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POTENTIALS OF LEACHATE CONTAMINATION OF DUMPSITES IN BAUCHI METROPOLIS

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ABSTRACT
Leachate quality of some selected active dumpsites LA, LB, LC and LD in the Bauchi metropolis are characterised, and their contamination or pollution potentials were analysed in this study using the Leachate Pollution Index (LPI). When generated from various dumpsites, the LPI tool quantifies the pollution potential of leachates. Pollutant variables: pH, TDS (Total Dissolved Solids), BOD_5 (Biological Oxygen Demand), COD (Chemical Oxygen Demand), Cl^- (Chloride), EC (Electrical conductivity), TKN (Total Kjeldahl Nitrogen), Total Iron, Ammonia Nitrogen, Copper, Zinc and Lead were investigated in all the selected dumpsites. The different samples collected at locations (LA, LB, LC and LD) yielded computed LPI values of 6.666, 5.861, 6.739 and 6.447 mg/l, respectively. The results showed a high concentration of heavy metals, and the concentrations of the leachate parameters fell below the permissible limit value of 7.38 mg/l by FMEnv standard LPI for treated leachates. Also, there is a sharp difference in the individual parameters' concentration of leachates computed here with the FMEnv standard. One crucial act in calculating any environmental index is obtaining the aggregation function. When the aggregation function is ambiguous, it will result in an unnecessary alarm. This shows a less polluted environmental situation as comparatively more contaminated. On the other hand, when the aggregation function is eclipsed, it may create a false sense of security. This will show that a seriously contaminated environment is less polluted. The study suggests exploring other means of obtaining LPIs and compared with the aggregation functions.
Keywords: Leachate, Landfill, Municipal solid waste, Contamination, LPI

1. INTRODUCTION

Solid waste improper management has resulted in high environmental and ecological disorder and consequent health problems. Primarily, landfills are ways of Municipal Solid Waste (MSW) control or discharge in various nations worldwide since they accommodate dumping of MSW in high quantities at relatively low costs, compared to other alternative disposal means such as incineration (Afsar *et al.*, 2015). Adequate sanitary especially properly designed landfills for wastes disposal by different governments agencies is almost absence and this has led to the proliferations of open dumps, scattered in many locations of the country (Salami, et al., 2015). Leachate settled at beneath dumpsites and thereafter sinks down steadily into the soil and cause contamination of ground water below and at perpendicular to surface water (Agbozu, and

Nwosisi, 2015). Dumpsites leachates generally differ in contents depending on the year history of the dumpsite and kind of wastes contained over the age. The extend of danger posed by leachates is deeply affected by the chemical compounds of the rubbish in the dumpsite, the quantity of leachates from mass waste gathered, and equally the distance of the dumpsites from bodies of water including both groundwater and surface water (Shubhra, et al., 2015; Chinade, et al., 2017).

Leachate Pollution Index (LPI*)*, developed by Kumar and Alappat (2003a), has been applied numerously in landfill in such areas as landfill sites ranking, allocation of resource for remediating landfill, analysis of trend and enforcement of standards, scientific research and public information. The contamination potential level of leachate in a given landfill is indicated by its LPI. The LPI values range from 5 to 100 just like a grade, and it expresses the overall leachate contamination potential of a landfill which is obtained from several leachate pollution parameters at a given time (Kundiri, et al., 2016). It is a linear progressing scale index, wherein a large value indicates a poor environmental condition. The LPI can 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 (Barjinder et al., 2007). The LPI can also be used to compare leachate contamination potential of different landfill in a given geographical area or around the world (Anurag & Singh, 2010 and Ana-Maria, et al., 2009). Other likely applications of LPI include enforcement of standards in leachate, remediation, scientific researches and public information (Kumar & Alappat, 2003a). The paper's aim is to analyze the leachate contamination potential using leachate pollution index.

