli old bus stand. It is having latitude of 15°19‘28.22N and longitude of 75°6‘34.61E, covering an area of 22 acres. The average temperature is 34°C and having an average rainfall of 792.98mm (Figure 1).

2.2 Methodology

Leachate quality also encourages the floral species and growth in the dumping site [23,24,25] This type of changes in the land maybe reversible, the reclamation value may decreased and overall pollution concentration in dump site leachate is calculated using Leachate Pollution Index (LPI) as proposed by Kumar and Alappat [26]. LPI is the mathematical tool to be used to appraise the contamination condition of different locations on

comparison level using an index is called as LPI. LPI is used for ranking of dumping sites, allocation of resources for dumping remediation, trend appraisal, scientific research and public information. LPI is a single number ranging from 5 – 100 can be used to measure and compare the leachate contamination in selected geographical location. In this paper, the concept of LPI was explained briefly and various possible techniques are reviewed and used to calculate the LPI using various appropriate functions developed by Delphi technique [9]. The index is a mathematical tool to calculate the chemical and biological values of the landfill site black liquid (Table 1).

Table 1 Significance and weights of polluted concentration considered in LPI [26]

Sl. No.	Contaminants	Significance	Contaminant weight (wi)
1	Chromium	4.057	0.097
2	Lead	4.019	0.096
3	COD	3.963	0.095
4	BOD3	3.902	0.093
5	Zinc	3.585	0.086
6	pH	3.509	0.084
7	Total Kjeldahal Nitrogen	3.367	0.080
8	Ammonia Nitrogen	3.250	0.078
9	Total Dissolved Solids	3.196	0.076
10	Copper	3.078	0.074
11	Iron	2.830	0.068
12	Chlorides	3.078	0.074
		41.834	1.0000

The brief description of the LPI is given below

$LPI = \sum_{i1}^{n} \quad W_i P_i$ (1)

Where wi and Pi are the weight and sub index values of the ith leachate pollutant parameter, correspondingly and is the total number of contaminant parameters. If the number of total contaminant parameters is equal to 12 then the total weight of the contaminant is equal to 1 and the LPI can be determined adopting equation (1), if the contaminants parameters are <12 the for determining using equation (2) is estimated by the total value of weights of the contaminant parameters and the LPI is determined using

$LPI = \frac{\sum_{i=1}^{m} \quad W_i P_i}{\sum_{i=1}^{m} \quad W_i}$ (2)Where m < n

Most appropriate aggregation function was selected based on the author applied to find out the LPI. In the current study, the leachate properties of selected location, leachate samples were collected from four different sites by adopting standard operating procedure. The LPI values were calculated for leachate samples at dumping sit using some aggregation functions. In this paper, four different indices (Table 2) applied to study the LPI in selected leachate samples in MSW dumping sites.

Table 2 Aggregation functions adopted by different publishers for LPI

Aggregation Function	Expression	Reference
Unweighted Additive Form (UA)	$LPI_{UA} = \frac{1}{n} \sum_{i1}^{n} \quad p_i$	[15,19,26]
Weighted Linear Additive Form (WA)	$LPI_{WA} = \sum_{i1}^{n} \quad w_i p_i$	[14,16,19,29,30,32]
Root sum Power function (r=2)	$LPI_2 = \left[\sum_{i=1}^{n} \quad p_i^2\right]^{1/2}$	[27,28]
Root sum Power function (r=4)	$LPI_4 = \left[\sum_{i=1}^{n} \quad p_i^4\right]^{1/4}$	[27,28]
Root sum Power function (r=10)	$LPI_{10} = \left[\sum_{i=1}^{n} \quad p_i^{10}\right]^{1/10}$	[27,28]
Root sum Power function	$LPI_{rm} = \left[\sum_{i=1}^{n} \quad p_i^2\right]^{1/2}$	[11,32]
LPI2.5 (Ambiguity and Eclipsity)	$LPI_{2.5} = \sum_{i=1}^{n} \quad \left(p_i^{2.5}\right)^{0.4}$	[32,33]

