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Environmental Impact of Landfill on Groundwater Quality in Maiduguri, Nigeria.

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ABSTRACT
This study was conducted on two landfills in Maiduguri, Nigeria to ascertain its impact on groundwater quality. Six shallow wells, three each from a landfill with depth ranged from 40-70m in the basement formation of Chad basin. Six-sampled point at Moduganari and Umarari landfills labeled A_1, A_2, A_3, B_1, B_2 and B_3 at a radial distance of 20m, 50m, 100m, 10m, 25m and 60m respectively from the centre of the landfill. The physiochemical parameters analysed were odour, colour, turbidity and temperature, pH, dissolved oxygen (DO), total dissolved solids (TDS), total hardness (TH), total nitrate, nitrite, chloride, calcium and heavy metals such as copper, zinc, iron, Mn, Cr and lead.) and bacteriological are total coli form bacteria and Escherichia coli. The pH ranged from 7.36 to 8.35 indicating alkalinity, which falls within the WHO acceptable limit. The turbidity values were between 0.80 and 5.88NTU, and the temperature ranged from 28.0°C to 30°C. The concentrations of chloride, nitrate, nitrite and calcium ranged from 2.0 to 51, 0.25 to 2.03, 0.13 to 1.4 and 30 to 55 mg/l respectively. Out of heavy metals, zinc and iron ranged from 0.002 to 0.08 mg/l, and 0.25 to 0.07mg/l respectively. Lead was not dictated in all the samples. 1.1 to 1.2 mg/l. Manganese and chromium were above WHO standard limit for wells B_1 and B_3, likewise total caliform bacteria and E- coliform were +4 which indicates human and animal faeces. Groundwater contamination is the function of time, types of waste, topography, soil, underlying geology, surface water ingression and direction of groundwater flow. Closed landfill has the capability of generating certain pollutants than existing landfill.

Keywords; *Groundwater, Heavy metals, Landfill and solid waste*

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I. Introduction

Groundwater quality is an important factor in the context of sustainable water management, the integrity of underlying aquifers is mainly affected by pollution from above ground sources, particularly solid waste disposal (Kumar et al., 2010). Uncontrolled urban growth and its resultant effect, especially in developing nations like Nigeria, can adversely affect the quality of underlying groundwater if not properly controlled (Putra, 2008). Once groundwater is contaminated; its quality cannot be restored and it is very expensive, and difficult to clean it up (Ramakrishnaiah et al., 2009). Groundwater is the most reliable water supply source for domestic, agricultural and industrial use in Nigeria and other countries across the world. However, despite its reliability, this precious and vital resource is under increasing threats attributed to above ground anthropogenic activities related to uncontrolled urbanization, incessant waste disposal and poor land use management. The Also, the usefulness of groundwater to humans essentially depends on its chemical status, thus, assessment of groundwater quality is important for the socio-economic development of most developing and developed countries of the world (Aizebeokhai, 2011). It is important to detect changes and early warning of change in groundwater systems, especially those resulting from pollution. The quality of groundwater reflects input from the atmosphere, soil and water-rock reaction as well as pollutant source such as domestic waste, land s clearance and agriculture In this area, apart from relative scarcity of water resource and quality degradation they face high evaporation rates and high levels of anticipated future demands (Offodile, 2002). Groundwater is the primary source of potable water in most part of Maiduguri metropolis, which relies on low-cost domestic (private) boreholes and/or hand-dug shallow wells in an unconfined aquifer. In Maiduguri, uncontrolled urbanization has resulted in increased above ground anthropogenic activities and heavy metals such as incessant waste disposal, proliferation of pit latrines and routine agricultural activities. Large pressure from these above ground pollution sources, can considerably affect negatively on the underlying aquifers. These pollutants may infiltrate into the upper aquifer of the study area, because of the unconfined nature of the upper aquifer of the Chad Basin around Maiduguri.

