



## Impact of Landfill Leachate on Groundwater Quality Index of Some Selected Areas of Maiduguri Borno State, Nigeria

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**Abstract:** The reliability of underlying aquifers is mostly affected by pollution through leachate, particularly from solid waste landfills. Solid waste landfills have been recognized as one of the major threats to groundwater resources. Therefore, groundwater requires continuous monitoring through quality assessments and management for sustainable use against contamination. The study investigates impact of landfill leachate on groundwater quality index of some selected areas of Maiduguri. To achieve the aim; water samples for dry and wet seasons were analysed for physicochemical properties; temperature, turbidity, electrical conductivity (EC), pH, dissolved oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Dissolved Solids (TDS), Nitrate (NO<sub>3</sub>), Zinc (Zn), Iron (Fe), Copper (Cu), Cadmium (Cd), Chromium (Cr), Lead (Pb), Arsenic (As) and Manganese (Mn). Temperature and pH were measured in situ using Turbo pH/mV/temperature meter. Total Dissolved Solid was measured using TDS meter (TDS-3). Turbidity and Electrical Conductivity were measured using Hach Turbidity Meter (2100N) and Hanna Electrical Conductivity Meter (HI98311) respectively. The BOD and DO were determined using Winkler method while the COD was analysed using Refluxing method. Colorimetric method was used to determine Nitrate by Hach Colorimeter (DR/890). The heavy metals (Cu, Zn, Mn, Cd, Pb, As, Cr and Fe) were analysed using the multi-wave plasma atomic emission spectrophotometer, (MP-AES 4200). 5ml of each water samples was measured placed in the system and standard code for each heavy metals were selected after calibration and run the system for analysis. The groundwater analysis revealed that the temperature variations in groundwater were function of climatic conditions. The concentration of heavy metals like Zn, Cu, Pb, Cd, Cr and Mn decreases with rise in water table of an aquifer (dry to wet season) while, Fe and As increases from dry to wet season and this was in line with high concentration of Fe and As in the soil samples. The computed water quality index for the water samples ranged from 10.61-72.4, it was observed that Seasonal variation has advance effect on soil as the concentrations increases with increase in leachate in wet season, which in turn pollute the groundwater. The uncontrolled accumulation of leachate over time at the dumpsites base will impose a significant threat to the groundwater quality.

**Key words:** Groundwater, Landfill, Leachate, & Solid Waste

## Introduction

Groundwater is one of the most important natural resources which contributes to the global freshwater supply. In Nigeria, subsurface water provides much of the public and domestic water supply, supports agricultural and industrial economies, and contributes its flow to rivers, lakes and swamps; and this helps in maintaining balance in the ecosystem (Aizebeokhai, 2011). Subsurface water is the primary source of potable water in most parts of Nigeria, particularly in rural areas, which depends on domestic (private) hand-dug wells (Aizebeokhai, 2011). According to Kumar (2013) 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. Furthermore, the usefulness of groundwater to humans, fundamentally depends on its chemical status, therefore, assessment of groundwater quality is important for the socioeconomic development of most developing and developed countries of the world (Kumar, 2013).

Groundwater quality is a significant factor in the context of sustainable water management. The reliability of underlying aquifers is mostly affected by pollution from ground sources, particularly solid waste disposal (Kumar, 2013). Uncontrolled urban growth and its resultant effect, particularly in developing nations like Nigeria, can adversely affect the quality of underlying groundwater if not properly controlled (Putra and Baier, 2008). With a fast population growth of about 2.5% per annum, the demand for water supply has gradually increased over the last three decades. The delivery of safe drinking water has really deteriorated - access in urban areas fell from 27 million to 55 million people in 2002 in African cities (Jacobsen et al., 2012). This is mainly due to poor management, inadequate technical capabilities, lack of investment and insufficient manpower and their training (Hanidu, 1990). Moreover, the institutions responsible for water supply in Nigeria are both ineffective and fragmented; consequently, a transition is needed to bring about a thorough and holistic change to the current system (Jefferies and Duffy, 2011).

Solid waste dumpsites which have been recognized as one of the major threats to groundwater resources receive a mixture of municipal, commercial and mixed industrial wastes. Besides, studies on the effects of unlined waste dumps on the host soil and underlying shallow aquifers have shown that soil and groundwater systems can be polluted due to poorly designed waste disposal facilities (Amadi et al., 2012). Groundwater contamination in a dumpsite facility occurs mainly due to the contaminant potential leachate from the waste body. These leachates are solutions, basically organic or inorganic complexes of biodegradation components of solid wastes flowing from the refuse dumps, saturated with rainwater (Kassenga and Mbluligwe, 2009).

## Statement of Research Problem

The problem of rapid urbanization has led to increase in municipal solid waste generation because of increasing population and some socio-economic factors in Nigeria. (Butu and Mshelia, 2014). Majority of the municipal solid waste disposal sites in Nigeria are still open dumps. Furthermore, in most cases the landfills are not properly engineered and operated to accepted world standards. Improper management of solid waste areas has resulted in serious ecological, environmental and health problems. Such practices contribution to widespread environmental pollution as well as spread of diseases (Susu

and Salami, 2011). Solid waste disposal by landfill poses a threat to groundwater and surface water quality through the formation of polluting liquids known as leachate (Mohammed *et al.*, 2013). Although groundwater quality within the aquifer varies, it is of high quality on the average, with some decline from south to north in Nigeria. Total dissolved solids are high in the Pliocene aquifer of Chad basin formation. Investigations of water quality in the Upper, the Middle and the Lower aquifer in Maiduguri area (Nigeria) have found considerably high concentrations of fluoride (BGS, 2003).