Weighted Ambiguity and Eclipsity	$LPI_{w2.5} = \sum_{i=1}^{n} w_i {p_i}^{2.5}$	[32]
Multiplicative Additive Form	$LPI_{MA} = \prod_{i=1}^{n} p_i^{wi}$	[17,32,33]

One of them is arithmetic index, originally proposed by Horton [30] for use in explaining water quality and also by Brown [29] by selecting variables and their weightages. This index is also reported by Kumar and Allapat [26] for appraising LPI. Another one is multiplicative additive index is reported by Brown [28] and Gupta [27] have reported same index to appraise the quality of coastal water. The properties of the leachate contaminants of the waste samples from dumping site are appraised. This black liquid is generated by a landfill site. The calculated data will be compared with five indices and correlated among the indices. Finally, the sensitivity appraisal is conducted out to determine the best suitable technique.

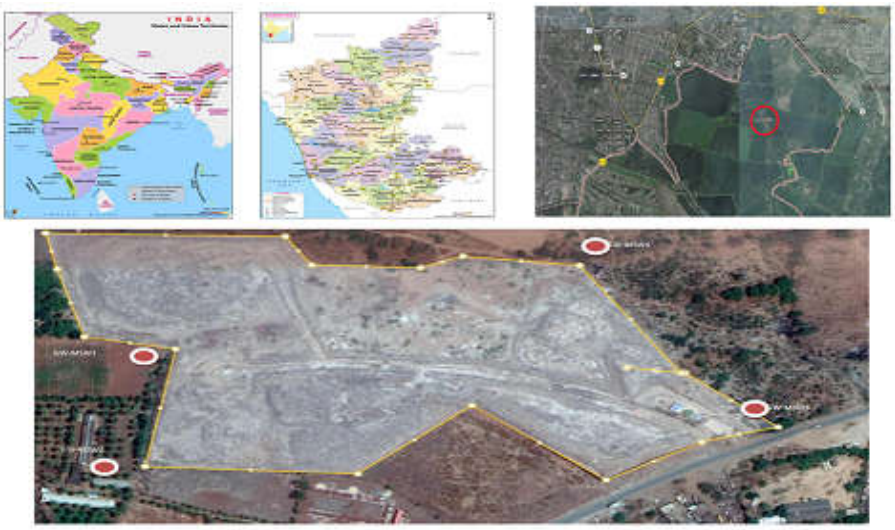

Fig 1. Four different Leachate sampling locations near MSW dumping site in Hubli

3 Result and Discussion

The study area was described; the leachate sampling locations and the LPI in and around the dumpsite for the two different periods were given in the (Table 3) using standard LPI indices. Primarily selection of Aggregation Functions is the most suitable aggregation function for appraising of LPI can be mainly determined and estimated on the basis of some criteria accordingly, all the LPI values are showing LPI(UA), LPI(WA), Root sum Power (r=2, r=4,r=10), LPI(RM), Unweighted multiplicative, Multiplicative Aggregation, Ambiguity and Eclipsity (Table 4). Also, the computed LPI values exceed the maximum values individual contaminants sub-index values.

Table 3 Characteristics of leachate, sub-LPI and Aggregation LPI Dump site

Sl. No.	Contaminants	LS-1	LS-2	LS-3	LS-4	Average	Sub-Index pi	Aggregation wipi
				Organic				
1	COD	486	487	489	491	488.25	7	0.66312
2	BOD3	38	36	34	38	36.5	5	0.46637
								1.1295
				Inorganic				
3	pH	9.2	9.4	9.6	9.8	9.5	5	0.41940
4	Total Kjeldahal Nitrogen	106.0	108.5	109.4	106.8	107.675	7	0.56339
5	Ammonia Nitrogen	56.0	52.0	51.0	48.9	51.975	6	0.46613
6	Total Dissolved Solids	1152.0	1195.0	1178.2	1124.0	1162.3	30	2.29192
7	Chlorides	350.2	361.2	368.4	359.4	359.8	10	0.73577
								4.4766
				Heavy Metals				
8	Copper	1.20	1.19	1.16	1.13	1.17	5	0.36788
9	Chromium	0.12	0.16	0.20	0.11	0.1475	5	0.48489

