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Evaluation of Leachate Pollution Potential of three major Dumpsites in Port Harcourt

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Abstract
This research has investigated the Leachate Pollution Index (LPI) of three major dumpsites in Port Harcourt, Nigeria. These dumpsites which include Eneka dumpsite (ED), Igwuruta dumpsite (ID) and Rumuolumeni dumpsite (RD) with locations of latitude $4°53'37.30''N$ *and longitude* $7°02'39.30''E$, *latitude* $4°57'18''N$ *and longitude* $7°01'14''E$, *and latitude* $4°49'N$ *and longitude* $6°58'E$ *respectively, were assessed by collecting random samples to form composite mixtures that were analyzed for 11 physicochemical parameters which include pH, total dissolved solids (TDS), ammonia-nitrogen, phenolic compounds, total iron, zinc, nickel, copper, total coliform bacteria (TCB), total kjeldhal nitrogen (TKN) and Chlorides. These dumpsites do not have any base liner or leachate collection and treatment system. Therefore, all the leachate generated finds its path into the surrounding environment. The results of the physicochemical parameters were used to calculate the LPI of the leachate parameters. It was observed that the LPI values of ED, ID and RD which were 14.76, 13.88 and 14.08 respectively all exceeded the International regulatory limit of 7.375 for disposal of landfill leachate. In conclusion, all dumpsites require immediate attention but priority should be on ED to protect the groundwater from pollution.*

Key words: *Leachate Pollution Index, Dumpsites, Environment*

1. Introduction

Solid Waste Management (SWM) includes the process of generation, collection, storage, transport and disposal or reuse and recirculation or incineration or any relevant method of disposal. SWM is one among the basic vital services provided by municipal authorities in the country to keep urban centres clean. However, it is among the most poorly rendered services in the basket- the systems applied are unscientific, outdated and inefficient; population coverage is low; and the poor are marginalized. These leaves waste littered all over leading to unhealthy living conditions (Asnani, 2006). Population explosion, rapid urbanization has been established to be linked with increased solid waste generation (Naveen et al., 2016). Open dumpsite is the common means of waste disposal in developing African countries, with Nigeria inclusive. They are the primary means of municipal solid waste (MSW) disposal in many countries worldwide as they offer high quantities of MSW at economical costs compared to other disposal methods such as incineration. These dumpsites are poorly constructed and maintained. These disposals also, are open to the air and unregulated, as a result, rain water and air mix with the decomposed waste materials and contaminants from these solid wastes are extracted into the liquid phase to form leachate which are generally heavily contaminated and consist of complex wastewater that is, difficult to handle (Mohajeri et al., 2010; Palaniandy et al., 2009; Foul et al., 2009; Daud et al., 2009; Raji and Adeoye, 2016).

Leachate, a liquid manifestation from open dumpsites and landfills which causes pollution of natural resources, especially surface and ground water systems, also leads to adverse effects of human health and hygiene. It is a tainted liquid emanating from the bottom of the solid heap of waste disposed in landfills or open dumps as a result of percolation of precipitation that contains both soluble organic and inorganic compounds as well as suspended particles (Naveen et al., 2016). Leachate is characterized by high concentration of organic matter (biodegradable and non-biodegradable), ammonia, nitrogen, heavy metals and chlorinated and inorganic salts of which the composition of depends upon the nature of the solid waste buried, chemical and biochemical processes responsible for the decomposition of the waste materials and the total water content in the waste (Fatta et al., 1999; Renou et al., 2008).

A combination of pollutants (BOD_5, COD, ammonia, inorganic salts, etc.) in higher concentration renders leachate a potential source of contamination both to ground and surface waters, thus there is much need for their treatment before to discharge to water resources (Bashir et al., 2010). However, this is not the case because the processes for leachate collection and treatment are complex and cost intensive (Youcai et al., 2000). Therefore, the remedial and preventive measures cannot be undertaken in all the existing closed and active landfill sites all at once due to how expensive this will be and also financial constraints. The remedial and preventive measures need to be taken up in a phase manner (Bhalla et al., 2014).

The overall pollution potential of landfill leachate can be calculated in terms of Leachate Pollution Index (LPI) as proposed by Kumar and Alappat (2003b). Due to the fact that identification and quantification of pollutants in landfill is the major limitation for its successful treatment (Trankler et al., 2005), LPI can be used as a means to ascertain whether a landfill requires immediate attention in terms introducing remediation measures. Kumar and Alappat (2003b) developed a technique to evaluate the leachate contamination potential of different landfills on a comparative scale using an index known as LPI. LPI has many applications which include the ranking of landfill sites, resource allocation for landfill remediation, trend analysis and enforcement of standards, scientific research and public information.

