The International Journal Of Engineering And Science (IJES)
|| Volume || 5 || Issue || 1 || Pages || PP -08-14|| 2016 ||
ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805

Assessment of Groundwater Quality status along River Ngadda in Maiduguri, Nigeria.

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ABSTRACT
The research was conducted on an unconfined aquifer of the Chad basin along the River Ngada in Maiduguri, Nigeria. Physical, chemical and bacteriological parameters were analysed to ascertain the effect of solid and liquid wastes on the groundwater quality. The water samples from the borehole (G1, G2, G3, B1, B2 and B3) with radial distances of 25, 55, 16, 15, 8, and 12m, respectively, away from the River. Parameters determined were the turbidity, temperature, pH, dissolved oxygen (DO), total dissolved solids (TDS), total hardness (TH), nitrate, nitrite, chloride, calcium and heavy metals like copper, iron, zinc, manganese, chromium and lead using standard laboratory procedures. The pH ranged from 8.05 - 8.97 indicating alkalinity. The turbidity values ranged from 0.00- 2.5 NTU, and the temperature ranged from 29.7°C- 32°C. The concentrations of chloride, nitrate, nitrite and calcium ranged from 2.0 to 51, 0.25 - 2.03, 0.13- 1.4 and 30 - 55 mg/l respectively. Out of heavy metals, zinc and iron ranged from 0.002 - 0.08 mg/l and 0.25 - 0.07mg/l respectively. Lead was not dictated in all the samples. Manganese and chromium were above WHO standard limit for wells B1 and B3, likewise total caliform bacteria and E- coliform were +4 which indicates human and animal faeces., The results showed that the wells G1, G2, G3 and B2 were less polluted, but B1 and B3 requires treatment before use. Proper municipal waste management system should encourage to prevent discharge of solid and liquid wastes to the River.

Keywords: *Groundwater, Pollution, domestic Wastes and Water quality.*

Date of Submission: 12 December 2015 | Date of Accepted: 07 January 2016

I. Introduction

Groundwater is a globally important and valuable renewable resource for human life and economic development. It 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 urbanisation, incessant waste disposal and poor land use management. In addition, the usefulness of groundwater to humans essentially depends on its chemical status, thus, assessment of groundwater quality is important for the socioeconomic development of most developing and developed countries of the world. 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). In the presence of surface water, contamination through human activities and the natural absence of surface water in some areas brought about the exploitation of underground water . 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 unconformably 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 interbedded 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).

Groundwater plays a vital role in the socioeconomic development of urban and rural areas in Nigeria. With a rapid population growth of about 2.5% per annum, the demand for water supply has progressively increased over the last three decades. The provision of safe drinking water has actually deteriorated - access in urban areas fell from 55 million people to 27 million people in 2002 alone (Jacobsen et al. 2012) largely due to poor management, inadequate technical capabilities, lack of investment and insufficient manpower and their training (Hanidu, 1990). Furthermore, the institutions responsible for water supply are both ineffective and fragmented; thus, a transition is needed to bring about a thorough and holistic change to the current system (Jefferies and Duffy, 2011). This change requires a long period to be effective, and into the future, it can only be achieved by empowering and engaging the relevant stakeholders in groundwater management issues. Rapid population growth and uncontrolled urbanisation further aggravates the increasing trend of above ground human activities that potentially affect the quality and quantity of the underlying groundwater by radically changing both recharge and abstraction, thus adversely affecting groundwater quality (Foster, 2001). Urbanisation, dense population concentrations and human activities all severely affect groundwater quality especially in developing countries of sub- Saharan Africa where the urban expansion is poorly planned (Putra and Baier, 2008). These problems pose a significant threat to the upper unconfined aquifer system of the Chad Basin around Maiduguri in northern Nigeria. This aquifer is the major water supply source for the city and it is hydraulically connected to the Ngadda River, which drains the city (Isiorho and Matisoff, 1990). These contaminants originate from both point and non-point sources across the city. The point source emanates from domestic and municipal waste disposal sites; as well as the Maiduguri water treatment plant etc. In addition, in the informal settlement areas, the ever-increasing utilisation of pit latrines is another major impediment. Impact from small businesses and other cottage industries such as dying, tanneries and local brick making cannot be overruled. Consequently, construction sites due to urban expansion are other potential sources of contamination. Non-point-sources of pollution in Maiduguri are largely from agricultural activities near the Alau Dam where extensive irrigation, which involves intensive fertiliser application. Other presumed sources are the widespread commercial car wash centers, cattle markets and abattoirs. The potential pathways taken by these contaminants to travel are mostly through the environment (Stuart et al., 2012). Direct pathways for municipal, agricultural and industrial pollutants are largely through the pore spaces and fractures that exists in the sedimentary formations of the area; where the contaminants infiltrate into the unsaturated zone and then to the saturated zone. In addition to this, the presumption that some of these pollutants may infiltrate into the upper aquifer of the study area is because of the unconfined nature of the upper aquifer system. This consequently poses unacceptable health risks to the local population, more especially the urban poor who largely depend on the groundwater without any form of treatment. Past and current groundwater management approach in Maiduguri need to be reviewed to develop a strategy for a sustainable framework, which will address the problems, associated with the current system. The transition management approach focuses on uncertainty, learning by doing and doing by learning, and the organisation of processes that look at a number of solutions in attaining the goals. The objective of this study is to assess the variation in physical, chemical and biological properties of groundwater quality along river Ngadda as result of incessant and ineffective waste disposal, which in turn affects the integrity of the underlying aquifers, and to determine the degree of deviation of this water body from the World Health Organization (WHO) guidelines.

