Physico-Chemical Characterization and Pollution Index Determination of Leachates from Warri Waste Dumpsite, Southern Nigeria

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ABSTRACT: This study characterizes the leachates quality of an active dumpsite in Warri, Delta State and also analyses its contamination or pollution potential. Leachate Pollution Index (LPI) - a tool for quantifying pollution potential of leachates generated from dumpsites - has been used to quantify the leachates contamination potential of the dumpsite. The LPI values for the different sample locations L1, L2 and L3 were computed to be 5.69, 6.18 and 5.89 respectively with a mean value of 5.80, while the control had a value of 4.82. These LPI values were also compared with the LPI standard (7.38) for treated leachates. Comparison of the mean LPI value (5.80) with the standard (7.38) indicated a relatively low contamination potential of the leachates. Moreover, it was observed that the concentration of the individual parameters of the leachates is quite variable. The organic strength (BOD$_5$ divided by COD) of the dumpsite was less than 0.5, while the pH values indicated that all sample locations in terms of age was mature, an indication of dumpsite stabilization. The study recommends continuous monitoring of leachates and upgrade to an engineered landfill to forestall possible pollution problems in future. ©JASEM

KEYWORDS: Dumpsites, Leachates, Leachate Pollution Index, Leachates Quality, Municipal Solid Waste, Physico-chemical Parameters, Warri

INTRODUCTION

Nigeria is pestered by a myriad of environmental issues, of which a lack of proper solid waste management system is chief. The annual generation of municipal solid wastes (MSW) in Nigeria is 25 million tonnes (Ogwueleka, 2009) and this may increase due to rapid urbanization and population growth rate. Improper management of solid wastes has resulted in serious ecological, environmental and health problems. Landfills are primary means of 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 (Muhammmad *et al.*, 2010). Majority of the MSW disposal sites are still open dumps especially in under developed and developing countries (Susu and Salami, 2011). The absence of proper sanitary (engineered) landfills for disposal of wastes by the local and state governments has given room for the proliferations of open dumps that are scattered in every nook and cranny of the country (Susu and Salami, 2011). These refuse dump sites have become an eyesore to first time visitors to most cities in Nigeria including Warri, one of the hubs of Nigerian oil and gas industry, where the study was undertaken.

Open dumps have been demonstrated by several scholars to pose serious threat to groundwater and surface water resources (Fatta *et al*., 1999), especially those constructed and operated without impermeable liners to reduce the potential of contamination. They are capable of releasing large amounts of harmful chemicals to nearby water sources and air via leachates and landfill gas respectively (Christensen *et al*., 2001; Ikem *et al*., 2002; Alimba *et al*., 2006). The degree of threat is strongly influenced by the composition of the wastes in the dumpsite, the volume of leachates from the waste mass generated, as well as the location of the dumpsites from water bodies; groundwater and surface water (Slomwcznska and Slomcyznski, 2004). The liquid which is generated as a result of runoff from dumpsites is known as leachates. This accumulates at the bottom of dumpsites and subsequently percolates slowly into the soil to contaminate aquifer beneath it and adjacent surface water bodies. Leachates is a widely used term in the environmental sciences where it has the specific meaning of a liquid that has dissolved or entrained environmentally harmful substances which may then enter the environment and pollute the surrounding water sources and contamination of soil (Khan, 2011). Leachates from dumpsites vary widely in composition depending on the age of the dumpsite and type of waste that it contains. Dumpsite leachates may be characterized as a water based solution of four groups of contaminants; dissolved organic matter (alcohols, acids, aldehydes, short chain sugar etc.), inorganic macro components (common cations and anions including sulphate, chloride, iron, aluminium, zinc and ammonia), heavy metals (Pb, Ni, Cd, Hg), and xenobiotic organic compounds such as

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halogenated organics (PCBs, dioxins etc.) (Christensen *et al.,* 2001, Torabian *et al.,* 2004, and Pivato and Gaspari, 2005). The physical appearance of leachates when it emerges from typical dumpsite is a strongly coloured black, yellow or orange cloudy liquid. The smell is acidic and offensive and may be very pervasive because of hydrogen, nitrogen and sulphur rich organic species such as mercaptans (Singh *et al.,* 2007).

It is therefore expedient that a comprehensive study be carried out on the assessment of pollution levels from these dumpsites, taking into account related parameters, which provide the overall perspectives of the pollution of the dumpsites. This study was therefore aimed at characterizing the leachates quality of a dumpsite in Warri, Delta State and determining its pollution potential, with the view of knowing its content and likely environmental consequences. Leachate Pollution Index (LPI) was used for the assessment of the contamination potential of the leachates. LPI was formulated using Rand Corporation Delphi Technique (Kumar and Alappat, 2003a). The LPI represents the level of contamination potential of a given landfill. It is a single number ranging from 5 to 100, which expresses the overall contamination potential of a landfill based on severe pollution parameters at a given time. It is an increasing scale index, where a higher value indicates a poor environmental condition (Kumar and Alappat, 2003b). The standard value of LPI is 7.38 (Kumar and Alappat, 2003a).

MATERIALS AND METHOD
Study Area: This study was carried out in Warri located between latitude $5^0 31$'N and longitude $5^0 45$'E. The city is one of the major hubs of petroleum activities and businesses in Southern Nigeria. It is a commercial capital City of Delta State and one of the cosmopolitan cities in Southern Nigeria, comprising originally of Itsekiri, Urhobo and Ijaw people.

