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EFFECT OF OPEN WASTE DISPOSAL ON THE PHYSICO-CHEMICAL QUALITY OF GROUNDWATER IN SABON GARI AREA OF KANO STATE- NIGERIA

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Abstracts

Water is one of the most essential resources that define the socio-economic wellbeing of man. Despite the abundance of water, access to safe drinking water is still a challenge to water resource managers due to increasing human activities which lead to water pollution. Open disposal of wastes in urban areas has potential forcreating serious ecological, environmental and health problems around the globe. In Nigeria, the effects could lead to pollution of groundwater due to leachates, which could affect the well-being of the populace. This paper is aimed at assessing thephysico-chemical quality of groundwater within SabonGari area of Kano State-Nigeria, with a view to establish correlation between leachates from the waste dumpsites at various locations in relation to the positions of the open wells and boreholes within the study area. Leachates and sewage as well as open wells and boreholessamples were collected and assessed using standard laboratory methods. Reconnaissance survey was conducted to assess the closeness of groundwater to possible sources of pollution.A total of ninety (90) samples were obtained to examine their physical and chemical parameters using gravimetric, titrimetric, colorimetric and atomic absorption spectrophotometer in accordance with APHA procedures were employed.The study established an average distance of the waste dumps to water sources of 10 meters within the study area. Further findings revealedthat water from boreholes and wells in the study area have temperature within the ambient range of 28.8^{0}C,with unobjectionable taste, odourless, and have low mean values (3.2 Hazen) for colour, electrical conductivityand other physico-chemical parameters.. Mean values ranging from (630 – 2410 mg/L) for total dissolved solids were recorded for wells and boreholes. High mean levels of heavy metals such as chromium (ranging from 1.5 mg/L to 4.0 mg/L for well and borehole samples respectively), lead (ranging from 0.5 mg/L to 4.9 mg/L for well and borehole samples respectively) and cadmium (ranging from 1.0 mg/L to 2.8 mg/L for well and borehole samples respectively) were obtained. High level of hardness (ranging from 356.0mg/L to 612.3mg/L for well and borehole samples) was also recorded as opposed to WHO limit of 500mg/L. Theseare indicative of pollution of the groundwater resulting largely from the proximity of the groundwater sources to waste dumps within the study area.

Keywords: Wastewater; Groundwater; Leachate; Borehole; Well; Pollution

1.0 Introduction

Water is essential for livelihood and a key factor in gauging socio-economic development of any community, hence considered to be 'the mother of all living world'. Water covers majority of earth's surface, however a very small percentage of is available as fresh water that human can use (Musa, 2014). Freshwater has become a scare resource due to over exploitation and pollution. Pollution is caused when a change in the physical, chemical and or biological condition in the environment harmfully affect quality of human life including animals' life. Industrial sewage and municipal waste are been continuously added to water bodies hence affect the physical and chemical quality of water making them unfit for use (Musa, 2014).

In Nigeria, the rate of urbanization characterized by high population growth, increasing industrial activities coupled with environmental pollution/degradation and indiscriminate disposal of all types of wastes constitute serious pollution threats with its associated health hazards on groundwater quality especially in the urban areas (Eni *et al*., 2011)

Solid waste dumps are heterogeneous in nature and the degradation time results in longer retention of the waste thereby increasing the chances of movement of leachate into the groundwater source thus contaminating the water (Mohammed, 2011)

Access to safe clean drinking water and adequate sanitation is a fundamental right and a condition for basic health. However, in developing world, one person in three lacks safe drinking water and sanitation (Zektser*et al*., 2005). According to WHO (2000), about 1 billion people in developing countries lack access to drinking water. The provision of clean drinking water, especially in developing countries like Nigeria, has always been a major challenge (Raji and Ibrahim, 2011).

Majority of the world's population, especially in most parts of Africa and Asia, do not have access to safe drinking water due to population growth, industrialization, land degradation, poor sanitation, etc; with about 6 million children dying daily as a result of waterborne diseases linked to scarcity of safe drinking water or sanitation (TWAS, 2002). A large percentage of the population in developing countries lack adequate potable water supply (Welch *et al*., 2000; Jamielson *et al*,. 2004). According to Mintz *et al*., 2001, safe drinking water remains out of reach for about 1.1 billion people in the world. About 52% of Nigerians do not have access to improved water supply (Orebiyui, *et al*., 2010). In Nigeria, the rate of urbanization characterized by high population concentration, increasing industrial and agricultural activities coupled with environmental pollution/degradation and indiscriminate disposal of all kinds of wastes are perceived to pose serious pollution threats with all its associated health hazards on ground water quality especially in urban areas (Kehinde, 1998, Eni *et al.*, 2011, Ocheri and Ode, 2012).