II. Materials And Method

Study area

River Ngada transposes through the centre of Maiduguri, Nigeria. The city is located between latitude $11^0 51^1$ – 11^0 55^1N and longitude 13^0 02^1-13^0 16^1E. It lies on a vast open plain, which is flat with gentle undulations at an average elevation of 345m above sea level. According to Hess *et al*. (1996), the climate of the region is characterized by a cool-dry season (October to March), the hot season (April to June) and a rainy season (July to September). The area is fragile and highly susceptible to drought with relative humidity of 13% in dry seasons and 65% in rainy seasons. The area is also highly vulnerable to desertification Dibal, (2002). The study area dominantly derives its groundwater resources from the Chad Formation shown in Figure 1, which is the youngest stratigraphic unit of the Chad Basin and the most prolific in terms of groundwater resources. The river flows in a northeasterly direction, which originates from Rivers Yedzram and Gombole, which meet at a confluent at Sambisa both in Nigeria, and in flows as River Ngadda into Alau Dam and stretches down across Maiduguri then empties into Lake Chad. The river is used for various human activities including fishing, irrigation, bricks making and by residences along the riverbanks for bathing, washing and as drinking water by animals. The river receives copious amounts of wastes from residential houses and abattoirs sited along its course.

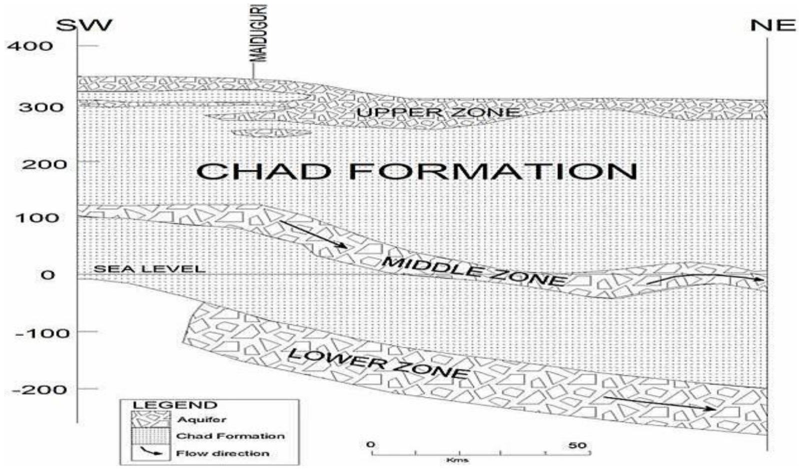

Figure 1: Cross section of the multilayered aquifer system of the Chad Basin

Water sampling

Six water samples from 6" diameter shallow wells with depth ranged from 52 to 78m in an unconfined aquifer were collected along River Ngada on both sides (three each) of the river, which correspond to the notable point source pollution (liquid and solid wastes) discharge into the River Ngada. Three water Samples were collected at Gwange side down to Ngamboru bridge and labeled G1, G2 and G_3 at a distance of 25m, 55m and 16m respectively from the River Ngada. At the Bulabulin side down to Ngamboru cattle Market three water Samples were collected and labeled $B_{1,}$ B_2 and B_3 at a distance of 15m, 8m and 12m respectively from the river Ngada. At each sampling point 1litre of water sample was collected in a sterilized plastic bottle for laboratory analysis.