10	Lead	0.10	0.11	0.10	0.10	0.1025	5	0.48035
11	Zinc	4.2	4.6	5.0	4.9	4.675	5	0.42848
12	Iron	0.0730	0.0730	0.0730	0.0730	0.073	-	-
								1.7616
								7.3677

Table 3 gives the calculations of sub-LPI and overall LPI for two periods in four locations of leachate sampling. The Analytical values of black liquid samples components of organic, inorganic and heavy metals function (Table 3).

Table 4 LPI values for black liquid properties of dumpsite using different Aggregation forms

Sl. No.	Contaminants	LPI(UA)	LPI(WA)	Root sum Power			LPI(RM),	Multiplicative		Ambiguity and Eclipsity
				R=2	R=4	R=10		Unweighted	Aggregation,	
					Organic					
1	COD	7	0.66312	24.5	600.30	28247524.90	4.74	0.583	1.202	7.0
2	BOD3	5	0.46637	12.5	156.30	976562.50	3.62	0.417	1.169	5.0
					In Organic					
3	pH	5	0.41940	12.5	156.30	976562.50	3.62	0.417	1.169	5.0
4	Total Kjeldahal Nitrogen	7	0.56339	24.5	600.30	28247524.90	4.74	0.583	1.170	7.0
5	Ammonia Nitrogen	6	0.46613	18.0	324.00	6046617.60	4.19	0.500	1.149	6.0
6	Total Dissolved Solids	30	2.29192	450.0	202500.00	5904900000000.0	15.19	2.500	1.297	30.0
7	Chlorides	10	0.73577	50.0	2500.00	10000000000.0	6.31	0.833	1.185	10.0
					Heavy Metals					
8	Copper	5	0.36788	12.5	156.30	976562.50	3.62	0.417	1.169	5.0
9	Chromium	5	0.48489	12.5	156.30	976562.50	3.62	0.417	1.169	5.0
10	Lead	5	0.48035	12.5	156.30	976562.50	3.62	0.417	1.169	5.0
11	Zinc	5	0.42848	12.5	156.30	976562.50	3.62	0.417	1.169	5.0
12	Iron	-	-	-	-	-	-	-	-	-
	Total	90	7.368	642.0	207462.00	59050068401042.40	57.93	7.50	12.919	90.0
	LPI Values	7.5	7.368	642.0	2.0E+5	5.9E+13	57.93	7.50	12.91	7.5