## Materials and Methods

### Materials

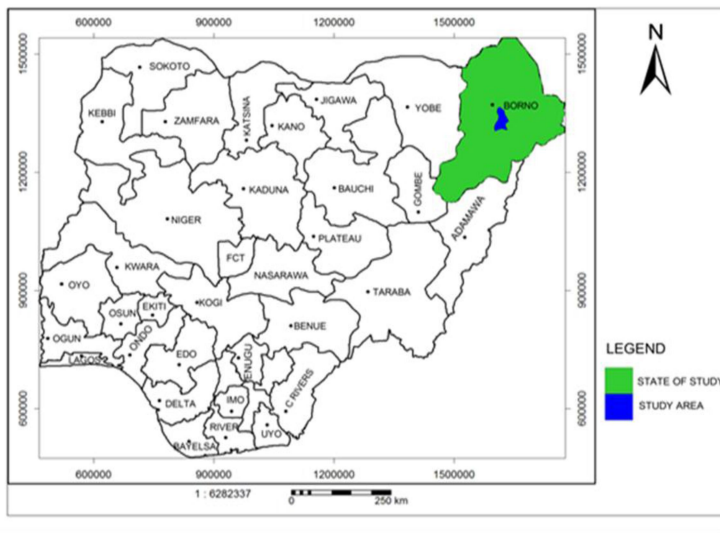
The following materials were used for this study as presented in Table 2.1.

**Table 2.1: Models and Manufacturers of the Materials**

Material	Model	Manufacturer
Soil auger	A15-30	local
Sorting platform/bins	-	-
Sampling bottles	P120	-
Weighing balance	ISO900	<u>Panomex</u> Inc. New Delhi, India
pH/mV/temperature	T352	Turbo WF6, United Kingdom
Hanna EC Meter	H198311	Hanna Woonsocket, Rome, Italy
<u>Hach</u> turbidity meter	2100N	<u>Hach</u> Company, Colorado, USA
<u>Hach</u> colorimeter	DR/890	<u>Hach</u> Company, Colorado, USA
TDS meter	TDS-3	Turbo WF6, United Kingdom
Spectrophotometer	MP-AES 4200	<u>Spectro</u> Kleve, Germany

### The Study Area

Maiduguri is located between latitude  $11^{\circ} 5'' - 11^{\circ} 55''$  N and longitude  $13^{\circ} 02'' - 13^{\circ} 16''$  E. It lies on a vast sedimentary basin, with gentle undulating gradient of altitude 345m above mean sea level as shown in Figure 2.1. The vegetation of the study area is of Sahel Savannah, surface water is very limited within the location and its environment. Hence, the people they depend on groundwater for meeting water needs of the metropolis. The area dominantly derives its groundwater resources from the Chad Formation, which is the youngest stratigraphic unit of the Chad Basin and the most prolific in terms of groundwater resources (Hess *et al.*, (1996). Maiduguri is estimated to have a population of about 1,197,497 in 2009 (NPC, 2006). More than 80% of this population depends on groundwater resources, with per capita water consumption of 10-40 litres of water per day (UN, 1988).

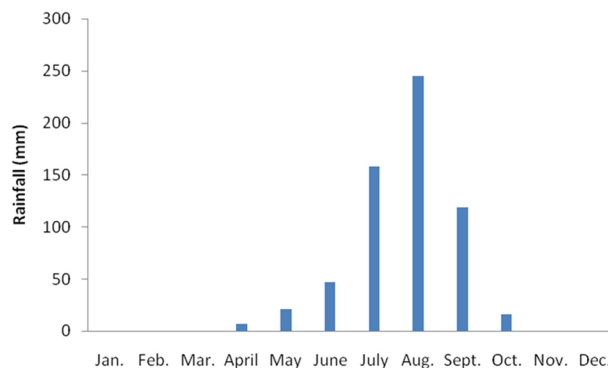


**Figure 2.1 : Map of Nigeria showing the study area (Maiduguri)**

Source: (Bakari, 2014)

### Study Area Climate

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 600mm and Mean monthly rainfall of Maiduguri from 1995 – 2014 as shown in Figure 2.2. The cold (dry harmattan) season runs from November to March when temperatures fall to about 20°C and a dry dusty wind blows from the Sahara desert (Jaekel, 1984). The area is fragile and highly susceptible to drought with relative humidity of 13% in dry seasons and 65% in rainy seasons.



**Figure 2.2: Mean monthly rainfall of Maiduguri from 1995 – 2014**

### Characteristics of Lake Chad Area Aquifer Formation

Barber and Jones (1960) divided the Chad Lake Aquifer Formation into three water bearing zones; designated upper, middle and lower aquifers shown in Figure 2.3. It is Plio-Pleistocene in age and consists mainly of argillaceous sequence with three well-defined erinaceous horizons referred to as phreatic (Upper), Early Pliocene (Middle) and Continental Terminal (Lower) aquifer zones (Maduabuchi, 2005).

### **The upper aquifer system**

The Upper aquifer system consists of three sub-zones in most part of the area. These zones, referred to as A,B and C, are found at depth of 10-40 m, 40-70 m and 78-99 m respectively (Bunu, 1999). 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 m<sup>2</sup>/day and the aquifer yield in Maiduguri is between 2.5 to 3 l/s (Akujieze *et al.*, 2003).