Laboratory analysis

The adopted analysis methods for all parameters in water samples were in accordance with standard recommendation. All samples were analyzed for selected physico-chemical, heavy metals and bacteriological parameters. Various physico-chemical parameters examined in groundwater samples include: Colour, Odour, turbidity, Temperature (^oC), pH, Electrical conductivity (EC), Total dissolved Solid (TDS),Total hardness (TH), Dissolved Oxygen, Calcium (Ca), Nitrate (NO_3),Nitrite (NO_2) Chloride (Cl^-). The heavy metals analyses include copper (Cu), Zinc (Zn), Iron (Fe), Manganese (Mn), Chromium (Cr) and Lead (Pb) and the Bacteriological parameters were Total coli form bacteria and *Escherichia coli.* The qualitative analysis was carried out in the Geology laboratory, University of Maiduguri, Nigeria. The pH, EC and TDS were determined using pH/EC Metter (Combo type meter). The 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 meter teledo DO meter. Nitrate (NO3), Nitrite (NO2) and Calcium (CA) were determined using UV/V spectrophotometer (Model Lamba 35) while, chloride was determined using Titration method. The concentrations 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). In addition, Mckonky broth media was used for the determination of total coli form bacteria and *Escherichia coli.* All the results were compared with the World Health Organization (WHO 2004) and the Nigerian Standard for Drinking Water Quality (NSDWQ 2007) values.

Statistical analysis

The analyzed data were subjected to descriptive statistical analysis, table, as well as inferential statistic like correlation. Correlation analysis was used to verify the relationship between examining variables with the aid of SPSS package. Concentration of the examined parameters was arranged in tabular form separately to examine the spatial variation in the concentration of physiochemical and heavy metals parameters in surrounding wells on the both sides of the river Ngada. The result of each sample was compared with WHO,2004 and NSDQW,2007 standard limit.

III. Results And Discussions

The results of physical, chemical, heavy metals and bacteriological analyses and their comparison with the World Health Organization and the Nigerian Standard for Drinking water quality were presented in Tables 1, 2, 3 and 4 respectively.

Table 1. Physical characteristics of the water samples analysed

Sample	Colour	Odour	Turbidity (NTU)	Temperature (^{o}c)
G_1	colourless	odourless	0.00	30.0
G_2	colourless	odourless	0.00	30.0
G_3	colourless	odourless	0.50	29.8
B_1	colourless	odourless	2.50	29.7
B_2	colourless	odourless	1.00	30.0
B_3	colourless	odourless	1.30	32.0

The results of all examined wells for Gwange and Bulabulin sites were colourless and odourless as shown in table 1. The turbidity of each sample is shown in table 1 which ranges from 0 to 2.5NTU, indicates the estimate of suspended matter. The WHO acceptable limit for turbidity is 10NTU and all samples analysed fell within this limit. The temperatures recorded ranged from 29.7 to 32°C, with an average of 30.25°c as shown in table 1, all the water samples collected from the two sites were found to have temperatures higher than the natural background levels of 22 to 29°C for waters in the tropics (Stumn and Morgan, 1981). While cool waters are generally more potable for drinking purposes, waters with temperature above the normal human body temperature are usually preferred in the tropics, though not totally objected. However, high temperature conditions may not be desirable for water samples as it encourages the growth of microorganisms, which have the potentials of altering the odour, taste and colour of the water. Temperatures obtained for all the water samples correspond with previous studies across the Basin (Goni, 2006 and Kolo et al., 2009).

Table 2. Chemical constituents in the boreholes and their comparison with the WHO Standard (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
G_1	25	8.68	197	14.	111	170	30	0.60	0.31	12
G_2	55	8.40	141	14	88	150	40	0.70	0. 35	2.0
G_3	16	8.97	170	10.5	112	170	55	0.60	0.30	2.0
B_1	15	8.44	240	11	156	285	50	1.80	1.40	6.0
B_2	8	8.44	161	11.5	88	150	50	0.25	0.13	2.0
B_3	12	8.05	484	12.7	338	215	33.8	2.03	0.267	51