2. MATERIALS AND METHOD

Integrated leachate samples were collected from four (4) randomly selected locations within Bauchi metropolis. Bauchi LGA, Bauchi state is situated between latitude 100 17' – 100 20'north and longitude 90 49' – 100 05' east, on an altitude of 690.2m above sea level. All the landfill locations are of non-engineered, low lying and open dumps. The dumpsites include Gwallaga, Jahun – Makama new extension, Yelwa makaranta and Kobi and were named as LA, LB, LC and LD respectively. The dimensions of the dumpsite were 12 × 9.6m; 8 × 7.8m; 12 × 10.3m; and 13 × 12m while depth of samples collection were 0.24m, 0.30m, 0.42m and 0.48m respectively for LA, LB, LC & LD. The soil color appeared to be dark brown comprising of shallow water tables and moderate water quality containing predominantly municipal solid wastes dumped in all the dumpsite locations. There were no leachates collectors in the landfill sites, hence randomly sampled leachates were collected at the base of the landfills each from three different surrounding locations. Containers made of plastic of 2-liter capacity, rinsed properly with little samples, were used to sample the leachates. The acclimatization was necessary before collecting the samples in order to stimulate containers to the leachate environment. All the different sites where samples are collected have neither bottom liners nor systems of collecting and treating of leachate, hence, the generated leachate seep into the surrounding environment. The variables of pollution; pH, TDS (Total Dissolved Solids), BOD_5 (Biological Oxygen Demand), COD (Chemical Oxygen Demand), Cl^- (Chloride), EC (Electrical conductivity), TKN (Total Kjeldahl Nitrogen), Total Iron, Ammonia Nitrogen, Copper, Zinc and

Lead, were investigated to measure the potentiality of pollution of the discharged leachate from the municipal solid waste landfill sites and to measure the potentiality of pollution of the leachate.

The magnitude of the available parameters was measured numerically based on the significant degree of the different pollutants, and curves of average sub-index parameters were drawn to show a relationship between the parameters' concentration and leachate pollution. The weighted sum linear aggregation function was also used to add up the behaviours of the various leachate pollutants.

Equation (1) was used to find the Leachate Pollution Index:

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

Where LPI = Leachate Pollution Index of the weighted additive,
w_i = the ith pollutant variable weight,
p_i = the value of ith leachate pollutant variable of sub index,
n = leachate pollutant variables' number used in calculating LPI

$$\sum_{i=1}^{n} w_i = 1 \tag{2}$$

However in leachate pollutant variables, if a certain data to be included in LPI calculation is missing, the LPI would be obtained from the available variables of the particular pollutants of the leachate. In such a case, equation (3) was used to find the LPI.

$$LPI = \frac{\sum_{i=1}^{m} w_i P_i}{\sum w_i} \tag{3}$$

Where m is the leachate pollutant variables number for which data is available, and it is given that
$m < 18$ and $\Sigma w_i < 1$.

3. RESULTS AND DISCUSSIONS

3.1 Results

The physiochemical analysis results of leachates from different dumpsites (LA, LB, LC and LD) in the Bauchi metropolis are presented in Table 1, and the leachate pollution indices are shown in Tables 2a, 2b, 2c, and 2d, respectively.

Table 1**:** Concentration of physiochemical parameters of leachate

S/N	Leachate parameter	LA	LB	LC	LD
1.	pH	6.7	6.8	6.5	6.7
2.	EC	620	592.1	630	670
3.	TDS	491	352.1	2760	3460
4.	BODS	324	256.4	2430	2340
5.	COD	78.25	86.30	46.10	138.40
6.	Nitrogen	29.5	24.8	22.4	32.9
7.	Phosphate	4.95	3.24	4.26	5.42
8.	Sulphate	9.02	10.11	11.17	9.04
9.	Chloride	82.47	136.02	115.3	78.42
10.	Chromium	0.321	0.354	6.283	0.340
11.	Copper	054	0.74	0.64	0.69
12.	Zinc	1.78	2.0	1.67	1.88
13.	Iron	3.128	2.112	4.320	0.814
14.	Lead	0.018	0.16	0.011	0.05
15.	Calcium	0.03	0.05	0.010	0.02