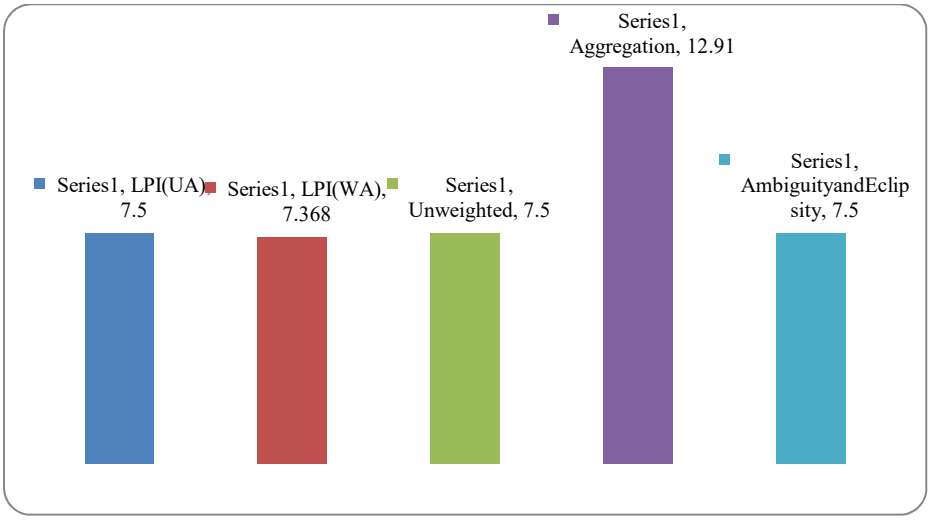

Fig. 2 Graph indicating LPI values of index techniques

Among the nine indices selected for study, unweighted LPI(UA) is simpl aggregation form which is an arithmetic average of the unweighted sun-indices. The most popular aggregation form is multivariate LPI(WA) is considered and Unweighted multivariate (LPIum) is adopted for comparison purposes. The ambiguity and eclipsing forms are adopted to overcome from the problems. The general forms of these indices are presented in Table 2. The LPI values of leachate samples collected from dumpsite are calculated by adopting formula given in Table 2. The LPI(RM), and aggregation value are 12.91 ad 57.93 respectively, where as the LPI values of other are in the range of 7.63 to 7.5 (Figure 2).

In the study, to measure the intensity and degree of linear significance between two variables, Karl Pearson (1867-1936), developed an equation called correlation coefficient (r) value was calculated. This is also referred as product-moment correlation coefficient (Gupta and Kapoor, 2002). The random variables of LPI are taken to findout the correlation between two of the five is appraised. The correlation coefficients between the indices are given in Table 5.

Table 5 Product-moment correlation coefficients

Indices	LPI(UA)	LPI(WA)	Unweighted	Aggregation	Ambiguity & Eclipsity
LPI(UA)	1.000				
LPI(WA)	0.988	1.000			
Unweighted	0.892	0.903	1.000		
Aggregation	0.888	0.894	0.912	1.000	
Ambiguity & Eclipsity	0.712	0.789	0.812	0.882	1.000

From the correlation coefficients in Table 5, it can be noted that all the five indices are showed correlation relationship among the each other. LPI(UA) is highly significant with LPI(WA), unweighted, aggregation and also closely related with ambiguity & Eclipsity. The order of the indices estimated by the correlation coefficients are in the line LPI(UA)(0.988)> LPI(UW) (0.892)>LPI(Agg)(0.888)>LPI(AE)(0.712). Although all the five indices have indicated significant relationship with each other, unweighted [LPI (UW)] was the lowest of five. One should hence, consider any four indices to find the best of the above four indices, the sensitive analysis is considered.

4 Conclusions

Four samples collected from dump site situated near Hubbali. Leachate samples were analysed for twelve different parameters like inorganic (pH, TDS, TKN, Ammonia Nitrogen, chlorides), Organic (COD, BOD) and Heavy metals (Zinc, Copper, Chromium, Lead, Iron). The average results of the leachate indicated variables were (9.5, 1162.3mg/L,107.68mg/K, 519.75mg/L, 359.8mg/L), (488.25mg/L, 36.5mg/L) and (4.675mg/L, 1.17mg/L, 0.1475mg/L, 0.1025mg/L, 0.073mg/L) correspondingly. The overall LPI of the selected leachate samples in and around the dumping site was found to be 7.368. The LPI of black liquid indicated that the slightly near to the leachate disposal standards to inland surface water as per Municipal Solid Waste (Management and Handling Rules, 2000, Government of India is 7.378. Hence, necessary actions should be taken to limit the leachate pollution in and around the dump site. And also this may contaminate the ground water table.
Aggregation form has shown ambiguity in index values. The product moment correlation coefficients have indicated the least preference to Ambiguity & Eclipsity. The weightages of the variables is necessary in terms of toxicity. Hence, the arithmetic leachate pollution index (LPIA) is the most acceptable option for calculating LPI of an unlined solid waste dumpsite as it indicates better results.