In this study, attempts were made to assess the LPI of 3 major dumpsites in Port Harcourt Metropolis, Rivers State (Nigeria) for 11 significant leachate pollutant variables which includes pH, TDS, TKN, Ammonia-nitrogen, Copper, Zinc, Nickel, Total Iron, Phenolic compounds, TCB and Chloride (Cl^-); in order to ascertain the dumpsites that need urgent attention.These dumpsites do not have any base liner or leachate collection and treatment system. Therefore, all the leachate generated finds its path into the surrounding environment.

2. Materials and methods

2.1. Concept of LPI

An effort made to develop a method for comparing the leachate pollution potential of various landfill sites in a given geographical location resulted to the formulation of LPI which is an index formulated using the Rand Corporation Delphi Technique. The formulation process and complete description on the development of the LPI has been discussed here- (Kumar and Alappat, 2003b). The LPI represents the level of leachate contamination potential of a given landfill. It is a single number ranging from 5 to 100 (like a grade) that expresses the overall leachate contamination potential of a landfill based on several leachate pollution parameters at a given time. It is an increasing scale index, wherein a higher value indicates a poor environmental condition. The LPI can also be used to report leachate pollution changes in a particular landfill over time. The trend analysis so developed for the landfill can be used to assess the post closure monitoring periods. The leachate trend at a given landfill site can facilitate design of leachate treatment facilities for other landfills in the same region. 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 potential application of LPI include ranking of landfill sites based on leachate contamination potential, resource allocations for landfill remediation, enforcement of leachate standards, scientific research and public information (Kumar and Alappat, 2003b). The important consideration of the LPI developed are discussed below.

2.1.1. Pollutant variable selection

Eighteen leachate pollutant variables were chosen to be included in LPI. They include pH, total dissolved solids (TDS), biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), total kjeldahl nitrogen (TKN), ammonium-nitrogen, total iron, copper, nickel, zinc, lead, chromium, mercury, arsenic, phenolic compounds, chlorides, cyanide and total coliform bacteria (TCB).

2.1.2. Pollutants variable weights

The weights for these eighteen parameters were calculated based on the significance levels of the individual pollutants. The weight factor indicates the importance of each pollutant variable to the overall leachate pollution. For example, the weight factor for chromium is 0.064, and so it is most important variable than the other pollutant variables, while total iron with a weight factor of 0.045 is least important variable as compared to other pollutant variables included in LPI (Kumar and Alappat, 2003b). The weights for other pollutant variables are TDS: 0.050; BOD5: 0.061; COD: 0.062; TKN: 0.053; Ammonia Nitrogen: 0.051; Copper: 0.050; Nickel: 0.052; Zinc: 0.056;

Lead: 0.063; Mercury: 0.062; Arsenic: 0.061; Phenolic Compounds: 0.057; Chlorides: 0.049; Cyanides: 0.058 and Total Coliform Bacteria: 0.052. The sum of the weights of all the eighteen parameters is one.

2.1.3. Pollutants variable curves

The averaged sub index curves for each parameter were drawn to establish a relation between the leachate pollution and strength or concentration of the parameter. The sub-index curves for all the pollutant variables are reported in Kumar and Alappat (2005a).The averaged sub index curves are the curves that represent the relation between leachate pollution index and the strength or concentration of the parameter.

2.1.4. Variable aggregation

The weighted sum linear aggregation function was used to sum up behavior of all the leachate pollutant variables. The various possible aggregation functions were evaluated by Kumar and Alappat (2004) to select the best possible aggregation function. The Leachate Pollution Index can be calculated using Equation (1):

$$LPI = \sum_{i=1}^{n} w_i \, p_i \qquad (1)$$

where LPI = weighted additive leachate pollution index, w_i= weight for the ith pollutant variable, p_i = sub index value of the ith leachate pollutant variable, n = number of leachate pollutant variables used in calculating LPI when $\sum_{i=1}^{n} w_i = 1$.

However, 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. In that case, the LPI can be calculated with marginal error using Equation (2) (Kumar and Alappat, 2005b):

$$LPI = \sum_{i=1}^{m} w_i \, p_i / \sum w_i \qquad (2)$$

where m is the number of leachate pollutant parameters for which data is available, but in that case, m < 18 and $\sum w_i$< 1.

2.1.5. Procedure to calculate LPI

LPI is calculated by following this stepwise process:

Step 1: Testing of leachate pollutants

Analytical laboratory tests should be performed on leachate samples collected from the landfill sites to find out the concentration of the leachate pollutants.