16.	Magnesium	0.12	0.29	0.16	0.27
17.	Nitrate	0.07	0.09	0.06	0.03

EC is in µmhos/cm, other parameters in mg/l

Table 2a: Leachate pollution index for LA

S/N	Leachate parameter	Concentration	Pollutant weight (Wi)	Sub- index value (pi)	Overall pollutant (wi.pi)
1.	pH	6.7	0.005	6	0.03
2.	FC	620	-	-	-
3.	TDS	419	0.050	6	0.3
4.	BODs	324	0.061	10	0.61
5.	COD	78.25	0.061	7	0.434
6.	Nitrogen	29.5	0.053	7	0.371
7.	Phosphate	4.95	-	-	-
8.	Sulphate	9.01	-	-	-
9.	Chloride	82.47	0.049	8	0.329
10.	Chromium	0.231	0.064	5	0.32
11.	Copper	0.54	0.050	5	0.25
12.	Zinc	1.78	0.056	6	0.336
13.	Iron	3.128	-	-	-
14.	Lead	0.018	0.063	6	0.378
15.	Calcium	0.03	-	-	-
16.	Magnesium	0.12	-	-	-
17.	Cadmium	0.07	0.002	6	0.012
Total LPI Value Using Equation 2			0.515	-	3.433

EC is in µmhos/cm, other parameters in mg/l

$$LPI = \sum_{i=1}^{n} \left(\left(\frac{wi.pi}{\Sigma wi} \right) \right) = \frac{3.433}{0.515} = 6.666$$

Table 2b: Leachate pollution index for LB

S/N	Pollutant parameter	Concentration	Pollutant weight(wi)	Sub index value(pi)	Overall pollutant(wi.pi)
1.	pH	6.8	0.005	5	0.025
2.	EC	592.1	-	-	-
3.	TDS	352.1	0.050	6	0.53
4.	BODs	256.4	0.061	6	0.366
5.	COD	86.30	0.062	5	0.31
6.	Nitrogen	24.8	0.053	5	0.265
7.	Phosphate	3.24	-	-	-
8.	Sulphate	10.11	-	-	-
9.	Chloride	136.02	0.049	10	0.49
10.	Chromium	0.354	0.64	5	0.23
11.	Copper	0.74	0.050	5	0.25
12.	Zinc	2.0	0.056	6	0.336
13.	Iron	2.112	-	-	-
14.	Lead	0.016	0.063	5.5	0.3465
15.	Calcium	0.05	-	-	-
16.	Magnesium	0.29	-	-	-
17.	Cadmium	0.09	-0.002	5	0.010
Total LPI value using equation 2			0.515	-	3.01085

EC is in µmhos/cm, other parameters in mg/l

$$LPI = \sum_{i=1}^{n} \left(\left(\frac{wi.pi}{\Sigma wi} \right) \right) = \frac{3.0185}{0.515} = 5.861$$

Table 2c: Leachate pollution index for LC

S/N	Pollutant	Pollutant	Sub- index value	Over roll pollutant

	Parameter	Concentration	weight(wi)	(pi)	(wi.pi)
1	pH	6.7	0.005	5.5	0.0275
2	EC	670	-	-	-
3	TDS	3460	0.050	8	O.40
4	BOD_S	2340	0.061	10	0.061
5	COD	138.14	0.062	6	0.327
6	Nitrogen	32.9	0.053	5	0.265
7	Phosphate	5.42	-	-	-
8	Sulphate	9.04	-	-	-
9	Chloride	98.42	0.094	5	0.245
10	Chromium	0.340	0.064	6	0.384
11	Copper	0.69	0.050	6	0.30
12	Zinc	1.88	0.056	7	0.392
13	Iron	0.814	-	-	-
14	Lead	0.05	0.063	5	0.315
15	Calcium	0.02	-	-	-
16	Magnesium	0.27	-	-	-
17	Cadmium	0.03	0.002	5	0.010
Total LPI Value Using equation 2			0.515		3.3205