References

1. Kumar D, and Alappat, B.J, Selection of the appropriate aggregation function for calculating leachate pollution index, ASCE Practice Periodicals of Hazardous, Radioactive and Toxic Wastes, 8(4), pp. 253-264.
2. Kumar D, and Alappat, B.J. Errors involved in the estimation of leachate pollution index, ASCE Practice Periodicals of Hazardous, Radioactive and Toxic Wastes,. 9(2). 103-111.
3. Renou S., Givaudan J.G., PoulainS., Dirassouyan F., Moulin P. (2008). Landfill leachate treatment: review and opportunity,J. Hazard Mater., Vol. No.150, pp.468-493
4. Liu Y, Kong F, Santibanez Gonzalez EDR, (2017). Dumping, waste management and ecological security: Evidence from England, Journal of Cleaner Production (2017)
5. Biswas A K., Kumar S., Babu S S., Bhattacharyya J K, Chakrabarti T. Studies on environmental quality in and around municipal solid waste dumpsite, Resources, Conservation and Recycling Vol. No 55, pp. 129-134.
6. Phillips J., Mondal M.K. Determining the sustainability of options for municipal solid waste disposal in Varanasi, India,Sustainable cities and society Vol.No.10, pp. 11-21.
7. Shaoli De., BiswajitDebnath (2016). Prevalence of Health Hazards Associated with Solid Waste Disposal-A Case Study of Kolkata, India, Procedia Environmental Services Vol.No.35, pp.201-208.
8. Suman M, Khailwal R, Dahiya R P, Chandra A. Leachate Characterization and Assessment of Groundwater pollution near Municipal Solid Waste Landfill site,Environmental Monitoring and AssessmentVol. No118.pp.435-456.
9. K. Prasanna, R.Annadurai & P.Vanamoorthy Kumaran. Assessment of Heavy Metal Concentration present in Subsurface water due to Solid Waste Dumping, Journal of Engineering Science & Technology, (2018) Vol 13,Is11, pp3632-3647.

