Investigation of Groundwater Quality near a Municipal Landfill Site (IGQMLS)

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***Abstract*—Groundwater contamination due to Municipal Landfill Site (MLS) is a serious threat to groundwater integrity. This current research characterized leachate from Solous Landfill Site and assessed the groundwater quality at different distances from the landfill site. The contaminants examined are Lead, Zinc, Copper, Nickel, Chromium, Iron, Manganese, Magnesium, Calcium, Sodium, Potassium and Chloride. Descriptive Statistical tools especially mean, variation, standard deviation, standard error and coefficient of variation were used to analyze the basic features of the results. The mean, variance, and standard deviation in this work were found to have the following ranges respectively 0.004 to 1.3314, 2.56×10^{-6} to 5.76×10^{-2} and 1.60×10^{-3} to 2.40, while standard error and coefficient of variance were also found to have the following ranges 7.15×10^{-4} to 1.07×10^{-1} and 1.00×10^{-2} to 6.9×10^{-1} in that order. The results showed that the concentration levels of contaminants examined in groundwater samples fall within the maximum acceptable concentration stipulated by World Health Organization (WHO) and National Agency for Food and Drug Administration and Control (NAFDAC), however, it is necessary to upgrade the Landfill Site to prevent future contamination of groundwater.**

***Index Terms*—Contaminant, groundwater, landfill, threat.**

I. Introduction

The intensity of man's activities has led to increasing volume of solid waste worldwide, despite the current level of technological advancement and industrialization. Explosive population growth is one major factor responsible for increased municipal solid waste (Longe and Balogun, 2010). Solid waste includes all the discarded solid materials from commercial, municipal, industrial and agricultural activities. (Henry and Heinke, 1989). Landfilling of Municipal Solid Water (MSW) is a common waste management practice and of the cheapest methods for organized Waste Management in many parts of the world (El-Fadel et al, 1997; Jhamnani and Singh, 2009; and Longe and Balogun, 2009). However poorly designed landfills can create contamination of groundwater, soil and air. The most commonly reported danger to human health from various landfills is from the use of groundwater that has been contaminated by leachate (Chain and DeWalle, 1976; Kouzeli-Katsiri, et al, 1999; Farquhar, 1989; and Saarela, 2003).

The precipitation that falls into a landfill, coupled with any disposed liquid waste, results in the extraction of water soluble compounds and particulate matter of the waste and the subsequent formation of leachate. The creation of leachate presents a major threat to the current and future quality of groundwater. Leachate composition varies relative to the amount of precipitation and the quantity and type of waste disposed. In addition to numerous hazardous constituents, leachate generally contains non-hazardous components that are also found in most groundwater systems.

These constituents include dissolved metals (e.g. Iron and Manganese), Salts (e.g. Sodium and Chlorides) and an abundance of common anions and cat ions (e.g. bicarbonates and sulfates).

However, these constituents in leachate typically are found at concentrations that may be in order of magnitude greater than concentrations present in natural groundwater systems.

Threats to the groundwater from the unlined and uncontrolled landfills exist in many parts of the world particularly in the underdeveloped and developing countries where the hazardous industrial waste is also co-disposed with municipal waste and no provision to separate secured hazardous landfills exist (Kumar and Alappat, 2003; Ogundiran and Afolabi, 2008; Tricys, 2002; Yusuf, 2007). Even if there are no hazardous wastes placed in municipal landfills, the leachate is reported as a significant threat to the groundwater. A number of incidences have been reported in the past where leachate had contaminated the surrounding soil and polluted the underlying groundwater aquifer or nearby surface water (Kumar et al, 2002; Kumar and Alappat, 2003; Masters, 1998; Lo, 1996; Chain and DeWalle, 1976 and Kelly, 1976). This paper therefore aimed at characterizing leachate and assessing the level of groundwater contamination due to leachate percolation from the unlined Solous Lanfill Site in Igando Area of Lagos State as the leachate characterization and assessment of groundwater quality in the area is both timely and important which justifies this work.

