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VULNERABILITY ASSESSMENT OF BOREHOLES LOCATED CLOSE TO LEMNA LANDFILL IN CALABAR METROPOLIS, NIGERIA

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ABSTRACT: *Solid waste mostly garbage, agriculture and industrial waste are disposed in landfills where it decomposes and produces a leachate that can contaminate underlying groundwater. Waste management has remained an undisputable environmental problem in Nigeria. This has manifested in the form of indiscriminate disposal of wastes and illegal landfills and dumps along main roads and streets, and the problem is compounded by the generation of enormous quantities of waste. In the developing world such as Nigeria, borehole water users hardly treat water before usage and this poses a serious threat to their health since the utilized this untreated water for consumption, domestic uses, agriculture and industrial purposes. Groundwater studies have ascertained that leachates from landfill migrate in the direction of groundwater flow to contaminate the underlying aquifer. The study assessed the vulnerability of borehole located close to Lemna dumpsite in Calabar Municipality. Borehole water samples were collected from ten designated boreholes and their physicochemical parameters were analysed. The length, breadth and depth of the landfill were measured with a tape and meter rule. The length of the landfill was 960m, the width 430m and the depth 180m. Geographical positioning system (GPS) was used to obtain the static water level from where the groundwater flow map was deduced. Parameters such as BOD, DO,* Fe^{2+}, Ni^{2+}, Zn^{2+}, *faecal and total coliform count values when compared with world health organization standard (WHO) were seen to exceed the recommended value. The research revealed that groundwater flow from the North to South, carrying along with it dissolved waste materials and leachates which infiltrates into the borehole water and contaminates it, thereby rendering it unsuitable for drinking and domestic use. The researchers therefore suggested that the base of landfills should be properly coated with concrete or cellophanematerials to avoid leachates infiltrating into the groundwater. Recycling of municipal waste, proper education and awareness on solid waste management should be encouraged in the study area.*

KEYWORDS: Landfill, solid waste, leachate, contaminants and infiltration

INTRODUCTION

The rapid growth of cities in the developing world in recent times has resulted in increased consumption of resources to meet the growing demands of urban population and industry, this situation have generated large amount of municipal solid waste which are collected and disposed off in landfills. Leakage in landfills is capable of polluting groundwater, because landfills are made up of varieties of hazardous chemicals, contaminants and non-contaminants which constitute a trait to groundwater quality (Eni, 2011). In Calabar Municipality landfills are constructed without considering its closeness to borehole water, and its potential impact on groundwater (Eni, 2013). As rain drops and infiltrates into the soil, harmful substances from landfills finds their way into boreholes, hence polluting the water body and makes it unfit for domestic and other purposes. A plume of contamination occurs whenever a reasonable permeable material exist below the soil strata. Organic contaminants called leachate drains into groundwater where there is no base lining and carries along with it anions and cations of iron and manganese which contaminates borehole water easily. A release of leachate to groundwater presents several risks to human health, damage to the environment, and an increased in toxicity. These changes depend on the materials underlying the landfill, the hydraulics of the groundwater system and the chemistry of the leachate. (Carter et, al 2009). The amount of leachate produced in a land fill depends on the amount and distribution of rainfall, evaporation from soil cover and thawing.

Contaminated landfill has been seen to deprive the present and future generations of valuable water resources and encouraged waste production instead of pollution control and waste reduction. The frequent use of fertilizers and pesticides to obtain high crop yield is a source of groundwater contamination in Calabar Municipality. Polluted water, irrespective of the pollutants when consumed, may lead to a variety of diseases such as cholera, typhoid, dysentery, skin rashes and mental disorder.

The over increasing demand for water by industrialization and high population growth is the major cause of pollution derived from solid waste disposal in landfills. Once waste is deposited at the landfill pollution can arise from the migration of both gas and leachate. Predicting and assessing the extent of groundwater pollution in landfill site depends on a thorough knowledge of the characteristics of groundwater flow, the chemical and biochemical interactions that occur between waste components, groundwater and aquifer minerals. Leachate from landfills are highly concentrated in such a way that small amounts of leachate can pollute large quantity of borehole water and render it unsuitable for domestic and consumption purposes.

