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Environmental risk assessment of a tropical landfill: a case study of Aladinma landfill, Imo state, eastern Niger delta basin, southeastern Nigeria

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ABSTRACT

Environmental risk assessment of Aladinma Landfill in Owerri metropolis of Imo State, Eastern Niger Delta Basin, Southeastern Nigeria was investigated by analyzing the soil and ambient air quality within the landfill as well as nearby surface and groundwater resources using standard soil equipment, Growcon digital gas monitors, standard plate count and Atomic Absorption Spectrophotometer (AA S) . The results of the soil analysis shows that the soil samples obtained at depths of 1.0m and 2.5m within the landfill are acidic (pH range: 5.40- 6.30). The mean concentrations of Cd^{2+} and Pb^{2+} in the soil at the depth of 1.0m are 466.67 and 412mg/kg respectively while the mean values at 2.5m depth are 406.67 and 406mg/kg respectively; these values are not in conformity with PCD soil standard. Except for Na^{+} , Cu^{2+} and PO_4^{3-} , all other measured chemical parameters in the soil decreases with increase in depth. The ambient air quality analysis within the landfill shows that the mean concentrations of NO_2 and SO_2 are 0.33 and 15.33 ppm respectively and these values do not conform with United State Environmental Protection Agency (USEPA) 2004 ambient air quality standard. Other measured gaseous emissions were in conformity with USEPA (2004) air quality standard. The investigation also show that about 1,500 persons who live 100m away from the landfill are at very high risk to the effects of air pollution from the landfill while about 12,000 persons who live 5km from it are at low risk. The chemical analysis of groundwater within 4km from the landfill indicates that they are acidic (pH range: 6.30-6.45). Although the pH of the closest surface water (Otamiri River) located at a distance of about 8km from the landfill conformed with World Health Organization(WHO) 2006 drinking water standard, the microbial assay did not conform with the standard. Other measured chemical parameters in the groundwater and surface water were in conformity with WHO (2006) standard. The acidic nature of the soil within the landfill as well as the groundwater resources near it is attributed to the high concentrations of $SO_2$and NO_2 at the landfill while the high concentrations of Cd^{2+} and Pb^{2+} in the soil at the depths of 1.0 and 2.5m are mainly from the electronic waste which constitute about 6% of the wastes in the landfill. The pH of the soil can be corrected using lime while that of the groundwater can be corrected using sodium bicarbonate (Na_2CO_3); the high levels of SO_2 and NO_2 can be minimized by installing scrubbers at the landfill. The direct health impacts such as respiratory sickness arising from gaseous emissions (SO_2, NO_2, CH_4,CO) at the landfill can be reduced by relocating people who live very close to the landfill and preventing scavengers who do brisk business at the landfill. The gases can also be processed and treated to produce electricity, heat, fuels and various chemical components. However, the long term solution to the risk offered by the landfill is its replacement by a sanitary landfill.

Introduction

There are six principal methods of disposing solid wastes and they are: sanitary landfill, ordinary landfill, on -site incineration, swine feeding, composting and open dump. These disposal methods can constitute

A threat to the environment if not properly handled. However, sanitary landfill has been recognized as the best method of disposing solid wastes. This is based on the minimal environmental impacts offered by this method. Unfortunately, sanitary landfill which emerged in the early 1930,s is yet to be embraced by many Nations of the World especially the developing ones. In Nigeria, where the study area (Fig. 1) is located, ordinary landfill is a common method of disposing solid wastes. The landfills are mostly abandoned quarries and burrow pits and they constitute a variety of environmental risk (air quality degradation, soil and water pollution and direct health impacts). The Aladinma Landfill

(Fig. 1), is located on an elevation of about 73m above sea level in Owerri metropolis of Imo State, Eastern Niger Delta Basin, Southeastern Nigeria. It is precisely located within latitudes 5° 26′ N and 5° 29′ N and longitudes 6 ° 58 ′E and 7 ° 10 ′ E (Fig. 1). The landfill which is about 7.5km^2 receives a variety of wastes (Table 1) from the inhabitants of Owerri metropolis and environs. It was established in 1990 by the Imo State.

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Environmental Protection Agency (ISEPA). The location of the landfill at the heart of Owerri metropolis, the capital of Imo State calls for regular environmental risk assessment. Apart from risk to urban dwellers, the landfill is also a threat to the soil within and around the landfill as well as nearby groundwater and surface water resources.

Table 1: Classification of Wastes at Aladinma Landfill

Serial Number	Type of Waste	Composition %
1	Vegetable/Food	60
2	Plastics	12.20
3	Electronic Waste (E-Waste)	6
4	Textile	1.40
5	Leathers	0.80
6	Sand/Dirts	1.60
7	Ashes	0.40
8	Paper	6.50
9	Metals	1.00
10	Bottles/Glass	10.1

Figure 1: Map of the study area showing sample locations

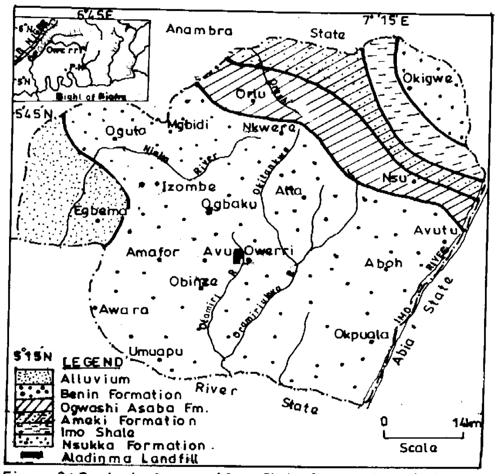


Figure 2 : Geological map of Imo State Showing the study area

Although some studies (Ahiarakwem, 2011, Ahiarakwem, 2004, Ibe and Onu, 1999) have been carried out on some landfills in some parts of Imo State , the Aladinma landfill which is a prominent disposal site is yet to be studied. The proximity of the landfill to urban dwellers and water resources calls for regular environmental evaluation within and around the landfill. The high population growth rate of the area is a further factor that supports the need for constant environmental risk assessment. The population of Owerri metropolis which was 400,000 and 1,197, 000 in 192 and 1991 respectively has been estimated to rise over 3,000,000 in 2012 (World Gazetteer 2011).