10. Ebong G.A,Dan E.U, Inam E, Offiong N.O. Total concentration, speciation, source identification and associated health implications of Trace metals in Lemna dumpsite soil, Calabar, Nigeria, Journal of King Saud University Science,doi:org/10.1016/j.jksus.2018.01.005
11. Adelopo A O, Haris P I, Alo, B I Huddersman, (2018). Multivariate analysis of the effects of age,particle size and landfill depth on heavy metals pollution content of closed and active landfill precursors, Waste Management, Vol. No.78, pp. 227-237.
12. Mingjun Deng, Dave T.F.Kuo et al (2018) Organophosphorus flame retardants and heavy metals in municipal landfill leachate treatment system in Guangzhou, China, Journal of Environmental Pollution Vol. No.236, pp. 137-145.
13. Olatunji Sunday Aboyeji, Stephen Femi Eigbokhan, Evaluations of groundwater contamination by leachates around Olusosun open dumpsite in Lagos metropolis, Southwest Nigeria, Journal of Environmental Management, Vol. No.183, pp. 333-341
14. Olusola T. Kayode,HilaryI.Okagbue,Justina A. Achuka, Water quality assessment for groundwater around a municipal waste dumpsite, Data in Brief, Vol. No.17, pp. 579-587
15. Prasanna K, Annadurai R., (2016) Study on subsurface water quality in and around Perungudi solid waste dumping site in ChennaiRasayan Journal of Chemistry, 9(2), 287-293.
16. Khalil, Christian,AlHageh, Cynthia Korfali, Samira Khnayzer, Rony S,µMunicipal leachates health risks: Chemical and cytotoxicityassessment from regulated and unregulated municipal dumpsites in Lebanon,Chemosphere Vol. No.208, pp. 1-13
17. Magda M. Abd El-Salam, Gaber I. Abu-Zuid(2014) µImpact of landfill leachate on the groundwater quality: A case study in Egypt, Journal of Advanced Research. doi:10.1016/j.jare.2014.02.003
18. Maiti S.K, De S.Hazra, Debsarkar T, Dutta A., µCharacterization of Leachate and Its Impact on Surface and Groundwater Quality of a Closed Dumpsite ± A Case Study at Dhapa, Kolkata, India,Procedia Environmental Sciences, Vol. No.35, pp. 391-399.
19. Monika Singh, MohiniVerma, R. Naresh Kumar(2018), µEffects of open dumping of MSW on metal contamination of soil, plants, and earthworms in Ranchi, Jharkhand, India, Environmental Monitoring and Assessment, Vol. No.190, Issue No 3.
20. Anchal Sharma, Ashok Kumar Gupta, Rajiv Ganguly (2018), Impact of open dumping of municipal solid waste on soil properties in mountainous region, Journal of Rock Mechanics and Geotechnical Engineering, Vol. No.10, Issue No 4, pp. 729-734.
21. Ali S, Perviaz A, Afzal Bet al(2014), Open dumping of municipal solid waste and its hazardous impacts on soil and vegetation diversity at waste dumping sites of Islamabad city, Journal of King Saud University, Vol. No.26, Issue No 1, pp. 59-65.
22. K Prasanna, E. Annadurai & P Vanamoorthy Kumaran (2018), Study on the characsterstrics of leachate and identifying leacjhate pollution index due to solid waste in semi urban area, Journal of advanced research in Dynamical abnd control systems, 08 special issue, pp. 565-570.
23. K Prasanna, E. Annadurai, S Vimal Kumar & M Aravind (2018). Removal of COD and Ammonical Nitrogen in Leachate using Sequencing Batch Reactor, Journal of Advanced Research in Dynamical and control systems, 08 special issue, pp. 547-553.
24. Musa A (2012). Effect of municipal solid waste on geotechnical properties of soils, International Journal of Environmental Science. Management and Engineering Research Vol.no.1 Issue.no.5.
25. Arunbabu V, Indu K S Ramasamy E V (2017), Leachate pollution Index as an effective tool in determining the phytotoxicity of municipal solid waste leachate, Journal of Waste Management. Vol. No.68, pp. 329-336.
26. Kumar, D. and B.J. Alappat, 2003. A technique to quantify landfill leachate pollution. Proc., 9 Int.thLandfill Symp., pp: 243-244
27. Gupta, A.K., Gupta, S.K. and Patil, R.S. (2003) 'A comparison of water quality indices for coastalwater', Journal of Environmental Science and Health, Vol. A38, No. 11, pp.2711–2725.
28. Brown, B.M. et al. (1973) 'Validating the wqi', Paper presented at National Meeting of Amer. Soc.Civil Engr. on Water Resources Engineering, Washington, DC.
29. Brown, R.M., McClelland, N.I., Deininger, R.A. and Tozer, R.G. (1970) 'A water quality index –do we dare?', Water and Sewage Works, Vol. 117, No. 10, pp.339–343.
30. Horton, R.K. (1965) 'An index number system for rating water quality', J. Wat. Poll. Control Fed.,Vol. 37, No. 3, pp.300–306.
31. Dinius, S.H. (1987) 'Design of an index of water quality', Water Resources Bulletin, Vol. 23,No. 5, pp.833–843.
32. Kumar, D. and B.J. Alappat, 2004. Selection of the Appropriate Aggregation Function for Calculating Leachate Pollution Index. Practical Periodic Hazardous, Toxic, Radioactive Waste Management, 8(4): 253-264.
33. Swamee, P.K. and A. Tyagi, 2000. Describing water quality with aggregate index." J. Environ. Eng., 126(5): 451-455.
34. Gupta, S.C. and Kapoor, V.K. (2002) Fundamentals of Mathematical Statistics, Sultan Chand &Sons Publishers, New Delhi, India.