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Evaluation of Leachate Contamination Potential of Lagos Dumpsites Using Leachate Pollution Index

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Authors' contributions

This work was carried out in collaboration among all authors. Author LS designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript and managed literature searches. Authors OF, RJP and OK managed the analyses of the study and literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Leachate generated from municipal solid wastes is a threat to surface and groundwater integrity. The leachate contamination potential of four different dumpsites in Lagos, Nigeria, that is Soluos dumpsite (SD), Ewu Elepe dumpsite (EED), Epe dumpsite (ED) and Olusosun dumpsite (OD) were evaluated using leachate pollution index (LPI) technique which is a tool for quantifying pollution potential of leachate generated from dumpsites. The LPI values were computed to be 17.85, 16.87, 18.99 and 23.54 for SD, EED, ED and OD respectively. These LPI values were compared with the standard and it was revealed the LPI values of all the dumpsites evaluated were above the standard which indicated the leachates generated from these dumpsites are contaminated and remediation measures should be put in place. The LPI value is also a useful tool to prioritise the order of attention, which in this work, OD should be given the first attention.

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Keywords: Landfill leachate; contamination; potential; dumpsite and pollution index.

1. INTRODUCTION

Improper management of solid waste area has resulted in serious ecological, environmental and health problems. Landfills are primary means of municipal solid waste (MSW) disposal in many countries worldwide because they offer dumping high quantities of MSW at economical costs in comparison to other disposal methods such as incineration [1]. Majority of the municipal solid waste disposal sites are still open dumps especially in under developed and developing countries [2]. The main source of leachate is liquid, which generally comes into existence during the organic dissolution in the Landfill. Landfill leachate produced from MSW landfill sites is generally heavily contaminated and consists of complex waste water that is very difficult to deal with [1–5]. Many factors influence the Leachate composition including the types of wastes deposited in the landfill, composition of wastes, moisture content, the particle size, the degree of compaction, the hydrology of the site, the climate, age of the landfill and other site specific conditions such as landfill design and type of liner used if any [6-8].

The environment can be polluted by leachates which occur at the end of decay solid waste, mixed with precipitates of surface water. As a result, surface water collection system (rivers, creeks, lakes), subsurface collection system (groundwater reservoirs) and solid system (different soil layers) have been seriously polluted due to the production of leachate and transportation of the contamination to farther point in the ecosystem. A number of incidences have been reported in the past where leachate has contaminated the surrounding soil and polluted the underlying groundwater aquifer or nearby surface water [9-18].

In an effort to develop a method for comparing the leachate pollution potential of various landfill sites in a given geographical area, and index known as leachate Pollution Index (LPI) was formulated using Rand Corporation Delphi Technique [10]. The LPI represents the level of leachate contamination potential of a given landfill. It is a single number ranging from 5 to 100, which expresses the overall leachate contamination potential of a landfill based on severe leachate pollution parameters at a given time. It is an increasing scale index, where a higher value indicates a poor environmental condition [19]. The standard value of LPI is 7.37 [19].

The LPI can be used to report leachate pollution changes in specific landfill overtime. The trend analysis so developed for the landfill can be used to assess the post closure monitoring periods. The LPI can also be used to compare leachate contamination potential of different landfills in a given geographical area or around the world. The other uses of LPI include ranking of landfill sites based on leachate contamination potential, resource allocation for landfill remediation, enforcement of leachate standard, scientific research and public information [10,19]. Therefore, the aims and objectives of this work are (i) to evaluate and compare leachate contamination potential of four dumpsites in Lagos State, Nigeria (ii) to determine whether the dumpsites require immediate attention in terms of introducing remediation measures which can be achieved through the evaluation of the LPI of the dumpsites. The LPI of Lagos State dumpsites will serve as an important information tool for Lagos State Government about the leachate pollution threat from the state dumpsites.