There has been an increasing concern for the environment in which man lives. Solid waste, mount of rubbish, garbage and sewage are being produced everyday by our urban society. In an attempt to dispose these waste materials, man has carelessly polluted the environment including groundwater. Organic wastes can undergo degradation into simpler substances through biochemical reactions involving dissolution, hydrolysis, oxidation and reduction processes generating leachate which can percolate into groundwater. The leachates i.e. the liquid drains from the dump, mainly organic carbon largely in form of fulvic acid migrate downward and contaminate the groundwater (Ugwu *et al.*, 2009)

The deleterious effect of pollutions include harm to human health, hindrance to aquatic activities and the inability of the water to support agriculture, industrial and other related economic activities. A noted source of pollution in groundwater supplies is the latrine/septic tank, causing an increase in biochemical oxygen demand (BOD), chemical oxygen demand (COD), nitrate, inorganic chemicals (Chapman, 1992).

Effluents discharge alters the physical, chemical and biological nature of receiving water reservoirs. Some of these effluents contain heavy metals and small amounts of these heavy metals are common in our environment, diet and the air. They are actually necessary for good health, but large amounts of any of them may cause acute or chronic toxicity (poisoning). Heavy metals cannot be degraded or destroyed and as such they are hazardous as they tend to bio-accumulate (Sangodoyin, 1991).

The short-term effect of excessive nitrate in drinking water is the occurrence of methemoglobinemia which is a blood disorder caused by having too much nitrate in the human body. This blood disorder has very visible signs and mainly affects infants. In babies less than six months of age, high levels of nitrate in the blood will prevent blood from delivering oxygen effectively to different parts of the body. As a result, the infant will have blueness around the mouth, hands and feet (hence the name "blue baby syndrome"). Others signs of the blue baby syndrome include vomiting, diarrhea and convulsion. On the long term, excess nitrate has the potential to result in increased starchy deposits and hemorrhaging of the spleen. Nitrates can react with amines or amides in the body to form nitrosamines which is known to cause cancer (Dinesh and Chandel, 2010). This is also collaborated by Kolawole and Afolayan (2017) that excessive nitrate in drinking water constitutes a significant risk factor for little babies, causing blue baby syndrome or "blue baby" disease.

The scarcity of pipe borne water has made many communities to find alternative sources of water of which groundwater sources is the ready source (Okoro*et al*., 2014). According to Sabo *et al*., 2013, groundwater is increasingly gaining significance as the main solution to water supply problems in

Nigeria. Most of the houses in Sabon Gari rely on groundwater for their domestic use and as such open well and boreholes adorn almost every compound. More worrisome is the disposal of the sewage or domestic waste into open gutters which may or may not flow from their point of origin. There is also poor management of waste coupled with indiscriminate citing of pit toilets, septic tanks and soak away close to boreholes and unprotected hand dug well in the study area.

2.0 Materials and Methods

2.1 Demography of the Study Area

The study area is located at latitude of 12.0217^o and longitude of 8.5222^o with population put at 675,982 as at 2013 population census. Sabon Gari literally meaning new settlement in Hausa is one of the densely populated areas in Kano. It is predominantly the settlement for people from different cultural, ethnic and social background with the majority of the dwellers being Igbo and Yoruba speaking populace. The people are predominantly business men and women, and it is home to all kinds of businesses ranging from food stuff to industrial activities such as printing, sale of different kinds of chemicals, lead batteries, petrochemical products, cosmetics, spare parts etc. A lot of solid wastes and sewage are generated from these activities without commensurate safe disposal facilities. It was reported by Bichi and Amatobi (2013) that 57.5% of solid waste generated in Sabon Gari is made up of food/putrescible and vegetable matters which are susceptible to biodegradation.