Step 2: Calculating sub-index values

In calculating the LPI, the sub-index value – ‘p’ value of the parameters is computed from the sub-index curves based on the concentration of the leachate pollutants obtained during the tests. The ‘p’ values are obtained by locating the concentration of the leachate pollutant on the horizontal axis of the sub-index curve for that pollutant and noting the leachate pollution sub-index value where it intersects the curve.

Step 3: Aggregation of sub-index values

The ‘p’ values obtained are then multiplied with the respective weights assigned to each parameter. Then Equation (1) or Equation (2) is used to calculate LPI.

2.2. Study area

This study was conducted on three dumpsites in Port Harcourt, namely Eneka, Igwuruta and Rumuolumeni dumpsites. Port Harcourt is the capital of Rivers State and the most important city in the Niger Delta region of Nigeria and also one of Nigeria’s most important industrial towns (Gobo and Josiah, 2014). It lies within latitude $4°49'27''$N and longitude $7°02'01''$E. Port Harcourt climate falls within sub equatorial climate belt. Temperature and humidity are high throughout the year.

Eneka Dumpsite is situated west of the city of Port Harcourt, along Igwuruta/Eneka road on latitude $4°53'37.30''$N and longitude $7°02'39.30''E$. Igwuruta is located on latitude $4°57'18''$N and longitude $7°01'14''$E and is a moderately populated sub-urban environment. Rumuolumeni is situated between latitude $4°49'$N and longitude $6°58'$E.This latitudinal location implies that the study area lies within the tropical region with all its climate and topographic characteristics.

2.3. Field sampling and leachate collection

Leachate samples were collected using random sampling technique. Sampling was carried out on the 6th of September 2017. The following processes were duly followed in the collection of the leachate samples:

a. Three leachate samples were randomly collected from three different locations of the dump sites.
b. Leachates were scooped from the base of the heap of waste where leachate had drained out by gravity using a hand shovel which was then rinsed and dried prior to collection from another dumpsite.
c. Samples were collected in 1-litre polyethylene bottles which were properly

cleaned with detergent and rinsed with clean water and allowed to dry prior to sampling.

d. Samples were cooled to 4°C in an ice container en route to the laboratory.

2.4. Laboratory analysis

After collection, leachate samples were transferred shortly to the laboratory and stored under dark. The leachate samples were analyzed according to the American Public Health Association (APHA, 2005). The various parameters determined in the leachate samples include: pH (using pH meter), total dissolved solids (TDS) (Gravimetric method), chloride (Argentometric Method), zinc (Atomic Absorption Spectrometry (AAS)), copper (AAS), phenol (Spectrophotometer), total kjedjal nitrogen (TKN) (Kjedhal Trimetric Method), nickel (AAS), total coliform bacteria (TCB) (Standard Multiple Tube Fermentation), ammonium nitrogen (Spectrophotometer) and total iron (AAS).

3. Results and discussion

Leachate samples of MSW dumpsites were collected and analyzed for 11 significant leachate pollutant variables which include pH, TDS, TKN, ammonium nitrogen, total iron, copper, nickel, zinc, phenolic compounds, chlorides and TCB as seen from the various possible errors estimated by Rafizul et al. (2012), as the leachate pollutant parameters that yielded the least error of 0.542%; taking into consideration what Kumar and Alappat (2005b) reported; that the errors may be high if the data for the pollutants with the significantly high or low concentration is not available. The results of leachate parameters of Eneka dumpsite (ED), Igwuruta dumpsite (ID) and Rumuolumeni dumpsite (RD) with the leachate disposal standards from the Thirteenth International Waste Management and Landfill symposium, Proceedings Sardine (2011), are shown in Table 1. This standard was used because standard for leachate disposal in Nigeria is very scarce.

Table 1: Leachate pollutant concentration of the three dumpsites and their comparison with leachate disposal standards

Leachate Pollutant Variables*	Eneka Dumpsite (ED)	Igwuruta Dumpsite (ID)	Rumuolumeni Dumpsite (RD)	Leachate Disposal Standards**
pH	6.46	6.52	5.68	5.5 - 9.0
TDS	924	954	618	2100
Chloride	499.8	309.9	100.2	1000
Phenolic Compounds	18.37	10.07	11.09	1.0
TKN	0.51	0.36	1.05	100.0
Ammonium Nitrogen	3.32	1.52	1.07	50.0
Copper	0.00584	0.038416	0.08615	3.0
Zinc	0.06942	0.13927	0.04398	5.0
Nickel	1.57231	0.81054	1.02481	3.0
Total Iron	4.38946	10.1962	7.60045	No Standard
TCB	2800	3400	3700	No Standard

