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Assessment of Leachate Pollution Potential of Unlined Landfill Using Leachate Pollution Index (LPI), Nigeria

Churchill Ebinimitei Simon[1*], Opololaoluwa Oladimarum Ogunlowo[2]
[1]Department of Civil Engineering, Faculty of Engineering, Federal University Otuoke, P.M.B. 126, Yenagoa, Bayelsa State, Nigeria.
[2]Department of Civil Engineering, Faculty of Engineering, Federal University Otuoke, Otuoke, Bayelsa State, Nigeria.
*simionchurchill24@gmail.com

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ABSTRACT: *Leachate produced from unlined landfills has become a global concern in recent times as a result of their interference with the environment. This is because of how complex leachate has become, given rise to serious pollution of nearby water resources. The effects of Leachate on the environment can be as a result of the toxicity of pollutants within the leachate which is largely tied to the waste generation patterns and climatic factors. This research work therefore, is to determine the leachate pollution index (LPI) at Yenagoa Central Waste Dump and its potential impact on nearby water resources during the first quarter of 2019 (March, 2019). Four different leachate samples were taken randomly from different locations of the dumpsite and mixed for homogeneity. Physico-chemical and microbial parameters were analyzed to identify the character of the leachate within the dumpsite during March, 2019 using standard laboratory methods. Parameters analyzed were, pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Total Hardness (TH), Ammonium (NH_4^+), Sulphate (SO_4^{2-}), Nitrate (NO_3^-), Phosphate and Heavy Metals such as Cadmium (Cd), Chromium (Cr), Copper (Cu_2^+), Lead (Pb), Zinc (Zn), Calcium (Ca_2^+), Magnesium (Mg_2^+), Sodium (Na^+), Iron (Fe_2^+) and Potassium (K^+) ions, as well as Total coliform count. The leachate pollution index was computed to be 17.004 which was compared with the Indian standards for leachate disposal on Inland Waters (7.378). The results indicated that the leachate generated from the dumpsite was contaminated and therefore remediation measures should be put in place before it comes in contact with the environment.*

KEYWORDS*:* leachate, Leachate Pollution Index (LPI), homogeneity, remediation, environment

INTRIDUCTION

Leachate contamination of nearby water resources had recently gained global attention as a result of our waste generation/management patterns across the globe, of which Bayelsa State is no exception. Landfill leachates had been observed by various researchers to vary from season to season depending on various factors including the types of waste generated, the age of the landfill, the climatic factors and the degree of stabilization (Reinhart and Grosh, 1998). The stabilization of waste is suggested to proceed in five sequential or distinct phases, and the rate of progress through these stages is dependent on the physical (availability of free oxygen), chemical and microbiological conditions developed within the landfill with time (Pohland *et al*., 1985).

Wastes disposed in landfills are exposed to the harsh environmental elements of physical, chemical and biological actions. These wastes are subjected to hydrolyzation, microbial action, solubilization and final transportation by gravity to the base of dumpsites (Ramaiah, *et al.*, 2014). As the newly formed chemical solution is transported by gravity downwards, it picks up a variety of inorganic and organic compounds, flowing out of the wastes to accumulate at the bottom of the landfill (Bahaa, 2005). The resulting contaminated water is termed 'leachate' and can percolate through the soil and spread to water resources within the environment (Mor, *et al*., 2006). Municipal landfill leachate are highly concentrated complex effluents which contain dissolved organic matters; inorganic compounds such as ammonium, calcium, magnesium, sodium, potassium, iron, sulphates, chlorides and heavy metals such as cadmium, chromium, copper, lead, zinc, nickel; and xenobiotic organic substances (Lee and Jones-Lee, 1993).

Landfills have massively contributed to issues of surface water pollution as a result of precipitation and overland flow into receiving water bodies like ponds, lakes, streams, rivers as well as percolation that leads to ground water pollution (Kola-Olusanya, 2012). According to Al Sabhai *et al.*, (2009), the main problem associated with landfills is the formation of leachate and eventual contamination of water resources and soil due to contaminant migration.