Climatic Setting

The Aladinma landfill is located within the equatorial rain forest belt of Nigeria. The mean monthly temperature of the area varies from 25 to 28.5 ^{o} C while the mean annual rainfall is about 2.500 mm most of which fall between the months of May and October (National Root Crop Research Institute' 2011). The rainy season (May-October) is usually characterized by moderate temperature and high relative humidity. The months of November to April have scanty rainfall, higher of temperature and low relative humidity (National Root Crop Research Institute, 2011). The wind direction in Owerri area and environs (of which the study area is a part) is mainly South-West, North-West and West. However, the South-West wind direction is the strongest (Anyanwu and Iwuagwu. 1994). The wind direction is a major factor that controls the dispersal of the gaseous emissions within and around the landfill.

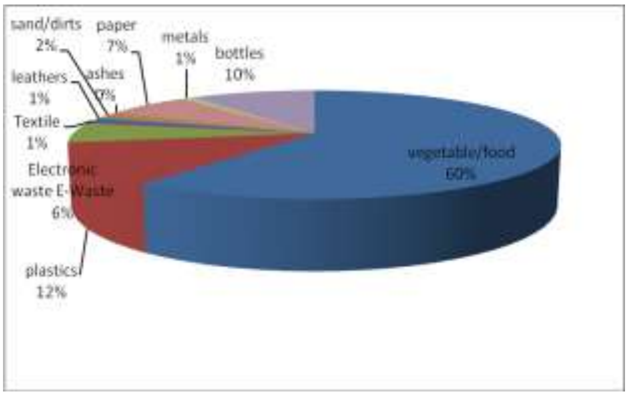


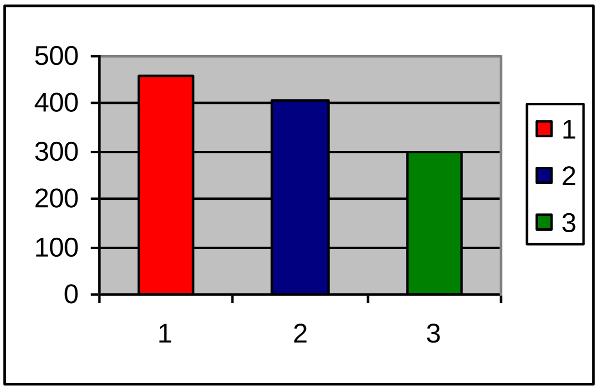
Figure. 3. Composition (%) of Aladinma landfill wastes

Geology and hydrology

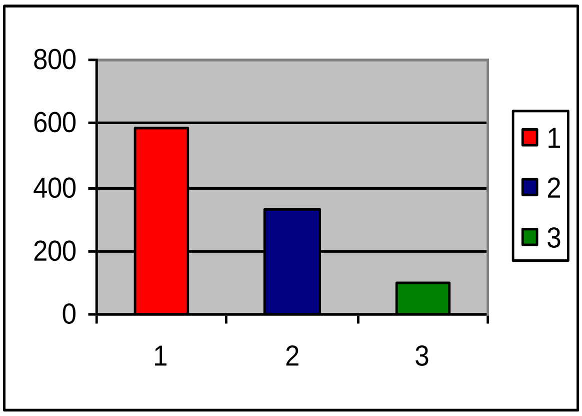
The study area is underlain by the Benin Formation which is a major stratigraphic unit in the Niger Delta basin of Nigeria (Fig.2). The Benin Formation consists of friable sands with intercalations of shale/clay lenses of Pliocene to Miocene age. The formation contains some isolated gravels, conglomerates and very coarse sandstone (Ananaba et al.,1993). The average thickness of the formation in the study area is about 800 m while the average depth to water table is about 29 m (Avbovbo, 1978).The study area is drained by River Otamiri (Fig. 1). The river flows Southwards from Egbu past Owerri and through Nekede, Ihiagwa, Eziobodo, Olokwu Umuisi, Mgbirichi and Umuagwo (all in Imo State) to Ozuzu in Etche in Rivers State, from where it flows to the Atlantic Ocean. The Otamiri river watershed which covers about 10,000km^2 contains depleted rain forest vegetation. The river provides water for both domestic and commercial purpose; It is also used for fishing, recreation and sand extraction activities. The rivers also serves as tourist and research center. The study area is also blessed with abundant groundwater resources which are also used for domestic and commercial water supply among others. The aquifer rocks of the area is unconfined and the overlying sediments are highly porous and permeable (Uma, 1984).

Materials and methods

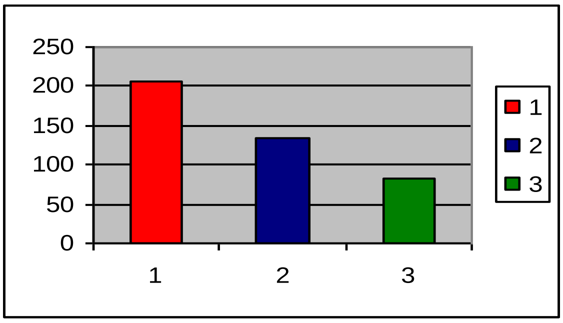
A total of three groundwater and one surface water (Otamiri River) samples were investigated. The water samples were obtained with the aid of sterilized 1.5 liters plastic containers using the grab sampling method. In this method, the sample bottles were corked immediately the samples were obtained so as to prevent the oxidation of the constituents. The water samples were sent to the laboratory within 24 hours of collection for analysis. The physical parameters (pH, electrical conductivity, Total Alkalinity, TDS and DO) in the surface water and groundwater resources were determined using digital meters. The BOD was determined after incubating the water samples in the dark for five days at 25^{o} C and measuring the dissolved oxygen consumed. The cations and anions in the water resources were determined using Atomic Absorption Spectrophotometer (AAS) while the microbial assay of the water resources were determined using standard plate count. Soil samples (within the landfill) were obtained at depths of 1.0, 1.5 and 2.5m respectively using the hand auger. However, soil samples at a neutral point located at about 10km away from the landfill was obtained at the depth of 1.0m. The soil samples were were obtained in clean black polyethylene bags and sent to the laboratory within 24 hours of collection for analysis. The samples were given Nitric hydrochloric acid digestion followed by filtration through 0.45 micron membrane. The resultant filtrate were aspirated into AAS equipment analyzed for sodium, calcium, magnesium, potassium, chromium, zinc, copper, lead, nickel, cadmium, manganese, barium, iron, sulphate, chloride and phosphate. The microbial assay of the water resources near the landfill was determined using standard plate.