The stratigraphy of the Chad Basin (Bornu sub-Basin) shows a depositional sequence from top to bottom, which includes the younger Quaternary sediments, Plio-Pleistocene Chad Formation, Turonian-Maastrichtian Fika shale, the late Cretaceous Gongila formation and the Albian Bima Formation (Maduabuchi et al., 2006). The Bima sand stone forms the deeper part of the aquifer series and rests unconformable on the basement complex rocks. Its thickness ranges from 300 to 2000 m and the depth between 2700 and 4600 m (Obaje, 2009). A pioneer investigation carried out by Barber and Jones (1960) revealed that the Chad formation reaches a thickness of at least 548 m at Maiduguri; in the central part of the basin the thickness may reach 600 to 700 m (Offodile, 1992). The Plio-Pleistocene Chad Formation and the Quaternary sediments are the main sources of groundwater supply in the Maiduguri area. The Chad formation dips gently east and northeast towards Lake Chad in conformity with the slope of the land surface. Except for a belt of alluvial deposits around the edge of the basin, the formation is of lacustrine origin and consists of thick beds of clay intercalated with irregular beds of sand, silt and sandy clay (Miller et al., 1968). As shown in Figure 1, Barber and Jones (1960) divided the Chad Formation into three water bearing zones designated upper, middle and lower aquifers (Miller et al., 1968; Odada et al., 2006; Adelana, 2006). The upper aquifer is a Quaternary alluvial fans and deltaic sediments of Lake Margin origin. The reservoir in this system is composed of inter-bedded sands, clays, silts and discontinuous sandy clay lenses which give aquifer characteristics ranging from unconfined, through semi-confined to confined types (Maduabuchi et al., 2006). It extends from the surface to an average depth of 60 m but locally to 180 m. The transmissivity of this aquifer system ranges from 0.6 to 8.3 m2/day and the aquifer yield in Maiduguri is between 2.5 to 30 l/s (Akujieze et al., 2003). Other potential pathways results from improper drilling of wells or poor well development activities, abandoned old wells can also serve as a conduit for direct vertical migration to depths closer to shallow municipal aquifers. Thus, there is an urgent need to investigate the current level of contamination that will help in developing a feasible and practical solution that will mitigate the impact of above ground activities on groundwater quality.

Landfills are the classic solution for waste disposal. During the last years, there has been a growing concern about the effect of landfills in public health, because leaching water can contaminate nearby aquifers. The conversion of the open dumps characteristic of many cities around the world to control and sanitary landfills is a critical step in protecting public health and the environment (Belghazal et al. 2013). Landfill is not just a place where waste is disposed, but it is a technological plant designed, realized and managed to obtain a minimum of negative effects. Sanitary land filling is a fully engineered disposal option that avoids the harmful effects of uncontrolled dumping by spreading, compacting and covering the waste of land that has been carefully engineered before use (ESTs, 2000). Solid waste is the unwanted or useless solid materials generated from combined residential, industrial and commercial activities in a given area. It may be categorized according to its origin (domestic, industrial, commercial, construction or institutional) according to its contents (organic material, glass, metal, plastic, paper etc); or according to hazard potential (toxic, non-toxin, flammable, radioactive, infectious etc). Waste in landfills converts to organic and inorganic compounds in the gas/liquid states by undergoing various chemical and biological transformations, leading to the formation of landfill gas (LFG) and landfill leachate (SSWPU, 2000). Solid waste disposed in landfills is usually subjected to a 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 water resources, it may cause surface water and ground water pollution (Abbas et al. 2009). It has been well recognized that the quantity of leachate generated in a landfill depends on the climate in which the landfill is situated, as well as the type of waste and the water content at which it is a land filled (Kangsepp and Mathiasson, 2009). If groundwater exists close to the surface, or if e.g. sands and gravels or cavernous limestone underlies the site, it may be sensible to provide a leachate control system, regardless of the climate (Lou et al, 2009). However, even in an arid climate, there are occasional wet seasons. The influence of warm climate on landfill performance is complex and the increase in leachate production after precipitation is rapid (Lema et al. 1998). However, co-disposal of wastewater (septic wastewater) inside the landfill, which is practiced in most of the Maiduguri landfills, increased the leachate production significantly and should be considered as a major source of leachate generation (Vavilin et al. 2006). On the other hand, generation and chemical characteristics of leachate depend also upon other factors, such as the MSW composition, moisture content, capillary action, water content of subsurface soil and ambient temperature. The MSW composition in Maiduguri is mainly organic in nature and has high moisture content at about 52%,. Wastes generated in these areas are incessantly disposed in open spaces and dumps. These wastes, over a period and the influence of climatic conditions, could leach down and pollute underlying groundwater. This study was therefore conceived to investigate the impact of anthropogenic and natural sources of contamination on the groundwater quality of the upper unconfined aquifer system of the Chad Basin around Maiduguri, and to ascertain whether the water in this system is within the acceptable limit for human consumption as set aside by World Health Organisation (WHO).