The scale of pollution threat depends on the concentration and toxicity of contaminants in leachate, type and permeability of geologic strata, depth of water table, the direction of groundwater flow, the topography and rainfall intensity (Al-khaldi, 2006). Many studies have used Leachate Pollution Index (LPI) as a method of investigating the concentration of leachates in landfills. This method can be used for comparing leachate pollution potential of various landfill sites in a given geographical area as well as pollution potential of leachate from the same landfill at different times, using the Rand Corporation Delphi Technique (Kumar *et al*., 2003). 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 with the standard LPI value of 7.37 (Kumar *et al*., 2003).

At the moment, landfill leachate, its effects and management are gaining serious global attention particularly in developing countries like Nigeria with emphasis on its toxicity and harmful environmental concerns, (Nta, *et al*., 2020). Therefore, the proper application of leachate pollution index will enable environmental practitioners to take the most appropriate steps to manage the environment.

Study Objectives

The objectives of the study are;

- To evaluate the characteristics of leachate generated from Yenagoa central waste dumpsite during the first quarter of 2019 through physico-chemical and biological analysis.
- To use leachate pollution index (LPI) as an evaluation tool to ascertain the quality of leachate produced during the sampling period.
- To compare the leachate pollution index value with the standard value of treated leachate ready to be disposed into the environment.
- To discuss the leachate's potential adverse impacts on nearby environment.

MATERIALS AND METHOD

Study Area

The Yenagoa Central waste dumpsite is situated in Yenagoa Local Government Area of Bayelsa State. It services Yenagoa municipality and located at Abanigi road, Etelebu in Yenagoa Local Government Area of Bayelsa State, which is an offshoot of the Amassoma - Tombia road. The dumpsite lies at latitude 4^{0}59'28.44276" North and longitude 6019'40.47568" East respectively (Koinyan, *et al.*, 2013). The solid waste dump site mainly accommodates residential wastes, commercial waste, institutional wastes, sewage from disposal companies, wastes from animal slaughter houses and information technology (IT) industries. It is in fact the final resting place for more than 95% of all the wastes generated across the growing city.

Sample collection and analysis

The leachate accumulating at the base of the waste dumpsite was sampled randomly from four different locations within the waste dump and mixed for homogeneity prior to laboratory analysis. The samples for Physico-chemical and microbiological analysis were taken in 50 ml sterile universal containers, and analysis conducted. The leachate sample was analyzed for the relevant physico-chemical parameters according to internationally accepted procedures and standard methods. The parameters analyzed included pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Chemical Oxygen Demand (COD), Total Hardness (TH), Sodium (Na^+), Sulphate (SO_4^{2-}), Ammonium (NH^{4+}), Iron (Fe), Zinc (Zn), Cadmium (Cd), and Lead (Pb). The concentrations of heavy metals were determined using atomic absorption spectrophotometer (APAH, 2005). Microbial enumeration was carried out using serial dilutions on the leachate samples collected. Table 1 presents the leachate sampling points within the dumpsite.

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Table 1.0: Site Specific Leachate Sampling Locations

S/n	Sampling locations	Latitude and Longitude	Notation
1.	Beginning of the dump site at the northernmost part.	$4^0$59'50.28216"N $6^0$20'3.71184"E	LE 1
2.	250m into the dump site	$4^0$59'39.99552"N $6^0$19'54.69924"E	LE 2
3.	250m into the dump site	$4^0$59'36.42504"N $6^0$19'51.07872"E	LE 3
4.	Ending of the dump site at the southernmost part.	$4^0$59'28.44276"N $6^0$19'40.47528"E	LE 4

Calculation of Leachate Pollution Index (LPI)

The data from the laboratory analysis of samples as indicated in Table 2.0 below, were used in the LPI analysis.