Cd $^{2+}$



Mn $^{2+}$



$\mathbf{SO_4^{2-}}$

The concentrations of gaseous emissions (CO, NO_2, SO_2, NH_3, H_2 S and CH_4) within and around the landfill were determined at six gauge stations using Growcon digita gas monitor which is calibrated in parts per million (ppm). The gas monitors was also used to measure the gaseous emissions at a neutral point which is located at a distance of about 10km from the landfill.

The concentrations of the major cations and anions in milligram/liter (mg/l)were converted to milliequivalent/liter (meq/l) using the equation 1 (Clark et. al.,1977) below:

$$\text{Milliequivalent/liter (meq/l)} = \frac{\text{Milligram /liter}}{\text{Equivalent mass}} \quad \text{……..equ. 1}$$

The concentrations in meq/l were used to prepare Piper trilinear and Stiff diagrams as well as calculation of Sodium Adsorption Ratio (SAR). The SAR was determined using the equation developed by Wilcox (1955).

$$SAR= \frac{Na^{+}}{\sqrt{\frac{(Ca^{2+} + Mg^{2+})}{2}}} \quad \text{…………..equ. 2}$$

The parameters considered for the determination of the pollution index (PI) of the water samples were pH, Total Alkalinity, Total Hardness, Total dissolved solids (TDS), sulphate and chloride. The PI was calculated using the equation developed by Horton (1965).

$$PI= \sqrt{\frac{(maxC_i/L_j)^2 + (meanC_i/L_j)^2}{2}} \quad \text{……….equ.3}$$

Where

C_i = concentration of chemical parameters

L_j = World Health Organization (2006) permissible limit.

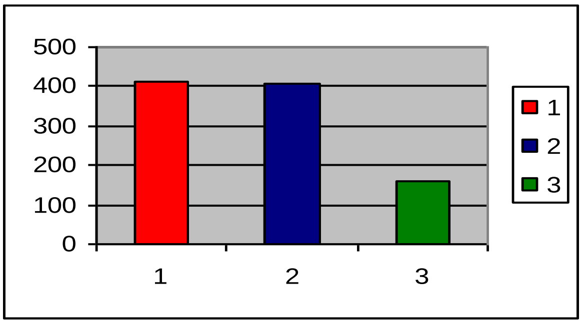
Groundwater vulnerability

The groundwater vulnerability of the study area was determined using the GOD model developed by Marga, (1968); where:

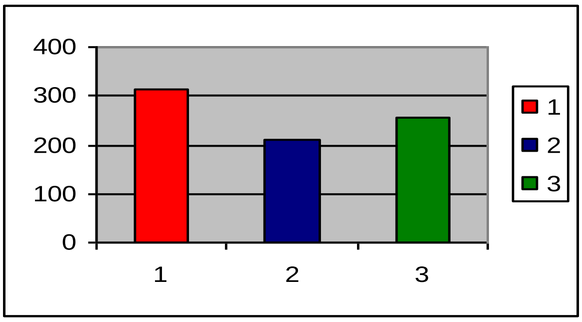
G= Groundwater aquifer type (confined, unconfined, etc)

O=Overlying sediments above the aquifer (sands, silts, etc)

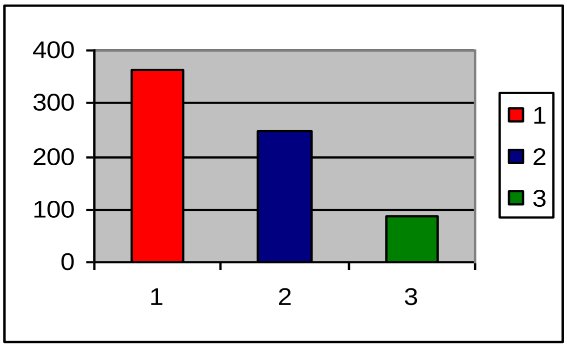
D= Depth to water table



Pb $^{2+}$



$\mathbf{Na^{+}}$



Cl^-

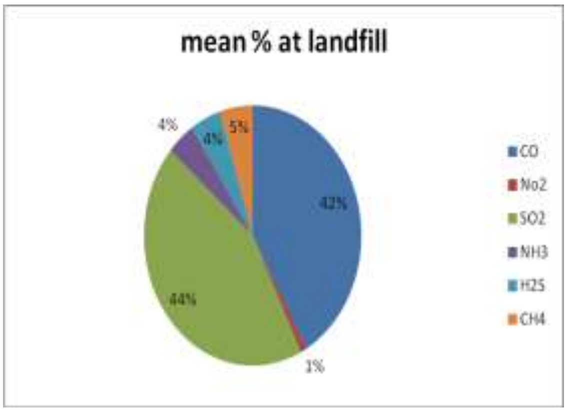


Figure. 5. Mean concentrations (%) of gaseous emission at landfill

Results and discussion

The composition of the Aladinma wastes is shown in Table 1 while the chemical analysis of the soil at landfill is summarized in Table 2. The chemical analysis of soil at a neutral point located about 10km away from the landfill as well as ambient air quality are shown in Tables 3 and 4 respectively. The hydro-geological data and biochemical analysis of groundwater and surface water resources near the landfill is shown in Table 5 while he concentrations of major cations and anions of the water resources is shown in Table 6. The pollution index of water resources is indicated in Table 7.