Borehole water contamination from chemical landfills sites attracts public interest, but other sources like pesticide from agricultural land, fertilizers application and underground storage tanks also posed great threat to groundwater. Borehole water pollution hazard is the interaction between the aquifer pollution vulnerability and the contaminant load that is applied on the surface of the environment as a result of human activity at land surface (Igboekwe et al, 2011). The usage of alternative uncontrolled dumped sites will increase pollution problem, the time to pollute the borehole water which occurs if the landfill was built near areas of aquifer recharge. The risk of borehole water contamination by any leachate that is not caught by collection systems is determined by factors such as concentration of contaminants, permeability of geologic strata, type of geologic strata and toxicity of the contaminants (Aibinet et al, 2007). Groundwater flow direction or paths which are located close to landfills have a greater capability to contaminate borehole water, because of the close proximity of the potential pollution source. Contamination of borehole water resource poses a substantial risk to local resource user and to the natural environment.

The quality of leachate is determined by the composition and solubility of the waste constituents. If waste is changing in composition due to weathering and biodegradation, then leachate quality will change with time. This is the specific case in landfills containing municipal waste like what is obtainable in Calabar Municipality. Leachate produced in the early stages of decomposition of waste is typically generated under aerobic conditions producing a complex solution with a neutral pH. Waste becomes anaerobic as decomposition processes develop because the composition of leachate depends upon the nature of solid waste buried, chemical and biochemical processes responsible for the decomposition of waste materials, and water content in total waste (Baalousha, 2006).

In Calabar metropolis landfills remains the major method of disposing waste due to the emerging population, waste generation has become alarming and to cope with it, deposition in landfills is a preferred option. This study that seeks to assess the vulnerability of borehole located close to landfill is based on the pollution and contamination that emanates from the deposition of solid waste in landfill. The gap this paper intends to fill is that leachates leak into groundwater in areas characterized by high rainfall no matter the level of concrete at the base of the landfill. These leachates have reduced the quality status of borehole water in the study area and have rendered it unsuitable for consumption and drinking purposes.

Study Area

Calabar Municipality lies geographically along longitudes 08°18'E and 08°26'E Greenwich meridian and latitudes 04°55'N and 04 ° 58'N of the equator. In the North, Calabar Municipality is bounded by Odukpani and Akamkpa Local Government Areas, at the East by the Great Kwa River. At the South it is bounded by the Calabar River and Calabar South Local Government Area. It has an area of 331.551 square kilometers. Calabar Municipality is characterized by a double maxima rainfall regime which occurs in June and September. It has an annual rainfall of 3000mm and a harmattan wind blowing over the area in December and January respectively.

The annual temperature is 28°C with a high evapotranspiration and an average humidity of 90%. The vegetation of the study area is characterized by mangrove swamp and rainforest, but due to human activities like cutting down of trees, for roads, building of houses, schools and market it has resulted in the depletion of the rainforest. The soil is composed of coastal plain sand which belongs to tertiary deposits. The alluvial deposits are used for construction with light brown and grey colour. According to Cross River Basin Authority (CRBDA, 1982) Cross River State Hydrological Province are grouped into four units namely: basement and intrusive rocks, sandstone, shale and alluvial deposits.The lithology is characterized by an underlying aquifer. The surface and ground water bodies are recharged by high precipitation. The aquifer is confined with few aquicludes made up of silt, clay and sandstone.

METHOD OF STUDY

The research utilized both primary and secondary data. The primary data were obtained directly from the field through observation and measurement of landfill depth, width and length using the metre rule and a tape. Water samples for the analysis were collected from designated boreholes located very close to the identified landfill site. A $100cm^3$ polyethylene container was used in collecting the water sample and immediately transferred in an ice cooler box to the laboratory for analysis within 24 hours. A total of ten (10) water samples were collected for the determination of its physico-chemical properties. Simple random sampling technique was utilized in the selection of boreholes. The co-ordinates of each borehole were deduced with the help of a global positioning system (GPS). The flow direction of groundwater around the landfill vicinity was also determined from the elevation values obtained from the GPS reading.