The region experiences moderate rainfall and moderate humidity for most part of the year. The area is characterized by tropical equatorial climate with mean annual temperature of 32.8^0C and annual rainfall amount of 2673.8 mm. There are high temperatures of 36^0C and 37^0C. The natural vegetation is a rainforest with swamp forest in some areas. The forest is rich in timber trees, palm trees, as well as fruit trees.

The study area is an active dumpsite located at Udu Street along Igbudu road (figure 1). This place can be found behind the popular Igbudu market in Warri, Delta state. This dumpsite serves as the major means of waste disposal to the people of the community, especially the market sellers.
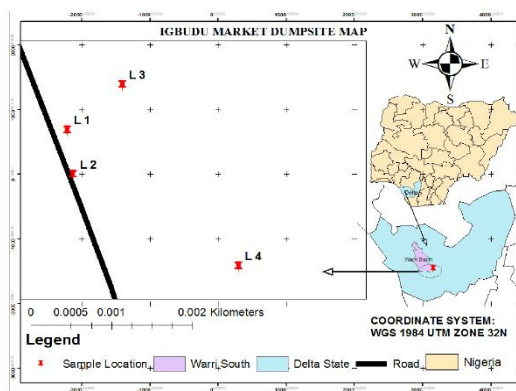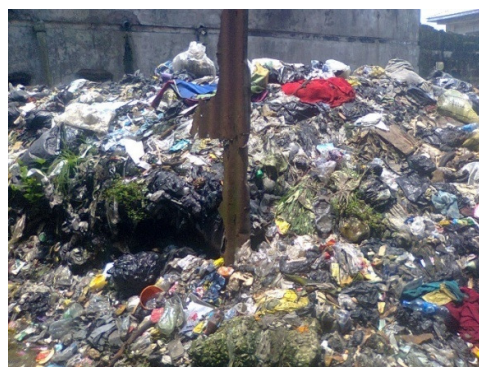

Fig. 1: GIS based Map of Study Area

The coordinates of the locations of the sample in the study area are as shown in Table 1 below:

Table 1: Showing Sample Identification with their GPS Coordinates

Sample Code	Northings	Eastings
L1	$05^0 31$'01.4''	$005^0 45$'31.0''
L2	$05^0 31$'01.3''	$005^0 45$'31.0''
L3	$05^0 31$'01.5''	$005^0 45$'31.1''
L4 (Control)	$05^0 31$'01.2''	$005^0 45$'31.3''

Fig 2: Igbudu market dumpsite, Warri, Delta state

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Sample Collection and Analysis: Leachates samples were collected from 3 trenches dug into the dumpsites with 1 control sample taken outside the dumpsite area (1.5m depth). Since the landfill site was not equipped with a leachates collector, the leachates collected at the base of the landfill was sampled randomly from three different locations. 2-liter plastic containers were used to collect the leachates. Prior to collection, the containers were rinsed with the samples in order to acclimatize to the sample environment.

In order to avoid chemical and biological changes that have the potential to change the natural homogeneity of the samples, the sample for heavy metals analysis was preserved by adding 1ml of conc. HNO_3 while 2ml Concentrated H_2SO_4 was added to samples for COD analysis**.** The samples were immediately transferred to ice chest and transported to the laboratory for analysis. In-situ parameters such as pH, total dissolved solids and electrical conductivity were measured using Hanna hand held pH and conductivity/TDS meter.

All the parameters were measured according to the standard method for the examination of water and wastewater by APHA, 2005. pH was determined by glass electrode method with a standard calibrated pH. Dissolved solids, and conductivity were measured in situ. An Atomic Absorption Spectrophotometer was used for metals analyses after samples were digested, using concentrated trioxonitrate (V) and the volume made up to 50ml with deionized water. BOD was computed from dissolved oxygen (DO) - determined by Azide modification of Winkler's method – analyzed over a 5 day period. Open reflux method utilising potassium tetra-oxo chromate (VI) in boiling concentrated tetra-oxosulphate (VI) solution in the presence of silver catalyst was used to determine COD. Phosphate, chloride and sulphate were analysed by colorimetry using molybdovanadate method.

Calculation of Leachate Pollution Index (LPI): The data from the analyses 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) shown in equations below.

$$LPI = \sum_{i=1}^{n} w_i p_i \tag{1}$$

Where, *LPI* = the weighted additive leachate pollution index*, wi*= the weight for the Ith pollutant variable, *pi* = the sub index value of the Ith leachate pollutant variable, *n = 18 and Σ wi =1.*
However, when the data for all the pollutant variables included in *LPI* is not available, the *LPI* can be calculated using data set of the available pollutants by the equation
Where,

$$LPI = \frac{\sum_{i=1}^{n} w_i p_i}{\sum w_i} \tag{2}$$

Where pollutant parameter for which data is available in this study as, m < 18 (16) and Σ wi<1

RESULTS AND DISCUSSION
The results obtained from the physico-chemical analyses of leachates from the Igbudu market dumpsite, Warri City municipal dumpsite are presented in Table 2. The organic strength of the dumpsite is shown in Table 3, Table 4 shows the comparison of the mean values of the study with the Nigerian FMENV standard, LPI derived from Kumar and Alappat (2003) computation is presented in Table 5 and Figure 3 while Table 6 shows the comparison of the mean values of the pollutant variables of the dumpsite with the available Leachate Disposal Standards.