### **The middle aquifer system**

This is the most widespread and best-exploited confined aquifer in the Nigerian sector of the Chad Basin with a surface area in excess of 50,000 km<sup>2</sup>. Its depth ranges from about 200 to 350 m. Litho-logically it is the most varied aquifer, consisting mainly of sand and gravels with silt and clay intercalations (Bunu, 1999). Recharge to this aquifer is reported to occur by horizontal inflow around the ridge of the rocky areas fringing the Chad basin and by lateral percolation from a ridge popularly referred to as the Bama ridge. Yields of boreholes tapping this aquifer range between 5 and 10 l/sec (Bunu, 1999). The Lower Zone aquifer is also separated from the Middle Zone aquifer by a thick clay layer of about 120 m. It consists of sand of various grain sizes and shapes. It occurs at a depth range of 500-650 m with average thickness of 90 m (Dar Al Handasah, 1981). Most of the wells tapping the aquifer are artesian and some are sub artesian. However, this aquifer is not tapped as much as the others due to high cost of drilling to that depth and is also kept as strategic reserve of groundwater to the inhabitants of the area.

### **The lower aquifer system**

The lower aquifer system is found at depths of 420-650 m, with varying yields according to location ranging from about 15 l/s to as high as 30 l/sec. Initially it was thought that the aquifer was mainly confined to the Maiduguri area but a recent geophysical survey indicates its presence beyond Maiduguri (UN, 1988). Typically, the depth to water table in the unconfined parts range from 15 to 75 m. Artesian conditions occur in confined aquifers at 75 to 100 m depth at the eastern edge of the basin; however, the piezometric levels are usually about 50 m depth further west. The upper and middle aquifers are exploited intensively in the Maiduguri area (UN, 1988). Recent decline in groundwater levels in the Chad Basin is believed to be due to over-exploitation of the aquifers in the basin. This has necessitated drilling to greater depths in order to tap the lower aquifer.



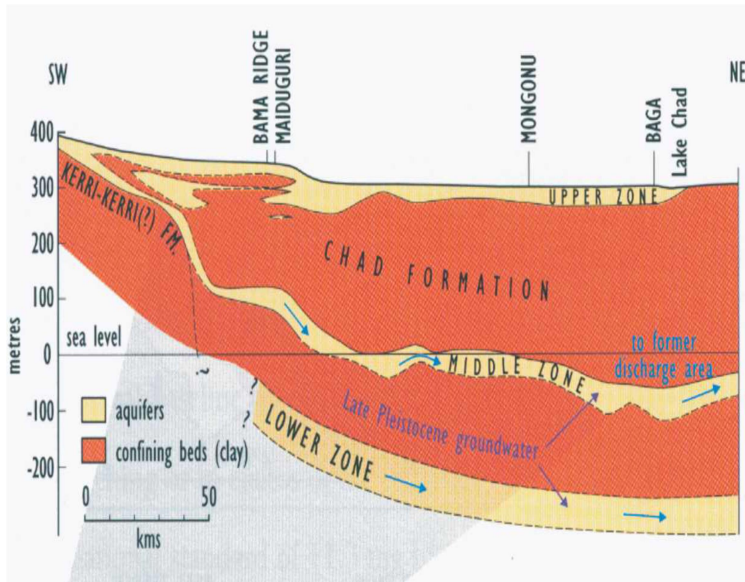


Figure 2.3: Cross-section of the Chad Formation showing the three aquifer zones Source: (Goni *et al.*, 2005)

Purposive sampling technique was adopted to identify two open Municipal solid waste (MSW) dumpsites A & B which ranged from 18-23 years in age at Kumshe and Bakasi in Maiduguri respectively at a distance of 7.16km apart. Four hand-dug boreholes with depth ranging from 24 – 32m with a distance of 55.2m and 657.8m between the centre of dumpsite A and the two boreholes respectively. While, for dumpsite B the distance was 25.7m and 317.3m respectively as shown in Figure 2.4. The sampling coordinates for the dumpsites and wells were presented in Table 2.2 and 2.3. Composite sampling method was adopted for both the water and soil samples.

**Table 2.2: Sampling coordinates of the hand-dug wells and dumpsite A**

Sampling point	Latitude (°)	Longitude (°)
GWA	11.857836	13.147581
GWA <sub>c</sub>	11.864072	13.148281
SAO	11.858228	13.147317
SAN <sub>1</sub>	11.858269	13.147347
SAN <sub>2</sub>	11.858289	13.147319
SAE <sub>1</sub>	11.858242	13.147422
SAE <sub>2</sub>	11.858278	13.147458
SAE <sub>c</sub>	11.857994	13.147511
SAS <sub>1</sub>	11.858214	13.147381
SAS <sub>2</sub>	11.858181	13.147411
SAS <sub>c</sub>	11.858419	13.147261
SAW <sub>1</sub>	11.858222	13.147361
SAW <sub>2</sub>	11.858194	13.147317
SAW <sub>c</sub>	11.858022	13.146950

Table 2.3: Sampling coordinates of the hand-dug wells and dumpsite B

Sampling point	Latitude (°)	Longitude (°)
GWB	11.799939	13.119197
GWB <sub>c</sub>	11.798961	13.116678
SBO	11.799906	13.119431
SBN <sub>1</sub>	11.799919	13.119436
SBN <sub>2</sub>	11.799947	13.119436
SBN <sub>c</sub>	11.800094	13.119464
SBE <sub>1</sub>	11.799928	13.119450
SBE <sub>2</sub>	11.799939	13.119472
SBE <sub>c</sub>	11.799964	13.119672
SBS <sub>1</sub>	11.799903	13.119428
SBS <sub>2</sub>	11.799847	13.119625
SBS <sub>c</sub>	11.799550	13.119689
SBW <sub>1</sub>	11.799902	13.116667
SBW <sub>2</sub>	11.799908	13.119389
SBW <sub>d</sub>	11.799833	13.122419