The groundwater flow was predicted by utilizing the knowledge of the variation in static water levels across the study area. Data on static water levels were imported into the GIS software anchoring on their coordinates. An interpolation technique called Kriging was applied on the data and contours were automatically generated at two meter interval. Data products from surfer were exported as shape files and imported into ArcGIS where they were organized along with other geo-referenced layers of data such as administrative boundaries, rivers, roads, boreholes and dumpsite locations, to make a map showing flow direction of groundwater across the study area.

RESULTS AND DISCUSSING OF FINDING

The data obtained from the field were presented in tables as shown below:

Table 1:Areal extend of Lemna landfill site

Length	960m
Width	430m
Depth	180m

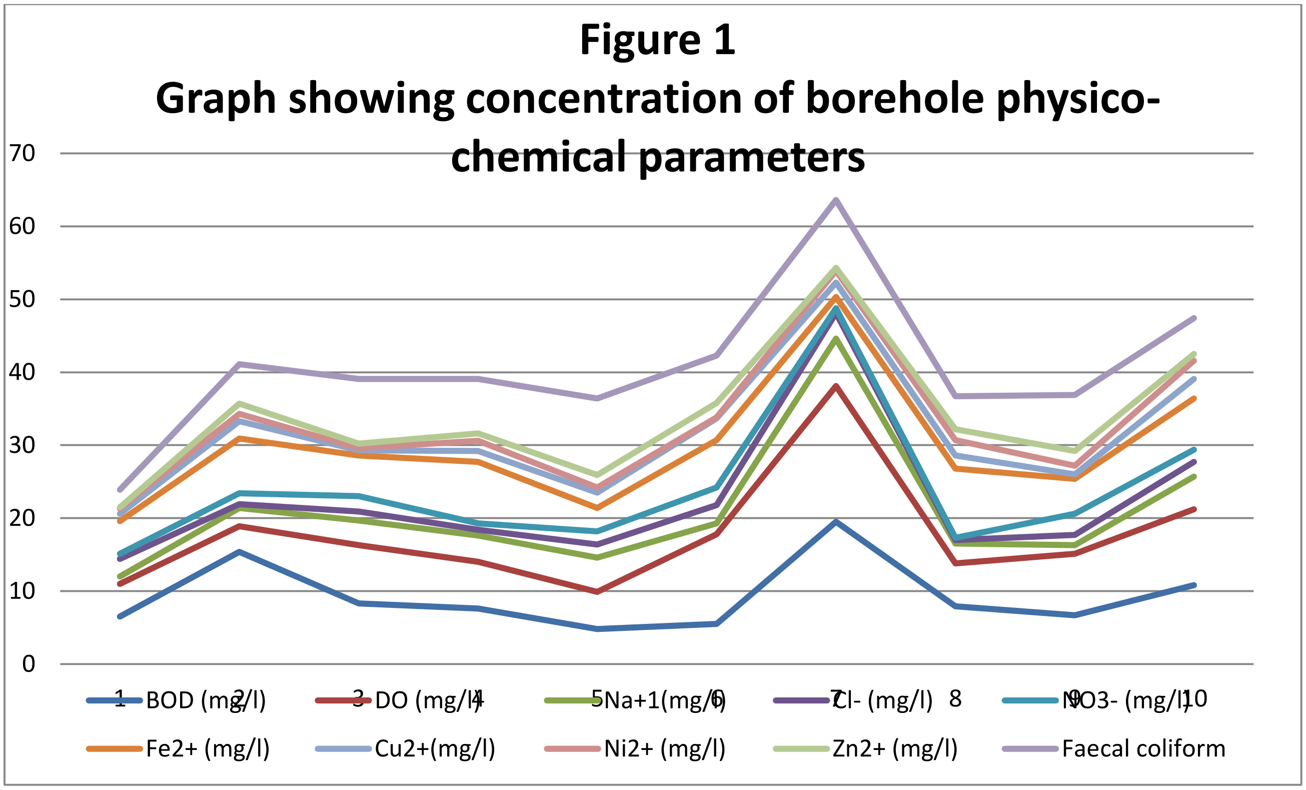
Table 1 revealed that the total length of the landfill was 960m; the width is 430m and the depth 180m. This indicates that the waste covered a large proportion of the study area and could be detrimental to the health and environmental conditions of the inhabitants living close to the landfills. The rate of production of municipal solid waste has been on the increase in Calabar Metropolis. This shows a clear lack in waste management practices, especially in proper land filling, coupled with the rapid increase in solid waste which poses a negative effect on the immediate environment.