*All values are in mg/l, except pH and TCB; TCB unit is in cfu/ml

** Thirteenth International Waste Management and Landfill symposium, Proceedings Sardine (2011)

3.1. Calculated LPI

The procedure explained above has been used to calculate the LPI for the dumpsites. The sub-index curves of the 11 studied leachate pollutant variables which include pH, TDS, TKN, Ammonia-nitrogen, Copper, Zinc, Nickel, Total Iron, Phenolic compounds, TCB and Chloride can be viewed in the works of Kumar and Alappat, (2005a) which were utilized to compute sub-index values for leachate obtained from Eneka Dumpsite (ED) and that of the standards given for disposal of leachate into rivers as shown in Fig.1a - k. The LPI value of ED, ID and RD of Port Harcourt and also the LPI of leachate disposal standards given under the Thirteenth International Waste Management and Landfill symposium, Proceedings Sardine (2011) was calculated using the above procedure and reported in Tables 2, 3, 4 and 5.

The extrapolated values for the pollutant concentration in leachate obtained from ED were deduced from the correlations or sub-index curves as developed by Kumar and Alappat, (2005a) as shown in Figure 3.1a to 3.1k. Similar extrapolations for leachate obtained from ID and

RD of Port Harcourt were deduced in similar manner. It's important to note that, the horizontal axis represents the pollutant concentration and the vertical axis represents the sub index scores.