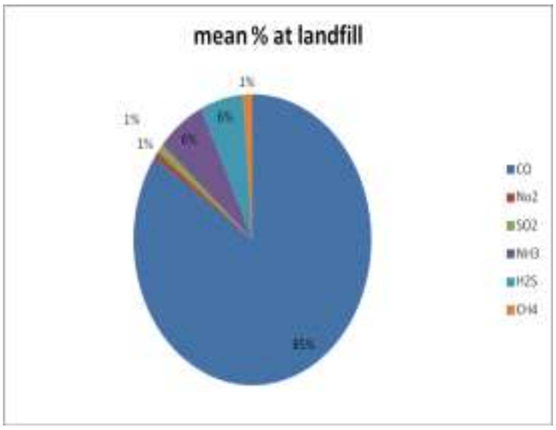


Figure. 6.Concentration (%) of gaseous emissions at neutral point.

Composition of Aladinma wastes

The wastes (Table1) disposed at Aladinma landfill consists of vegetable/food (60%), plastics (12.20%), bottles/glass (10.10%), paper (6.50%) and electronic waste or E-waste (6%). The composition of the waste is also illustrated in a pie chart (Fig. 3).These wastes are derived from various sources such as residential homes, industries, institutions, hotels and hospitals to mention but a few. The quantity of plastic materials and bottles/glass at the landfill attracts human scavengers who makes brisk business at the risk of their lives. An average of twenty scavengers visits the landfill on daily basis and this number of people stands the risk of contacting respiratory sickness and cancer. Apart from the human scavengers, the bottles and plastic cans disposed at the landfill are commonly used to produce fake materials such as drugs and bottled water and this constitute a risk to consumers of such products.

Soil chemistry

The results of the analysis of the soil (Table2) within Aladinma landfill shows that the mean concentrations of pH at depths of 1.00, 1.50 and 2.50m does not conform with PCD soil standard; the results also indicates that the mean concentrations of Cd^{2+} and Pb^{2+} at depths of 1.0 and 2.50m respectively are not in conformity with PCD soil standard.

pH

The mean concentrations of pH of the soil varies from 5.45 at 1.00m depth to 6.28 at the depth of 2,50m. Although, the pH increased gradually from 1.00 to 2.50m depth, the soil remained acidic within this sampled depth interval. This trend is typical of most tropical landfills in southeastern Nigeria (Ibe and Onu, 1999). Although acidic oils are favourable for certain crops such as Indian bamboo, cassava and palm trees, it is inimical to survival of vegetables and some verities of fruits such as apple. The acidic nature of the soils is attributed to formation of acid rain deposition following the reaction of SO_2 and NO_2 gases released at the landfill with water (Ahiarakwem, 2011).

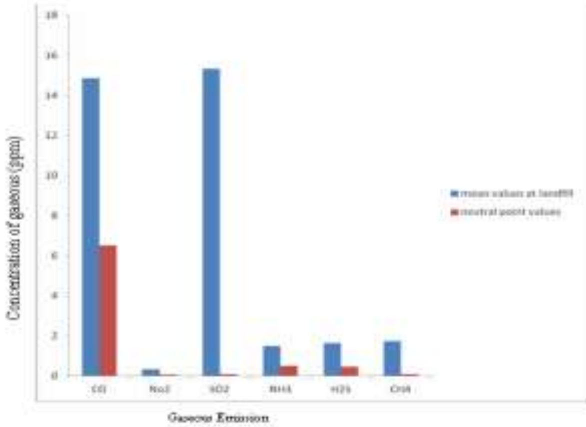


Figure. 7. Comparison of gaseous emission at landfill and neutral point (ppm)

Heavy metals

The mean concentrations of Cd^{2+} at depths of 1.00 and 1.50mare 460.33 and 406.67mg/kg respectively while the mean concentrations of Pb^{2+} at the same depth intervals are 412 and 406mg/kg respectively. The mean concentrations of Cd^{2+} and Pb^{2+} at these depths are not in conformity with PCD soil standard. However, the mean concentrations of Cd^{2+} and Pb^{2+} at depth of 2.50m were in conformity with PCD soil standard. This implies gradual vertical loading of these constituents. Other determined chemical parameters (Cu^{2+} and Cr^{3+}) conformed with PCD soil standard although their mean concentrations at various depths also shows continuous vertical loading of these constituents. Many heavy metals such as Cd^{2+} , Cu^{2+} and Pb^{2+} are problematic environmental pollutants, with well known toxic effects on living systems. Nevertheless, because of their useful physical and chemical properties, some heavy metals including mercury, cadmium and lead are intentionally added to certain consumer and industrial products such as batteries, switches, circuit boards, and some pigments (Michael, 2008).