Table 2: Concentration of Physicochemical Parameters of leachates from Igbudu Market waste dumpsite

S/N	Parameters	Location 1 (L1)	Location 2 (L2)	Location 3 (L3)	Mean	Location 4 (Control)
1.	pH	7.78	8.79	8.55	8.28	8.0
2.	TDS (mg/l)	348.9	630	411	403.73	225
3.	Electrical Conductivity (µs/cm)	591.2	1,254.3	820.7	778.18	446.5
4.	BOD (mg/l)	32.95	56.72	43.11	38.65	21.80
5.	COD (mg/l)	82.38	121.29	98.82	89.23	54.50
6.	Phosphate (mg/l)	3.69	6.19	4.90	3.81	0.46
7.	Sulphate (mg/l)	10.24	16.78	13.61	11.45	5.16
8.	Chloride (mg/l)	61.70	149.37	105.13	93.16	56.42
9.	Nickel (mg/l)	0.020	0.041	0.035	0.028	0.013
10.	Chromium (mg/l)	0.973	1.618	1.022	0.969	0.262
11.	Copper (mg/l)	0.126	0.159	0.146	0.131	0.092
12.	Zinc (mg/l)	0.335	0.583	0.864	0.467	0.102
13.	Iron (mg/l)	2.201	8.247	5.220	4.145	0.913
14.	Lead (mg/l)	0.094	0.121	0.106	0.0865	0.025
15.	Cadmium (mg/l)	0.006	0.013	0.009	0.0075	0.002

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Table 3: Organic Strength (BOD$_5$ and COD ratio)

S/N	Parameters	Location 1	Location 2	Location 3	Mean	Location 4 (Control)	FMENV Standard
1.	BOD$_5$ (mg/l)	32.95	56.72	43.11	38.65	21.80	30
2.	COD (mg/l)	82.38	121.29	98.82	89.23	54.50	75
3.	Organic Strength $= \frac{BOD5}{COD}$	0.399	0.468	0.436	0.433	0.40	-

Table 4: Comparison of the mean values of the study with the Nigerian FMENV standard

S/N	Parameters	Mean	FMENV Standard
1.	pH	8.28	6.000 - 9.000
2.	TDS (mg/l)	403.73	NA
3.	Electrical Conductivity (µs/cm)	778.18	125.000
4.	BOD$_5$ (mg/l)	38.65	30.000
5.	COD (mg/l)	89.23	75.000
6.	Phosphate (mg/l)	3.81	50.000
7.	Sulphate (mg/l)	7.67	100.000
8.	Chloride (mg/l)	93.16	100.000
9.	Nickel (mg/l)	0.028	5.000
10.	Chromium (mg/l)	0.969	0.200
11.	Copper (mg/l)	0.131	0.050
12.	Zinc (mg/l)	0.467	5.000
13.	Iron (mg/l)	4.145	0.500
14.	Lead (mg/l)	0.0865	0.010
15.	Cadmium (mg/l)	0.0075	0.010

Table 5: Leachate Pollution Index for L1, L2, L3, LM and L4-C

S/N	Leachate Pollutant Parameters	Samples Results					Variable Weight (W$_1$)	Pollutant Sub Index Value (P$_I$)					Overall Pollutant Rating wi.pi				
		L1	L2	L3	LM	L4-C		L1	L2	L3	LM	L4-C	L1	L2	L3	LM	L4-C
1.	pH	7.78	8.79	8.55	8.28	8.0	0.055	5	5	5	5	5	0.275	0.275	0.275	0.275	0.275
2.	TDS (mg/l)	348.9	630	411	403.73	225	0.05	5	6	5	5	5	0.250	0.300	0.250	0.250	0.250
3.	Electrical Conductivity (µs/cm)	591.2	1,254.3	820.7	778.18	446.5	-	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4.	BOD$_5$ (mg/l)	32.95	56.72	43.11	38.65	21.80	0.061	6	7	7	6	5	0.366	0.427	0.427	0.366	0.305
5.	COD (mg/l)	82.38	121.29	98.82	89.23	54.50	0.062	8	10	9	9	7	0.496	0.620	0.558	0.558	0.434
6.	Phosphate (mg/l)	3.69	6.19	4.90	3.81	0.46	-	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
7.	Sulphate (mg/l)	10.24	16.78	13.61	11.45	5.16	-	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
8.	Chloride (mg/l)	61.70	149.37	105.13	93.16	56.42	0.049	5	5	5	5	5	0.245	0.245	0.245	0.245	0.245
9.	Nickel (mg/l)	0.020	0.041	0.035	0.028	0.013	0.052	5	5	5	5	5	0.260	0.260	0.260	0.260	0.260
10.	Chromium (mg/l)	0.973	1.618	1.022	0.969	0.262	0.064	7	8	7	7	5	0.448	0.512	0.448	0.448	0.320
11.	Copper (mg/l)	0.126	0.159	0.146	0.131	0.092	0.05	5	5	5	5	5	0.250	0.250	0.250	0.250	0.250
12.	Zinc (mg/l)	0.335	0.583	0.864	0.467	0.102	0.056	5	5	5	5	5	0.280	0.280	0.280	0.280	0.280
13.	Iron (mg/l)	2.201	8.247	5.220	4.145	0.913	0.045	5	5	5	5	5	0.225	0.225	0.225	0.225	0.225
14.	Lead (mg/l)	0.094	0.121	0.106	0.0865	0.025	0.063	6	6	6	6	5	0.378	0.378	0.378	0.378	0.318
15.	Cadmium (mg/l)	0.006	0.013	0.009	0.0075	0.002	-	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	TOTAL						**0.610**						**3.473**	**3.772**	**3.596**	**3.538**	**2.937**
	LPI Value using Equation 2												**5.693**	**6.184**	**5.895**	**5.800**	**4.814**

Where; L1=Location 1, L2=Location 2, L3=Location 3, LM=Location Mean, L4-C =Location Control, NA = Not Available, NS = No Standard