The study area was divided into three zones namely: Zone A: south (from France road to new road), Zone B: central (from middle road to Aba road) and Zone C: north (from Ijebu road to Zungeru road) (Figure 1)

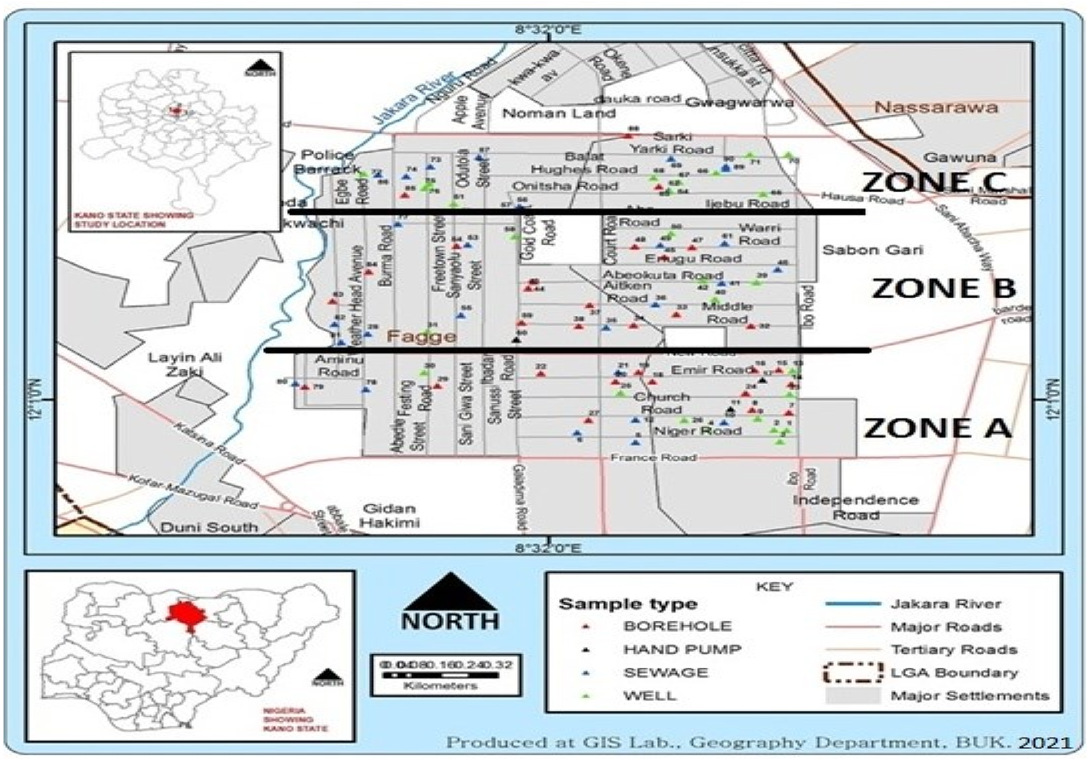

Figure 1: Map of SabonGari Area of Kano, Kano State Indicating Sampling Location and Points

2.2 Field Survey

Field survey was carried out mainly to assess the location of soak away, pit toilets, solid waste disposal practices as well as proximity of solid waste disposal sites to ground water sources in the study area. Measuring tape was used for the measurement and GPS (etrex) was used to determine the coordinates.

2.3 Water Sampling and Analysis

Samples were collected in 1litre plastic containers which were washed win non-ionic detergent and rinsed with de-ionized water as part of quality control measures. Before the final collection of water sampling was done, the bottles were rinsed three times with the sample at the point of collection. Each bottle was labelled accordingly, preserved at 4^0C in an ice box and transported to the laboratory (Longe and Balogun, 2010). Leachate samples mixed with sewage were also collected similarly.

A total of 90 samples comprising of leachate of varying concentrations, open well and borehole/hand pump were collected from the study area for laboratory analysis. The global position system coordinates (GPS) of the sampling points were taken using portable etrex GPS instrument. Parameters such as temperature, pH, electrical conductivity, turbidity and dissolved oxygen were conducted immediately on site using portable meter (Multimeter PH – 2608 and LaMotte Smart 2 colorimeter). Total alkalinity, total hardness, calcium, magnesium and chloride were determined using titrimetric method APHA (2005). Heavy metals such as iron, lead, chromium, cadmium and other parameters were analysed using Atomic Absorption Spectrophotometer (AAS) model 240FS (New life medical instrument England).Nitrate, sulphate and phosphate were determined using colorimeter spectrum lab 752S (Agilent Technologies).