Table 2: Chemical analysis of Soil at Aladinma Landfill

		Concentrations at Sampling Points				
Depth (m)	Parameters	1	2	3	Mean Concentration	PCD Soil Standard
1.0	PH@2S° C	5.50	5.46	5.40	5.45	6.5- 8.5
	Cd^{2+} (mg/kg)	450	464	485	466.33	400
	Pb^{2+} (mg/kg)	410	421	405	412	400
	Cu^{2+} (mg/kg)	1.20	4.24	0.97	2.14	
	Mn^{2+} (mg/kg)	500	650	610	586.67	800
	Total iron (mg/kg)	234	280	228	247.33	
	Na^{+} (mg/kg)	350	275	320	315	
	Cr^{3+} (mg/kg)	1.76	2.40	5.80	3.32	10
	SO_4^{2-} (mg/kg)	240	120	260	206.67	
-	Cl^{-} (mg/kg)	365	412	310	362.33	
	PO_4^{3-} (mg/kg)	3.0	1.20	10	4.73	
1.5	PH@25° C	5.60	5.56	5.45	5.54	6.5-8.5
	Cu^{2+} (mg/kg)	1.00	3.40	1.20	1.87	
	Cd^{2+} (mg/kg)	410	408	402	406.67	400
	Pb^{2+} (mg/kg)	405	412	401	406	400
	Mn^{+} (mg/kg)	300	245	450	33.67	800
	Cr^{3+} (mg/kg)	1.00	1.20	2,30	1.50	10
	Total iron (mg/kg)	154	200	197	183.67	
	Na^{+} (mg/kg)	146	254	226	208.67	
	SO_4^{2-} (mg/kg}	115	98	187	133.33	
	Cl^{-} (mg/kg)	246	300	200	248.67	
1.5	PO_4^{3-} (mg/kg)	0.50	1.20	2.20	1.30	
2.5	PH@25° C	6.30	6.20	6.34	6.28	6.5- 8.5
	Cu^{2+} (mg/kg)	214	156	87	152.33	400
	Cd^{2+} (,mg/kg)	350	320	234	301.33	400
	Pb^{2+} (mg/kg)	220	120	145	161.57	400
	Mn^{2+} (mg/kg)	140	78	90	102.7	800
	Cr^{3+} (mg/kg)	0.78	1,10	1.60	1.16	400
	Na^{+} (mg/kg)	300	250	220	256.67	
	Total iron (mg/kg)	150	110	160	140	
	SO_4^{2-} (mg/kg)	65	80	100	81.67	
	Cl^{-} (mg/kg)	76	120	60	85.33	
2.5	PO_4^{3-} (mg/kg)	11	30	45	28.67	

Table 3: Chemical analysis of soil at neutral point (10km away from the Aladinma landfill)

Depth (m)	Parameters	Concentration	PCD Soil Standard
1.0	PH@25^0 C	6.50	6,5- 8.5
,,	Cd^{2+} (mg/kg)	Nd	400
,,	Cu^{2+} (mg/kg)	0.50	400
,,	Pb^{2+} (mg/kg)	Nd	400
,,	Mn^{2+} (mg/kg)	5.65	800
,,	Cr^{3+} (mg/kg)	Nd	400
,,	Total iron (mg/kg)	156	
,,	Na^{+} (mg/kg)	187	
,,	SO_4^{2-} (mg/l)	58.50	
,,	Cl^{-} (mg'l)	24.80	
‘’	PO_4^{3-} (mg/kg)	Nd	

Nd= Not detected

Table 4: Ambient Air Quality at Aladinma Landfill and neutral point

	Concentrations at Gauge Stations								
Parameters	1	2	3	4	5	6	Mean	USEPA 2004 limit	Neutral Point 10km away
CO (ppm)	8.00	12.50	10.00	18.00	24.60	16.00	14.85	<35.5	6.50
NO_2 (ppm)	0.20	0.30	0.16	0.36	0.40	0.54	0.33	0.155	0.06
SO_2 (ppm)	10.50	12.40	20.0	16.503	15.80	18.00	15.53	0.145	0.08
NH_3 (ppm)	1.40	1.80	1.10	2.00	1.00	1.70	1.50		0.50
H_2S (ppm)	1.00	1.70	1.50	2.10	1.56	1.90	1.63		0.45
CH_4 (ppm)	2.00	1.50	1.80	1.30	2.20	1.60	1.73		0.10

Table 6: Concentrations of the major cations ad anions and SAR values of the water resources near Aladinma Landfil)

		Concentrations (meq)				%, epm			
Parameters	Equivalent Mass	BH. 1	BH. 2	BH. 3	Otamiri River	BH 1	BH 2	BH 3	Otamiri River
Ca^{2+}	20	0.148	0.135	0.151	0.160	34.4	32.9	34.7	37.7
Mg^{2+}	12.2	0.020	0.025	0.021	0.019	4.7	6.1	4.8	4.5
Na^{+}	23	0.226	0.220	0.225	0.217	52.6	53.5	51.7	51.2
K^{+}	39.1	0.036	0.031	0.038	0.028	7.5	8.8	6.6	
TOTAL		0.430	0.411	0.435	0.424	100	100	100	100
HCO_3^{-}	61	0.246	0.233	0.293	0.287	54.5	55.9	62.9	63.4
SO_4^{2-}	48	0.067	0.064	0.071	0.079	14.9	15.3	15.2	17.4
Cl^{-}	35.5	0.135	0.118	0.099	0.084	29.9	28.3	21.3	18.5
NO_3^{-}	62	0.003	0.002	0.003	0.003	0.7	0.5	0.6	0.7
TOTAL		0.451	0.417	0.466	0.453	100	100	100	100
SAR		0.78	0.77	0.76	0.74				

In developing Nations of the World such as Nigeria, second hand electronic wares is still in vogue, significant quantities of electronic waste (E-waste) are disposed at landfills. This results in the precipitation of significant concentrations of heavy metals from landfill leachates. Moller (2006) observed that Cd^{2+} and Cu^{2+} are most efficiently removed from leachate while Cr^{3+} is the least efficiently removed precipitate. Consumption of crops grown on soils containing high concentrations of Cd^{2+} can result in kidney failure in humans while consumption of crops grown in soils containing high levels of Pb^{2+} causes cancer and interfers with vitamin D metabolism in human body; it also affects mental development in infants and is toxic to the central and peripheral nervous system.

Other parameters

The results of the soil analysis also show that the mean concentrations of Na^+, Mn^{2+}, SO_4^{2-}, Cl^-, PO_4^{3-} and total iron at the depths investigated were within PCD recommended soil standard . However, these parameters should be monitored on a regular basis since the composition of the waste is a major determinant factor of the soil chemistry.