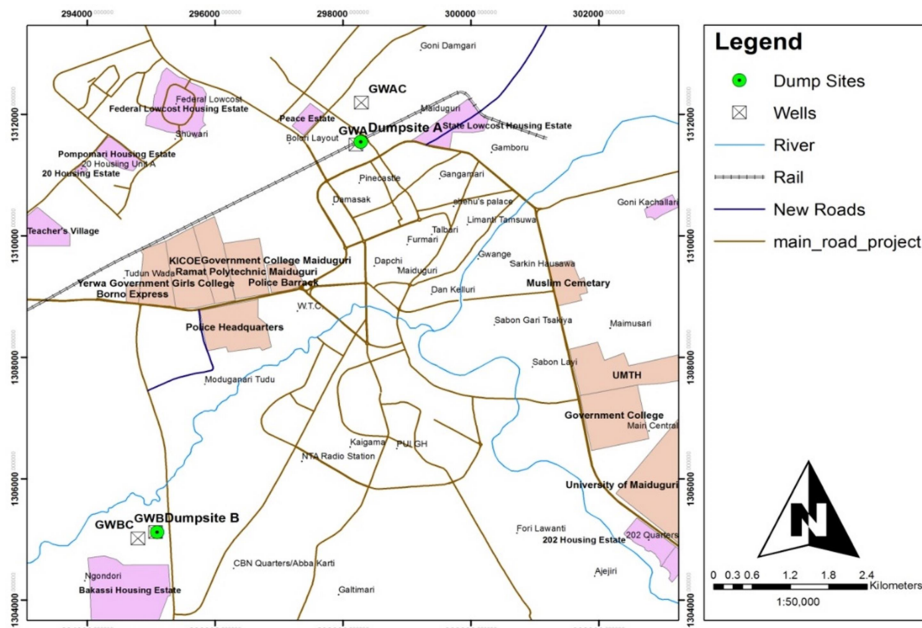


Figure 2.4: GIS Map of Maiduguri showing the location of the sampling points

Table 2.4: Characterization of the dumpsites

	Dumpsite A	Dumpsite B
Elevation (m)	312	323
Area (m <sup>2</sup> )	17.25	14.46
Depth (m)	1.27	1.45
MC of solid waste (%)	17	14
Topography	Flat	Slopy
Drainage	No	No
Human activities	Industrial/Commercial	Farming

Water sampling was carried out according to the National Field Manual for the Collection of Water-Quality Data (USGS, 2006). Four boreholes were identified, two each from the two dumpsites (one each within the proximity of the dumpsite and a control), with depth

ranged from 24 - 32m. The water sampling was conducted in the months of January and August 2017 under average temperature and relative humidity of 24.4°C and 16.4%, and 32.25°C and 59.8% for the dry and wet season respectively. Three replicates of each sample was collected in a 120ml of sterilized plastic bottles and placed in an ice block container (the sampling was repeated three times for each borehole) for laboratory analysis. The water samples were labeled GWA & GWAc, and GWB & GWBc for dumpsite A and B respectively.

Table 2.5: Description of sampling points of dumpsites A and B

Sampling point	Description
<b>Dumpsite A</b>	
SAO	Soil sample at the dump site centre
SAN	Soil sample along the north axis
SAE	Soil sample along the east axis
SAEc	Control sample along the east axis
SAS	Soil sample along the south axis
SASc	Control sample along the south axis
SAW	Soil sample along the west axis
SAWc	Control sample along the west axis
<b>Dumpsite B</b>	
SBO	Soil sample at the dump site centre
SBN	Soil sample along the north axis
SBNc	Control sample along the north axis
SBE	Soil sample along the east axis
SBEc	Control sample along the east axis
SBS	Soil sample along the south axis
SBSc	Control sample along the south axis
SBW	Soil sample along the west axis
SBWc	Control sample along the west axis

The laboratory analysis of water and soil samples were carried out at sanitary chemistry laboratory, department of Water Resources and Environmental Engineering, Soil Science laboratory, department of Soil science and Multi-user Science laboratory, Ahmadu Bello University Zaria.

### Water analysis

The water samples for dry and wet seasons were analysed for physicochemical properties; temperature, turbidity, electrical conductivity (EC) , pH, dissolved oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Dissolved Solids (TDS), Nitrate (NO<sub>3</sub>), Zinc (Zn), Iron (Fe) , Copper (Cu), Cadmium (Cd), Chromium (Cr), Lead (Pb), Arsenic (As) and Manganese (Mn). Temperature and pH were measured in situ using Turbo pH/mV/temperature meter. Total Dissolved Solid was measured using TDS meter (TDS-3). Turbidity and Electrical Conductivity were measured using Hach Turbidity Meter (2100N) and Hanna Electrical Conductivity Meter (HI98311) respectively. The BOD and DO were determined using Winkler method while the COD was analysed



using Refluxing method. Colorimetric method was used to determine Nitrate by Hach Colorimeter (DR/890). The heavy metals (Cu, Zn, Mn, Cd, Pb, As, Cr and Fe) were analysed using the multi-wave plasma atomic emission spectrophotometer, (MP-AES 4200). 5ml of each water samples was measured placed in the system and standard code for each heavy metals were selected after calibration and run the system for analysis.

### Data Analysis

Geographical information system (GIS) was used to map out the soil and water sampling point in the study area. Physio-chemical variables of the soil and water samples were analysed using descriptive statistical analysis to produce a table, which contain the minimum, maximum, mean and standard deviation (SPSS V. 20). Correlation coefficient of physicochemical variables of the soil and water samples was compared using Microsoft excel (2013). Correlation analysis is a bivariate statistical method used to describe the degree of relation between two variables (Venkatramanan *et al.*, 2013). A correlation coefficient (r) was used to represent the association between the variables. A correlation coefficient near 1 or -1 indicates a strong relationship between two variables, while r closer to zero suggests no relationship between the variables (Ha and Ha, 2011). A positive value of r indicates a direct relationship between the variables while a negative value of r indicates an inverse relationship (Salvendy, 2012). Parameters showing  $r > 0.7$  are considered to be strongly correlated, whereas if the r-value is between 0.5 and 0.7, the two parameters have a moderate correlation (Venkatramanan, 2013).