Plate 1: Open waste dump site

Plate 2: Open well close to unprotected wastewater drainage

3.0 Results and Discussion

The reconnaissance survey carried out revealed poor waste disposal practices in all the zones. The distance of boreholes and wells from the sources of pollution such as waste dump, septic tanks and pit toilets ranges from 2 – 15metres. This indicates that wells and boreholes are located less than 30m from sources of contamination which is not inconformity with standards. According to WHO (2013) recommended standard, the effective distance between septic tank and other sources of pollution and any drinking water source is estimated to be a minimum of 30m and above.

The mean concentrations of the parameters for the leachate, well and borehole with their ± SE (standard error) of the zones is presented in Table 1 and 2.

The mean concentrations of the chemical parameters especially heavy metals such as iron, zinc, lead, chromium and cadmium were high above the WHO permissible limits for leachates, wells and boreholes in all the zones with high heavy metal concentrations for the leachates/wastewater.

The physical parameters with the exception of total dissolved solids are within the standard permissible limits of World health Organization (WHO) and Nigerian Standard for Drinking Water Quality (NSDWQ) for the wells and boreholes. The electrical conductivity ranged from 2.60±0.39 – 3.76±0.46µS/cm, 2.28±0.09 - 3.24±0.21µS/cm and 1.59±0.23 – 2.25±0.09µS/cm for leachates, well and boreholes respectively. This is similar to the findings of Afolayan *et al*., (2012), in their study on the impact of solid waste disposal on groundwater quality in the urbanized area of Lagos Nigeria with the electrical conductivity ranging from 0.17 – 9.94 µS/cm. Though the results of the electrical conductivity of the well and borehole samples are below the WHO permissible limits of 1,400µS/cm, the similarity in the results of electrical conductivity of the leachate and sewage with that of the well and borehole water samples connotes the possible infiltration of the leachate and sewage into the wells and boreholes in the study area.

The pH results for leachates, wells and boreholes ranges from 7.18±0.08 – 7.59±0.13, 7.04±0.11 – 7.25±0.04 and 6.53±0.09 – 6.67±0.13 respectively. The pH for the wells and boreholes conforms to the WHO drinking water standard (6.5 -8.5) and agreed with the results of Ogbonna *et al*., (2010) for various groundwater samples. The importance of the hydrogen ion concentration (pH) of water is evident in the manner it affects the chemical reactions and biological systems (Kolawole *et al*., 2013).

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Table1: Mean concentrations of the physical parameters of leachate/sewage, wells and boreholes.

Location	Source	Electrical Conductivity (µS/cm)	pH	Turbidity (NUT)	Total Dissolved Solids (mg/L)	Total Suspended Solids (mg/L)	Total Alkalinity (mg/L)	Total Hardness (mg/L)
SGS	Leachate/ Sewage	3.76 ± 0.46	7.59±0.13	297.0±64.85	2181.67±346.27	2.43 ± 1.33	196.67±36.39	547.68±131.7
	Well	3.24 ± 0.21	7.25±0.04	2.0 ± 18.47	2260.0 ±149.78	0.28 ± 0.31	210.0±20.78	448.92±51.53
	Borehole	2.25 ± 0.09	6.53±0.09	1.4 ± 5.02	1570.0 ±56.53	3.11 ± 0.22	160.0±28.42	612.32±42.55
SGC	Leachate/ Sewage	2.6 ± 0.39	7.18±0.10	104.4± 26.08	1806.25 ±263.15	0.85 ± 0.10	269.38±16.76	635.34±46.45
	Well	2.3 ± 0.30	7.04 ± 0.11	2.43 ± 1.15	1620.0 ±209.06	0.72 ± 0.06	185.0± 26.17	468.37±72.96
	Borehole	1.6 ± 0.09	6.65 ± 0.10	2.09 ± 0.44	1124.0 ±61.08	0.9 ± 0.19	204.7 ±23.05	524.05±71.18
SGN	Leachate/ Sewage	3.13 ± 0.24	7.18 ± 0.08	158.7 ±29.53	2178.57±169.97	1.28 ± 0.62	353.5 ±17.65	518.18±22.46
	Well	2.278 ±0.09	7.17 ± 0.06	2.69 ± 0.70	159.0 ±63.55	0.158 ± 0.05	198.0±37.05	355.99±42.53
	Borehole	1.59 ± 0.23	6.67 ± 0.13	0.61 ± 0.54	1118.33±162.10	0.21 ± 0.05	256.67±24.45	464.63±60.77
	WHO Standard	1000	6.5 – 8.5	5.0	500		100	500