Ec in µS/cm

The results in Table 2 indicate that pH from Gwange area (G_1, G_2 and G_3), ranged from 8.40 to 8.97 with an average of 8.68. In Bulabulin area (B_1, B_2 and B3), the pH varied from 8.05 to 8.44 with an average of 8.31. This distribution of pH suggests that the groundwater in Gwange and Bulabulin were alkaline, while the mean pH value of Gwange is above the WHO tolerable limit. Waters with pH values above 10 are exceptional and may reflect contamination by strong base such as NaOH and $(CaOH)_2$ Afolayan (2012). The major cations show that the Alkaline and Alkali metals are dominant in all the groundwater samples of both sites; EC and TDS values as shown in Table 2 for Gwange ranged from 141 to 197 µS/cm, and 88 to 112 mg/L, with mean values of 169.33 µS/cm and 103.67 mg/l respectively. Also for Bulabulin the EC values ranged from 161 to 48 µS/cm, with a mean value of 168 µS/cm; the TDS varied from 88 to 338 mg/L with a mean value of 194 mg/L. The mean EC and TDS values for both sites are within WHO acceptable limits. The relatively low value for EC and TDS in both sites except B_1 with 484 µS/cm and 338mg/L EC and TDS respectively signifies presences of point and non-point sources of pollution in the river Ngada. In addition, the occurrence of low EC values indicates a low degree of mineralization and input from the agricultural activities upstream of both sites, consequently, the water quality is good, and thus, it is safe for drinking and domestic purposes. Furthermore, the low TDS values found for both sites can be attributed to the continuous recharge of the groundwater from rainfall, which causes significant dilution. Such situations are usually found in shallow unconfined aquifers (Kumar, 2010). Consequently, the low TDS values also suggest that inputs of salts from the anthropogenic sources of pollution in both sites are minimal. The conductivity of water is a more-or-less linear function of the concentration of dissolved ions. The concentration of Dissolved Oxygen (DO) ranged from 10.5mg/L to 14.5mg/L, which are below the WHO and NSDWQ limits, though still low, indicated an indirect impact of waste disposal on them. Similar result was 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). Total Hardness is normally expressed as the total concentration of Ca^{2+} and Mg^{2+} in mg/L, equivalent CaCO3. Total hardness ranged from 150 to 285Mg/L with an average of 190Mg/L, which is within the WHO limit, but B_1 and B_3 were above WHO limit, that indicates potential solid and liquid waste pollution from the main tributary and abattoir respectively along the riverside. This agrees with the findings of Afolayan et al. (2012). Calcium is among the general elements essential for human health and metabolism and should be available in normal drinking water. However, if this element occurs in the water above certain limits, the water may become intolerable to consumers and even become hazardous to their health. This cation is present in tolerable amounts in the groundwater of both sites; which ranged from 30 to 55Mg/L that are within WHO standard limit. The implication is that forming lather with soap will be a major challenge for domestic users (Akinbile, 2006). Among the anions, preference has been given to nitrate, nitrite and chloride because their concentration in the groundwater will signify the influence of above ground anthropogenic activities. The result in Table 2 shows the concentration of nitrate across the boreholes of Gwange and Bulabulin, nitrate concentration ranged from 0.6 to 0.7 Mg/L and 0.25 to 2.03 mg/L respectively, which are within the WHO limit. But, nitrate recorded highest concentration along Bulabulin site at B_1 and B3 (1.8Mg/L and 2.03Mg/L) respectively. In both sites, The source of nitrate in the study areas can be linked to the wide spread of point-source pollution, such as the open dumpsites, pit latrines, abattoir, and the uncontrolled domestic wastewaters emanating from the Monday market through Ngadabul which emptied into River Ngada, as well as agricultural inputs from upstream manure application in farm lands. Nolan et al. (2002), Squillace et al. (2002) and Singleton et al. (2005) estimate that nitrate concentration in the range of 13 to 18 mg/l are considered to indicate anthropogenic input. Hence, the average concentrations of Nitrate as reported in this study is 0.63 Mg/L and1.36Mg/L for Gwange and Bulabulin sites respectively, fall below the limit set aside by WHO (1993). Studies have shown that high nitrate in the water can lead to blue baby syndrome or infantile methemoglobinaemia (WHO, 1984), cancer (WHO, 1984; Uslu and Turkman, 1987), urinary tract diseases (Wasik et al., 2001). Furthermore, increased concentration of nitrate often cause blood disorders. In addition, Adelana et al (2003) has suggested that chronic exposure to high levels of nitrate in drinking water may have adverse effects on the cardiovascular system. Nitrite ranged from 0.3 to 0.35 mg/l and 0.13 to 1.4Mg/L for Gwange and Bulabulin sites, with an average of 0.32Mg/L and 0.599Mg/L respectively. All these 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 2 to 12 mg/l with an average of 5.33Mg/L for Gwange and 2 to 51Mg/L with an average of 19.67Mg/L for Bulabulinn. The low level of chloride in all the samples of both sites except $B_{3,}$ suggests that anthropogenic input of sewage is moderate, and infiltration reduces the concentration. Mean concentration of chloride for both sites fall below the WHO permissible limit of 250 mg/L. This agrees with the findings of (Igbinosa & Okoh 2009).