2. DESCRIPTION OF DUMPSITES

2.1 Soluos Dumpsite (SD)

The Soluos dumpsite is situated at Ikotun/Igando Local council development area of Alimosho Local Government in Lagos State, Nigeria. The dumpsite covers 3.2 hectares and surrounded by commercial and industrial set up as well as clustered human settlement. It started operation in 2006. The dumpsite has witnessed rehabilitation which comprised reclamation of land, construction of accessible road for case of tipping, spreading and compaction of waste since inception [20]. The wastes are of different types, ranging from organic to inorganic, hazardous and non hazardous. Like in all other existing dumpsites in the state, the waste stream is made up of domestic, market, commercial, industrial and institutional origins [20]. The Soluos dumpsite is a non-engineered landfill with a huge heap of waste. Trucks from different parts of Alimosho area of Lagos State collect and bring wastes to this site and dump them in irregular fashion. An average of 39, 672.55 m^3 of wastes per month are dumped on this site [21]. The wastes are dumped without separation but the rag pickers who constitute the informal sector rummage through the waste, help in segregating them by collecting the plastic and metals and sell them to the recycling industries.

2.2 Ewu Elepe Dumpsite (EED)

Ewu Elepe Dumpsite is situated in Ewu Elepe area of Ikorodu Local Government in Lagos State, Nigeria. Operation started on this site in 2008 and the site is surrounded by commercial and clustered human settlement. The dumpsite is a swampy valley with a gulley behind it. Refuse is normally pushed to the gulley which is a way of filling the gulley. There is a medical waste section separately which is not far from the main dumpsite. Both the medical waste section and main dumpsite have no liners. The dumpsite has witnessed rehabilitation which comprised reclamation of land and construction of accessible road for easy operation. Trucks from different parts of Ikorodu areas of Lagos State collect and bring wastes to this site and dump them in irregular fashion. An average of 42, 326.41 m^3 of wastes per month are dumped on this site [21]. The wastes are dumped without separation but the rag pickers who constitute the informed sector rummage through the waste, help in segregating them by collecting the plastics and metals and sell them to the recycling industries.

2.3 Epe Dumpsite (ED)

Epe Dumpsite is situated in Epe Local Government area in Lagos State, Nigeria, which happens to be the rural part of Lagos. The dumpsite is a swampy area with bushes all around it. It started operation in 2009. There is a lagoon and mini water works which are about 1.5 and 2.5km from the dumpsite. The dumpsite has no facilities for collection and treatment of leachate. The site is a non engineered landfill with a heap of wastes. Trucks from different part of Epe areas of Lagos State collect and bring wastes to this site and dump them in an irregular pattern. An average of 26, 025.98 m^3 of wastes per month are dumped on this site [21]. Like the other dumpsite in the state, the wastes are dumped without separation but the rag pickers from the informal sector rummage through the waste, help in segregating them by collecting the plastics and metals and sell them to the recycling industries. Human settles in a scattered form within this non engineered landfill site.

2.4 Olusosun Dumpsite (OD)

Olusosun Dumpsite which is the biggest dumpsite in Lagos State is situated at Ojota areas of Lagos State. An average of 177, 055.10 m^3 of wastes per month are dumped on this site [21]. The dumpsite was established in 1991 but operation started in 1992. The dumpsite which is in one of the main cities in Lagos State is a non engineered landfill which covers forty two (42) hectares of Land. The site is a valley and swampy in nature. There is a petrol station at the boundary of the site and human settles in a clustered form round this site. The site has no industrial waste section just like Ewu Elepe Dumpsite. The subsurface of the site is laterite in nature. The wastes from majority parts of the state are dumped in the site in an irregular manner. Just like the practice in other dumpsites in the state, the rag pickers from the informal sector rummage through the waste, help in segregating them by collecting the plastics and other valuable items and sell them to the recycling industries.

3. METHODOLOGY

3.1 Sampling and Analysis

Leachate samples were collected using 1-litre plastic bottles that had been cleaned by soaking in 10% nitric acid and rinsed with distilled water in order to avoid contamination and allowed to dry before use. In each of the sampling site, the treated bottles were rinsed twice with the leachate to be sampled prior to filling to avoid dilution. In Soluos dumpsite, leachate samples were taken during rainy season in the month of August, 2013. Since the dumpsites were not equipped with leachate collector system, leachate were sampled from the four extremes of dumpsite using the treated bottles after which the samples were properly mixed into homogenous sample in a 5-litre plastic container which then formed the Soluos dumpsite sample. The sample was then transferred to the laboratory in an ice cooler and stored in cold room at a temperature of 4℃. Prior to analysis, the samples were allowed to return to room temperature and measurement for leachate parameters were carried out. The same was done for Epe, Ewu Elepe and Olusosun dumpsites. Tables 1 and 2 showed the parameters measured for each dumpsite. All the parameters were measured according to the standard method for the examination of water and wastewater by APHA, 2005 [22] using a spectra AA-20 (Varian) atomic absorption spectrometer in the analytical laboratory of the university of Lagos. All experiments were carried out in triplicate and the results were found reproducible within ±3% error.