EC is in µmhos/cm, other parameters in mg/l

$$LPI = \sum_{i=1}^{n} \left(\left(\frac{wi.pi}{\Sigma wi} \right) \right) = \frac{3.469}{0.515} = 6.739$$

Table 2d: Leachate pollution index for LD

S/N	Pollutant Parameter	Concentration	Pollutant weight(wi)	Sub- index value (pi)	Over roll pollutant (wi.pi)
1	pH	6.5	0/005	7	0.035
2	EC	630	-	-	-
3	TDS	2760	0.050	8	0.40
4	BOD_S	24.30	0.061	6	0.366
5	COD	46.10	0.062	7	0.343
6	Nitrogen	22.4	0.053	6	0.318
7	Phosphate	426	-	-	-
8	Sulphate	11.76	-	-	-
9	Chloride	115.3	0.049	10	0.49
10	Chromium	6.283	0.064	7	0.448
11	Copper	0.64	0.054	5	0.28
12	Zinc	1.67	0.049	5	0.245
13	Iron	4.320	-	-	-
14	Lead	0.011	0.063	7	0.441
15	Calcium	0.010	-	-	-
16	Magnesium	0.016	-	-	-
17	Cadmium	0.06	0.002	6	0.012
Total LPI value using equation 2			0.515	-	3.469

EC is in µmhos/cm, other parameters in mg/l

$$LPI = \sum_{i=1}^{n} \left(\left(\frac{wi.pi}{\Sigma wi} \right) \right) = \frac{3.3205}{0.515} = 6.447$$

Also, the overall pollutant of leachate pollution index and the dumpsite leachate characteristics of the compared to the Federal Ministry of Environment (FMEnv) leachate disposal standards are presented in table 3 and 4 respectively

Table 3: The overall pollutant of leachate pollution index for LA, LB, LC & LD

S/N	Pollutant parameter	LA	LB	LC	LD

1	pH	0.03	0.025	0.0275	0.035
2	EC	-	-	-	-
3	TDS	0.3	0.53	O.40	0.40
4	BOD$_S$	0.61	0.366	0.061	0.366
5	COD	0.434	0.31	0.327	0.343
6	Nitrogen	0.371	0.265	0.265	0.318
7	Phosphate	-	-	-	-
8	Sulphate	-	-	-	-
9	Chloride	0.329	0.49	0.245	0.49
10	Chromium	0.32	0.23	0.384	0.448
11	Copper	0.25	0.25	0.30	0.28
12	Zinc	0.336	0.336	0.392	0.245
13	Iron	-	-	-	-
14	Lead		0.3465	0.315	0.441
15	Calcium	-	-	-	-
16	Magnesium	-	-	-	-
17	Cadmium	0.012	0.010	0.010	0.012
Total LPI Value Using Equation 2		3.433	3.01085	3.3205	3.469

EC is in µmhos/cm, other parameters in mg/l

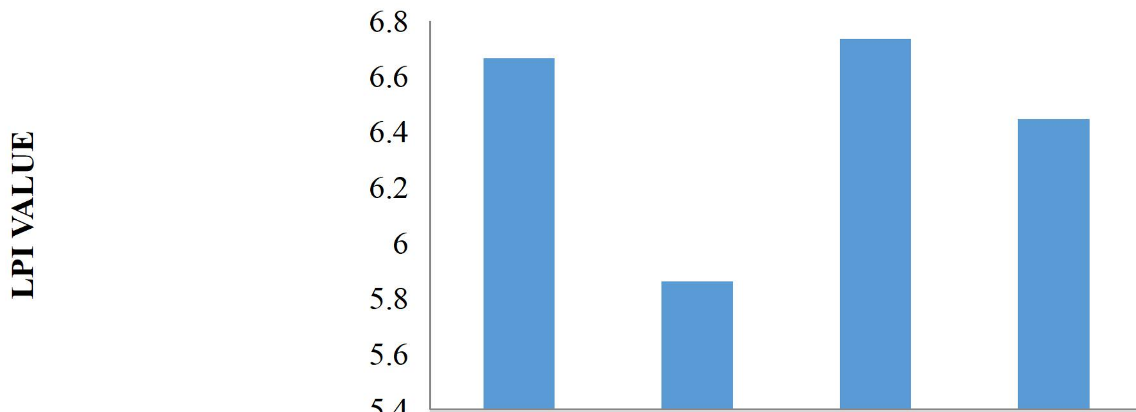
Table 4: Characteristics of the dumpsite leachate and the FMEnv leachate disposal standards