II. Materials And Method

The study area

Moduganari and umarari were important wards in Maiduguri, Nigeria. The city is located between latitude $11^0 51^1 – 11^0\ 55^1$N and longititude $13^0\ 02^1$-$13^0\ 16^1$E. It lies on a vast sedimentary basin, which is flat with gentle undulation at an average elevation of 345m above sea level. According to Hess *et al (1996),* the climate is semi-arid with three distinct seasons, cool-dry season (October to March), hot season (April to June) and a rainy season (July to September). The annual rainfall ranges from 560 to 600 mm. the cold (harmattan) season runs from November to March when temperatures fall to about 20°C and a dry dusty wind blows from the Sahara desert (Eugster and Maglione, 1979; Jaekel, 1984). The area is fragile and highly susceptible to drought with relative humidity of 13% in dry seasons and 65% in rainy seasons. The vegetation of the study area is Savannah woodland, which is divided into two zones: Sudan Savannah to the south and Sahel Savannah to the north. The area dominantly derives its groundwater resources from the Chad Formation (Fig. 1), which is the youngest stratigraphic unit of the Chad Basin and the most prolific in terms of groundwater resources.

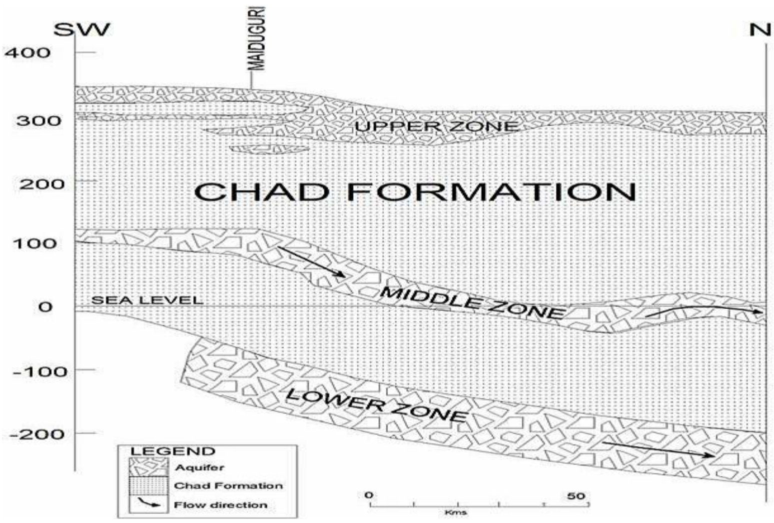

Figure 1: Cross section of the multilayered aquifer system of the Chad Basin (Barber and Jones 1960)

Water sampling

Two landfills at Moduganari and umarari was selected using stratified random sampling. At Moduganari landfill, three existing 6" diameter shallow wells with depth ranged from 40-70m in the basement formation located at the distance of 20, 50, and 100 m radially away from the centre of the landfill were used as the sampling points labeled A_1, A_2 and A_3 respectively. At Bolori landfill, three existing 6" diameter shallow wells with depth ranges from 40-60m in the basement formation located at the distance of 10, 25 and 60m radially away from the centre of the landfill were used as the sampling points labeled B_1, B_2 and B_3 respectively. For each well, 1litre of water sample was collected in sterilized plastic bottle for laboratory analysis.