Weighted Arithmetic Water Quality Index was adopted for this study because it incorporates data from multiple water quality parameters into a mathematical equation that rates the health of water body with number and is widely used by various scientists in the word as reported by Brown *et al.* (1972).

### 1. Constant of proportionality (k)

$$k = \frac{1}{\sum_{i=1}^n \frac{1}{S_i}} \quad 2.1$$

Where, k = constant of proportionality

$S_i$  = standard permissible limit for the  $i^{\text{th}}$  parameter

N = number of parameters.

### 2. Relative weight ( $W_i$ )

$$W_i = \frac{k}{S_i} \quad 2.2$$

The unit weight ( $w_i$ ) of the various water quality parameters are inversely proportional to the recommended standards for the corresponding parameters as presented in Table 7.

### 3. Water quality rating of the $i^{\text{th}}$ parameter ( $Q_i$ )

$$Q_i = \frac{100(V_i - V_{id})}{S_i - V_{id}} \quad 2.3$$

Where,  $V_i$  = observed value of the  $i^{\text{th}}$  parameter,

$V_{id}$  = ideal value of the  $i^{\text{th}}$  parameter in pure water.

All the ideal values ( $V_{id}$ ) are taken as zero (0) for drinking water except pH and dissolved oxygen. For pH, the ideal value is 7.0 (for natural/pure water) and the standard permissible value is 8.5 for drinking water. Therefore, the quality rating for pH is calculated from equation 2.4

$$Q_{pH} = \frac{100(V_{pH} - 7.0)}{8.5 - 7.0} \quad 2.4$$

Where, pH = observed value of pH.

For dissolved oxygen, the ideal value is 14.6 mg/l and the standard permissible value for drinking water is 5 mg/l. Therefore, its quality rating is calculated from equation 2.5

$$Q_{DO} = \frac{100(V_{DO} - 14.6)}{5 - 14.6} \quad 2.5$$

Where,  $V_{DO}$  = observed value of dissolved oxygen.

#### 4. Water quality index (WQI)

$$WQI = \frac{\sum_{i=1}^n W_i Q_i}{\sum_{i=1}^n W_i} \quad 2.6$$

Where, n = number of variables or parameters,

$W_i$  = relative weight of the  $i^{\text{th}}$  parameter

$Q_i$  = water quality rating of the  $i^{\text{th}}$  parameter.

Table 2.6. Weight Arithmetic Water Quality Index method rating

Range	Rating of Water Quality	Grading
0-25	Excellent water quality	A
26-50	Good water quality	B
51-75	Poor water quality	C
76-100	Very Poor water quality	D
Above 100	Unsuitable for drinking purpose	E

Source: (Brown *et al.*, 1972).

Table 2.7: Relative weight ( $W_i$ ) for each parameter

P (mg/l)	$S_i$	$1/S_i$	K	$W_i$
Turb			3548	
pH	7		2087	
EC			001774	
TDS			003548	
DO			3548	
COD	5		0222	
BOD			3548	

NO <sub>3</sub>		774	0355
Zn	3		5913
Fe	3		9133
Cu			77
Pb			4
As			4
Cd	3		3333
Cr			48
Mn			37
Total	5		

Temperature (°C), Turbidity (NTU) and EC (µs/cm)

## Results and Discussion

The results of field work comprised the average values of the mass-based composition of waste materials generated in the study area; the percentage composition of the municipal wastes for dry and wet season of dumpsites A and B as presented; dumpsites A revealed that Earth/garbage constitute the highest proportion of wastes generated with 30% and 34% for dry and wet season respectively. The higher proportion of Earth/garbage waste consist of biodegradable materials like waste food and vegetables, and these could be responsible for the inherent odour problems arising from most of the refuse transfer depots in the study area. Metals constitute 20% and 22% of the wastes for dry and wet season respectively. Other waste materials generated include; polythene 16% and 13%, plastic 12% and 11%, glass 11% and 13%, textiles 6% and 5%, and paper 5% and 2% for dry and wet season respectively. The percentage composition of these materials depends largely on the community needs and standard of living, as reported by (Napoleon *et al.*, 2011), that low-income areas produce relatively more of organic wastes.

Dumpsites B revealed that glass waste constitute the highest proportion of wastes generated with 27% and 29% for dry and wet season respectively. The high percentage of glass was due to car repairing garages round the area. Plastics constitute 25% and 26% of the wastes for dry and wet season respectively. Other waste materials generated include; earth/garbage 20% and 21%, polythene 12% and 11%, textiles 9% and 6%, paper 5% and 3%, and waste battery 2% and 4% for dry and wet season respectively. The seasonal variation of solid waste composition could be due to the demanding period of the material, like increase in percentage composition of earth/garbage, plastic, glass, and waste battery from dry to wet season for dumpsite B. The high composition of non-biodegradable wastes from these results bears implication of the requirement for alternative waste management solutions for attaining sustainable and environmental friendly waste management system in the study area and this study agreed with Amori *et al.* (2013).

The mean percentage composition of solid waste at the two dump sites were earth/garbage (26%), metal (21%), glass (20%), plastic (19%), polythene (13%), textile (7%), battery (5%) and paper (3%). At 95% confidence level there was a significant difference between the compositions of the solid wastes at the two dump sites as presented in Table 2.8. This was due to the differences in socio-economic status of the people around the two sites, solid waste variation depends on food habits, cultural tradition, socioeconomic and climatic conditions, not only from city to city but even within the same

city. The effect of seasons on the compositions of the solid wastes at the two sites was not significant at 95% confidence level. There was a significant difference at 99% confidence level between the compositions at each of the dump sites as presented in Table 2.9.