Except for Na^+ (Fig.4), $Cu^{2+}$and PO_4^{3-} , the mean concentrations of other determined chemical parameters decreases with increase in depth (Fig. 4). This is probably due to attenuation of these constituents by clays, metallic oxides, hydroxides and organic matter; the attenuation process is capable of reducing the constituents to tolerable levels before they enter the groundwater. However, excessive loading of constituents at a rapid rate can result in the increase of the concentrations at deeper levels and this can result in the pollution of the groundwater within a short term interval. Generally the migration of constituents from landfills through the soil to groundwater is principally dependant on the type of constituent, loading rate, porosity and permeability of the sediments as well as coefficient of dispersion. The study area is characterized by high porosity and permeability and moderate coefficient of dispersion (Uma. 1984) and this permits easy migration of constituents downwards but at a moderate rate.

The result of the chemical analysis of the soil at a neutral point (Table 3) located 10km away from the landfill indicates that all the determined parameters were conformity with PCD soil standard. Since this sampling location is not near a pollution source such as landfill, it implies that the determined constituents in the soil within the Aladinma landfill owe their sources from it.

Table 5: Hydro-geological data and Bio-chemical analysis of groundwater and surface water resources near the Aladinma Landfill

	Groundwater			Surface water	
parameters	BH.1	BH.2	BH.3	Otamiri River	WHO (2006)
PH @25^{o}C	6.30	6.40	6.45	6.50	6.50- 9.00
Electrical Conductivity ($\mu\frac{S}{cm}$)	30.50	25.04	20.00	16.80	1,400
TDS (mg/l)	18.40	15.50	12.00	10.40	1,500
Total Alkalinity (mg/l)	7.10	6.60	7.70	8.00	
Total Hardness (mg/l)	12.00	11.50	12.40	12.80	
DO (mg/l)	6.20	6.70	7.40	8.20	
BOD (mg/l)	1.40	1.20	0.80	1.50	
Total iron (mg/l)	0.05	0.03	0.01	0.02	0.03- 10
Ca^{2+} (mg/l)	2.96	2.70	3.02	3.20	200
Mg^{2+} (mg/l)	0.24	0.30	0.25	0.23	150
Na^+ (mg/l)	5.20	5.06	5.17	5.00	500
K^+ (mg/l)	1.40	1.20	1.50	1.10	500
HCO_3^- (mg/l)	15.00	14.20	17.90	17.50	500
SO_4^{2-} (mg/l)	3.20	3.10	3.40	3.80	400
Cl^- (mg/l)	4.80	4.20	3.50	3.00	500
NO_3^- (mg/l)	0.20	0.10	0.18	0.17	40-70
PO_4^{3-} (mg/l)	0.09	0.04	0.02	1.00	10
Cd^{2+} (mg/l)	0.03	0.01	Nd	Nd	0.05
Pb^{2+} (mg/l)	0.02	0.01	Nd	Nd	0.05
Zn^{2+} (mg/l)	0.06	0.03	Nd	Nd	5.00
Cu^{2+} (mg/l)	Trace	Nd	Nd	Trace	1.00
Mn^+ (mg/l)	Trace	Nd	Nd	Trace	0.20
Ni^+ (mg/l)	Trace	Trace	Nd	Nd	0.05
Cr^{3+} (mg/l)	Trace	Trace	Nd	Nd	0.05
Hg^+ (mg/l)	Nd	Nd	Nd	Nd	0.05
Total Coli form (cfu/100ml)	Nd	Nd	Nd	85.00	10
Borehole Depth (m)	80	76	75		
Static Water Level (m)	30	30	28		
Aquifer type	unconfined	Unconfined	Unconfined		
Groundwater Vulnerability	Moderate	Moderate	Moderate		
Distance from Landfill (Km)	0.70	2.00	4.00	8.00	

Table 7: Pollution Index of water resources near Aladinma landfill

		Concentrations (L_{ij})				(C_{jj}/L_{jj})			
Parameters	L_{IJ}	BH. 1	BH. 2	BH. 3	OTAMIRI RIVER	BH 1	BH 2	BH 3	OTAMIRI RIVER
pH	6.50	6.30	6.40	6.45	6.50	0.969	0.985	0.992	1.000
TDS (mg/l)	500	18.40	15.50	12.00	10.40	0.037	0.031	0.024	0.021
Total Hardness (mg/l)	50	12.00	11.50	12.40	12.80	0.240	0.230	0.248	0.256
Total Alkalinity (mg/l)	100	7.10	6.60	7.70	8.00	0.071	0.066	0.077	0.080
SO_4^{2-} (mg/l)	400	3.20	3.10	3.40	3.80	0.008	0.008	0.009	0.010
Cl^- (mg/l)	250	4.80	4.20	3.50	3.00	0.019	0.017	0.014	0.012
TOTAL						1.344	1.337	1.364	1.379
MEAN						0.224	0.223	0.227	0.230
POLLUTION INDEX (PI)						0.703	0.714	0.720	0.720

Ambient Air Quality

The mean concentrations of CO, No_2, SO_2, NH_3, H_2S and CH_4 at the landfill are 14.85, 0.33, 12.53,1.50, 1.63 and .73ppm (Table4) respectively while the values of these parameters at a neutral point located 10km away from the landfill are 6.50, 0.06, 0.08, 0.50, 0.45 and 0.10ppm respectively (Table 4).

