Assessment of Age Effect of Dumpsite on Biodegradability and Pollution Potentials of Leachate

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Abstract

The increase in world's population has led to increase in waste generation and is a source of concern for stakeholders across the world. These wastes end up in dumpsites which undergo different stages of decomposition thereby producing Leachate which have a tendency of polluting groundwater. This study assessed biodegradability and Leachate Pollution Index (LPI) of dumpsite relative to its age. Three dumpsites Orile (O), Solous 3 (S₃) and Solous 1 (S₁) dumpsites with different ages: - less than 5, between 5-10 and greater than 10 years old respectively were studied. Leachate samples were collected from each dumpsite; Physico-chemical parameters: pH, chloride, Iron, Zinc, Arsenic, Total nitrogen, Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD₅), Total Dissolved Solid, Electricity Conductivity and heavy metal: Lead, Chromium and Copper were analysed to determine the LPI while BOD₅/COD was determined to ascertain the level of biodegradability of the dumpsites. The BOD₅/COD results for O, S₃ and S₁ leachates were in the decreasing order of 0.37, 0.29 and 0.21 respectively while LPI results for: O, S₁ and S₃ leachate were 10.00, 11.20 and 15.68 respectively which were above the standard limit of 7.38. The results showed that O and S₁ dumpsite leachate had least and highest sign of biodegradability respectively. The LPI result showed that O and S₁ dumpsite leachates had the highest and the least pollution potentials respectively. Leachate from dumpsites less than 5 years has higher pollution potentials and lesser biodegradable than leachates from dumpsites more than 5 years. Leachate from O dumpsite will impact negatively on groundwater quality than leachates from S₁ and S₃ dumpsites. The age of a dumpsite leachate determines its pollution potential and biodegradability.

Keywords: Leachate, dumpsite, pollution, biodegradability and solid waste

Introduction

Dumpsites are organized or illegitimate means of solid waste disposal in land depression such as abandoned quarries, excavations or valleys (Clark, 2006). According to El-Fadel *et al.* (2005) dumpsites are widely the most used method of waste disposal in the world in comparison to others such as incineration, recycling etc. In most developing countries of low and medium income, almost 100% of the waste generated goes to dumpsite (Longe and Balogun, 2010). Dumpsites are generally grouped into open dumpsite, controlled dumpsite (engineering landfill) and sanitary dumpsite (engineered landfill).

Dumpsite undergoes phases of decomposition over time, depending on the type of the materials on it. The decomposition occurs under the prevailing influence of climatic conditions and affects the materials differently depending on the quality of the deposits (Barlaz *et al.*, 1991; Ohman, 1991; Perrson, 1996).

The initial anaerobic phase starts immediately the waste is dumped and is a short period depending on the climate. Degradation of waste starts before disposal at the dumpsite, the biodegradable solid

waste reacts with oxygen in the dumpsite to form water and carbon dioxide. The temperature at this stage is about 16.7°C (Ostman *et al.*, 2006).

At the acidic anaerobic phase, sulphate (SO₄) is reduced and hydrogen sulphide (H₂S) is produced. The pH of the leachate is around 5 and at this stage the metal leaching is at its peak.

Oxygen is not required at this stage to breakdown the waste into hydrogen, ammonia, carbon dioxide and organic acid (Ostman *et al.*, 2006). The Methane phase includes the transformation of acetic acid, carbon dioxide and hydrogen into methane by bacteria that are strictly aerobic. Half of the gas produced is methane while half is carbon dioxide.

The breakdown of degradable organic material in the dumpsite leads to formation of leachate which marks the beginning of humic phase (Barlaz *et al.*, 1991). The leachate which accumulates at the bottom of unlined dumpsite and contains heavy metals, organic and inorganic compounds percolates into the groundwater and this poses risk to the groundwater quality (Adewole, 2009). The organic strength of leachate expressed in terms of BOD₅/COD determines the level of biodegradability of a dumpsite leachate. It is necessary to know the variations that occur in the leachate due to biodegradation of MSW and how it impacts on ground water quality.

The LPI is a technique used to determine the pollution potential of dumpsite leachate in a comparative scale. It ranges between 5 and 100 with a standard value of 7.38; any value above 7.38 implies that the dumpsite requires attention in terms of remediation measures. The study is therefore aimed at assessing the pollution potentials of three selected dumpsite leachate in Lagos, Nigeria.

Materials and Methods

The 3 different dumpsites considered in this work were in the age range of less than 5 years and more than 10 years (O; less than 5 years, S₁; between 5-10 years and S₃; above 10 years) which depicts young, intermediate and old dumpsites respectively according to Chain and Dewale, 1976). The S₁ dumpsite (fig. 1) is located in Igando, beside Material Recovery Facility in Alimosho Local Government Area of Lagos State. It started operation on February 1996 and covers a total area of 2.9 hectares with a life span of 10 years. It receives average of 10,000 tons of waste per week (LAWMA, 2011). It is a non engineered, low lying, controlled open dumpsite which lies within the latitude 6° 57' 17''N and longitude 3° 25' 28"E. It has neither bottom liner nor leachate collection and treatment system. The leachates generated find its path into groundwater and surrounding environment.