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

Sample	distance (m)	Fe	Zn	Pb	Cu	Mn	Cr
NSQD		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
G_1	25	0.70	0.002	ND	0.00	0.02	ND
G_2	55	0.31	ND	ND	0.045	ND	ND
G_3	16	0.32	ND	ND	ND	ND	ND
B_1	15	0.50	0.02	ND	0.15	0.02	ND
B_2	8	0.25	0.002	ND	0.04	ND	ND
B_3	12	0.675	0.08	ND	0.03	0.667	1.605

The groundwater samples were analyzed for heavy metal such as Iron (Fe), Zinc (Zn), Lead (Pb), copper (Cu), manganese (Mn) and Chromium (Cr) as shown in table 3, which are characterized as undesirable metals in drinking water. Presence of Iron in water can lead to change the colour of groundwater. Extreme dissolved of iron concentration result to taste problem. Iron levels ranged from 0.31 to 0.7Mg/L with an average of 0.44Mg/L and 0.25 to 0.675Mg/L with an average of 0.475Mg/L for Gwange and Bulabulin respectively, both sites fall within the WHO limit. This result agreed with Afolayan (2012). Zinc concentration varied from 0.002 to 0.08Mg/L with an average of 0.035Mg/L for both sites. The G_1 and B_2 were within the WHO limit, but B_1 and B_3 were above standard limit, which indicates a point-source pollution from human and abattoir waste respectively. Carlos *et al*. (1997) reported that consumption of Zn in excess of WHO recommended value may lead to gastrointestinal disturbances such as pain, cramping, nausea and vomiting, diarrhea and pancreatic toxicity. However, Zn was not detected in G_2 and G_3 wells. In all the examined wells for Gwange and Bulabulin, lead (Pb) was not detected, so therefore, all the well are lead free. However, the presence of Cu and Mn that ranged from 0.00 to 0.15 mg/l and 0.02 to 0.667 mg/l, with an average of 0.053Mg/L and 0.24Mg/L respectively. The values of Cu in all the examined wells for both sides were within the WHO standard limit, but Cu was not detected in G_3. The values of Mn in G_1 and B_1 were below the WHO limit, while B_3 is above standard limit, that indicates a point-source pollution from Maiduguri abattoir, but Mn was not detected in $G_{2,}$ G_3 and $B_{2.}$ The concentration of Cr in B_3 was high above the WHO standard limit; Cr was not detected in all the remaining wells.

Bacteriological characteristics

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
G_1	total coliform bacteria	0.00	-1
	Escherichia coli	*0.00*	*-1*
G_2	total coliform bacteria	0.00	-1
	Escherichia coli	*0.00*	*-1*
G_3	total coliform bacteria	0.00	-1
	Escherichia coli	*0.00*	*-1*
B_1	total coliform bacteria	5.00	+4
	Escherichia coli	*5.00*	*+4*
B_2	total coliform bacteria	0.00	-1
	Escherichia coli	*0.00*	*-1*
B_3	total coliform bacteria	5.00	+4
	Escherichia coli	*5.00*	*+4*

The bacteriological characteristics of the samples tested are as reported in Table 4, total coliform bacteria and *Escherichia coli* results showed that $G_{1,}$ $G_{2,}$ G_3 and B_2 satisfy the WHO requirements for bacteriological characteristics in human consumption. *While B_1 and B_3 shows* high values of total coliform bacteria and *Escherichia coli* and greater than one being an indication of faecal pollution of human wastes from the main tributary (Ngadabul) of River Ngada and Maiduguri abattoir. The variance from the WHO was also more than 75%, which further confirmed bacteriological pollution, not limited to human sources and coming perhaps from the remains of dead animals. It was remarked that the probability of packing faeces from the public disposal systems due to the lack of functional sewage systems in some parts of Maiduguri was high. A thorough treatment of water from these wells would be required before its domestic consumption. This result agreed with Akinbile, (2012)