Organic waste in landfills decomposed to form gaseous products and as the change from aerobic to anaerobic condition, carbon dioxide level continues to increase as methane concentration builds up. Methane is very inflammable and if not properly harnessed, it can result in potential fire and explosion hazard in the study area.

Table 2: Result of physico-chemical parameters obtained from Boreholes located close to LEMMA Lanfill

S/No	Water Parameters	LOCATIONS									
		L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8	L_9	L_{10}
1.	pH	5.7	6.2	5.4	8.7	8.3	5.1	6.0	8.7	5.5	6.6
2.	Turbidity(NTU)	14.5	3.9	15.5	7.8	13.4	5.4	14.6	15.8	5.2	12.8
3.	Hardness	1.40	21.0	160	110	150	180	80	170	50	220
4.	Temperature(°C)	25.00	27.5	26.5	25.5	29.5	26.0	28.0	26.5	30.5	27.5
5.	TDS (mg/l)	3.40	5.50	4.20	3.00	5.40	6.80	8.50	10.50	5.80	7.50
6.	BOD (mg/l)	6.50	15.40	8.30	7.60	4.80	5.50	19.50	7.90	6.70	10.80
7.	DO (mg/l)	4.50	3.50	8.00	6.40	5.10	12.30	18.60	5.90	8.40	10.40
8.	Na^{+1}(mg/l)	1.00	2.50	3.40	3.60	4.70	1.50	6.50	2.70	1.20	4.50
9.	Cl^- (mg/l)	2.40	0.50	1.20	0.80	1.80	2.50	3.50	0.50	1.40	2.00
10.	NO_3^- (mg/l)	0.70	1.50	2.10	0.90	1.80	2.40	0.70	0.30	2.90	1.70
11.	Fe^{2+} (mg/l)	4.50	7.50	5.60	8.40	3.20	6.50	1.50	9.50	4.80	7.00
12.	Cu^{2+}(mg/l)	1.00	2.40	0.70	1.50	2.10	3.00	2.00	1.80	0.60	2.70
13.	Ni^{2+} (mg/l)	0.70	1.00	0.30	1.40	0.70	0.10	1.60	2.10	1.20	2.50
14.	Zn^{2+} (mg/l)	0.20	1.40	0.60	1.00	1.70	2.00	0.40	1.50	2.00	0.90
15.	Faecal coliform	2.40	5.40	8.90	7.50	10.50	6.50	9.30	4.50	7.70	4.90
16.	Total coliform	3.10	7.60	4.90	8.40	5.60	3.90	7.80	9.40	3.50	5.70

The result in table 2 indicated that parameters such as BOD, Hardness, No_3^-, Fe^{2+}, Fe^{2+}, Zn^{2+}, NO_3^- total and faecal coliform values were higher in some sampled boreholes. Composition of leachate depends on the nature of solid waste buried, chemical and biochemical processes responsible for the decomposition of waste materials and water content in the total waste (Long et al, 2006).



The research revealed that all the parameters analysed varied from one location to another depending on their proximity to the landfill. It was discovered that boreholes located very close to the landfill were more contaminated than those located far away from it. This situation occurs because the gravitational movement of fluid and leachate is hindered by the mass of solid soil matter. Figure 1 above revealed that borehole at location 7 had high values of physico-chemical parameters which indicated high contamination by leachate in the study area.