Table 5 above illustrates the calculation of LPI values from Warri waste dumpsite. Since the data for all the parameters included in LPI are not available, the LPI has been calculated on the basis of the available data. The site specific variation in LPI is shown in Figure 2 below
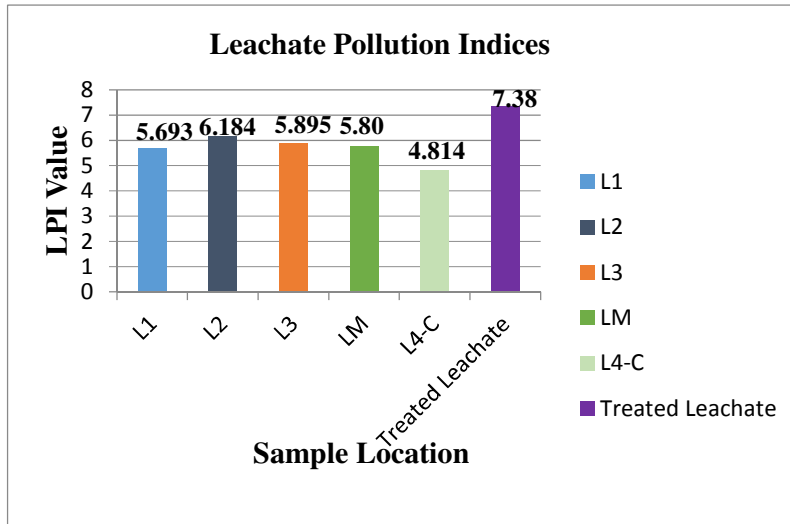
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Fig 2: Site Specific Variations in Leachate Pollution Index

Table 6: Comparison of the Mean values of the pollutant variables of the dumpsite with Indian Leachate Disposal Standards (Municipal Solid Waste Management and Handling Rules, 2000)

S/N	Leachate Pollutant Parameters	Location Mean	*Indian Leachate Disposal Standards*	Remark
1	pH	8.28	5.5 - 9.0	The pH value was within the standard
2	Total Dissolved Solid (mg/l)	403.73	2100	The TDS value exceeds the standard
3	Electrical Conductivity (μS/cm)	778.18	No Standard	
4	Biological Oxygen Demand (mg/l)	38.65	30	The BOD value exceeds the standard
5	Chemical Oxygen Demand (mg/l)	89.23	250	The COD value was below the standard
6	Phosphate (mg/l)	3.81	No Standard	
7	Sulphate (mg/l)	7.67	No Standard	
8	Chlorides (mg/l)	93.16	1000	The Chloride value was below the standard
9	Nickel (mg/l)	0.028	3.0	The Nickel value was below the permissible standard
10	Chromium (mg/l)	0.969	2.0	The Chromium value was below the permissible standard
11	Copper (mg/l)	0.131	3.0	The Copper value was below the permissible standard
12	Zinc (mg/l)	0.467	5.0	The Zinc value was below the standard
13	Iron (mg/l)	4.145	No Standard	
14	Lead (mg/l)	0.0865	0.1	The Lead value exceeds the permissible standard
15	Cadmium (mg/l)	0.0075	No Standard	

Leachates are generally found to have pH between 4.5 and 9 (Christensen *et al*., 2001). The pH of young leachates is less than 6.5 while old landfill leachates has pH higher than 7.5 (Abbas *et al*., 2009). Stabilized leachates shows fairly constant pH with little variations and it may range between 7.5 and 9. The pH values of the leachates samples from the various points ranged from 7.78 – 8.79, with a mean value of 8.28 and the control had a value of 8.0. This shows that the leachates are alkaline. The dumpsite can be classified as a representative of an old dumpsite. The pH value could be attributed to a result of the biological stabilization of the organic matter present in the dumpsite. Chian and DeWalle (1977) reported that the pH of leachates increased with time due to the decrease of the concentration of the partially ionized free volatile fatty acids. The increase in pH suggested that a steady state has been reached between acid producing processes (for example, cellulose and lignin degradation) and acid consuming processes (for example, methane formation) at the landfill (Chu *et al.*, 1994). Kulikowsk and Klimiuk (2008); and Tatsi and Zouboulis (2002), reported similar range of pH from old landfill sites, that is 7.46 - 8.61 and 7.3 - 8.8 respectively. However, the

reported values were in variance with Salami *et al* (2015) who reported a range of 3.96 - 5.01.

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 (Al-Yaqout and Hamoda, 2003; Muhammad *et al.,* 2010). The TDS of the dumpsites investigated ranged from 225 - 630 mg/l with L1 having the lowest value and L2 having the highest value. The leachates from L2 can be said to have undergone more mineralization process because of the high value than leachates from L1 and L3 which have lesser values. The leachates from L2 has a very high tendency to change the physical and chemical characteristics of the receiving water more than the leachates from other dumpsites. The values vary significantly from those reported by Agbozu and Nwosisi (2015); and Salami *et al* (2015) who reported ranges of 70.7 to 4,985.2 mg/L and 581 to 1,960 mg/L respectively. The TDS of this study (a mean of 403.73) is less than the FMENV standard of 500mg/l.