II. Materials and Methods

A. Study Area

The Solous Landill Site is situated at Ikotun / Igando Local Council Development Area of Alimosho Local Government in Lagos State, Nigeria. The landfill site covers approximately 3.2 hectres, surrounded by commercial, industrial and residential set-ups. It started operation in 1996 and has witnessed rehabilitation which comprised reclamation of land, construction of accessible roads for ease of tipping, spreading and compaction of waste since inception (Longe and Balogun, 2010).

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The wastes are of different types, ranging from organic to inorganic, hazardous and non-hazardous. Just like all other existing landfills in the state, the waste stream is made up of domestic, market, commercial, industrial and institutional origins (Longe and Balogun, 2010). The Solous Landfill Site shown in plate 1 is a non engineered landfill with a huge heap of waste. Trucks from different parts of Lagos State collect and bring wastes to this site and dump them in irregular fashions. After dumping the wastes indiscriminately and without any separation, the ‘rag-pickers’ who constitute the informal sector rummage through the waste and help in segregating them by collecting the plastic and metals which are then sold to the recycling industrial outfits. However, the major source of water for people in this area is groundwater.

B. *Sampling of Leachate and Groundwater*

Since the landfill site was not equipped with a leachate collector, leachates were collected at the base of the landfill randomly from four different locations and were mixed prior to their analyses. The leachate samples were taken to determine the contaminants concentrations. Leachate samples were collected using one cubic meter (1 m^3) plastic bottles that has been cleaned by soaking in 10% Tri ox-o Nitrate V acid (HNO_3) and rinsed with distilled water. At the sampling site, the bottles were rinsed three times with the leachate to be sampled prior to filling and labeled LS (i.e. Leachate Samples).

In an effort to assess the groundwater quality, five sampling sites were selected within 500 m from the landfill site where samples were taken. Details of the sampling points are presented in Table I. Samples were collected using one cubic meter (1 m^3) plastic bottles which had been thoroughly cleaned by soaking in 10% Tri ox-o Nitrate V Acid (HNO_3) and rinsed three times with groundwater to be sampled prior to filling and the five bottles were labeled GW1 to GW5

C. *Analytical Method*

After sampling the leachate and groundwater, the samples were quickly transferred under black cellophane wrappers to the Laboratory and stored in a cold room (4^{o}C). The analyses were commenced without delay in the laboratory based on the priority to analyses parameters as prescribed by the Standard Methods for the Examination of Water and Wastewaters (APHA, 1992). The analyses of contaminants concentrations such as Fe, Cu, Pb, Cr, Cd, Ni, Zn, Mn, Na, K, Ca, Mg, and Cl of Leachate and groundwater samples were determined using a modern Atomic Absorption Spectrophotometer (AAS).

TABLE I: SITE SPECIFICATION FOR SAMPLES

Sample Code	Sampling Location	Distance from Landfill Site (m)	Depth (m)
GW 1	Commercial Centre	64	22
GW2	Block Industry	103	22
GW3	Religious Centre	194	22
GW4	Religious Centre	235	22
GW5	Residential Building	296	22
LS	Solid waste landfill	-	-

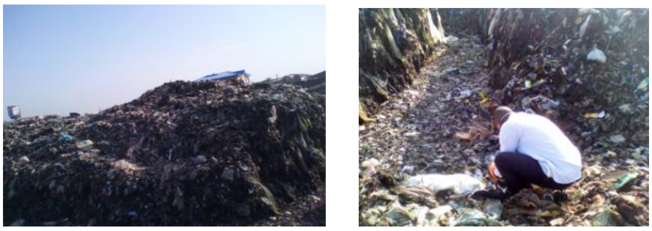

Fig. 1. (a) View of solous landfill site. (b) Sampling at the solous landfill site