3.2 Calculation of Leachate Pollution Index (LPI)

The data from the analysis of samples were used. The ‘P’ values or sub-index values for all the parameters analyzed were computed from the sub-index curves based on the concentration of the leachate pollutions obtained during the analysis. The ‘P’ values were obtained by locating the concentration of the leachate pollutant on the horizontal axis of the sub index value where it intersected the curve was noted. The ‘P’ values obtained for the parameters analyzed were multiplied with the respective weights assigned to each parameters The LPI for each of the dumpsite leachate was calculated using the equation of Kumar and Alappat, (2003a) [10] shown in equation (1).

$$LPI = \frac{\sum_{i=1}^{m} w_i p_i}{\sum w_i} \quad (1)$$

Where

LPI = Leachate pollution index
w_i = The weight for the i pollutant variable
p_i = The sub index value of the i leachate pollution variable
m = The number of leachate pollutant parameters for which data is available

4. RESULTS AND DISCUSSION

Figs. 1 and 2 presented the average sub index curves of pollutants. Table 1 showed the characteristics and LPI of leachate from Soluos dumpsite and Ewu-Elepe Dumpsite while Table 2 revealed the characteristics and LPI of leachate from Epe Dumpsite and Olusosun Dumpsite. Table 3 presented the characteristics and LPI of leachate disposal standard. In Tables 1 and 2, arsenic, cyanide, phenol and mercury values were not available hence they were not used in computing the leachate pollution index for the dumpsite. In Table 3, there was no standard for total coliform and total iron which was the reason they were not used in computing the leachate pollution index for leachate disposal standard. Fig. 3 showed a chart of LPI of the dumpsite investigated and standard LPI value.

Leachate is generally found to have pH between 4.5 and 9 [23]. The pH of the dumpsites analysed falls within the range of 3.96 and 5.01 which supports the findings of Christensen et al. [23]. The pH of young leachate is than 5.5 while old landfill leachate has pH higher than 7.5. The pH values of the dumpsites analysed were all less than 6.5. EED has the lowest pH of 3.96 while ED has the highest pH of 5.01 among all the dumpsites. According to Abbas et al. [24], the leachates from all the dumpsite can be referred to young leachate. Initial low pH may be due to high concentration of volatile fatty acids [25]. There is possibility of high concentration of volatile fatty acids in the dumpsites because of the low pH values. Stabilized leachate shows fairly constant pH with little variation and it may range between 7.5 and 9 [1,25,26]. Kulikowsk and Klimiuk [26] and Tatsi and Zouboulis [27] reported similar range of pH from old landfill sites, that is 7.46 - 8.61 and 7.3 - 8.8 respectively. The pH of leachates from the dumpsites can be said not to be in the stabilization stage because of the pH which ranges from 3.96 to 5.01. OD which is over 20 years and having a leachate of low pH alludes to the possibility of high concentration of volatile fatty acids in the leachate.

TDS comprises mainly of inorganic and dissolved organics. The amount of TDS reflects the extent of mineralization and a higher TDS concentration can change the physical and chemical characteristics of the receiving water [1,28]. The TDS of the dumpsites investigated ranged from 581 to 1,960 mg/L with ED having the lowest value and EED having the highest value. The leachate from EED can be said to have undergone more mineralization process because of the high value than leachate from ED which has a low value. The leachate from EED has a very high tendency to change the physical and chemical characteristics of the receiving water more than the leachates from other dumpsites.