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The electrical conductivity of the various sampling points are 591.2 µs/cm, 1,254.3 µs/cm and 820.7 µs/cm for L1, L2, and L3 respectively. The mean concentration was 778.18 µs/cm, far exceeding the FMENV standard of 125 µs/cm, while the control had a value of 446.5 µs/cm. The high value of electrical conductivity in this study is indicative of the presence of inorganic material in the samples. Conductivity is a measure of water's capability to pass electrical flow and is directly related to the concentration of ions, which come from dissolved salts and inorganic materials such as alkalis, chlorides, sulfides and carbonate compounds. The more ions that are present, the higher the conductivity of water. Likewise, the fewer ions that are in the water, the less conductive it is. This means, the leachates from this site contains lots of inorganic material. This is indicative of a high degree of pollution.

The BOD_5 values ranged from 21.80 mg/l - 56.72 mg/l while COD ranged from 82.38 - 121.29 mg/l. The values were in stark contrast to the values reported by Salami *et al* (2015) who reported ranges of 798 to 1,396 mg/L and 946 to 1,942 mg/L for BOD_5 and COD respectively. However, Agbozu and Nwosisi (2015) in their study reported much lesser ranges of 1.24 – 5.95 mg/l for BOD_5 and 3.10 – 14.87 mg/l for COD. In the initial acidogenic biodegradation stage, the leachate is characterized by high BOD_5 and COD (Jones *et al.*, 2006). For stabilized leachates, COD generally ranges between 5,000 - 20,000 mg/L (Li and Zhao, 2002). The mean value of the BOD_5 (38.65mg/l) of the leachates is greater than FMENV standard of 30.00 mg/l while COD with a mean of 89.23 mg/l also exceeds the FMENV of 75mg/l. The BOD_5 and COD values indicate the presence of a high amount of putrescible organic matter in the dumpsite.

Phosphate concentration of L1 was 3.69 mg/l, L2 had 6.19 mg/l, L3 had a concentration of 4.90 mg/l, the control had a concentration of 0.46 mg/l and the mean concentration for the locations was 3.81 mg/l. The mean concentration fell below FMENV limit of 50mg/l. The concentration of sulphate for L1, L2, and L3, are 10.24 mg/l, 16.78 mg/l and 13.61 mg/l. The mean concentration of the points was 7.67 mg/l and the control value was 5.16 mg/l. The mean concentration fell below the FMENV standard. It falls below FMENV standard of 100 mg/l.

Chloride concentration ranged from 56.42 mg/l to 149.37 mg/l, with L2 having the highest concentration of 149.47 mg/l, L1 with a concentration of 105.13 mg/l, L3 61.70 mg/l and the control with the lowest value of 56.42 mg/l. The mean concentration of L1, L2 and L3 was 93.16 mg/l, lower than FMENV standard of 100 mg/l. According to Deng and Englehardt (2007), the concentration of chlorides may range between 200 - 3000 mg/l for a 1 - 2 year old landfill and the concentration decreases

to 100 – 400 mg/l for a landfill greater than 5 - 10 years old. Hence, the dumpsite can be classified as mature.

Heavy Metals: In the case of heavy metals, the concentration of heavy metals in Landfill leachate is fairly low (Kumar and Alappat, 2003b). From the results of the study, lead ranged from 0.025 – 0.121 mg/l, zinc ranged from 0.102 – 0.864 mg/l, chromium ranged from 0.262 – 1.618 mg/l, copper ranged from 0.092 – 0.159 mg/l, nickel ranged from 0.013 – 0.041 mg/l, iron ranged from 0.913 – 8.247 mg/l and cadmium ranged from 0.002 – 0.013 mg/l. 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 (Christensen *et al.,* 2001). As a result of increased pH at later stages, a decrease in heavy 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 (Deng and Englehardt, 2007). 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 (Jones *et al.,* 2006). 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 lead concentration a mean value of 0.0865 mg/l exceeded the FMENV acceptable limit of 0.01 mg/l. The mean concentration of zinc (0.467mg/l) fell below FMENV limit of 5.00 mg/l. Chromium with a mean value of 0.969 mg/l exceeded FMENV standard of 0.20 mg/l. The mean copper concentration (0.131mg/l) exceeded FMENV limit of 0.05 mg/l. The mean value (0.028 mg/l) for nickel fell below FMENV standard of 5 mg/l. The mean iron concentration of 4.145 mg/l exceeded the FMENV limit of 0.50 mg/l. Cadmium concentration of L1, L2, L3 and the mean (0.0075 mg/l) were all below FMENV limit of 0.10 mg/l.

Though there were variations; some of the heavy metals fell below FMENV while some others exceeded it. There is a significant heavy metals concentration in the leachates from this dumpsite that can pollute the environment.

Strength of Organics (BOD_5/COD ratio)**:** Organics in leachates are characterized by different levels of biodegradability. Generally, the organic strength describes the degree of biodegradation and gives information on the age of a dumpsite. A decline in BOD_5 concentrations can be attributed to a combination of reduction in organic contaminants available for leaching and the increased

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biodegradation of organic compounds (Krug and Ham, 1995). A constant decrease in COD is also expected as degradation of organic matter continues (Ehrig, 1989).

The organic strength is given by;

Organic Strength $= \frac{BOD5}{COD}$ (Rivas *et al*., 2004; Kurniawan *et al*., 2006)

The biodegradability of the leachates will also vary with time. Checking the BOD_5/COD ratio can monitor changes in the biodegradability of the leachates. Ratios in the range from 0.4 to 0.6 are taken as an indication that the organic matter in the leachates is readily biodegradable. For a young landfill, the BOD_5/COD ratio may be in the range of 0.4 to 0.6 or higher, whereas the ratio in old or matured dumpsites may be in the range of 0.05 to 0.2 suggesting that the organic matter in the leachates is not readily biodegradable.