Laboratory analysis

The laboratory analysis covered physical (odour, colour, turbidity and temperature), chemical (pH, dissolved oxygen (DO), total dissolved solids (TDS), total hardness (TH), total nitrate, nitrite, chloride, calcium and heavy metals such as copper, zinc, iron, Mn, Cr and lead.) and bacteriological (total coli form bacteria and *Escherichia coli*) properties of the water samples from each well. The qualitative analysis was carried out at the Geology laboratory, University of Maiduguri, Nigeria. The pH, Ec and TDS were determined using pH/EC Metter (Combo type meter). Analog mercury thermometer was used for temperature measurement and a Hach 2100A turbidity meter was used for turbidity determination. Total hardness and dissolved oxygen were determined using metter teledo DO meter. Nitrate (NO_3), nitrite (NO_2) and calcium (Ca) were determined using UV/V spectrophotometer (Model Lamba 35) while, chloride was determined using Titration method. The con-centrations of heavy metals such as copper, zinc, iron, Mn, Cr and lead in the water samples were determined with flame atomic absorption spectrophotometer (Model AAnalyst 400). Also, Mckonky broth media was used for the determination of total coli form bacteria and *Escherichia coli.*

Statistical Analysis

The obtained data were subjected to descriptive statistical analysis , table, as well as inferential statistic like correlation. Correlation analysis were used to verify the relationship between examined variables with the aid of SPSS package. The concentration of examined parameters in both closed landfills were compared with the result from Balogun and Longe , 2008 in close landfill to verify the rate of variation in relation to time. Concentration of the examined parameters were arranged in tabular form separately to examine the spatial variation in the concentration of heavy metals and physicochemical parameters in surrounding wells around the closed and operational landfill. The result of each sample were compared with WHO,2004 and NSDQW,2007 standard limit.

III. Results And Discussions

The results of physical characteristics and their comparison with the World Health Organization and the Nigerian Standard for Drinking water quality are presented in Tables 1.

Table 1. Physical characteristics of the water samples analysed

Sample	Odour	Colour	Turbidity (NTU)	Temperature (^{o}c)
A_1	colourless	odourless	0.89	29.0
A_2	colourless	odourless	0.90	28.0
A_3	colourless	odourless	1.46	29.6
B_1	colourless	odourless	5.88	28.7
B_2	colourless	odourless	5.43	29.0
B_3	colourless	odourless	3.32	30.0

All the water samples were colourless and odourless that confirmed no infiltration of leachate into the wells (Mohamed *et al*. 2009). The turbidity values ranges from 0.89 to 5.88 NTU A_1 and A_2 were below unity, while A_3 and B_3 have slightly increases from 1.46 and 3.32 NTU respectively, but all the samples were below the WHO and NSDWQ standard limit of 10NTU as the maximum above which disinfection is inevitable.. The observed turbidity value in samples B_1 and B_2 was slightly higher than the recommended value and might be due to the proximity to the landfill indicating a higher sediment flow when compared with others, hence there is a need for treated before use.. Similar high turbidity values were also reported by Shyamala *et al*. (2008) and Akinbile (2006) indicating that the wells might be unlined, hence the soil particles may have found their way into the wells from the unstable side walls thereby increasing the water turbidity. Water temperatures, which ranged from 28.0°C to 30.0°C, where the temperatures obtained for all the water samples correspond with previous studies across the Basin (Goni, 2006 and Kolo et al., 2009). Jaji et al. (2007) reported a similar view in his studies.