The gaseous emissions at landfills are formed as a result of decomposition of the waste (Farguhar and Rover, 1973; Flower,1976) ; this accounts for the higher concentrations of the gases at the landfill than at the neutral point (Figures 5,6 and 7). Except for NO_2 and SO_2, the mean concentrations of other measured gaseous emissions at the landfill conformed with the United States Environmental Protection Agency (USEPA) 2004 ambient air quality standard. Gaseous migration from landfills can modify the recipient environment by causing air, soil and water pollution (Ahiarakwem, 2011; Mohsen, 1975). NO_2 reacts with water forming nitric (HNO_3) and nitrous (HNO_2) acids while SO_2 reacts with water forming sulpuric (H_2SO_4) and sulphurous (H_2SO_3) acids. These gases thus contributes to acid rain deposition and thus are responsible for the low pH of the soil within the landfill as well the nearby groundwater resources. Apart from acid rain, NO_2 is a pulmonary irritant and one of the greenhouse gases which contributes significantly to global warming ; high concentrations of NO_2 (as is the case with the study area) causes high accumulation of fluid in the lung tissue. NO_2 also causes visibility as well as production of photochemical smog. SO_2 also contributes to global warming and accelerates the decay of paints of buildings, monuments, statues and sculptures which are part of our cultural heritage. It also reduces visibility and causes plant damage and water quality degradation. Although other measured gaseous emissions conformed with USEEPA (2004) standard, they also cause some direct health impacts such as respiratory sickness, cardiac arrest , aggravation of asthma aesthetic damage.

Demographic study of the study area shows that about 1,500 persons live 100m away from the landfill while the second group of persons numbering about 2,500 live 500m from the landfill; the third group of persons numbering about 5,000 persons live 1,000m from the landfill while the fourth consists of about 12,000 persons living 5,000m from the landfill. This statistics implies that the first group are at very high risk of the effects of the gaseous emissions from the landfill while the second group of persons are considered to be at high risk. The third and fourth groups are considered to be at moderate and low risks respectively to the effects of the gaseous emissions from landfill (Fig. 8).

Groundwater hydro-geological data and vulnerability

The static water level (SWL) of the first borehole located about 700m from the landfill is 30m while the SWL of the second borehole located about 2km from the landfill is 30m. The SWL of third borehole located at about 4km from the landfill is 28m. The total drilled depth (TDD) of the first and second and third boreholes are 80, 76 and 75m respectively. The borehole depths are considered moderately deep while the static water levels are shallow. The sediments overlying the aquifer in the study area are highly porous and permeable and contains little sorption materials (Uma, 1984). The porous and permeable overlying sediments provides pathway for migration of constituents from the landfill to the aquifer. The migration of the constituents is further enhanced by the unconfined nature of the groundwater in the study area. On the basis of GOD model, the vulnerability of groundwater is rated low, moderate, high and extreme (Margat, 1968). The groundwater vulnerability of the study area based on GOD model is rated as moderate. This implies that the groundwater is moderately vulnerable to pollution and this must be considered in the design and construction of landfills and water boreholes in the study area.

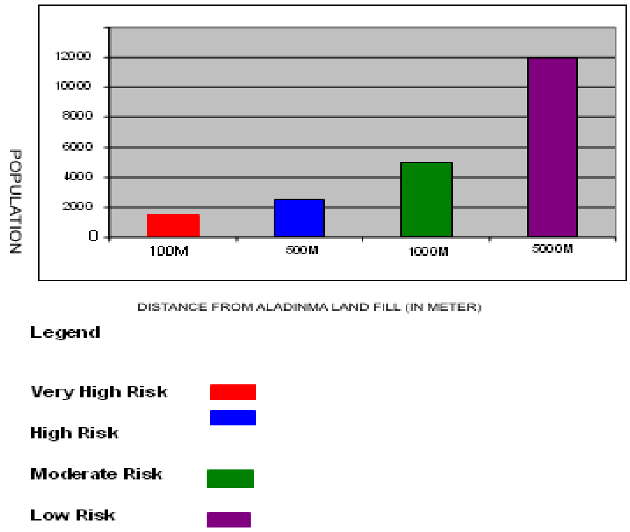


Figure. 8. Risk Assessment of Exposure to air pollutants from Aladinma Landfill

Bio-chemical assay of water resources

Physical parameters

The PH of the groundwater resources near the landfill varies from 6.30 to 6.45 while that of Otamiri River is about 6.50. Although the pH of the surface water (Otamiri river) located about 8km away from the landfill conformed with World Health Organization (WHO) 2006 drinking water standard, the pH of the groundwater resources near the study area is not in conformity with WHO (2006) and thus constitute environmental risk to consumers of the water. The pH of the groundwater in the area was observed to decrease (becomes more acidic) as one moves towards the landfill. This implies that the landfill has impact on the groundwater in terms of pH. Other determined physical parameters (TDS, electrical conductivity and total alkalinity) in both the groundwater and surface water resources near the landfill conformed with WHO (2006) standard (Table 5)

Major cations and anions

The determined major cations and anions of the groundwater and surface water resources near the landfill conformed with WHO (2006) standard and thus do not constitute any environmental risk at the moment.

Piper trilinear plot (Fig.9) of the water resources near the landfill shows that they are potable while Stiff diagram (Fig. 10) shows slight changes in their concentrations but similar shape suggesting a close source.