From Table 3, BOD_5/COD ratio for the respective locations are 0.399 mg/l, 0.468 mg/l, 0.436 mg/l and 0.40 mg/l, for L1, L2, L3, and L4 respectively, while the mean ratio is 0.433. This figure (0.433) shows that the organic matter in the leachates is readily biodegradable, and has a high organic strength which can be attributed to fact that the study site is active or open, being fed waste on a daily or continuous basis, which possibly contains organic matter that undergoes biodegradation continually. During the methanogenic phase, the organic strength of the leachates is reduced by methanogenic bacteria such as methanogenic archaea and the concentration of volatile fatty acids also reduces which results in a ratio of BOD_5/COD less than 0.1 (Rivas *et al*., 2004; Kurniawan *et al*., 2006; Deng and Englehart, 2007; Harmsen, 1983). The calculated ratio of 0.433 suggests high organic strength for the dumpsites and this ratio is similar to those obtained by previous researchers (Agbozu and Nwosisi, 2015; Amina, 2004; Baha, 2005; Yoshida *et al*., 2002). Salami *et al,* (2015) reported BOD_5/COD ratio of 1.476, 0.54, 0.46 and 0.54 in their study of four dumpsites in Lagos, Nigeria. None of these ratios is less than 0.1 which shows the leachates from all the dumpsites have not reached methanogenic phase. In addition, Irene (1996) asserted that as the age of the landfill increases, the BOD_5/COD ratio decreases.

Observed Trends in the Physico-chemical Concentrations of Leachates in the Dumpsite
From the results of the leachates analyses carried out on the Igbudu market dumpsite, there were variations in the concentrations of the parameters tested for at the various sampling points; L1, L2, L3, and L4 (control).

From the results obtained, L2 has the highest concentration of the parameters tested for. This may be due to its proximity with the road and hence easier access by the people. It may also be due to the large amount of ash disposed on this point of the study site. This location also has a greater slope which makes

leaching more possible down to this point. L3 has the next highest concentration of the physico-chemical and heavy metals parameters tested for. This may be due to the fact that it is at the other edge of the dumpsite with an easy access, hence a greater accumulation of waste. This means it will contain a greater constituent of matter to be leached out of the waste during rainfall or water percolation. L1 has the lowest concentrations of the parameters. It is located in the middle of the dumpsite and had a gentler slope. This means, the degree of leaching from the top would not be so fast or great compared with the other points.

L4 (control) was taken outside the dumpsite, it served as a standard to compare the concentrations of the parameters tested for from the three locations (L1, L2, and L3), within the dumpsite. This location had by far the lowest concentrations of the physico-chemical parameters tested for. This may be accounted for to be as a result of the fact that it is outside of the dumpsite and had no form of waste from which any leachates could have contaminated it, at the time of the study.

Thus, L2 can be attributed to be the most contaminated location of the study site.

Analysis of the Pollution Indices of the Dumpsite Leachates: Based on the evaluated results, the LPI for L1, L2 and L3 was found to be 5.69, 6.18 and 5.89 respectively with a mean value of 5.80 while the control had a value of 4.82. Kumar and Alappat (2005) calculated LPI values for two active landfill sites and reported LPI of 36.4 and 39. Their reported values are higher than the observed values in this study. This can be ascribed to the lower individual pollution ratings of the dumpsite due to the relatively low concentrations of BOD_5, COD and to lesser extent the chlorides than the landfill sites studied by Kumar and Alappat (2005).

Salami *et al* (2015) calculated LPI values for four dumpsites in Lagos, Nigeria and reported values of 17.85, 16.87, 18.99 and 23.54. Their values were far higher than the results of this study and also the LPI standard and as a result offered a veritable cause for concern. Urgent remediation measures were advised as the dumpsites were adjudged to pose serious threat to public health and the environment.

Agbozu and Nwosisi (2015) also calculated LPI values for three dumpsites (one active and two closed dump sites) within Port Harcourt metropolis in Nigeria. They reported LPI values of 3.91 and 4.71 for the two closed dumpsites and 7.12 for the active dumpsite. They advised that though all the values fell below the LPI standard of 7.38, immediate attention should be given to the active dumpsite in order to avoid a big pollution incident to the environment and threat to human health. Their reported values for the closed dumpsites were understandably lower than the

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values of this study (being an active dumpsite), while the value of the active dumpsite in their study was higher than the value of this study.

Moreover, it can be depicted that the comparatively low values of the LPI for a landfill site is attributed to low concentrations of heavy metals in the samples. Landfill age also plays an important role in the leachates characteristics and hence, influences the LPI value (Lo, 1996).

*Comparison with Standards***:** Nigeria has no known leachates disposal standard and as a result, a standard in India has been used. The Indian standards for the disposal of treated leachates to inland surface water as per Municipal Solid Waste (Management and Handling) Rules, 2000 for the various parameters are presented and compared with the mean values of the pollutant variables of the dumpsite in Table 6 above.

Comparing the analysed parameters in all dumpsites investigated with the leachate disposal standard, it was observed that the concentrations of all the parameters of the leachates fell below the permissible limits of treated leachates discharged into inland surface water except TDS, BOD and Lead; while there were no standards to compare electrical conductivity, phosphate, sulphate, iron, cadmium and manganese values with.

The LPI value of the standards for the treated leachates is calculated and reported in Table 5. The LPI value of the treated leachates shall not exceed 7.38. The comparison of the leachates characteristics with the standards set for the disposal of treated leachates shows that the leachates generated from the dumpsite is mildly contaminated. The low values of LPI 5.69, 6.18 and 5.89 (all below 7.38) indicate the relatively low contamination potential of the leachates. However, the individual contaminants shall meet the discharge standards before discharge of leachates into any surface water body (Rafizul *et al*, 2011).