Table 1. Characteristics and LPI of leachate from SD and EED

S/N	Parameters	Value		Sub index value		Variable weights		Overall pollutant rating	
		SD	EED	SD	EED	SD	EED	SD	EED
1	Cr	4.968	2.841	35	14	0.064	0.064	2.24	0.896
2	Pb	3.446	0.918	30	7	0.063	0.063	1.89	0.441
3	COD	946	1480	28	32	0.062	0.062	1.736	1.984
4	Hg	-	-	-	-	-	-	-	-
5	BOD_5	1396	798	30	15	0.061	0.061	1.83	0.915
6	As	-	-	-	-	-	-	-	-
7	Cyanide	-	-	-	-	-	-	-	-
8	Phenol	-	-	-	-	-	-	-	-
9	Zn	4.991	9.681	5	7	0.056	0.056	0.28	0.392
10	pH	4.9	3.96	11	59	0.055	0.055	0.605	3.245
11	TKN	7.36	8.83	5	5	0.053	0.053	0.265	0.265
12	Ni	3.991	6.448	25	55	0.052	0.052	-	-
13	TC	0.00	0.016	-	-	0.052	0.052	-	-
14	NH_3-N	8.77	9.45	5	5	0.051	0.051	0.255	0.255
15	TDS	649	1960	5	7	0.050	0.050	0.25	0.35
16	Cu	4.968	2.841	50	15	0.050	0.050	2.5	0.75
17	Chloride	346.3	596.4	5	6	0.049	0.049	0.245	0.294
18	Total Iron	8.543	9.923	5	5	0.045	0.045	0.225	0.225
Total						0.763	0.763	13.62	12.872
LPI								17.85	16.87

Note: All values are in mg/L except pH and TC; TC means total coliform (CFU/mL)

Table 2. Characteristics and LPI of leachate from ED and OD

S/N	Parameters	Value		Sub index value		Variable weights		Overall pollutant rating	
		ED	OD	ED	OD	ED	OD	ED	OD
1	Cr	7.426	0.884	55	6	0.064	0.064	3.52	0.384
2	Pb	2.841	5.004	28	55	0.063	0.063	1.764	3.465
3	COD	1849	1942	32	33	0.062	0.062	1.984	2.046
4	Hg	-	-	-	-	-	-	-	-
5	BOD_5	842	1041	25	30	0.061	0.061	1.525	1.83
6	As	-	-	-	-	-	-	-	-
7	Cyanide	-	-	-	-	-	-	-	-
8	Phenol	-	-	-	-	-	-	-	-
9	Zn	6.496	5.061	6	5	0.056	0.056	0.336	0.28
10	pH	5.01	3.98	10	60	0.055	0.055	0.55	3.3
11	TKN	11.32	9.68	5	5	0.053	0.053	0.265	0.265
12	Ni	5.041	2.849	35	10	0.052	0.052	1.82	0.52
13	TC	0.00	0.014	-	-	0.052	0.052	-	-
14	NH_3-N	6.32	4.13	5	5	0.051	0.051	0.25	0.30
15	TDS	581	1046	5	6	0.050	0.050	1.75	4.75
16	Cu	3.686	9.841	35	95	0.050	0.050	1.75	4.75
17	Chloride	439	698.2	5	7	0.049	0.049	0.245	0.343
18	Total iron	7.426	8.847	5	5	0.045	0.045	0.225	0.225
Total						0.763	0.763	14.489	17.963
LPI								18.99	23.54

Note: All values are in mg/L except pH and TC; TC means total coliform (CFU/mL)

Table 3. Characteristics and LPI of leachate disposal standard

S/N	Parameters	Leachate disposal standard	Sub Index value	Variable weights	Overall pollutant rating
1	Cr	2.0	9	0.064	0.58
2	Pb	0.1	5	0.063	0.32
3	COD	250	10	0.062	0.62
4	Hg	0.01	6	0.062	0.37
5	BOD_5	30	6	0.061	0.37
6	As	0.20	5	0.061	0.31
7	Cyanide	0.2	6	0.058	0.35
8	Phenol	1.0	5	0.057	0.29
9	Zn	5.0	6	0.056	0.34
10	pH	5.5 – 9.0	5	0.055	0.28
11	TKN	100	6	0.053	0.32
12	Ni	3.0	10	0.052	0.52
13	TC	No standard	-	0.052	-
14	NH_3-N	50	7	0.051	0.36
15	TDS	2100	7	0.050	0.35
16	Cu	3.0	18	0.050	0.90
17	Chloride	100	8	0.049	0.39
18	Total iron	No standard	-	0.045	-
Total					6.67
LPI					7.378

Note: All values are in mg/L except pH and C; TC means total coliform (CFU/mL) Source: Thirteen International Waste Management and Landfill symposium, Proceedings Sardine, 2011[19,21]