III. RESULTS

TABLE II: CHARACTERISTICS OF LEACHATE FROM SOLOUS LANDFILL AND GROUNDWATER SAMPLES FROM NEARBY LOCATIONS

S/N	CONTAMINANTS (Mg / m^3)	LS	GW1	GW2	GW3	GW4	GW5
1	Pb	0.010	0.009	0.006	ND	0.001	0.004
2	Cd	0.006	ND	ND	ND	ND	ND
3	Zn	0.861	0.461	0.986	0.424	0.594	0.281
4	Cu	0.189	0.046	0.052	0.061	0.059	0.060
5	Ni	0.196	0.028	0.036	0.019	0.020	0.016
6	Cr	0.011	0.010	0.011	0.014	0.012	0.014
7	Fe	0.156	0.110	0.121	0.116	0.122	0.134
8	Mn	0.326	0.324	0.332	0.451	0.432	0.338
9	Mg	1.067	1.020	1.004	1.022	0.671	0.771
10	Ca	1.204	1.611	1.422	1.301	1.201	1.122
11	Na	0.451	0.456	0.551	0.523	0.442	0.412
12	K	0.310	0.330	0.312	0.351	0.304	0.256
13	Cl	98.000	88.000	56.000	94.000	64.000	77.000

*ND: Not Detected

TABLE III: GUIDELINE ON DRINKING WATER BY WORLD HEALTH ORGANIZATION (WHO) AND NATIONAL AGENCY FOR FOOD AND DRUG ADMINISTRATION AND CONTROL (NAFDAC).

S/N	CONTAMINANTS (Mg / m^3)	Maximum Acceptable Concentration by W.H.O	Maximum Acceptable Concentration by NAFDAC
1	Pb	0.01	0.01
2	Cd	0.003	-
3	Zn	5.0	5.0
4	Cu	2.0	-
5	Ni	-	-
6	Cr	0.05	-
7	Fe	0.05 – 0.30	-
8	Mn	0.5	-
9	Mg	50	30
10	Ca	50	75
11	Na	-	-
12	K	1.0 - 2.0	10
13	Cl	200	200

Source: NAFDAC (2010)

IV. DISCUSSION

The soil stratigraphy of Solous Landfill consists of clay, intercalated with lateritic clay. This litho logy is capable of protecting the underlying confined aquifer from leach ate contamination (Longe and Balogun, 2010). This assertion could not be true of water table aquifer which has high contamination risk potential (Longe et al, 1987; Longe and

Balogun, 2010). The sub-surface geology of Solous Landfill Site is similar to that of Olushosun Landfill and thus suitable for an attenuation landfill (Longe and Enekwechi, 2007; Longe and Balogun, 2010) but entirely different from both Ewu Elepe (a surbub of Ikorodu) and Epe Landfill Sites, also in Lagos State.

TABLE IV: DESCRIPTIVE STATISTICS FOR CHARACTERISTICS OF GROUNDWATER SAMPLES

S/N	CONTAMINANTS (Mg / m^3)	Range	Mean	Variance	Standard Deviation	Standard Error	Coefficient of Variation
1	Pb	0.005	0.004	7.60x10^{-6}	2.76 x10^{-3}	1.23 x10^{-3}	0.690
2	Zn	0.705	0.549	5.76x10^{-2}	2.40 x10^{-1}	1.07 x10^{-1}	0.455
3	Cu	0.015	0.0556	3.30x10^{-5}	5.75 x10^{-3}	2.57 x10^{-3}	0.103
4	Ni	0.02	0.0242	5.30x10^{-5}	7.28 x10^{-3}	2.57 x10^{-3}	0.103
5	Cr	0.004	0.0122	2.60x10^{-6}	1.60 x10^{-3}	7.15 x10^{-4}	0.131
6	Fe	0.024	0.1210	6.30x10^{-5}	7.95 x10^{-3}	3.55 x10^{-3}	0.066
7	Mn	0.113	0.379	2.70x10^{-3}	5.15 x10^{-2}	1.03 x10^{-2}	0.136
8	Mg	0.351	0.8976	2.20x10^{-2}	1.48 x10^{-1}	6.6 x10^{-2}	0.165
9	Ca	0.489	1.3314	3.00x10^{-2}	1.72 x10^{-1}	7.7 x10^{-2}	0.129
10	Na	0.139	0.478	2.70x10^{-3}	5.20 x10^{-2}	2.30 x10^{-2}	0.109
11	K	0.074	0.311	1.00x10^{-6}	3.17 x10^{-3}	1.42 x10^{-3}	0.010
12	Cl	38.000	75.80	202.56	14.23	6.364	0.188