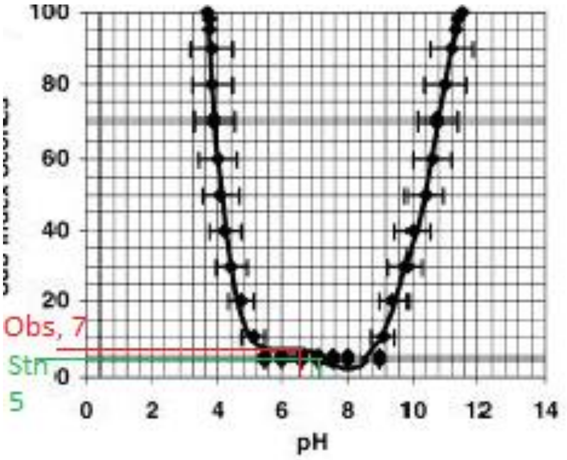

Fig.3.1a: Sub-Index of pH for ED

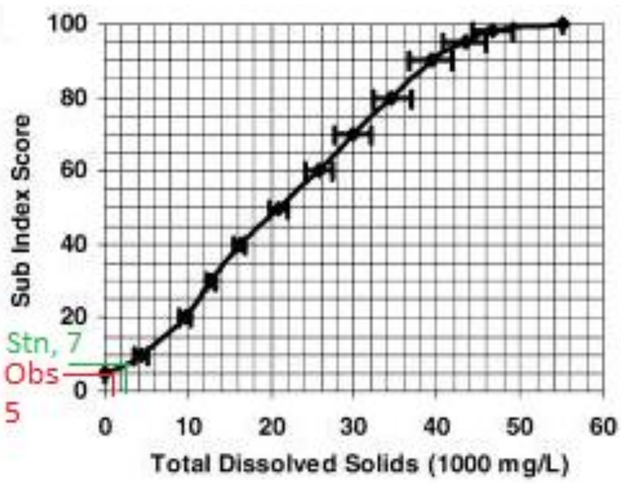

Fig.3.1b: Sub-Index of TDS for ED

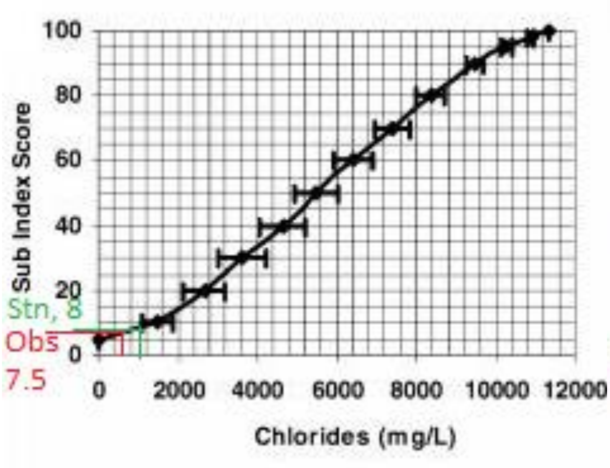

Fig.3.1c: Sub-Index of Chlorides for ED

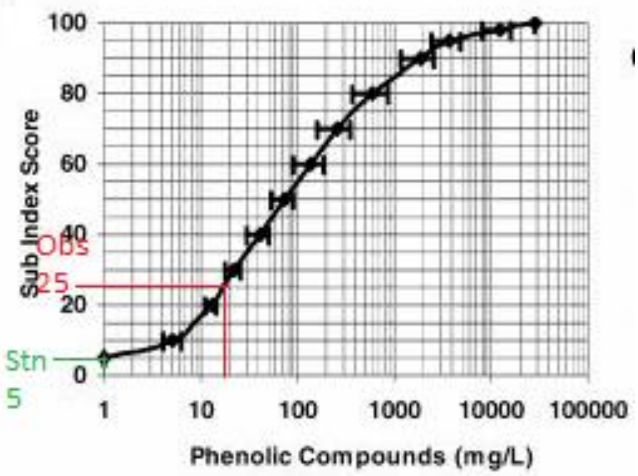

Fig.3.1d: Sub-Index of phenolic for ED

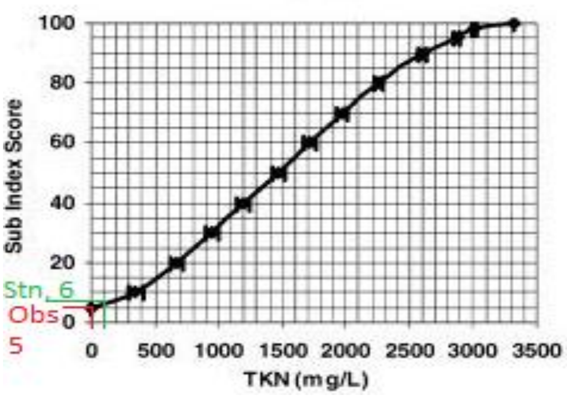

Fig.3.1e: Sub-Index of TKN for ED

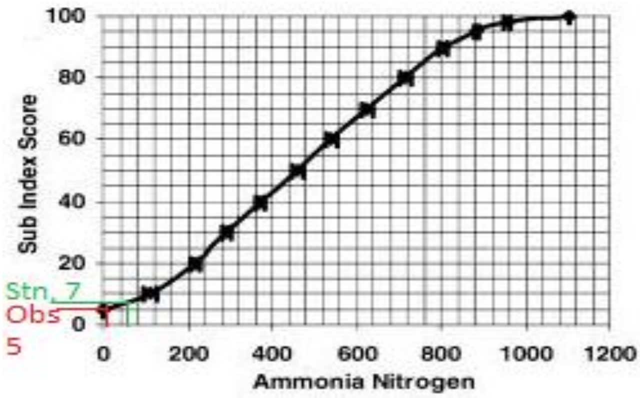

Fig.3.1f: Sub-Index of Ammonia-N for ED

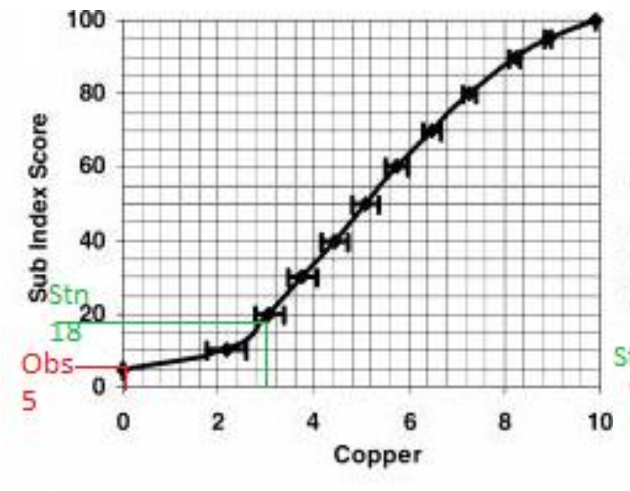

Fig.3.1g: Sub-Index of Copper for ED

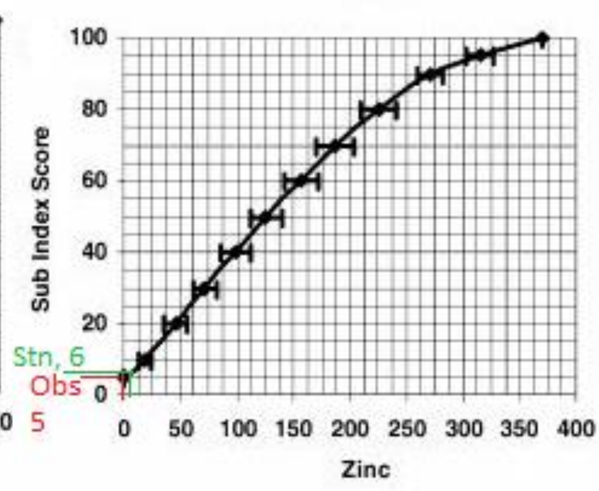

Fig.3.1h: Sub-Index of Zinc for ED

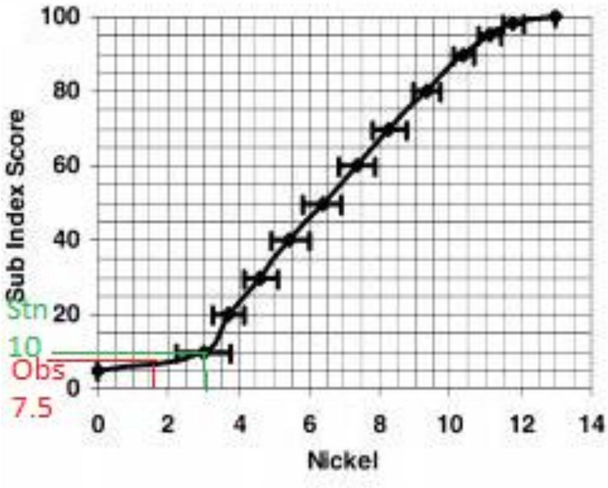

Fig.3.1i: Sub-Index of Nickel for ED

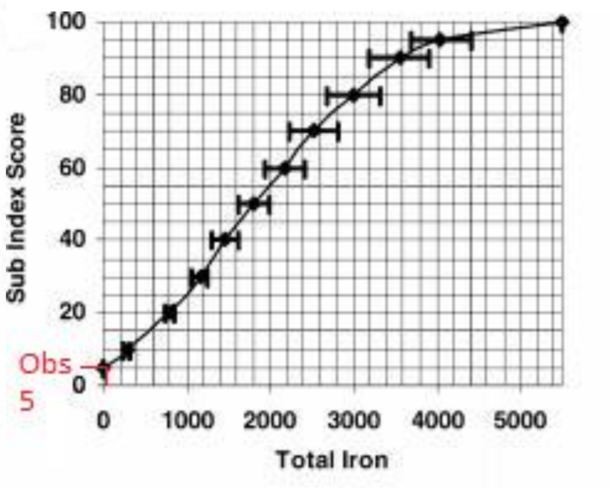