SGS- Sabon Gari South, SGC – Sabon Gari Central, SGN – Sabon Gari North

Turbidity of the well and borehole water samples generally varied between 0.61±0.54 and 2.69±0.70NTU. The total dissolved solids concentrations range from 1806.25±26.88 – 2181.67±346.27mg/L, 159.0±63.15 – 2260.0±149.78mg/ L and 1118.0±162.10 - 1570±56.55mg/L for leachates, well and borehole samples respectively. These results are in consonance with the study by Ogbonna *et al*., (2010) on well water.

The total dissolved solids (TDS) represents the percentage of inorganic substances available in the water which reveals the nature of water quality (Olajire and Imeokparia, 2001). The high concentration of total dissolved solids in the wells and boreholes is an indication of infiltration of leachate into the groundwater as the dissolved solids concentration in the leachate is high.

The mean hardness level of 355.99±42.53 mg/L – 612.32±42.35 mg/L in the well and borehole samples above the permissible limits is an indication that the water may not be appealing for domestic use. In a similar study by Mohammed (2011), the results show ranges from 112 – 444mg/L with some of the samples above the permissible limits of 400mg/L. He suggested that this may be due to dissolution of polyvalent metallic ions from sedimentary rocks, seepage and run off from soil. Christopher and Mohammed (2011), submitted that the values of hardness above 200 mg/L even though does not have adverse health-related effects on humans is an indication of deposits of calcium and magnesium ions. Their presence will prevent water from forming lather with soap hereby preventing the economical use and management of water resources.

The mean concentration for chloride (77.64 – 240.83mg/L) in wells and boreholes is below the permissible level of 250mg/L, though below the WHO and NSDWQ levels, its presence connote pollution from the leachate and wastewater from the open waste dump. The high levels chloride also connotes the leaching from soil due to infiltration from the landfill and other anthropogenic activities (Igbinosa and Okoh, 2009).

The values of 2.44±0.42 – 11.59±7.45 mg/L and 3.89±0.41 – 4.88±0.26 mg/L were recorded for iron in the well and borehole samples respectively. The mean value for concentration of lead ranges between 0.92±0.11 -1.42±0.38mg/L and 0.53±0.15 - 2.73±1.07mg/L for well and borehole samples respectively.

The WHO and NSDWQ maximum permissible level for iron is 1.0 mg/L and 0.1 mg/L for lead which implies that the water is poisonous if consumed without any form of treatment.

The concentration of Zinc ranged between 2.70±0.21 – 7.35±0.46mg/L for well and borehole samples. These values are above the maximum permissible level which indicates pollution. The zinc concentration may be as a result of wastes containing zinc metals which are dumped within the Sabon Gari area that have decomposed and found its way into the water table.

The concentration of chromium ranges from 2.59±0.19 – 3.08±0.23mg/L for leachate and waste water while the concentration of chromium ranges from 2.19±0.17 – 3.08±0.43 and 1.53±0.19 – 4.00±0.31mg/L well and borehole samples respectively. The concentration of cadmium for leachate samples gave values ranging from 1.84±0.51 – 2.34±0.1.8 and the concentration of the cadmium for well and borehole ranges from 1.33±0.19 – 2.54±0.28 and 1.02±0.19 – 2.82±0.32 mg/L respectively.

The mean concentration of heavy metals such as lead, chromium and cadmium are generally high above the WHO and NSDWQ levels and these could have originated from the dumping of toxic wastes perhaps from disposed of battery cells, aerosol cans and other materials with high concentrations of the heavy metals. A similar result was reported by Christopher and Mohammed in 2011. Chromium compounds are used as pigments, mordents and dyes in the textiles and as a tanning agent in leather. This suggests the pollution of the groundwater by the laundry wastewater as well as the decomposition of household textiles materials in the study area. Though an essential trace nutrient and a vital component for the glucose tolerance factor, chromium toxicity damages the liver, lungs and causes organ hemorrhages (O'Flaherty, 1995) The pollution of cadmium in groundwater could be the leaching of nickel-cadmium based battery waste from the battery charging businesses and disposal of household plastic waste materials that are abundant in the study area in addition to possible release of sediment based metal.