Table 2: Summary of Physico-Chemical Properties of Leachate Sample during the First Quarter of 2019

Sample ID	Units	MARCH, 2019
pH	**-**	7.7
Temperature	**^{0}C**	21.7
Conductivity	**µS/cm**	12,250
TDS	**mg/l**	6,125
SO_4^{2-}	**mg/l**	160
NO_3	**mg/l**	0.4
PO_4^{3-}	**mg/l**	5
NH_4	**mg/l**	0.09
Alkalinity	**mg/l**	2,037
BOD	**mg/l**	10
COD	**mg/l**	366
Hardness	**mg/l**	560
Pb	**mg/l**	BDL
Cu	**mg/l**	0.02
Zn	**mg/l**	0.11
Fe	**mg/l**	8.04
Ca	**mg/l**	4.02
Mg	**mg/l**	47.18
K	**mg/l**	1.27
Na	**mg/l**	513.69
Cd	**mg/l**	BDL
Cr	**mg/l**	BDL
Total Plate Count	**cfu/ml**	2800000

N.B: BDL means below instrument detectable limits

The LPI for the dumpsite leachate was calculated using the equation of Kumar and Alappat, (2003a) shown in equation (1) below.

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

Where;
LPI = Leachate pollution index
w_i = The weight for the ith pollutant variable
p_i = The sub-index value of the ith leachate pollution variable
m = The number of leachate pollutant parameters for which data is available
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 corresponding value on the vertical axis of the curve from the concentration of the leachate pollutant on the horizontal axis where it intersected the sub-index curve. The 'P' values obtained for the parameters analyzed were multiplied with the respective weights assigned to each parameters.

RESULTS AND DISCUSSION

Figures. 1 and 2 presented the average sub-index curves of pollutants, while Table 3.0 showed the characteristics and LPI of leachate from Yenagoa Central Waste dumpsite.

Table 3.0: Characteristics and LPI of leachate from Yenagoa Central Waste Dumpsite during March, 2019

Parameters	**MARCH, 2019 Laboratory Analysis Data**	**Individual Pollution rating {Sub-index Value pi)**	**Variable Weights (wi)**	**Cumulative Pollution Rating (piwi)**
pH	7.7	5	0.055	0.275
TDS	6,125	12	0.05	0.6
NO_3	0.4	5	0.051	0.255
BOD	10	5	0.061	0.305
COD	366	20	0.062	1.24
Cu	0.02	5	0.05	0.25
Zn	0.11	5	0.056	0.28
Fe	8.04	5	0.045	0.225
TC	2800000	100	0.052	5.2
Total			**0.482**	**8.63**
LPI				**17.90456432 (Using eq. 1)**

Note: All values are in mg/l except pH and TC; TC means total coliform count (CFU/ml)

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Nine (9) out of the Twenty-three (23) variables were used for the LPI analysis because they were the available data. When the data for all the leachate pollutant variables included in LPI is not available, the LPI can be calculated using the data set of the available leachate pollutants (Barjinder *et al.*, 2014). Therefore, Eq. 1 above was used to calculate the Leachate Pollution Index.

This study adopted the Indian standard of leachate disposal since such standards are very scarce in Nigeria. According to Kumar *et al*., (2003), the leachate disposal standards had a value of 7.378 in his study. This implied that any LPI value which falls below the stipulated standard (7.378) is accepted, while any value above the standard is not accepted. The LPI of this study however was 17.004, which implied that the leachate of this dumpsite during the March, 2019 sampling regime was having the potential to contaminate and subsequently pollute the environment when released. This poses a serious threat to public health and the environment, therefore, there is an urgent need for the Bayelsa State Government to swing into remediation action in the interest of the citizens, particularly for those who come in contact with it daily. However, when compared to other leachate pollution index studies conducted by Surajit *et al*., (2016), the 17.095 value was below the LPI values of 34.02 and 31.80 gotten from an active and an abandoned dumpsite respectively. This showed that the leachate of this study was not as toxic as those from the latter. But considering the standard value, it was observed that the leachate was indeed not suitable for disposal without first treating it.

CONCLUSION

LPI as a hazard identification tool can be used to assess the leachate pollution potential from landfill sites particularly at places where there is a high risk of leachate migration and pollution of water resources and therefore can help to take necessary decisions.

The high value of LPI of this site indicated that leachate generated from it was contaminated and proper treatment will have to be ensured before discharging.
I
n the present study, the LPI value of 17.004 for the landfill site indicated that the waste deposited has not yet stabilized.