Fig.3.1j: Sub-Index of Total Iron for ED

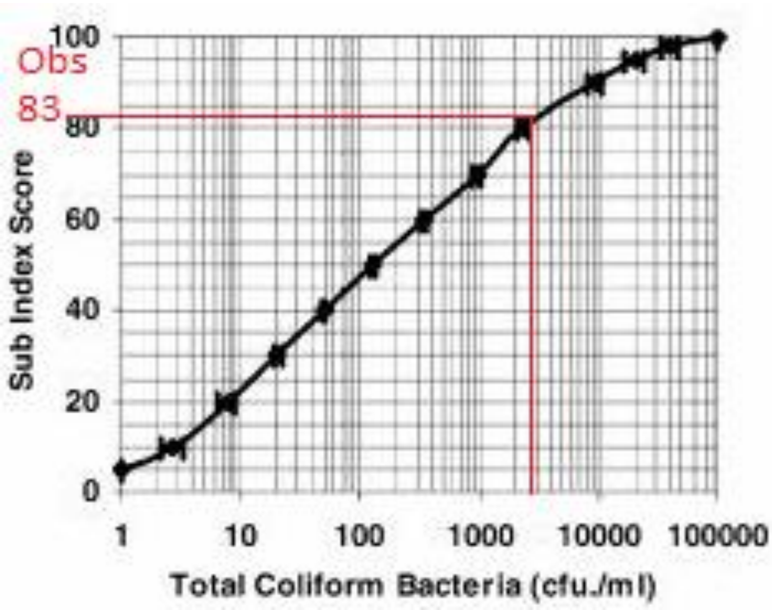

Fig.3.1k: Sub-Index of TCB for ED

Table 2: LPI of leachate from Eneka dumpsite

Leachate Pollutant Variables*	Pollutant Conc. Ci^*	Pollutant Sub-Index Value pi	Variable Weight wi**	Aggregation $pi.wi$
pH	6.46	7	0.055	0.385
TDS	924	5	0.050	0.250
BOD_5	-	-	-	-
COD	-	-	-	-
TKN	0.51	5	0.053	0.265
Ammonium Nitrogen	3.32	5	0.051	0.255
Total Iron	4.38946	5	0.045	0.225
Copper	0.00584	5	0.050	0.250
Nickel	1.57231	7.5	0.052	0.390
Zinc	0.06942	5	0.056	0.280
Lead	-	-	-	-
Chromium	-	-	-	-
Mercury	-	-	-	-
Arsenic	-	-	-	-
Phenolic Compounds	18.37	25	0.057	1.425
Chlorides	499.8	7.5	0.048	0.360
Cyanide	-	-	-	-
Total Coliform Bacteria	2800	83	0.052	4.316
Total			**0.569**	**8.401**
LPI value using Eq. (2)				**14.76**