Topography, type of waste and the hydrology of the study area were other contributing factors that aided leachate migration into groundwater. About seventy percent (70%) of the waste generated in the area were organic in nature. This is buttressed by the research carried out by Vasanthi (2001) where he proved that high concentration of TDS, Hardness, Nitrates, Chlorides and Sulphates in groundwater near landfill deteriorates the quality of water. It was observed that the major threat to borehole water comes from inadequate controlled landfills where leachate generated from the fill is allowed to escape to the surrounding and underlying water body. The chemical composition of the landfill leachate depends in the nature of the refuse, the leachate rate, and the age of the fill. The date obtained from the study areas indicated that the landfill leachate is grossly polluted and a poses a threat to groundwater quality. The hardness of leachate and contaminated ground water is due to the present of carbodioxide (Co2) generated during the decomposition of the refuse. This CO_2 forms carbonic acid which dissolves calcium compounds in the soil materials and causes increase in the hardness of ground water. Permeability of rocks within the reservoir plays an important role in the transmission of contaminants from landfills without concrete linning into borehole, especially if the aquifer is characterized by high permeable membrane. Evidence at the field proved that leachate from landfills affects borehole water quality through percolation in the subsoil.

Table 3: Comparing means of physico-chemical parameters with WHO standard for drinking water

S/No	Physico-chemical Parameters	Mean Values	WHO Standard
1.	pH	6.6	6.5 – 8.5
2.	Turbidity	9.8	$\geq$5.00
3.	Hardness	147	$\geq$300
4.	Temperature	27.3	25^{o}C
5.	TDS	6.06	1000
6.	BOD	9.30	0
7.	DO	8.31	0
8.	Na^+	3.16	0
9.	Cl^-	4.66	2.50
10.	No_3^-	1.50	$\geq$0.3
11.	Fe^{2+}	5.85	1.0
12.	Cu^{2+}	2.80	$\geq$0.01
13.	Ni^{2+}	3.16	$\geq$0.001
14.	Zn^{2+}	2.17	$\geq$0.01
15.	Faecal coliform	6.76	0
16.	Total coliform	5.99	0

Table 3 indicates that some parameters values exceeded that of the world health organization standard for drinking water when compared. BOD, DO, Na^+, Cl^-, No_3^-, Fe^{2+}, Cu^{2+}, Ni^{2+}, Zn^{2+}, faecal and total coliform had mean values of 9.30mg/l, 8.31mg/l, 3.16mg/l, 4.66mg/l, 1.50mg/l, 5.85mg/l, 2.80mg/l, 3.161mg/l, 2.17mg/l, 6.76 and 5.99 respectively. All these means values exceeded the W.H.O. recommended standard for drinking water. The landfill in the study area was characterized by municipal, industrial and clinical waste and there are hazardous with leachable toxic components like Nickel, Copper and Zinc. The residents suffered from stinking smell and foul odour. The presence of contaminants in borehole water posses serious health challenge to the environment.

Scientist believed that the soil layers above the water table act as natural filters that prevent many pollutants from infiltrating down to the groundwater. But findings revealed that those soil layers often do not adequately protect aquifers from contamination as leachates move down the soil strata, because they allow some microbes to penetrate even at great depth (Eni, 2013).

High coliform populations in borehole water are indications of poor sanitary conditions in the area. Human waste contaminant in water causes water-borne diseases such as diarrhea, typhoid and hepatitis. Inadequate and unhygienic handling of faeces and solid wastes due to urban growth could have generated high concentration of microbial organisms in borehole water.

The dumpsite through the process of percolation and infiltration contaminates the groundwater in that area. This agrees with Cunningham & Cunningham (2005), who opined that water dissolves biodegradable materials in solid wastes and even some industrial wastes; it mixes with these wastes and contaminates the groundwater through infiltration and recharge process. They also affirmed that dumping of wastes close to recharge zones or on recharge zones leaks through and contaminates the aquifer.

The landfill poses a great threat as it is a major cause of environmental degradation, groundwater contamination and public health concerns in Calabar Metropolis. This agrees with Ohiman (2002) who reported that landfill contains a mixture of toxic, infectious and radioactive waste which degrade the environment, contaminates groundwater and can cause serious harm to scavengers.

The implication of the dumpsite on groundwater hydrology is that leachates from dumpsite infiltrates into the ground and also move in the direction of groundwater flow thereby contaminating the groundwater along its path (fig. 1). This movement is from the north (higher pressure gradient) down south (lower pressure gradient). This is affirmed by Henry Darcy who postulated that groundwater moves from higher elevations or higher pressure gradient to lower pressure gradient. Thus, movement of sediments and water also follow this pattern. In addition, Taylor and Allen (2005) affirmed that landfill is a major source of groundwater pollution as the migration of this leachate follows the flow of groundwater movement, for this reason, landfill must be kept off from the direction of flow of groundwater.