The concentration of sulphate and phosphate in the well and borehole samples ranges from 4.31±0.25 – 15.84±0.18mg/L and 6.85±2.28 – 7.73±0.77mg/L respectively. The presence of high concentrations of sulphate and phosphate, though below the WHO permissible limits provides high nutrient which for the growth of bacteria.

The concentration of nitrate in the well and borehole water samples ranges from 8.55±0.38 – 10.92±0.64mg/L and 7.78±0.46 – 8.86±0.54mg/L respectively. These values are below the WHO and NSDWQ limits for drinking water. According to WHO (2007), the antibacterial properties of nitrate may play a key role in protecting the gastrointestinal tract against a variety of gastrointestinal pathogens. The presence of nitrate in water is used for the background monitoring since the presence is usually an indicator of nutrient status and the degree of organic pollution.

5.0 Conclusions

The study assesses groundwater quality in relation to open waste locations within the Sabon Gari Area of Kano state-Nigeria and herewith concludes as follows:

1. Waste disposal points in relation to groundwater sources in the study area are within 2 to 15 m which is less than the standard permissible distance of 15 to 30m.
2. Iron, Zinc, Lead, Chromium and Cadmium with the average of 5.17mg/L, 5.59.g/L, 1.28mg/L, 2.53mg/L and 2.10mg/L respectively in the groundwater have high concentration which poses serious health risk. These average values are higher than the WHO permissible levels.
3. High level of hardness of 530.62mg/L recorded in Sabon Gari south could be due to the leaching of Ca and Mg ions from the basement rock into the groundwater table.

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Table 2: Mean concentrations of the chemical parameters of leachate/sewage, wells and boreholes.

Location	Source	Calcium (mg/L)	Magnesium (mg/L)	Chloride (mg/L)	Iron (mg/L)	Zinc (mg/L)	Lead (mg/L)	Chromium (mg/L)	Cadmium (mg/L)	Sulphate (mg/L)	Phosphate (mg/L)	Nitrate (mg/L)
SGS	LEACHATE/ SEWAGE	166.73 ± 47.54	31.95 ± 2.27	111.53 ± 40.62	7.11 ± 1.00	7.35 ± 0.85	1.86 ± 0.23	3.08 ± 0.28	1.84 ± 0.51	15.84 ± 3.19	8.24 ± 0.60	9.38 ± 0.57
	WELL	79.31 ± 11.50	61.34 ± 21.75	240.83 ± 28.03	2.44 ± 0.42	7.35 ± 0.41	1.06 ± 0.14	3.08 ± 0.43	2.54 ± 0.28	8.76 ± 2.48	7.73 ± 0.77	10.92 ± 0.64
	BOREHOLE	163.67 ± 13.71	47.77 ± 9.82	235 ± 19.13	4.88 ± 0.26	7.35 ± 0.46	0.53 ± 0.15	1.54 ± 0.28	2.54 ± 0.20	6.78 ± 0.60	7.65 ± 0.50	8.86 ± 0.54
SGC	LEACHATE/ SEWAGE	188.14 ± 35.38	58.05 ± 7.20	175.73 ± 35.86	5.03 ± 0.49	6.07 ± 0.65	4.85 ± 3.11	2.98 ± 0.37	2.22 ± 0.42	3.81 ± 0.36	9.16 ± 0.41	8.38 ± 0.25
	Well	123.47 ± 34.74	39.43 ± 4.91	77.64 ± 18.28	11.59 ± 7.45	6.86 ± 0.49	1.42 ± 0.38	2.82 ± 0.38	2.12 ± 0.36	5.67 ± 1.43	6.85 ± 2.28	8.55 ± 0.38
	BOREHOLE	129.43 ± 17.47	44.97 ± 6.31	120.91 ±20.92	4.23 ± 0.69	6.47 ± 0.51	2.73 ± 1.07	4.00 ± 0.31	2.82 ± 0.32	5.12 ± 0.95	7.28 ± 0.07	8.71 ± 0.11
SGN	LEACHATE/ SEWAGE	119.3 ± 6.29	50.46 ± 2.20	152.56 ± 22.24	5.24 ± 0.39	3.08 ± 0.16	1.52 ± 0.09	2.59 ± 0.19	2.34 ± 0.18	5.25 ± 0.44	8.46 ± 0.22	8.34 ± 0.32
	WELL	79.85 ± 10.83	38.34 ± 4.29	98.5 ± 34.11	4.00 ± 0.32	2.70 ± 0.21	0.92 ± 0.11	2.19 ± 0.17	1.33 ± 0.19	4.46 ± 0.52	7.25 ± 0.36	8.59 ± 0.27
	BOREHOLE	115.96 ± 16.63	42.9 ± 4.93	95.58 ± 25.02	3.89 ± 0.41	2.61 ± 0.16	1.00 ± 0.21	1.53 ± 0.19	1.02 ± 0.22	4.31 ± 0.25	7.52 ± 0.36	7.78 ± 0.46
	WHO/NSDWQ Standard	None	0.2	250	0.3	3.0	0.01	0.05	0.003	100	None	50