Table 2. Chemical constituents in the boreholes and their comparison with the WHO Standard (in mg/l)

Sample	Distance (m)	pH	Ec	Do	TDS	TH	Ca	No_3	No_2	CL^-
NSDWQ		6.5 -8.5	1000		500	200	75	50	3	250
WHO		6.5 -8.5	1000		500	200	75	50	3	250
A_1	20	8.33	165	14.	90	126	32.5	0.31	0.07	22
A_2	50	8.00	202	14	104	180	46.8	2.55	0.62	38
A_3	100	8.23	190	11	114	112	42	2.25	0.18	22
B_1	10	7.36	680	10	643	364	29.7	5.40	0.04	142
B_2	25	8.35	795	11	517	295	33	6.83	0.63	148
B_3	60	8.10	335	12	176	136	31.6	6.31	0.59	120

The pH ranged from 7.36 to 8.35, which is slightly alkaline even though pH 7.0 is neutral and can be tolerated up to 8.5, provided microbiological monitoring indicated no deterioration in bacteriological quality (WHO 2004). The pH findings from this study agreed with the values obtained by (Ikem *et al*. 2002; Akinbile 2006; Longe & Balogun 2010) but did not agree with the opinions of (Jaji *et al*. 2007; Shyamala *et al*. 2008). The EC in the studied areas ranged between 165 t0 795 mg/l and was found to be high around umarari especially at sites B_2, B_1 and B_3 also in relation to high concentration of pH. The EC is a valuable indicator of the amount of material dissolved in water. Conductivity is the ability of a substance to conduct electricity. The conductivity of water is a more-or-less linear function of the concentration of dissolved ions. This study agreed with Afolayan et al. (2012). The concentration of Dissolved Oxygen (DO) ranged from 10 to 14 mg/L., which are below the WHO and NSDWQ limits, though still low, indicated an indirect impact of the landfill on them. Similar results were reported in Afolayan (2012) underlining the presence of pollutants in appreciable quantities. DO is an important factor used for water quality control and similar values were reported by Jaji *et al*. (2007). The total dissolved solids (TDS) ranged from 60 to 643 mg/l, the water samples $A_{1,}$ A_2, A_3 and B_3 though below the WHO and NSDWQ values still indicate pollution. The TDS concentration was found to be remarkably high at sites While B_1 and B_2 that were above the WHO and NSDWQ values, and it was due to the closeness and shallowness of the wells to the landfill. Akinbile (2012) reported similar result. Total hardness ranged from 112 to 364 mg/l, with B_1 and B_2 were above the WHO and NSDWQ levels, which may be due proximity of the wells to the landfill. However, the values above 200 mg/l for total hardness do not have any adverse health-related effects on humans but is an indication of Ca and/or Mg ions deposits. Their presence will disallow water from forming lather with soap, thereby preventing economic management of water resources. This agrees with the findings of Afolayan et al. (2012). Calcium levels though low, which ranged from 29.7 to 46.8 mg/l, still portend the danger of water hardness and are slightly higher than the values of (Chauhan & Rai 2010). The implication is that forming lather with soap will be a major challenge for domestic users (Akinbile 2006). Nitrate, the most highly oxidised form of nitrogen compounds, is commonly present in surface- and ground waters because it is the product of the aeilerobic decomposition of organic nitrogenous matter. Unpolluted natural waters usually contain only minute quantities of nitrate. The nitrate values in the study ranged from 0.31 to 6.83 mg/l, showing the presence of pollutants in all the water samples. High level of nitrate beyond permissible limit may result to the development of cyanosis in infant. Nitrite ranged from 0.04 to 0.63 mg/l and all this agreed with the observations made by Chauhan and Rai (2010), Igbinosa, and Okoh (2009) in their respective studies despite being below the WHO and NSDWQ values for potable water. Chloride ranged from 22 to 148 mg/l with $B_{1,}$ B_2 and B_3 have high concentration as compared to $A_{1,}$ A_2 and A_3, though being below the WHO and NSDWQ levels, its presence indicates pollution. The values above 250mg/l for chloride would result in detectable taste. This agrees with the findings of (Igbinosa & Okoh 2009).