The BOD_5 ranged from 798 to 1,396 mg/L while the COD ranged from 946 to 1, 942 mg/L. In the initial acidogenic biodegradation stage, the leachate is characterized by high BOD_5 and COD [29]. For stabilized leachates, COD generally ranges between 5,000-20,000 mg/L [30]. The COD of all the dumpsites analysed did not fall within the range stipulated for stabilized Leachate which is an indication that the leachates from all the dumpsites are in unstable state. During the methanogenic phase, the organic strength of the leachate is reduced by methanogenic bacteria such as methanogenic archaea and the concentration of volatile fatty acids also declines which results in a ratio of BOD_5/COD less than 0.1 [31-34]. The BOD_5/COD of SD, EED, ED and OD are 1.476, 0.54, 0.46 and 0.54 respectively. None of these ratios is less than 0.1 which shows the leachates from all the dumpsites have not reached methanogenic phase.

The ammonia-nitrogen content of the leachates analysed ranged from 4.13 to 9.45 mg/L with the EED having the highest value while OD has the least value. Ammonium represents the major proportion of total nitrogen. In comparison to soluble organics, the release of nitrogen from waste into leachate continues over longer period [27]. As a result, the concentration of ammonia nitrogen increases with the increase in age of the landfill which is due to hydrolysis and fermentation of nitrogenous fractions of biodegradable refuse substrates [24]. This is an indication that the range of ammonia nitrogen content is expected to increase in future in all the dumpsites investigated. Ammonia nitrogen is ranked as a major toxicant to living organisms, as established by various toxicity analysed using bioassays and various test organisms such as *Salmo gairdnieri* and *Oncorhynchus nerka* [32]. Higher concentrations of ammonia are also known to enhance algal growth, promote eutrophication due to decreased dissolved oxygen [31]. Due to its toxicity it can also disrupt biological leachate treatment operations [33]. In the dumpsites analysed, EED has the highest concentration of ammonia nitrogen which means there will be more growth of algae and extrophication in this dumpsite when compare with other dumpsites analyses. Comparing all the dumpsites, the disruption of biological leachate treatment operation will be highest in EED because it has the highest ammonia nitrogen value.