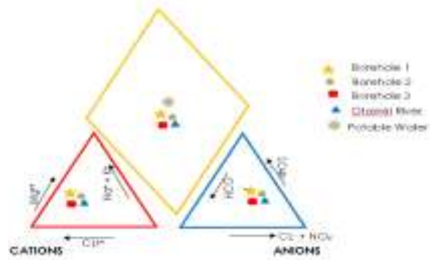


Figure. 9. Piper trilinear plot of water resources near Aladinma Landfill

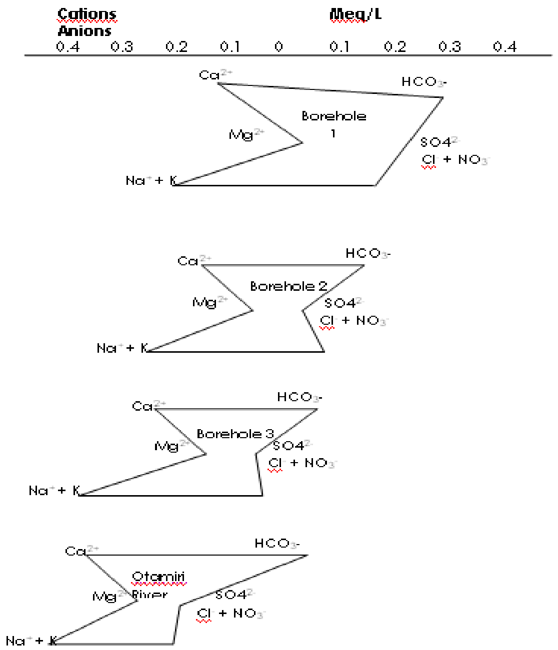


Figure. 10. Stiff plot of water resources near Aladinma landfill

Heavy metals

The concentrations of Cd^{2+} , Pb^{2+}, Cu^{2+} , Zn^{2+} , Hg^{2+} and $Cr^{\#+}$ of the water resources of the study area were in conformity (WHO, 2006). The concentrations Cd^{2+}, Pb^{2+} and Zn^{2+} were observed to increase towards the landfill. The loading rate of constituents into the groundwater is low probably due to their attenuation by sorption materials. There is therefore, need for constant monitoring of the chemistry of the groundwater. It is important to note that the first borehole located at about 700km is at the greatest risk of heavy metal pollution.

Other parameters

The concentrations Ni^{+} ,total iron, DO, BOD of the water resources near the landfill conformed with WHO (2006) drinking water standard and thus constitute no environmental risk at the moment.

Microbial assay

The microbial assay of the groundwater resources near the landfill conformed with WHO (2006) drinking water standard (Table 5). However, the total coli form count of the Otamiri river is about 85.0 cfu/100m and this does not conform with WHO (2006) standard. Based on the distance of the Otamiri River from the landfill, the microbial assay of the river may have been caused by other sources of pollution.

Sodium adsorption ratio (SAR)

The SAR value of Otamiri river is 0.74 while that of the first, second and third boreholes are 0.78, 0.77 and 0.76 respectively (Table 6). Water sample with SAR range of 0 to 10 is classified as excellent for irrigation purposes while that with SAR range of 10 to 18 is classified as good; water sample with SAR range of 18 to 26 is classified as fair while water with SAR value of more than 26 is considered as poor for irrigation purposes (Wilcox, 1955). Based on this classification, the surface and groundwater resources are excellent for irrigation implying that the landfill is yet to constitute an environmental risk to the water resources in terms of SAR values. It was observed that the SAR deceases (improves) as one moves way from the landfill.

Pollution index (PI)

The pollution index of the first, second and third boreholes are 0.703, 0.714 and 0.720 respectively while the PI value of Otamiri River is 0.720 (Table 7). Horton (1965), observed that the critical value of PI is 1 implying that water sample with PI value greater than one requires treatment. The PI values of the groundwater and surface water resources are within acceptable limit and thus do not constitutes no environmental risk at the moment.

Remediation

The pH of the soil within the landfill can be corrected using lime while the high concentrations of Cd^{2+} and Pb^{2+} at 1.00 and 2.50m respectively can be treated sing redox reaction or chemical precipitation methods (Aland, 1993). The poor microbial assay of the Otamiri River can be treated using chlorine. The pH of the groundwater resources can be corrected using sodium bicarbonate (soda ash) while the gaseous emissions at the landfill can be minimized by installing scrubbers. Landfill gas can be treated to remove impurities, condensate, and particulates. The treatment system depends on the use of the gas. Minimal treatment is required for the direct use of landfill gas in boiler, furnaces or kilns. Using the gas in electricity generation typically requires more in-depth treatment.

The treatment systems are divided into primary and secondary treatment processing. Primary processing systems remove moisture and particulates. Secondary treatment systems employ multiple cleanup processes, physical and chemical, depending on the specifications of end use. It is also possible to convert landfill gas to high Btu gas by reducing its carbon dioxide, nitrogen and oxygen content. The high-Btu can be piped into existing natural gas pipelines or in form of Compressed Natural Gas (CNG) or Liquefied Natural Gas (LNG). The CNG and LNG can be sold commercially (Urban et al., 2009). However, along tem pollution mitigation measure would be replacement of the Aladinma landfill with a sanitary landfill.

Conclusion

The Alainma landfill is simply an ordinary landfill and thus constitute some environmental risk. The mean concentration of the pH of the soil within the landfill indicates that the soil is acidic (pH range:5.45-6.28) at depth interval of 1.0 to 2.50m. The mean concentrations of Cd^{2+} and Pb^{2+} at depths of 1.00 and 1.50m did not conform with PCD soil standard. Except for Na^{+} , Cu^{2+} and PO_4^{3-} , the mean concentrations of other determined parameters show clear vertical changes typified by decrease of constitute with depth. The decrease of constituents with depth is attributed to pollution attenuation mechanism provided by sorption materials such as clays, metallic oxides and organic matter.

The pH of the groundwater resources near the landfill did not conform with WHO (2006). However, other measured parameters of the groundwater resources conformed with WHO (2006) drinking water standard. Except for microbial assay the concentrations of all the measured parameters conformed with WHO (2006) drinking water standard.

The ambient air quality study at Aladinma landfill reveals that the concentrations of NO_2 and SO_2 did not conform with USEPA (2004) ambient air quality standard. Apart from contribution to acid rain deposition and global warming, the gaseous emission also cause respiratory sickness. The 1,50 persons who live about 100m from the landfill were observed to be at very high risk to the effects of the gaseous emissions at the landfill.

The pH of the soil within the landfill can be corrected using lime while the concentrations of Cd^{2+} and Pb^{2+} can be corrected using redox reaction or chemical precipitation treatment methods while the pH of the groundwater near the landfill can be corrected using sodium bicarbonate. The gaseous emissions can be minimized using scrubbers or harnessing the gases for various purposes. However, it is important to replace the ordinary landfill with a sanitary landfill which offer minimal environmental risk.

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