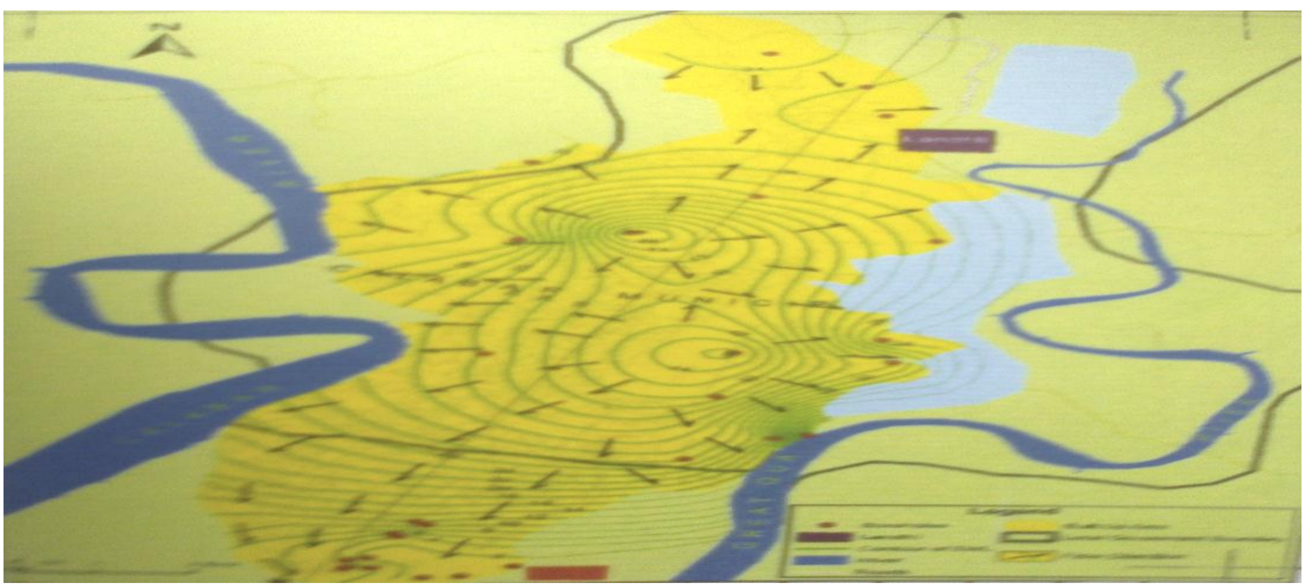


Figure 1 Map of Calabar showing the flow direction of groundwater

CONCLUSION

Solid waste disposed in landfills is usually subjected to series of complex biochemical and physical processes, which lead to the production of both leachate and gaseous emissions. When leachate leaves the landfill and reaches the water table, it results in borehole contamination. The quantity of leachate generated in a landfill depends on the climate in which the landfill is situated, type of waste, and the water content. The influence of climate on landfill performance is complex and increase in leachate production after precipitation is rapid.

Borehole water contamination from landfill, poses serious threat to the environment, but other sources of pollution such as fertilizer application, underground storage tanks, oil spillage are also dangerous contaminants. The research have revealed that landfill in Calabar has affected borehole water quality negatively due to its careless handling which has rendered it unsuitable for public consumption directly without treatment. Groundwater in Calabar is enriched with iron oxide and this is supported by Long & Saleem (2006), which opines that the principal product from urbanization alters the groundwater chemistry. The high concentration of these ions and the contamination by faecal and total coliform indicates that groundwater is contaminated by infiltration from the surface water polluted by the municipal solid waste, agricultural activities and industrial waste through leachate from the landfill.

The research has revealed that apart from physical parameters and heavy metals constituting the contaminants in borehole water, micro organisms like faucal and total coli forms also find their way into ground water through infiltration and leaching from soakaways and landfill located close to residential areas. Also the research reveals that ground water in the area flows from the northern part of the state to the southern part and carries along with it debris and leachates as it passes through different soil strata before getting to the water table.

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