The S₃ dumpsite (Figure 2) is also located in Igando between the General hospital and mini Water Works in Alimosho Local Government Area of Lagos State. It is an open controlled dumpsite which lies between latitude 6° 33' 54"N and longitude 3° 15' 4"E. It started operation in July, 2008 and covers a total area of 10.4 hectares with an average of 6,000 tons of waste per week (LAWMA, 2011). The dumpsite has no protective lining thereby allowing the percolation of leachate into groundwater. The wastes are dumped without segregation but they are compacted in layers to reduce the volume. It receives unprocessed wastes which range from organic to inorganic. Scavengers are always seen around looking for materials to be recycled or reused.

Figure 1: S₁ dumpsite

Figure 2: S₃ dumpsite

Orile dumpsite (Figure 3) is an open dumpsite which lies within Latitude $6^{\circ}28'42''\text{N}$ and Longitude $3^{\circ}20'46''\text{E}$. It is located opposite Doyin bus stop and beside Orile steel market and at the back of fruit market; it started operation August 2013. The dumpsite receives more of organic materials because it is located near a fruit market. It has no protective lining that inhibits the percolation of leachates into groundwater and the wastes are not being compacted.

Figure 3: O dumpsite

Sampling and analysis

Leachate samples were collected from the base of the waste heaps where the leachates drained out under gravity. The coordinates of collection points were S₁; longitude of $3^{\circ}26'02''\text{E}$ and latitude $6^{\circ}57'09''\text{N}$, S₃; longitude of $3^{\circ}25'60''\text{E}$ and latitude of $6^{\circ}57'18''\text{N}$, O; longitude of $3^{\circ}34'58''\text{E}$ and latitude of $6^{\circ}47'80''\text{N}$. The samples were collected in a 1.5 liters plastic container, labeled accordingly and stored in an iced cooler. The samples were transported to Chemistry Laboratory of the University of Lagos the same day for analysis using standard method (APHA, 2005). Heavy Metals were analyzed with Atomic Absorption Spectrophotometer (AAS) (Perkin Elmer Analyst

200). The Organic strength of the leachate which ascertains the level of biodegradability of each dumpsite was determined by the BOD₅/COD relationship

The Leachate Pollution Index (LPI) was computed by determining the pollutant parameters weight (Wi) and the concentration of the pollutant parameters. The pollutant sub index value (Pi) was deduced from a sub index curve. The pollutant rating was determined as a product of pollutant weight (Wi) and pollutant sub index value (Pi).

The LPI of pollutant parameters less than 18 was calculated using:

$$LPI = \frac{\sum WiPi}{\sum Wi} \quad (1)$$

Where

LPI = Leachate Pollutant Index

Wi = Pollutant weight

Pi = Sub index value

Results and Discussions

The results which showed the age effect on biodegradability and pollution potentials of dumpsites leachates are as presented below:

Biochemical Oxygen Demand (BOD₅)/Chemical Oxygen Demand (COD)

The result of the biodegradability of S₁, S₃ and O dumpsite expressed in terms BOD₅/COD as presented in table 1 below shows that O dumpsite with the highest value is less biodegradable and most unstable compared to S₁ and S₃. This agrees with results opined by Barjinder *et. al.*, (2012) of 0.24, 0.20 and 0.19 mg/l for dumpsites within the age range of 0 – 5 years, 5 – 10 years and 10 years above respectively.

Table 1: Biodegradability of the dumpsite's leachates

S/N	Parameters	S ₁ (> 10 yrs)	S ₃ (5-10 yrs)	O (< 5 yrs)
1	BOD ₅	10.21	146.30	197.29
2	COD	47.04	498.69	532.29
3	BOD/COD	0.21	0.29	0.37

The BOD₅ leachate value from O, S₃ and S₁ dumpsite were 197.29, 146.03 and 10.21 mg/l respectively. This is not in agreement with Zainol *et. al.*, (2012) for young leachate (less than 5 years) and old leachate (more than 5 years). The BOD₅ leachate values from O dumpsite and S₃ dumpsite were above the Federal ministry of environment limit of 30 mg/l while that from S₁ is less than the limit.

The COD is the measure of amount of oxygen required to completely oxidize chemically the organic waste constituents to inorganic end products in a given mass of leachate sample. The leachate COD value for O, S₃ and S₁ dumpsite were 532.68, 498.64 and 40.33 mg/l respectively. The value of COD from O and S₃ dumpsite were above the limit of Federal Ministry of Environment 75 mg/l. This also shows that S₁ is at stable methanogenic phase while O and S₃ are at anaerobic acid phase.

Tables 2, 3 and 4 showed the Leachate Pollutant concentrations and rating of S₁, S₃ and O dumpsites.