IV. Conclusions

This research revealed that point and non-point sources of pollution along the Riverside have a negative impact on the groundwater quality of the upper unconfined aquifer of the Chad Basin in Maiduguri. Results obtained showed that the water is alkaline, with those along Gwange side were above WHO acceptable limit., The physical, chemical and bacteriological parameters analysed for $G_{1,}$ $G_{2,}$ G_3 and B_2 fall below the WHO standard limit. Thus, the groundwater quality from these wells is good for drinking and other domestic use. However, G_1 and G_3 show the concentrations of some heavy metals and total coliform bacteria and *Escherichia coli, that implies* increasing utilisation of pit latrines, incessant domestic and municipal waste disposal, abattoir waste, Agricultural activities as the major sources of pollution along the River Ngada. These wells need to be treated before use.

References

[1] Adelana, S. M., (2006). A quantitative estimation of groundwater recharge in parts of the Sokoto Basin, Nigeria. Environ. Hydrol. 14(5):105-119.

[2] Adelana, S.M., Olasehinde, P.I.,and Vrbka, P. (2003). *Isotope and geochemical characterization of surface and subsurface waters in the semi-arid Sokoto Basin, Nigeria.* Afr. J. Sci. Tech. (AJST). 4(2):80-89.

[3] Afolayan, O. S., Ogundele, F. O. and Ayo, O. (2012). *Comparative analysis of the effect of closed and operational landfills on groundwater quality in Solous, Lagos Nigeria.* Journal of applied technology in environmental sanitation, Vol. 2, No. 1: 67-76,

[4] Akinbile, C.O. (2006). *Hawked water quality and its health implications in Akure, Nigeria.* Botswana Journal of Technology, **15**: 70–75.

[5] Akinbile, C.O. (2012). *Environmental Impact of Landfill on Groundwater Quality and Agricultural Soils in Nigeria. Soil & Water Res., 7, 2012 (1): 18–26*

[6] Akujieze, C. N., Coker, S. J. and Oteze, G. E. (2003). *Groundwater in Nigeria- a millennium experience-distribution, practise, problems and solutions.* Hydrogeology 11(2):259-274.

[7] Ashbolt, N.J. (2004). Microbial contamination of drinking water and disease outcomes in developing regions. Toxicology 198(1): 229-238.

[8] Barber, W. and Jones, D. G. (1960). The Geology and Hydrogeology of Maiduguri, Borno Province. Records of the Geological Survey of Nigeria, pp. 5-20.

[9] Carlos, D., Da Rosa, J.D., Lyon, J.S., Udall, S.L.and Hocker, P.M. (1997). *Golden Dreams, Poisoned Streams*. Mineral Policy Center. Washington D.C.

[10] Chauhan, J.and Rai, J.P.N. (2010): Monitoring of impact of ferti-irrigation by post-methanated distillery effluent on groundwater quality. Clean – Soil, Air, Water, **38**: 630–638.

[11] Dibal, J.M., 2002. Desertification in Nigeria. Causes, effects and review of control measures. University of Maiduguri Faculty of Engineering Seminar series, 2(1): 59-74.

[12] Foster, S. S. D. (2001). The interdependence of groundwater and urbanisation in rapidly developing cities. Urban water.3(3):185-192.

[13] Goni, I. B. (2006). *The challenges of meeting domestic water supply in Nigeria.* J. Min. Geol. 42(1):51-55.

[14] Hanidu, J. A. (1990). National growth, water resources and supply strategies in Nigeria in the 1990's. Water Resources J. Nigeria Association of Hydrogeologists.;1:1-6.

[15] Hess, T., Stephen, W. and Thomas, G. (1996). *Modeling NDVI from decadal rainfall data in the north east arid zone of Nigeria*. J. Env. Manag., 48: 249-261.

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

[17] Isiorho, S. A. and Matisoff, G. (1990). Groundwater recharge from Lake Chad: Limnology and grounOceanography.;35(4):931-038.