Environmental and Health Implications

Leachates have the possibility of leaching to groundwater or possibly to surface water. Once this occurs, the water becomes polluted and if consumed can lead to health implications. The concentration of total dissolved salts (TDS) gives an idea about the nature of quality and or the salinity of the water. According to WHO (2004), high level of TDS may be responsible for reduction in the palatability of water, inflict gastro-intestinal inconveniences in human and may also cause laxative effect particularly upon transits. The result of the analysis showed high values for the TDS which can cause any of the diseases mentioned above. The electrical conductivity (EC) of water is reflection of the quantity of ionic constituents dissolved in it. Once the leachates percolate, it increases the electrical conductivity of the water in contact and therefore reduces the potability of the

water. A minute value of phosphate as low as 0.01mg/l in groundwater may result in the water being slimy and also promotes the growth of algal (Adekunle *et al*., 2007). High quantity of sulphates in water is dangerous as it causes dehydration and diarrhea in children than adults (Longe and Balogun, 2010).

According to WHO (1997), high concentration of chlorides is detrimental to people with heart diseases and Kidney problem. The dumpsite is also prone to generation of gas and therefore violent explosions. Odour is also generated from the site which makes dwellers around the area uneasy. Fire is a common thing in this dumpsite as a result of methane gas generations and also the use of chemicals. Leachates cause decrease of soil pH and increase the electrical conductivity of the soil (Panahpour *et al*., 2011). Heavy metals could also be accumulated in the crops planted within the area.

*Conclusion***:** From the results obtained, the pH, temperature, phosphate, sulphate and chloride fell below the FMENV limits while electrical conductivity, BOD and COD exceeded the limits. Some of the heavy metals (nickel, zinc and cadmium) fell below FMENV limits while the others (chromium, copper, iron, lead) exceeded it. Pollution of the environment and health implications is very possible as a result of the presence of the dumpsite around residential areas.

Furthermore, though the mean pH of the dumpsite is indicative of a mature dumpsite, the organic strength (BOD_5/COD ratio) of 0.433mg/l is characteristic of a young dumpsite. This variation can be attributed to continuous biodegradation due to the daily disposal of wastes on the dumpsite. Hence, it cannot be classified as either young or mature; it is best described as intermediate (between 5 – 10 years old).

The concentrations of the parameters of the leachates except TDS, BOD and lead fall below the permissible limits of treated leachates discharged into inland surface water. The comparison of the leachates characteristics with the standards set for the disposal of treated leachates indicate a relatively low contamination potential of the leachates as the LPI values of all the sample location falls below value for treated leachates (7.38). It is however recommended that individual contaminants meet the discharge standards before discharge.

Finally, it is suggested that the waste management board of the state and the local government council should partner to upgrade the dump site and others into well engineered landfills.