*All values are in mg/l, except pH and TCB; TCB unit is in cfu/ml.
**For the variable weights; Source: Kumar and Alappat (2005a).

Table 3: LPI of leachate from Igwuruta dumpsite

Leachate Pollutant Variables*	Pollutant Conc. Ci^*	Pollutant Sub-Index Value pi	Variable Weight wi**	Aggregation $pi.wi$
pH	6.52	7	0.055	0.385
TDS	954	5	0.050	0.250
BOD_5	-	-	-	-
COD	-	-	-	-
TKN	0.36	5	0.053	0.265
Ammonium Nitrogen	1.52	5	0.051	0.255
Total Iron	10.1962	5	0.045	0.225
Copper	0.038416	5	0.050	0.250
Nickel	0.81054	6	0.052	0.312
Zinc	0.13927	5	0.056	0.280
Lead	-	-	-	-
Chromium	-	-	-	-
Mercury	-	-	-	-
Arsenic	-	-	-	-
Phenolic Compounds	10.07	17	0.057	0.969
Chlorides	309.9	6	0.048	0.288
Cyanide	-	-	-	-
Total Coliform Bacteria	3400	85	0.052	4.420
Total			**0.569**	**7.889**
LPI value using Eq. (2)				**13.88**

*All values are in mg/l, except pH and total coliform bacteria; total coliform bacteria unit is in cfu/ml
**For the variable weights; Source: Kumar and Alappat (2005a).

Table 4: LPI of leachate from Rumuolumeni dumpsite

Leachate Pollutant Variables*	**Pollutant Conc. Ci^***	**Pollutant Sub-Index Value pi**	**Variable Weight wi****	**Aggregation $pi.wi$**
pH	5.68	7	0.055	0.385
TDS	618	5	0.050	0.250
BOD_5	-	-	-	-
COD	-	-	-	-
TKN	1.05	5	0.053	0.265
Ammonium Nitrogen	1.07	5	0.051	0.255
Total Iron	7.60045	5	0.045	0.225
Copper	0.08615	5	0.050	0.250
Nickel	1.02481	6	0.052	0.312
Zinc	0.04398	5	0.056	0.280
Lead	-	-	-	-
Chromium	-	-	-	-
Mercury	-	-	-	-
Arsenic	-	-	-	-
Phenolic Compounds	11.09	18	0.057	1.026
Chlorides	100.2	5	0.048	0.240
Cyanide	-	-	-	-
TCB	3700	87	0.052	4.524
Total			**0.569**	**8.012**
LPI value using Eq. (2)				**14.08**

*All values are in mg/l, except pH and TCB; TCB unit is in cfu/ml
**For the variable weights; Source: Kumar and Alappat (2005a).

Table 5: LPI of leachate disposal standard

Leachate Pollutant Variables*	**Pollutant Conc. Cs^{*}****	**Pollutant Sub-Index Value ps**	**Variable Weight wi*****	**Aggregation $ps.wi$**
pH	5.5 - 9.0	5	0.055	0.28
TDS	2100	7	0.050	0.35
BOD_5	30	6	0.061	0.37
COD	250	10	0.062	0.62
TKN	100	6	0.053	0.32
Ammonium Nitrogen	50	7	0.051	0.36
Total Iron	No Standard	-	-	-
Copper	3.0	18	0.050	0.90
Nickel	3.0	10	0.052	0.52
Zinc	5.0	6	0.056	0.34
Lead	0.1	5	0.063	0.32
Chromium	2.0	9	0.064	0.58
Mercury	0.01	6	0.062	0.37
Arsenic	0.2	5	0.061	0.31
Phenolic Compounds	1.0	5	0.057	0.29
Chlorides	1000	8	0.048*	0.38
Cyanide	0.2	6	0.058	0.35
TCB	No Standard	-	-	-
Total			**0.903**	**6.66**
LPI value using Eq. 1.2				**7.375**

*All values are in mg/l, except pH and total coliform bacteria; total coliform bacteria unit is in cfu/ml. No standards for TCB and total iron, hence, they were not used in computing the LPI of the leachate disposal standard.
** Thirteenth International Waste Management and Landfill symposium, Proceedings Sardine (2011)
***For the variable weights; Source: Kumar and Alappat (2005a).