Table 3. Heavy metal contents in the boreholes and their comparison with the WHO Standard (in mg/l)

Sample	Distance(m)	Fe	Zn	Pb	Cu	Mn	Cr
NSQDW		0.5-5.0	0.01	3.0	1.0	0.2	0.05
WHO		0.5-5.0	0.01	3.0	1.0	0.1	0.05
A_1	20	0.46	ND	ND	ND	ND	ND
A_2	50	0.81	0.04	ND	0.050	ND	ND
A_3	100	1.20	0.06	ND	0.008	0.006	0.500
B_1	10	0.85	0.12	ND	0.009	0.053	0.277
B_2	25	0.62	0.09	ND	0.015	0.075	0.211
B_3	60	0.78	0.25	ND	0.010	0.055	0.865

From Table 3, the heavy metals tested for Moduganari landfill A_1 was not detected with the exception of iron, which is below the range of WHO and NSDWQ standard. Iron and zinc ranged from 0.46 to 1.2 mg/l and 0.04 to 0.25 mg/l respectively, though within the WHO and NSDWQ levels, however is an indication of pollution from the landfill. A similar result was reported by Ikem *et al*. (2002) and agreed with the findings of Shyamala *et al*. (2008), Longe, and Balogun (2010). The WHO (2004) report indicated that a range of values of 1 to 3 mg/l is permissible for iron metals in water above which an objectionable and sour taste in mouth is observed. It was also remarked that the formation of blue baby syndrome in babies and goiter in adults are the results of consumption of water containing iron above the specified quantity (Akinbile 2006; Shyamala *et al*. 2008). Lead was not detected for all the water samples that indicate the two landfills were free of lead materials. However, the presence of Cu and Mn that ranged from 0.008 to 0.05 mg/l and 0.006 to 0.075 mg/l, the four water samples with the exception of A_1 and A_2 that were not detected. The range was above the WHO and NSDWQ limit. The concentration of Cr in the studied area was greater than the WHO standard limit in detected samples. Out of all samples, Cr was not detected in two of them while the remaining was above the WHO and NSDWQ standard limit. It ranged from 0.211 to 0.865 mg/l

Bacteriological characteristics

The bacteriological characteristics of the water samples tested were the *Escherichia coli* and coli form bacteria.

Table 4. Bacteriological constituents in the boreholes and comparison with WHO Standard (in 1/100 ml)

Sample	Bacterial constituent	Water sample result	Variance from WHO
A_1	total coliform bacteria	0.00	-1
	Escherichia coli	*0.00*	*-1*
A_2	total coliform bacteria	0.00	-1
	Escherichia coli	*0.00*	*-1*
A_3	total coliform bacteria	0.00	-1
	Escherichia coli	*0.00*	*-1*
B_1	total coliform bacteria	0.00	-1
	Escherichia coli	*0.00*	*-1*
B_2	total coliform bacteria	0.00	-1
	Escherichia coli	*0.00*	*-1*
B_3	total coliform bacteria	0.00	-1
	Escherichia coli	*0.00*	*-1*

The results in table 4 showed that all the samples satisfy the WHO requirements for bacteriological characteristics in human consumption, being an indication that the two landfills were free from faecal pollution of human and animal wastes. However, treatment of some wells would be required before its domestic consumption.

IV. Conclusion

The study revealed that the concentration of waste materials in the landfill site had slightly polluted the groundwater quality over the time. Results obtained showed that the physio-chemical and bacteriological constituents of all the samples analysed fall within the WHO acceptable limit, except chromium and zinc in $B_{3.}$ The effect of such pollution as determined from the study declined away from the polluting sources. This implied that the contamination of the groundwater was more dependent on the proximity to the dumpsites. In addition, the influences of topography, type, state of waste disposal systems and, to some extent, hydrogeology of the area have effect on groundwater quality. Thus, the groundwater quality from these wells is safe for drinking and other domestic use. The research recommends appropriate material to cap the closed site and treatment after disposal.

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