SGS- SabonGariSouth, SGC – SabonGari Central, SGN – SabonGari North

References

Afolayan, O. S., Ogundele, F. O. and Odewumi, S. G. (2012) Hydrological Impact of Solid Wastes Disposal on Groundwater quality in Urbanized Area of Lagos state, Nigeria. *International Journal of Applied Science and Technology*. 2(5): 74 - 82

Bichi, M. H. and Amatobi, D. A. (2013)Characterization of household solid wastes generated in "SabonGari" area of Kano in Northern Nigeria. *American Journal of Research Communication*, Vol 1(4) ISSN 2325 -4076 pp 165 - 171

Chapman, D., (1992) Water Quality Assessments. *A Guide to the Use of Biota, Sediments and Water in Environmental Monitoring.* 1st Edition, UNESCO/ WHO/UNEP, Chapman and Hall, London.

Christopher, O. A. and Mohammed S. Y. (2011) Environmental Impact of Leachate Pollution on Groundwater Supplies in Akure, Nigeria, *International Journal of Environmental Science and Development*, Vol 2, No 1 ISSN 2010-0264, pp 81 -85

Denish, K. T. and Chandel, C. P. S. (2010) Analysis of the Major Ion constituentsin Groundwater of Jaippur City. *Nature and Science*. (10)8 56-57

Eni, D.V., Obiefuna,J, Oko, C and Ekwok,I. (2011) Impact of Urbanization on Sub-surface Water Quality in Calabar municipality, Nigeria. *International Journal of Humanities and Social Sciences*, Vol.1, Issue 10, pp.167-172

Gbonna, C. E., Njoku, H. O., Onyegba, R. A. and Nwaugo, V. O (2010) Effects of seepage from drilling borrow pit wastes Orashi River, Egbema, Rivers state, Nigeria. *Nigerian Journal of Microbiology*, 24(1): 193 – 200

Igbinosa E. O. and Okoh A. I. (2009) Impact of discharge wastewater on the physico-chemical qualities of a receiving watershed in a typical rural community,*International Journal of Environmental Science & Technology*, 6(2): 1735 – 1742

Jamielson, R., Gordon, R., Joy, D. and Lee, H. (2004) Assessing Microbial Pollution of Rural Surface Waters: A review of current watershed scale modeling approaches. Agricultural Water management, 70: 1-17

Kehinde, M. O. (1998) Impact of Industrial Growth on Groundwater Quality and Availibility in Osubtokun. Current Issues in Nigeria Environment, Ibadan Danidan Press.