[18] Jacobsen, M., Webster, M. and Vairavamoorthy, K. (2012). The Future of water in African cities: Why waste water? Direction in Development, Washington, DC, World Bank.

[19] Jaji, M.O., Bamgbose, O., Odukoya, O.O. and Arowolo, T.A. (2007). Water quality assessment of Ogun River, south west Nigeria. Environmental Monitoring and Assessment, **133**: 473–482.

[20] Jefferies, C. and Duffy, A. (2011). Switch Transition Manual, University of Abertay Dundee, Scotland, ISBN 978-1-899796-23-6;.

[21] Kolo, B. G., Jibrin, M. D. and Ishaku, I. N. (2009). *Elemental analysis of Tap and Borehole water in Maiduguri, semi-arid region, Nigeria.* Environ. J. Sci. 1(2):26-29.

[22] Kumar, P, (2010). *Tracing the factors responsible for arsenic enrichment in groundwater of the middle Gangetic Plain, India: a source identification perspective.* Environ. Geochem. Health 32(2):129-146.

[23] Maduabuchi, C., Faye, S. and Maloszewski, P. (2006). "Isotope evidence of palaeorecharge and palaeoclimate in the deep confined aquifers of the Chad Basin, NE Nigeria. Environment 370(1):467-479.

[24] Miller, R. E., Johnston, R. H., Olowu, J. A. I.and Uzoma, J. U. (1968). Groundwater hydrology of the Chad Basin in Borno and Dikwa Emirates, with special emphasis on the flow life of the artesian system. USGS Water Supply Paper. 1757.

[25] Nolan, B. T., Hitt, K.J. and Ruddy, B. C. (2002). *Probability of nitrate contamination of recently recharged groundwater in the conterminous United States.* Environ. Sci. Technol. 36:2138-2145.

[26] Obaje, N. (2009). Geology and Mineral Resources of Nigeria. Springer-verlag, Berlin Heildelberg. ISBN 978-3-540-92684-9.

[27] Odada, E. O., Oyebande, L. and Oguntola, J. A. (2006). Lake Chad. Experience and Lessons Learned Brief. Lake Basin Management Initiative (LBMI) Experience and Lessons Learned Briefs.

[28] Offodile, M. E. (1992). An approach to groundwater study and development in Nigeria. Mecon Services Ltd. pp. 66-78.

[29] Putra, D. and Baier, K. (2008). Impact of Urbanization on Groundwater Recharge – The Example of the Indonesian Million City Yogyakarta , In: UN Habitat- United Nations Settlement Programs: Fourth session of the World Urban Forum, Nanjing, China, ocumentations of Germany's Contribution to a Sustainable Urban Future;

[30] Ramakrishnaiah, C.R., Sadashivaiah, C. and Ranganna, G. (2009). Assessment of Water Quality Index for the Groundwater in TumkurTaluk, Karnataka State, India. E-J. Chem. 6(2):523-530.

[31] Singleton, M. J., Woods, K.N., Conrad, M.E., Depaolo, D. J. and Dresel, P.E. (2005). *Tracking sources of unsaturated zone and groundwater nitrate contamination using nitrogen and oxygen stable isotopes at the Hanford site,* Washington. Environ. Sci. Technol. 39:3563-3570.

[32] Squillace, P. J., Scott, J. C., Moran, M.J., Nolan, B.T. and Kolpin, D. W. (2002). *VOCs, pesticides, nitrate, and their mixtures in groundwater used for drinking water in the United States*. Environ. Sci. Technol. 36:1923-1930

[33] Stuart, M., Lapworth, D., Crane, E. and Hart, A. (2012). Review of risk from potential emerging contaminants in UK groundwater. Sci. Total Environ. 416:1-21.

[34] Stumn, W and. Morgan, J. I. (1981). *Aquatic chemistry: an introduction emphasizing chemical equilibria in natural waters.* New York: Wiley-Interscience P. 780.

[35] Uslu, O. and Turkman, A. (1987). Water pollution and control. Publication series of Environment General Directorate of Prime Ministry of Turkish Republic. 1:251-265.

[36] Wasik, E., Bahdziewic, Z. J. and Blasszczyk, M. (2001). Removal of nitrates from groundwater by hybrid process of biological denitrification and microfiltration membrane. Process Biochem. 37:57-64.

[37] World Health Organisation, (2011). Guidelines for drinking water quality (4th edn), World Health Organisation.