S/N	Pollutant parameter	LA	LB	LC	LD	FMEnv Standard
1.	pH	6.7	6.8	6.5	6.7	6.5-8.5
2.	EC	620	592.1	630	670	_
3.	TDS	491	352.1	2760	3460	500
4.	BODS	324	256.4	2430	2340	_
5.	COD	78.25	86.30	46.10	138.40	_
6.	Nitrogen	29.5	24.8	22.4	32.9	_
7.	Phosphate	4.95	3.24	4.26	5.42	< 5
8.	Sulphate	9.02	10.11	11.17	9.04	500
9.	Chloride	82.47	136.02	115.3	78.42	200
10.	Chromium	0.321	0.354	6.283	0.340	0.05
11.	Copper	0.54	0.74	0.64	0.69	0.1
12.	Zinc	1.78	2.0	1.67	1.88	1.0
13.	Iron	3.128	2.112	4.320	0.814	1.0
14.	Lead	0.018	0.16	0.011	0.05	0.05
15.	Calcium	0.03	0.05	0.010	0.02	_
16.	Magnesium	0.12	0.29	0.16	0.27	0.05
17.	Nitrate	0.07	0.09	0.06	0.03	10

EC is in µmhos/cm, other parameters in mg/l

3.2 Discussion of results

From the foregoing, leachates collected from the various parts of Bauchi metropolis have pH ranges from 6.4 to 6.8, with a mean value of 6.8, this shows alkalinity in the leachates and may be classified based on age as representatives of old dumpsites. The pH values may be attributed to biological property improvement of living matter in the dumpsites. As reported by Bhalla et al., (2013), leachates' pH raised over time mostly due to fall in the amount of free volatile fatty acids that have undergone partial ionization. It is also noticed that, increase in pH of the sites give alarm to the fact that an equilibrium reaction has been achieved between cellulose and lignin degradation and methane formation (acid producing processes and acid consuming processes) at the landfills (Singh et al., 1994). Other researchers such as Kulikowsk and Klimiuk (2008), found similar pH range; 7.46 to 8.61 from old landfill site.



	LA	LB	LC	LD
leachate pollution indices	6.666	5.861	6.736	6.447

Figure 1: Site specifications in leachate pollution index – (shows the site-specific variations in LPI (leachate pollution index).

From the available data, the LPI values of the different sites were found and site-specific variations with the LPI are as presented in Figure 1.

Similarly, the TDS of the dumpsites studied ranges from 352.1 to 3460 mg/l. The mean value is 1747 mg/l, which is more than the 500mg/l, the FMEnv standard. Sample from location LC has the highest TDS probably the mineralization process here is more than at the other sites. This also vindicate that the receiving water has changed significantly (physically and chemically) compared to the other dumpsites. However, these values contradict other researchers' values such as Agbozu and Nwosisi (2015); and Salami et al (2015) who discovered ranges of 70.7 to 4,985.2 mg/L and 581 to 1,960 mg/L respectively in the past. The electrical conductivity of the LA, LB, LC and LD sampling points are respectively 620 µs/cm, 592.1 µs/cm, 630 µs/cm and 625 µs/cm. These have exceeded the standard by the FMEnv (125 µs/cm). Electrical conductivity found here is high. It shows the existence of non-biological material present in the samples and a high pollution level.
The BOD_5 found ranges within 1700 mg/l to 3460mg/l. equally, COD found ranges from 3780 to 4620 mg/l. Salami et al., (2015) found, in their research, values ranging between 798 to 1,396 mg/L and 946 to 1,942 mg/L respectively for BOD_5 and COD. On the other hand, Agbozu and Nwosisi (2015) found much smaller values range: 1.24 to 5.95 mg/l for BOD_5 and 3.10 to 14.87 mg/l for COD in their study. Shubhra et al., (2006) discovered that during initial stage of acidogenic biodegradation, high BOD_5 and COD are always possible. However, in their paper,