Table II shows the contaminants concentrations in leachate and groundwater samples taken in July, 2012 while Table III shows the guideline on drinking water by World Health Organization and National Agency for Food and Drug Administration and Control. Table IV shows the descriptive statistics for contaminants in groundwater samples.

As distance increases from the landfill site, the concentration of contaminants is expected to decrease. (Jhamnani and Singh, 2009). However, this is not the case in the results of this study (Table II) except for Calcium, Sodium, Potassium and Chloride concentrations which are in line with the work of Jhamnani and Singh, (2009). The concentration of contaminants measured conforms to the Guideline on Drinking Water by both World Health Organization and National Agency for Food and Drug Administration and Control. The mean, variance and standard deviation of contaminants except for chloride range from 0.004 to 1.3314, 2.56×10^{-6} to 5.76×10^{-2} and 1.60×10^{-3} to 2.40 respectively while standard error and coefficient of variance range from 7.15×10^{-4} to 1.07×10^{-1} and 1.00×10^{-2} to 6.9×10^{-1} respectively.

Though the level of contaminants measured in ground water fall within the guideline of WHO and NAFDAC for Drinking Water, there is possibility that in future, as leachates builds up and accumulates, they will percolate through the sub-soil of Solous Landfill Site and contaminate the groundwater which will make it unfit for drinking. Therefore, there is the need to upgrade the Landfill Site. The soil stratigraphy of Lagos Metropolis makes land filling operation very risky, especially when one considers the prevalent high water table in Lagos. However, the stratigraphy at Solous Landfill Site consisting of clay and silty clay appears to have significantly influenced the moderate level of contaminants found in groundwater samples (Longe and Balogun, 2010). Solous Landfill Site started operation sixteen years ago. The age of the landfill and volumes of operation are also contending favorable factors.

In this study, the concentration of leachates increased from the Landfill Site as distance increased. One possible reason is that it rained heavily from early April to July, 2012. The rate of percolation of leachates when the downpour began heavily in Lagos (Early April) might be high. However, after some weeks of raining, the percolation rate might be slow, leading to less saturation of contaminants in the leachates at the Landfill Site.

Again, the Landfill Site is in a somewhat valley-like topography as a result of which the surroundings are on elevated environment. I therefore recommend that further study should be done probably during the dry season, especially between November and February the other year. The results then can be compared with the ones in this work,

V. CONCLUSION

Descriptive statistics which provides summary about the samples and measures such as mean, variance, standard deviation, standard error and coefficient of variance have been applied to describe the basic features of the results of the work. The calculated results ranged from 0.004 to 1.3314, 2.56×10^{-6} to 0.0576, 1.60×10^{-3} to 2.4×10^{-1}, 7.15×10^{-4} to 0.107 and 0.01 to 0.69 respectively excluding chloride. The contaminants concentration is expected to decrease as the distance from the landfill increases, but the results of this work do not conform to such a pattern. The contaminants concentration in groundwater samples fall within the Guideline of Maximum Acceptable Concentration for Drinking Water by both World Health Organization and National Agency for Food and Drug Administration and Control. However, upgrading of Solous Landfill is highly recommended to prevent future contamination of groundwater within the vicinity.

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