Table 2.8: ANOVA analysis of solid waste composition for two sites

Source of Variation	SS	df	MS	F	P-value	F crit
Both sites	1026.018	5	205.2036	2.902206	0.049951	2.90129
Season both sites	2.78118	3	0.92706	0.013111	0.997854	3.28738
Error	1060.59	15	70.7061			
Total	20891.43	23				

Table 2.9: ANOVA analysis of solid waste types for two sites

Source of Variation	SS	df	MS	F	P-value	F crit
Types of wastes	859.4167	5	171.8833	51.30846	0.000269	5.05033
Season	0.75	1	0.75	0.22388	0.656035	6.60789
Error	16.75	5	3.35			
Total	876.9167	11				

### Physicochemical Characteristics of the Water Samples in the Study Area

The results of laboratory analysis comprised the values of the physicochemical parameters of the water samples and summary of mean and standard deviation of physicochemical concentration of water samples and their comparison with National Standards for Drinking Water Quality (NSDWQ) and World Health Organization (WHO) standard limit of water quality for dry and wet season of boreholes A and B were presented in Table 2.10 and 2.11. The water samples temperature varied from 24.2°C to 25.15°C and 29°C to 30°C with mean and standard deviation of  $24.61 \pm 0.411$  and  $29.25 \pm 0.5$  for dry and wet season respectively. The measured temperature values were reflection of the sampling seasons and all the values were found within ambient temperature. Temperature affects movement of gases in water as higher temperature results in the decrease of solubility of oxygen.

The turbidity values ranged from 0.277 to 4.29 NTU and 0.933 to 18.2 with mean and standard deviation of  $2.66 \pm 1.764$  and  $6.2 \pm 8.197$  for dry and wet season respectively and all the values for dry season are within the desirable limit of NSDWQ and WHO standard limit of 5 NTU as shown in Table 2.10 and 2.11. The turbidity value of GWBc for wet season was found to exceed the NSDWQ and WHO limits, while the other three samples were within the standard limit of 5 NTU, but the concentration of turbidity especially in wet season was higher in the groundwater than the dry season, which might be due to the leachate percolation.

The EC values ranged from 146 to 1105  $\mu\text{S}/\text{cm}$  and 131 to 1329  $\mu\text{S}/\text{cm}$  with mean and standard deviation of  $454 \pm 452$  and  $498 \pm 567$  for dry and wet season respectively. The three groundwater samples (GWB, GWBc & GWAc) were within the permissible NSDWQ and WHO limit of 1000  $\mu\text{S}/\text{cm}$  for dry and wet seasons, while GWA is slightly above NSDWQ and WHO permissible limit for both seasons. The increased EC value at GWA is in

accordance with the observed increase in TDS, it may be attributed to the corresponding higher levels of anions and cations in the water (Jonathan, 2010). These results disagreed with Bayode *et al.* (2012) and agreed with Adamu *et al.* (2013) who found EC within the WHO limit in Kano Nigeria.

The pH values of all water samples in dry season ranged from 7.35 to 7.49 with mean and standard deviation of  $7.41 \pm 0.049$  respectively, all the values are slightly alkaline and are within the NSDWQ and WHO acceptable limit of 6.5–8.5. The pH values for wet season ranged from 8.8 to 12.3 with mean and standard deviation of  $10 \pm 1.59$  respectively, all the values were highly alkaline and are above the NSDWQ and WHO acceptable limit due to leachate percolation. Water with pH outside the normal range may cause a nutritional imbalance or may contain a toxic ion which can adversely affect the growth and development of aquatic life. As pH affects the unit processes in water treatment that contribute to the removal of harmful organisms, as reported by Ugwu and Nwosu (2009) that pH has an indirect effect on health due to its sensitivity to living organism in water.

There were great differences in the values of TDS in the water samples, which ranged from 69 to 821 mg/l and 70 to 906 mg/l with mean and standard deviation of  $357 \pm 57$  and  $322 \pm 395.1$  for dry and wet season respectively. The three groundwater samples (GWA, GWB & GWBc) were within the acceptable NSDWQ and WHO limit of 500 mg/l for both seasons, while GWA had high value above NSDWQ and WHO limit for both seasons. All TDS values increased in wet season as compared with dry season, the increasing value of TDS shows that, the contamination of groundwater was due to leachate, which might be from the solid waste dumpsite site. Afolayan *et al.* (2012) reported that increase in value of TDS also increased the electrical conductivity value of water, which might be cause by mineral content of the soil.

Dissolved oxygen (DO) levels varied from 40 to 70mg/l and 25 to 28mg/l with mean and standard deviation of  $55 \pm 12.910$  and  $26.5 \pm 1.732$  for dry and wet season respectively. The concentration of DO in all the water samples were above NSDWQ and WHO standard limit of 3mg/l for both seasons, and all DO values decreased in wet season as compared with dry season as shown in Table 2.10 and 2.11. BOD values of the water samples ranged between 20 and 30mg/l and 4 to 16mg/l with mean and standard deviation of  $22.5 \pm 5$  and  $8.755 \pm 5.5$  respectively. All the values for dry season exhibited higher levels of BOD concentrations as compared with NSDWQ and WHO standard limit of 5mg/l and all BOD values decreased in wet season through GWA and GWBc were still above NSDWQ and WHO standard limit as shown in Table 2.10 and 2.11. The highest BOD value was recorded at GWA for both season, this may be attributed to high biodegradable materials in the leachate from the dumpsites.