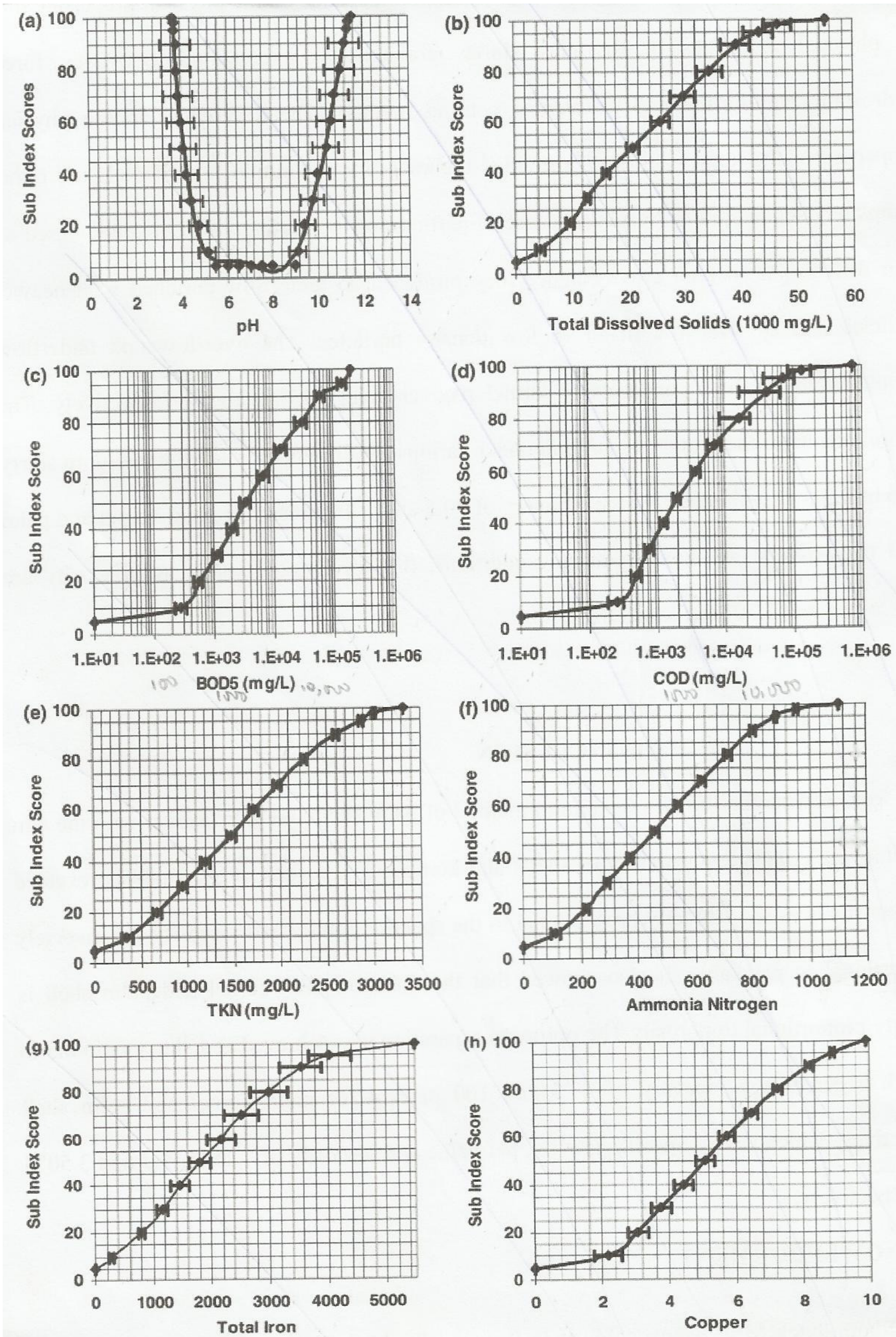

Fig. 1. The average sub index curves of pollutants [19]