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APPENDIX
Appendix A: The averaged sub index curves of pollutant
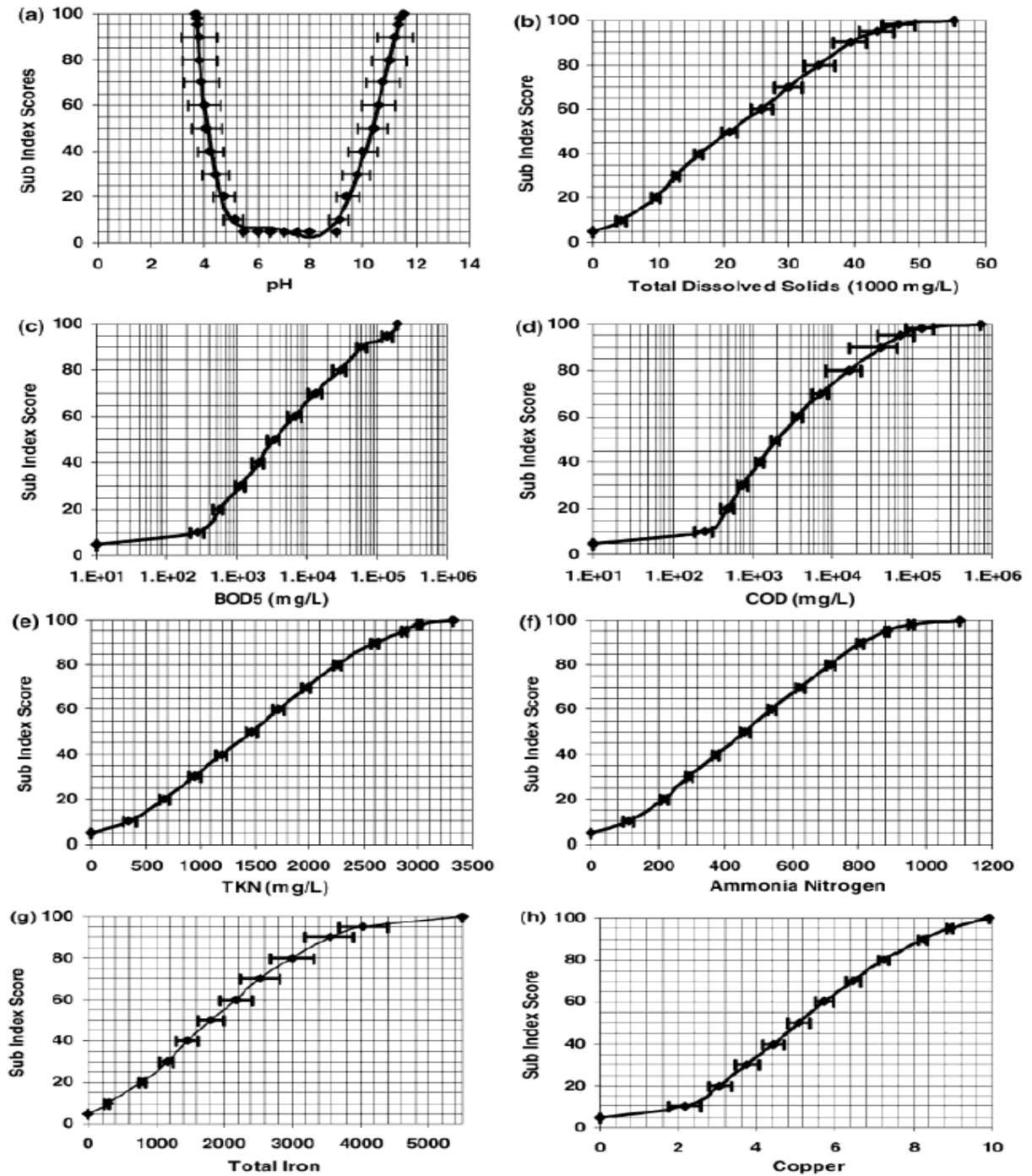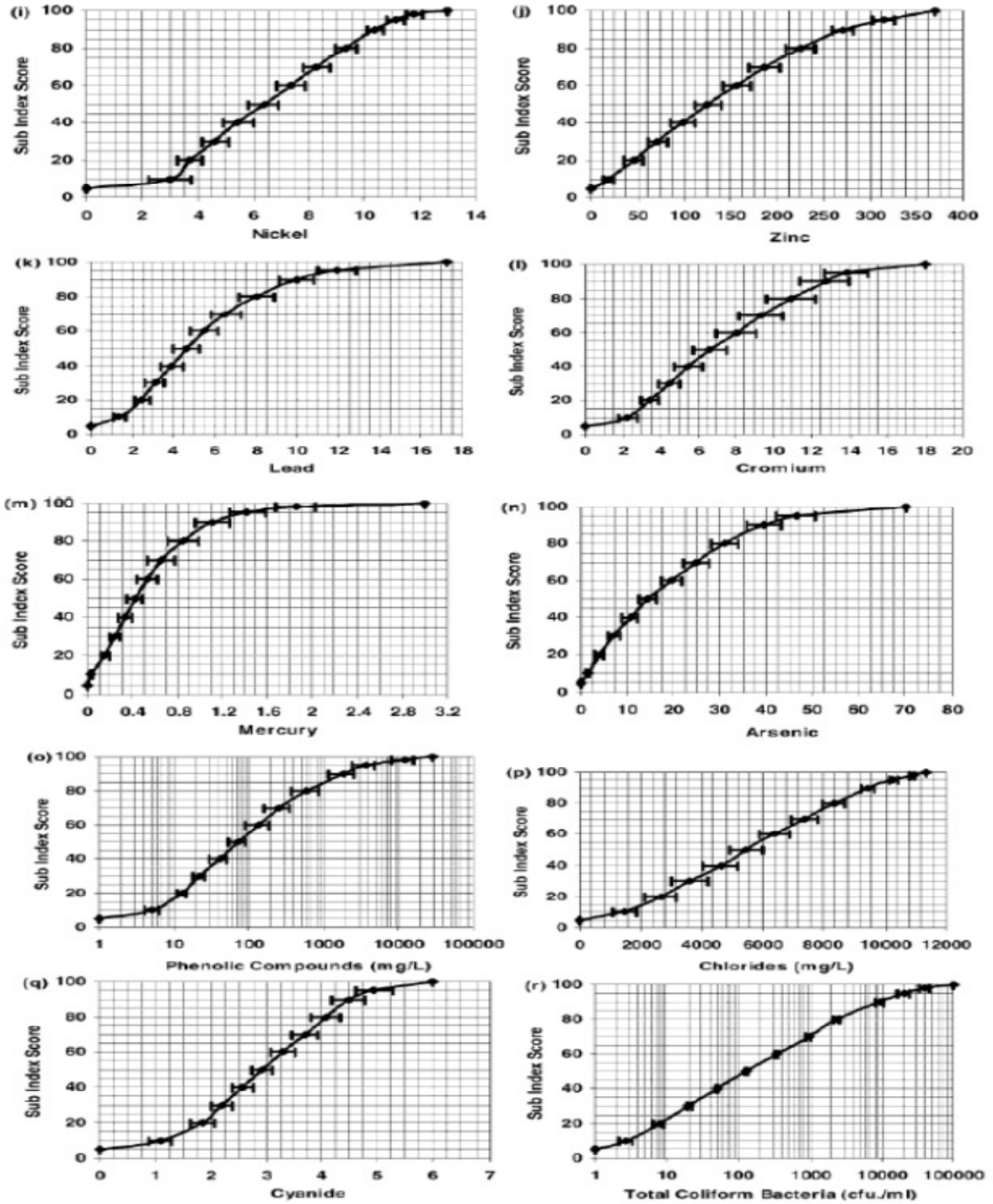
The averaged sub index curves of pollutant (a) pH (b) TDS (c) BOD_5 (d) COD (e) TKN (f) Ammonium nitrogen (g) Iron (h) Copper (i) Nickel (j) Zinc (k) Lead (l) Chromium (m) Mercury (n) Arsenic (o) Phenol (p) Chlorides (q) Cyanide (r) TCB (after Kumar and Alaappat, 2003).