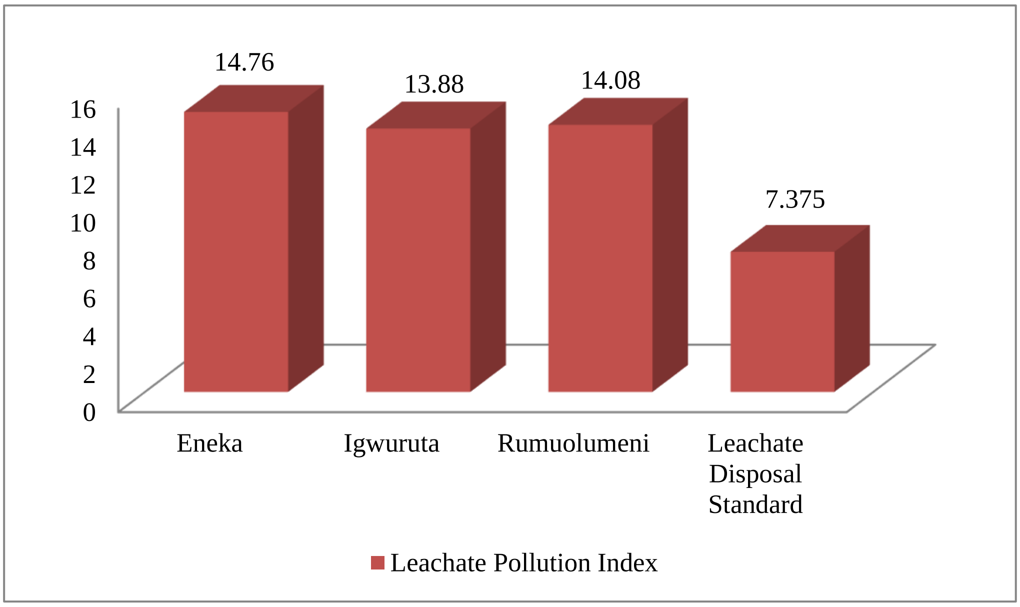

Figure 4: Comparison of the leachate contamination potential of the three dumpsites under study with the LPI of leachate disposal standards

3.2. Leachate pollution index (LPI) for Eneka, Igwuruta and Rumuolumeni dumpsites

The LPI values of 14.76, 13.88 and 14.08 were obtained for the three dumpsites, Eneka, Igwuruta and Rumuolumeni dumpsites respectively. The comparison of the LPI values of the three dumpsites with the LPI of the leachate disposal standard is shown in Figure 4. The LPI value of the standards for the disposal of leachate from Table 5 is 7.375 which is the permissible limit for the disposal of leachate as per the standards given under the Thirteenth International Waste Management and Landfill symposium, Proceedings Sardine (2011).

The comparison of the LPI values of the dumpsites i.e. 14.76, 13.88 and 14.08 for ED, ID and RD respectively, with the standards set for the disposal of leachate indicated that the leachate generated from all the dumpsites are highly contaminated and can therefore pose threat to the environment and human health. Hence, liners and leachate collection systems should be put in place after which the collected leachate can then be treated in a wastewater treatment facility before discharge into receiving water body.Thus all dumpsites need adequate attention and monitoring to protect the groundwater. The results also indicate that the Eneka Dumpsite has the highest LPI value in comparison with the other two dumpsites Igwuruta and Rumuolumeni dumpsites. Thus, attention should be given to Eneka dumpsite first. Similar work has been done in which the LPI calculated for the different study areas where compared with the LPI of the leachate disposal standard. This can be seen in Bhalla et al (2014), where the LPI for the various landfills, all exceeded the LPI of the leachate disposal. Also, Salami et al (2015), in this case four dumpsite leachate contamination potential were evaluated and all were seen to exceed the stipulated standard.

4. Conclusions

This study has revealed that leachate produced from three dumpsites, situated at Eneka, Igwuruta and Rumuolumeni had LPI values of 14.76, 13.88 and 14 respectively. The comparison of these LPI values from the three dumpsites with the LPI for leachate disposal standard (which was deduced to be 7.375) indicated that leachate obtained from those dumpsites has the potential of contaminating receiving water body which can pose serious problems in the environment. Thus, immediate attention should be given towards proper management of leachate obtained from the dumpsites.

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