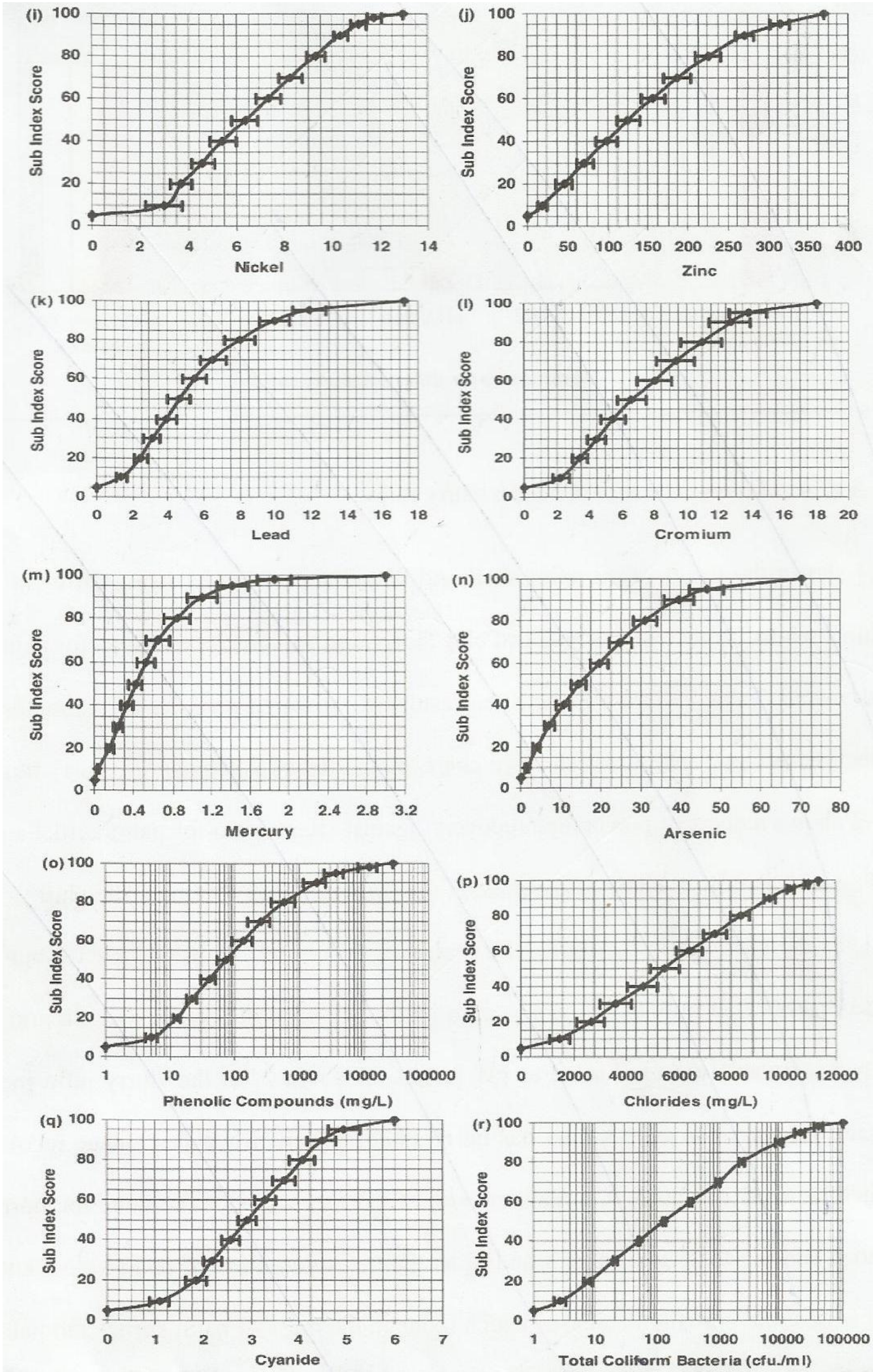

Fig. 2. The average sub index curves of pollutants [19]

In the case of heavy metals, the concentration of heavy metals in Landfill leachate is fairly low [19]. In all the dumpsite analysed, chromium ranged from 0.884 to 7.426 mg/L, lead ranged from 0.918 to 5.004 mg/L, zinc ranged from 4.991 to 9.681 mg/L, nickel ranged from 2.849 to 6.448 mg/L, and copper ranged from 2.841 to 9.841 mg/L. For chromium, EED has the highest value while OD has the least value, for lead, OD has the highest value while EED has the least value. In the case of zinc and nickel, EED has the highest value while SD and OD have the least values for zinc and nickel respectively. For copper, EED has the least value while OD has the highest value. Concentration of heavy metals in a landfill is generally higher at earlier stages because of higher metal solubility as a result of low pH caused by production of organic acids [23].

As a result of decreased pH at later stages, a decrease in metal solubility occurs resulting in rapid decrease in concentration of heavy metals except lead because lead is known to produce very heavy complex with humic acids [33]. This support the likelihood of decrease in the concentration of heavy metals in all the dumpsites analysed in later years. However, the solubility and mobility of metals may increase in the presence of natural and synthetic complexing ligands such as humic substances [29]. The presence complexing ligands in the dumpsites analysed will increase the concentration of heavy metals. In general, the condition in each of the dumpsites investigated determines the concentration of heavy metals in later years.

The concentration of chlorides ranged from 346.39 to 698.28 mg/L in all the dumpsites analysed with OD having the highest concentration and SD having the least concentration. According to Deng and Englehardt [33], the concentration of chlorides may range between 200-3000 mg/L for a one to two year-old landfill and concentration decreases to 100 - 400 mg/L for a landfill greater than 5 - 10 years old. This work is not totally in line with the work of Deng and Englehardt [33]. All the dumpsites analysed are more than five years and it is only SD having a chlorides concentration that fall with the range of 100 – 400 mg/L as stipulated by Deng and Englehardt [33]. The concentration of chlorides in other dumpsites is above 400 mg/L.

A standard for leachate disposal is very scarce in Nigeria and as a result, a standard in India has been used. Comparing the analysed parameters in all dumpsites investigated with the leachate disposal standard, chromium in OD was below the standard while in other dumpsites, the concentration of chromium exceeded the standard. The concentrations of lead, BOD_5 and zinc exceeded the stipulated standard in all the dumpsites investigated. The pH and total Kjeldahl nitrogen (TKN) values were below the stipulated standard in all the dumpsites. For nickel, the concentrations were exceeded the standard except for OD that was below the standard. Total coliform and total iron have no stipulated standard which make them difficult for comparism with the standard. Furthermore, the concentrations of ammonia nitrogen and total dissolved solids (TDS) were below the standard in all the dumpsites. In the case of chloride, the concentrations of the chloride in all the dumpsites exceeded the stipulated standard. The same was also the case for copper except in EED where concentration of copper was below the standard. It is possible to have a more dangerous contaminant be higher in one landfill that has a lower LPI value than another which is experience in this paper but the LPI gives an overall assessment of the factors contributing to the pollution potential of landfill leachate which is used for ranking of landfill sites and allocation of scare resources.