The comparison of the LPI value of this study i.e. 17.004, with the Indian standards set for the disposal of leachate to inland surface water indicated that the leachate generated from the landfill is highly contaminated and will have to be treated so that the LPI value reaches below 7.378.
This landfill site do not have any base liner or leachate collection and treatment system, hence a properly designed monitoring program should be initiated and maintained on a continuous basis to timely identify cases of leachate pollution.

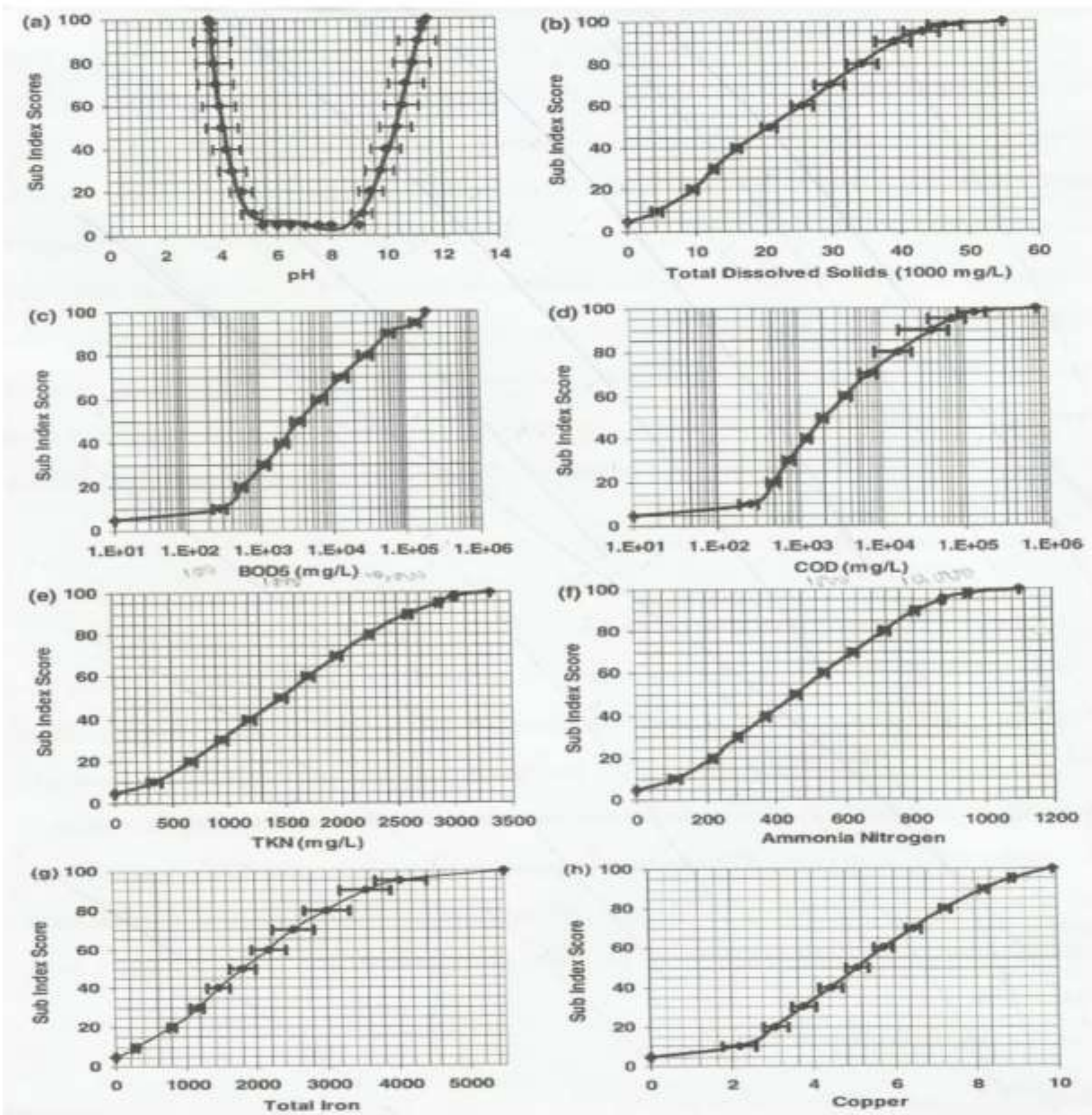

Figure 1.0: The average sub-index curves of pollutants (Kumar *et al.*, 2003)