Kundiri et al., (2016) discovered that leachates that has been stabilized will have COD ranges between 5,000 to 20,000 mg/L.

Phosphate concentration of LA, LB, LC and LD are 4.95, 3.24, 4.26 and 5.42 mg/l respectively. Sulphate concentration respectively for LA, LB, LC and LD, are 9.02, 10.11, 11.17 and 9.04 mg/l. These are quite below the FMEnv standard of 100 mg/l. Chloride content were in the range of 115.3 to 262.6 mg/l, with LA having the largest content; 262.6 mg/l. Chlorides content mostly range between 200 - 3000 mg/l for 1 to 2 years old landfill and it decreases to a range between 100 – 400 mg/l for landfills between 5 to 10 years old. Therefore, the dumpsites under investigation are said to be mature.

The concentration of heavy metals in landfill leachates is fairly low from tables 2a, 2b, 2c and 2d above. Lead ranged; 0.05 – 0.018 mg/l, zinc ranged; 0.1.67 – 2.0 mg/l, chromium ranges from 0.23 to 6.28 mg/l, copper ranges from 0.54 to 0.74 mg/l and iron ranges from 61 to 82 mg/l. At early stages, heavy metals concentration in any landfill is significantly high as a result of high solubility of metals present. This is in turn due to low value of pH due to the production of organic acids (Christensen et al., 2001; Dinesh Kumar and Babu, 2003). However, higher pH values leads to decreased in the solubility of heavy metal in later times resulting in speedy heavy metals concentration decrease, with exceptionality in lead. Hence the likelihood that heavy metals in all the dumpsites under study decrease in their concentration in years to come is high. Furthermore, as suggested by Shubhra, et al., (2016) metals solubility and mobility may increase when humic substances or other natural/synthetic ligands/complexing, are present. Thus, these ligands present in the dumpsites studied leads to heavy metals concentration increased It is noteworthy that the conditions in each of the studied dumpsites would indicate the concentration heavy metals in later years.

Bauchi dumpsite leachate have heavy metals in high concentration when compared to standard set by the federal ministry of environment (FMEnv) and water limits may be linked to the type of waste present at the dumpsites. Similar to this findings have been found by Kundiri *et al*. (2016) in their studies of heavy metal bioavailability in the leachate from dumpsites in the Metropolitan of Maiduguri, Nigeria, stating that within vicinity of dumpsites, ground water is at high risk of being contaminated by these toxic metals substances. Important enzymes can bind with heavy metals, and this has been known to deactivate the enzymes and also displace some important biological metals, such as Zinc, Calcium and Magnesium. This will interfere with a variety of some chemical reactions in the body (Sanjay, et al., 2009). Also, other dangers including kidney damage, decreased mental capacity, neurological damage, blood and bone disorders are at high risk with exposure to heavy metals, (NIEHS, 2002)

4. CONCLUSION

Pollution of the environment, especially water bodies have much health implications. This is even very dangerous with dumpsite around residential areas.

i. The concentrations of the leachate parameters has been determined and fall below the permissible limits of treated leachates set by the federal government of Nigeria, with the exceptionality in BOD, TDS and lead,.
ii. These properties of leachates when compared with the disposal of treated leachates' standards, indicated a relatively tolerable tendency to contamination of the leachates.

iii. This is seen in the values of LPI of all the dumpsites investigated, as the numerical figures of LPI are below the treated leachates set value, 7.38.

5. RECOMMENDATION

The study recommends exploring other means of obtaining LPIs and compare with the aggregation functions.

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