In general, any LPI value which falls below the stipulated standard of 7.378 [19] is accepted and any value above the standard is not accepted. The LPI values of all the dumpsites investigated were above 7.378. This implies the leachates from each of the dumpsites have the potential to pollute the groundwater within the vicinity of the dumpsites, the surrounding soil and the vegetation around the areas of the dumpsites. This poses a serious threat to public health and the environment hence there is an urgent need for Lagos State Government to swing into remediation action in the interest of the citizens.

LPI reflects the composite influence of the significant pollutant variables on leachate pollution and is a meaningful and easy to use method for assessing the leachate contamination potential of different landfill sites at a particular time. The LPI values of all the dumpsites analysed as well as the standard LPI values were presented in form of a bar chart shown in Fig. 3. All the LPI values of the dumpsites were above the standard stipulated with the OD having the highest LPI value and EED having the least value. In this present research work, leachates generated from these dumpsites are highly contaminated and proper treatment must be carried.

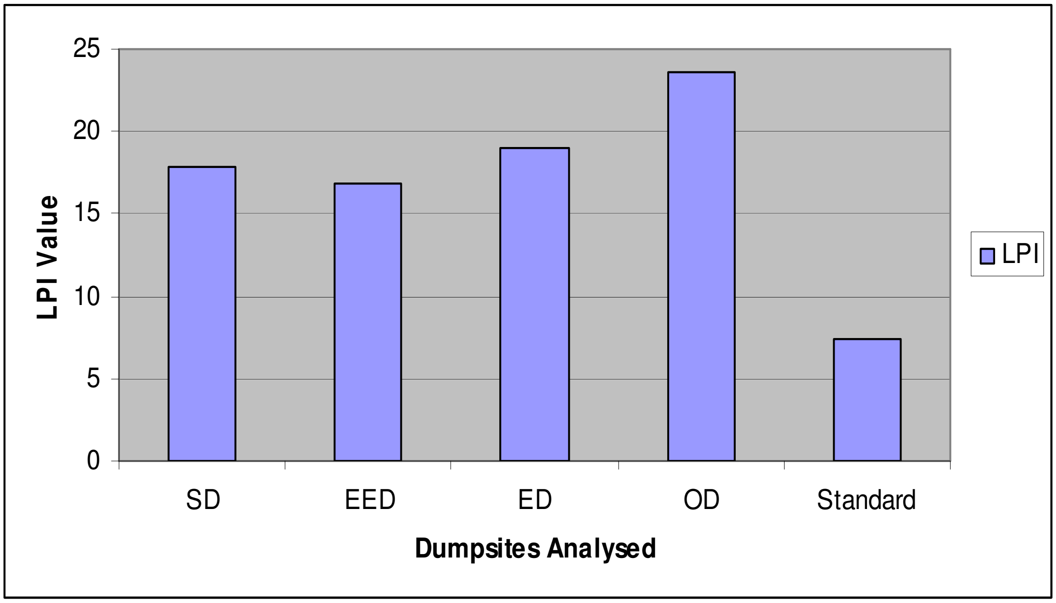

Fig. 3. A chart of LPI values of dumpsites investigated and standard LPI value

5. CONCLUSION

LPI is a very useful tool to assess and monitor the integrity of leachate generated from dumpsites and thus can assist to take necessary decisions. The evaluation of leachate contamination potential of four dumpsites in Lagos, Nigeria was carried out using leachate pollution index. The LPI values for SD, EED, ED and OD are 17.852, 16.87, 18.99 and 23.54 respectively. The LPI values were far above the stipulated standard of 7.378 which is an indication that the leachates generated from these dumpsites are contaminated and pose an environmental threat to the receiving soil, vegetation, surface and groundwater integrity. All the dumpsites required immediate attention. The LPI value can be used to prioritize the order of attention and among all the dumpsites evaluated, OD should be given the first attention because it has the highest value of LPI.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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