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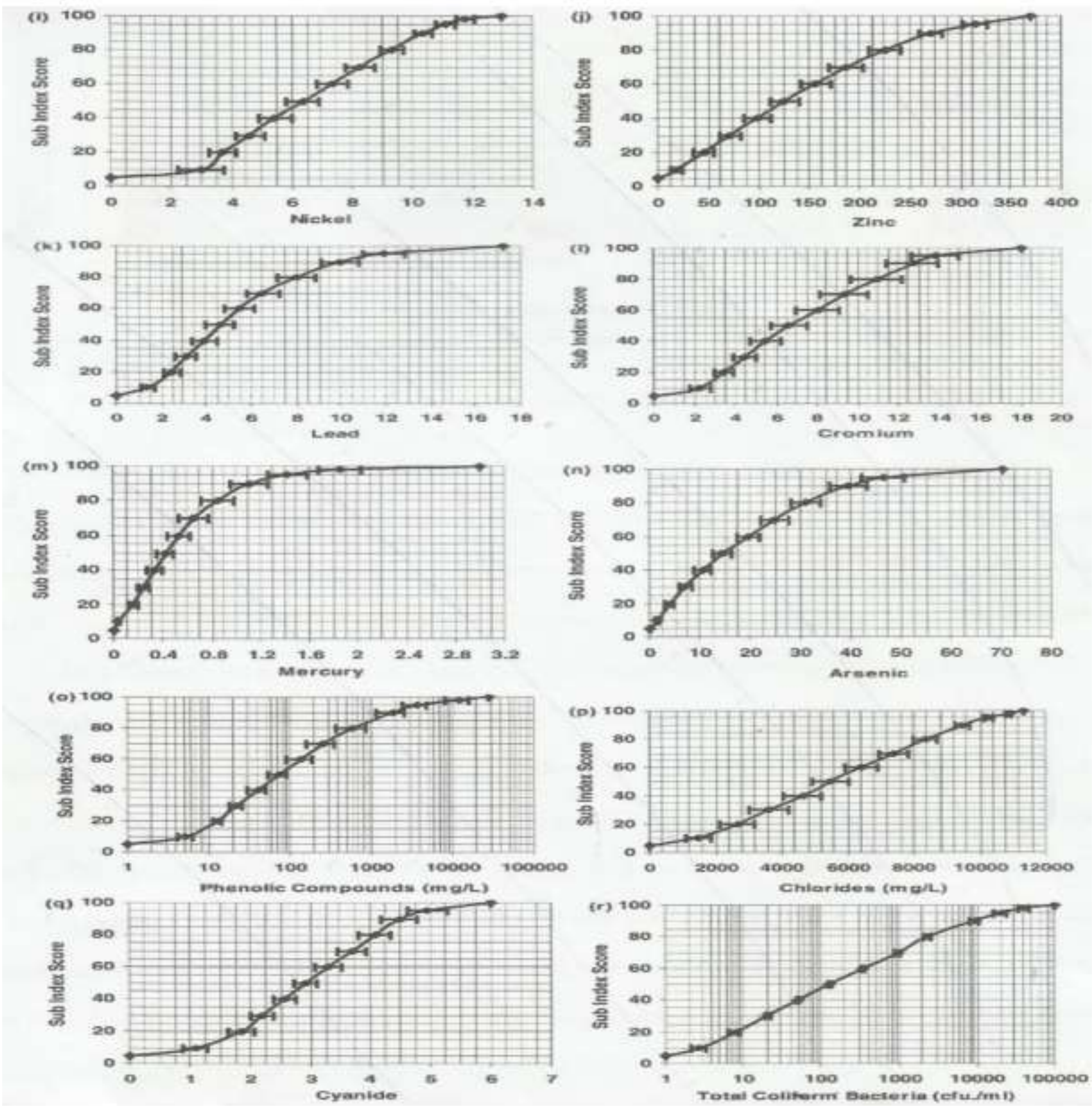

Figure 2.0: The average sub-index curves of pollutants (Kumar *et al.*, 2003)

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Conflict of Interest

Authors have declared that conflicting interests do not exist.