Chemical oxygen demand (COD) values of the water samples ranged between 1800mg/l & 2000mg/l and 150mg/l & 200mg/l with mean and standard deviation of  $1862 \pm 94.65$  and  $167.5 \pm 22.2$  for dry and wet season respectively. All the water samples exhibited higher levels of COD with decreased values in wet season as compared with dry season but all the concentrations were above NSDWQ and WHO standard limit of 80mg/l and 10mg/l respectively. The highest COD level was recorded at GWA for both seasons. The high level of COD in all the water samples is a clear indication that the solid waste infiltrates high oxygen demanding materials, which causes depletion of dissolved oxygen in water. The concentration of nitrate in all the water samples varied from 0.1 mg/l to 0.105



mg/l, with mean and standard deviation of 0.035mg/l and 0.0467 respectively. This indicates that nitrate concentration for all the samples are within the WHO desirable limit of 50 mg/l as shown in Table 20 and 21. This study was in conformity with Ocheri *et al.*, (2010).

The concentration of Zn and Fe analyzed for dry and wet season in all the water samples ranged from 0.082– 0.118 mg/l and 0.108 – 0.217 mg/l; 0.01 - 0.1226 mg/l and 0.649 – 0.812 mg/l with mean and standard deviation of  $0.105 \pm 0.016$  and  $0.158 \pm 0.052$ ,  $0.063 \pm 0.055$  and  $0.72 \pm 0.072$  respectively. The concentration of Zn decreased from dry to wet season due to raise in water table and all the water samples were within NSDWQ and WHO standard limit of 3 mg/l and 5 mg/l respectively. This result is in conformity with Tse and Adamu (2012) found heavy metals in traces from hand-dung well in Makurdi. The concentration of Fe increased from dry to wet season due to high concentration of Fe in the soil samples, and all the water samples were also within the WHO standard limit of 10.3mg/l. However, all the water samples for wet season were above NSDWQ standard limit of 0.3 mg/l. This result disagreed Mile et al., (2013) that high level of heavy metals might be attributed to mineralogy and land use management.

The concentration of Cu and Pb ranged between 0.095–0.226 mg/l and 0.068–0.3 mg/l, 0.011–0.143 mg/l and 0.003–0.055 mg/l with mean and standard deviation of  $0.151 \pm 0.058$  and  $0.166 \pm 0.097$ ,  $0.105 \pm 0.063$  and  $0.023 \pm 0.023$  for dry and wet season respectively. The concentration of Cu decreased from dry to wet season due to raise in water table and all the water samples were within NSDWQ and WHO standard limit of 1 mg/l and 2 mg/l respectively. This result disagreed with Mile et al. (2013). The concentration Pb in all the water samples for both seasons were above NSDWQ and WHO standard limit of 0.01 mg/l and decreased from dry to wet season. This result agreed with Ocheri and Odoma (2013), found that the major contributing factors were geological and leachate from landfill.

The concentration of As and Cd analyzed for all the water samples ranged from 0.072–0.28 mg/l and 0.116–0.24 mg/l, 0.29–0.514 mg/l and 0.001–0.006 mg/l with mean and standard deviation of  $0.148 \pm 0.091$  and  $0.177 \pm 0.065$ ,  $0.356 \pm 0.221$  and  $0.004 \pm 0.002$  for dry and wet seasons respectively. The concentration of As and Cd in all the water samples for dry season were highly above NSDWQ and WHO standard limit of 0.01 mg/l and 0.003mg/l respectively and also the concentration of As for wet season was above NSDWQ and WHO standard limit, while Cd concentration of wet season decreased for GWA and GWAc, which were within NSDWQ and WHO standard limit but for GWB and GWBc, which were above NSDWQ and WHO standard limit. These results were in conformity with Nwankwoala *et al* (2011) found Fe, Mg, Cr, Pb, Cd and Cu were above WHO limit in Yenegoa.

The Cr and Mn concentration in both seasons were within permissible limit of NSDWQ and WHO of 0.05 mg/l and 0.5 mg/l except GWAc in dry season. The Cr and Mn concentration ranged between 0.001–0.184 mg/L and 0.063–0.357mg/L, 0–0.001mg/l and 0–0.014 mg/l with mean and standard deviation of  $0.148 \pm 0.091$  and  $0.177 \pm 0.065$ ,  $0.356 \pm 0.221$  and  $0.004 \pm 0.002$  for dry to wet season respectively. The concentration of Cr and Mn ranged from 0.001–0.184 mg/l and 0.063–0.357 mg/l for dry season respectively and decreases from dry to wet season due raise in water table and low rate of infiltration. All the samples were within NSDWQ and WHO limit of 0.2 mg/l and 0.5 mg/l except GWAc. These results disagreed with Nwankwoala et al., (2011) found Fe, Mg, Cr, Pb, Cd and Cu were above WHO limit in Yenegoa.

**Table 2.10: Physicochemical characteristics of the water samples for dry and wet season in mg/l**

Parameter	GWA	GWAc	GWB	GWBC	GWA	GWAc	GWB	GWBC
	Dry Season				Wet season			
Temp	24.4	24.67	25.15	24.2	29	30	29	29
Turbidity	0.28	3.63	2.43	4.29	0.94	4.73	0.93	18.2
EC	1105	416	150	146	1329	390	131	140
pH	7.4	7.35	7.47	7.41	9.1	9.8	12.3	8.8
TDS	821	219	69	75	906	220	91	70
DO	70	40	50	60	25	28	28	25
COD	2000	1850	1800	1800	160	150	160	200
BOD	30	20	20	20	16	5	4	10
NO <sub>3</sub>	28.5	1.28	2.17	1.18	53.62	2.8	4.48	4.48
Zn	0.082	0.111	0.118	0.110	0.01	0.122	0.021	0.097
Fe	0.12	0.217	0.186	0.108	0.812	0.734	0.684	0.649
Cu	0.119	0.226	0.166	0.095	0.132	0.011	0.135	0.143
Pb	0.155	0.300	0.142	0.068	0.055	0.013	0.003	0.021
As	0.123	0.280	0.116	0.071	0.029	0.514	0.46	0.419
Cd	0.116	0.240	0.226	0.126	0.001	0.002	0.005	0.006
Cr	0.029	0.184	0.001	0.007	ND	ND	0.001	0.001
Mn	0.146	0.357	0.118	0.063	ND	0.004	0.014	0.001