Table 2: Leachate Pollutants Concentration and Rating for Solous 1

S/no	Leachate pollutant parameter	Pollutant weight (wi)	Pollutant concentration (mg/l)	Pollutant sub index value (Pi)	Pollutant rating (wiPi)
1	pH	0.055	9.020	4.00	0.220
2	TDS	0.050	5015.27	10.00	0.500
3	Cl	0.048	29.90	5.00	2.400
4	SO ₄	-	325.70	-	-
5	Cr	0.064	0.05	5.00	0.320
6	Cu	0.050	0.13	5.00	0.250
7	Fe	0.045	0.44	5.00	0.250
8	Pb	0.063	0.32	5.00	0.225
9	Zn	0.056	2.75	5.00	0.280
10	As	0.061	0.02	5.00	0.305
11	BOD ₅	0.061	76.76	6.50	0.397
12	COD	0.062	847.07	10.00	0.625
13	Total Cyanide	0.058	0.05	5.00	0.270
14	Total ammonium nitrate	0.051	917.07	35.00	1.785
15	Total nitrogen	0.050	305.69	3.30	0.615
16	Coliform bacteria	0.052	4.4 x 10 ⁴	95.00	2.375

Table 3: Leachate Pollutants Concentration and Rating for Solous 3

	Leachate pollutant parameter	Pollutant weight (wi)	Pollutant concentration (mg/l)	Pollutant sub index value (Pi)	Pollutant rating (wiPi)
1	pH	0.055	7.90	3.0	0.165
2	TDS	0.050	11,945.77	17.5	0.875
3	Cl	0.048	14.99	5.0	0.240
4	SO ₄	-	301.50	-	-
5	Cr	0.064	0.03	5.0	0.270
6	Cu	0.050	0.02	5.0	0.025
7	Fe	0.045	0.49	5.0	0.225
8	Pb	0.063	0.30	5.0	0.315
9	Zn	0.056	2.80	3.0	0.168
10	As	0.061	0.02	4.0	0.244
11	BOD ₅	0.061	146.30	5.0	0.305
12	COD	0.062	498.64	5.0	0.310
13	Total Cyanide	0.058	0.57	5.0	0.290
14	Total ammonium nitrate	0.051	1455.69	20.0	1.020
15	Total nitrogen	0.050	485.23	40.0	2.000
16	Coliform bacteria	0.052	4.40 x 10 ⁴	55.0	2.860

Table 4: Leachate Pollutants Concentration and Rating for Orile dumpsite

S/No	Leachate pollutant parameter	Pollutant weight (wi)	Pollutant concentration (mg/l)	Pollutant sub index value (Pi)	Pollutant rating (wiPi)
1	pH	0.055	4.500	5.0	0.275
2	TDS	0.050	909.000	8.0	0.400
3	Cl	0.048	183.840	5.0	0.240
4	SO ₄	-	960.000	-	-
5	Cr	0.064	0.032	5.0	0.027
6	Cu	0.050	0.516	9.0	0.030
7	Fe	0.045	0.418	5.0	0.225
8	Pb	0.063	0.090	5.0	0.315
9	Zn	0.056	3.730	5.0	0.280
10	As	0.061	0.500	10.0	0.610
11	BOD ₅	0.061	197.290	5.0	0.305
12	COD	0.062	532.280	5.0	0.310
13	Total Cyanide	0.058	0.950	15.0	0.870
14	Total ammonium nitrate	0.051	5.890	35.0	1.785
15	Total nitrogen	0.050	1.960	45.0	2.250
16	Coliform bacteria	0.052	1.940 x 10 ⁴	100.0	5.200

Leachate pollution index (LPI) of dumpsites

The value of LPI for O, S₃ and S₁ dumpsites were 15.86, 11.20 and 10.00 respectively as shown in Figure 5. The normal LPI value that will pose no threat to groundwater quality according to Kumar and Allapat (2005) is 7.38. This result shows that O dumpsite which is young (less than 5 years) has more pollution potential than S₃ and S₁ dumpsites which are intermediate (between 5 - 10 years) and old (more than 10 years) respectively.

Figure 5: Leachate Pollution Index (LPI) of the dumpsites

CONCLUSION

High BOD₅ and COD value of Orile and Solous 3 dumpsites leachates indicated that both dumpsites are in their acid anaerobic phase which is characterized by low value of pH and high risk of metal leaching whereas the BOD₅ and COD value of Solous 1 dumpsite leachate revealed that it is at methane phase which is characterized by high value of pH, emission of gas, low risk of metal leaching and low decomposition of organic compounds.

The study showed that Leachate from Orile dumpsite has a biodegradability value higher than Leachate from Solous 3 and Solous 1 dumpsites. This implies that biodegradability of a dumpsite increases with age, as shown in the leachates of the dumpsites of various ages considered.

Furthermore, the study also revealed that Leachate Pollution Index of younger dumpsites was higher than older ones. This indicates that younger dumpsite leachate has higher pollution potential than older dumpsite leachate.

It can also be deduced that Orile dumpsite which has high Leachate Pollution Index and biodegradability value poses more danger to groundwater quality than Solous 3 and Solous 1. A liner is therefore recommended to mitigate its negative impact on the groundwater quality.

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