Kolawole O. M. and Afolayan O. (2017) Assessment of Groundwater Quality in Ilorin, North Central Nigeria. *Arid Zone Journal of Engineering, Technology and Environment.* (1)13: 111-126

Kolawole, O. M., Alamu, F. B., Olayemi, A. B. and Adtitun, D. O. (2013) Bacteriological Analysis and effects of water consumption on the hematological parameters in rats. *International Journal of Plant, Animal and Environmental Sciences*, 3(2): 125 – 131

Longe, E. O. and Balogun, M. R. (2010) Groundwater Quality Assessment near a Municipal Landfill, Lagos, Nigeria. Research Journal of Applied Sciences, Engineering and Techology 2(1): 39-44

Mintz, E., Bartram, J., Lockery, P. and Wegellun, M. (2001). Not Jusy a Drop in the Bucket>Expanding Access to Point of Use of Water Treatment Systems. *American Journal of Public Health*. 91: 1565 - 1570

Mohammed S. (2011) Effect of refuse dumps on groundwater quality*Advances in Applied Research*, 2(6): 595 - 599

usa J. J. (2014) Effect of domestic leachate on quality parameters of groundwater, *Leonardo Journal of Sciences* ISSN 1583 -0233;Pp. 22 – 38

NSDWQ, Nigerian Standards for Drinking Water Quality, 2007, ICS 13.060.20.

Ocheri, M. I. and Ode, O. O. (2012) Water Quality from Hand Dug wells in Oju Town, Benue State, Nigeria. Nigerian Journal of Hydrological Sciences, 1:57 -66.

O'Flaherty E. J., Chromium toxicokinetics in R. A. Goyer and M. G. ClerianEds; (1995)*Toxicology of metals: Biochemical Aspects,* Springer-Verlerg, Heidelberg. pp 315 – 328

Ogbonna, D. N., Simeon, N., Chilaka, S. N. and Gobo, A. E. (2008) Effects of poor waste disposal practices and perennial flooding on groundwater in Port Harcourt. *Journal of Environmental Science*, 4(2). 59 – 65

Okoro, A., Boniface, C., Ekeleme, M. and Anthony, C. (2014). Prediction of Groundwater Quality in selected Locations in Imo State Nigeria. International Journal of Modern Engineering Research (IJMER) ISSN:2249-6645. 6(4).41-49

Olajire, A. A. and Imeokparia, F. E. (2001) Water quality assessment of Osun River: Studies on inorganic nutrients. *Environmental Monitoring Assessment* 69: 17 – 28

Orebiyi, E. O., Awomeso, J. A., Idowu, O. A., Martins, O., Oguntoke, O. and Taiwo, A. M. (2010). Assessment of pollution hazards of Shallow Well water in Abeokuta Environs, South-west, Nigeria. *American journal of Environmental Sciences* (1): 50-56

Raji, M. I. O. and Ibrahim, Y. K. E. (2011) Prevalence of water-borne Infections in North-Western Nigeria: A retrospective study. *Journal of Public Health and Epidemiology*, 3(8): 382-385

Sabo, A., Adamu, H. and Yuguda A. U.(2013). Assessment of Wash-borehole Water Quality in Gombe Metropolis, Gombe State, Nigeria. *Journal of Environmental and Earth Science* 3(1): 65-71.

Sangodoyin, A.Y. (1991). Groundwater and surface water pollution by open refuse dump in Ibadan, Nigeria. *Journal of Discovery and Innovations*. 3.1. 24- 31.

Third World Academy of Sciences -TWAS (2002). Safe Drinking Water the Need, the Problem, Solutions and an Action plan. Report of the Third World Academy of Sciences. Third World Academy of Sciences, Trieste Italy

Ugwu, S.A. and Nwosu, J.I. (2009), Effect of Waste Dumps on Groundwater in Choba using Geophysical Method, *Journal of Applied Sciences and Environmental Management*, 13(1), p. 85-89.

Welch, P., David, J., Clarke, T. A. P. D., Bertson, S., McDougall, L. and Adesiyin A. A. (2000) Microbial Sanitation of Water in Rural Communities of Trinidad. Pan American Journal of Public Health, 8(3):172-180

World Health Organization. (2000) Global Water Supply and Sanitation Assessment 2000 Report. United Nations, New York.

World Health Organization. (2003) WHO Guidelines for Drinking Water Quality, 3rd edition. Geneva, Switzerland

World Health Organization. (2006) WHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater: Volume II Wastewater use in Agriculture. Geneva, Switzerland

World Health Organization. (2007) Nitrate and nitrite in drinking water. Background document for preparation of guidelines for water quality. Geneva, Switzerland

Zektser, S., Loaiciga, H.A. and Wolf, J.T. (2005) Environmental impacts of groundwater overdraft: selected case studies in the southwestern United States, *Environmental Geology*, 47(3), p. 396-404.