Temp.(°C), Turbidity (NTU) and EC (µs/cm)

**Table 2.11: Mean and standard deviation of physicochemical characteristics of water samples for dry and wet season**

	Min.(mg/l)	Max.(mg/l)	M±S.D	Min.(mg/l)	Max.(mg/l)	M±S.D	NSDWQ	WHO
	dry Season			wet Season				
Temp.	24.20	25.15	24.61±0.411	29	30	29.25±0.5	NS	28.5
Turbidity	0.277	4.290	2.657±1.764	0.933	18.2	6.2±8.197	5	5
pH	7.35	7.47	7.408±0.049	8.8	12.3	10±1.59	6.5-8.5	6.5-8.5
EC	146	1105	454±452	131	1329	498±567.2	1000	1000
TDS	69	821	357±357	70	906	322±395.1	500	500
DO	40	70	55±12.91	25	28	26.5±1.732	NS	3
COD	1800	2000	1862±94.65	150	200	167.5±22.2	80	10
BOD	20	30	22.5±5	4	16	8.755±5.5	5	5
NO <sub>3</sub>	1.180	28.5	8.24±13.52	2.8	53.62	16.4±24.86	50	50
Zn	0.082	0.118	0.105±0.016	0.01	0.122	0.063±0.055	3	5
Fe	0.108	0.217	0.158±0.052	0.649	0.812	0.72±0.071	0.3	10.3
Cu	0.095	0.226	0.151±0.58	0.011	0.143	0.105±0.063	1	2
Pb	0.068	0.3	0.166±0.097	0.003	0.055	0.023±0.023	0.01	0.01
As	0.071	0.28	0.148±0.091	0.029	0.514	0.356±0.221	0.01	0.01
Cd	0.116	0.24	0.177±0.065	0.001	0.006	0.004±0.002	0.003	0.003
Cr	0.001	0.184	0.055±0.087	0	0.001	0.001±0.001	0.05	0.05
Mn	0.063	0.357	0.171±0.129	0	0.014	0.005±0.006	0.2	0.5

Temp. (°C), Turbidity (NTU) and EC (µs/cm)

### Correlation Coefficient and Water Quality Index of the Sampling Wells

The Correlation coefficient of the sampling wells at 5% significant level revealed that strong relationship exists between the sampling wells and the Nigerian standard of drinking water quality and WHO standard limit for drinking water quality, except GWAc1, GWB1 and GWBc1, which indicate no relationship between the sampling wells. As reported

by Ha and Ha (2011) that correlation coefficient near 1 or -1 indicates a strong relationship between two variables, while  $r$  closer to zero suggests no relationship between the variables. At 95% confidence level there was a significant difference between the physicochemical characteristics of the water samples as presented in Table 2.12. The effect of seasons on the physicochemical characteristics of the water samples was significant at 95% confidence level, due to rise in the water table of the aquifer as also presented in Table 2.12.

The computed water quality index for the water samples ranged from 10.61-72.4. The minimum value was recorded in sample GWA1, while the maximum value was in sample GWAc1. It was observed that sampling wells GWA2 and GWAc2 falls within the categories of excellent water quality (0-25), while the sampling wells GWB1, GWB2, GWBc1 AND GWBc2 were good water quality (26-50). The sampling wells GWA1 and GWAc1 indicate high level of groundwater pollution, which falls into poor water quality category as categorised by Brown et al. (1972) in Table 1. The high values of water quality index of wells GWA1 and GWAc1 was due to the concentration of Pb, As and Cd in the groundwater. The poor water quality index of GWA1 and GWAc1 in the dry season dropped to less than 20 in the wet season, due to rose in aquifer water table during the raining season.

**Table 2.12: ANOVA Analysis of physicochemical characteristics for two Sites**

Source of Variation	SS	Df	MS	F	P-value	F crit
All wells	2268.808	3	378.1346	229.7887	4.95E-5	3.811725
Season all wells	341.5578	3	6.45575	13.111	0.007854	1.28738
Error	1060.234	7	70.7061			
Total	3670.622	15				

## Conclusion

The study revealed that the two dumpsites were still in their active stage, with high percentage composition of non-biodegradable solid wastes like glass, metal, polythene and plastic. The seasonal variation of solid waste composition in wet and dry seasons was due to the demanding period of the material. The study also revealed that the particles size analysis for the two dumpsites were sandy loam with high mean percentage of sand. Generally, the seasonal variations in concentration of the soil parameters increase from dry to wet season due to increase in leachate from the solid waste dumpsites and there was no defined pattern of concentration movement within the soil profile. The soil samples collected far away from the solid waste dumpsites (control) have lower concentration compared to those within the vicinity of the dumpsites and all the concentration of the soil parameters were within NES permissible limit. Furthermore, the groundwater analysis revealed that the temperature variations in groundwater were function of climatic conditions. The concentration of heavy metals like Zn, Cu, Pb, Cd, Cr and Mn decreases with rise in water table of an aquifer (dry to wet season) while, Fe and As increases from dry to wet season and this was in line with high concentration of Fe and As in the soil samples. The computed water quality index for the water samples ranged from 10.61-72.4, it was observed that Seasonal variation has advance effect on soil as the concentrations increases

with increase in leachate in wet season, which in turn pollute the groundwater source. The uncontrolled accumulation of leachate over time at the dumpsites base will impose a significant threat to the groundwater quality.

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