Journal of Geology and Mining Research Vol. 3(9), pp. 219-231, September 2011
Available online http://www.academicjournals.org/JGMR
ISSN 2006-9766 ©2011 Academic Journals

Full Length Research Paper

Assessment of groundwater quality index for Jimeta-Yola area, Northeastern Nigeria

J. M. Ishaku

Department of Geology, Federal University of Technology, Yola, Adamawa State, Nigeria. E-mail: jmishaku@yahoo.com

Accepted 29 May, 2011

The objective of this work is to provide information on the physical and chemical properties of groundwater in Jimeta-Yola area in order to appreciate the impacts of indiscriminate waste disposal practice on the quality of groundwater and to discuss its suitability for human consumption from the water quality index values. This has been determined by collecting groundwater samples from hand-dug wells and boreholes in the dry season and rainy season periods and subjected to physicochemical analysis. The results indicate that electrical conductivity (EC), chloride, nitrate and dissolved oxygen exceeded World Health Organization (WHO) standards in the dry season and chloride, nitrate, dissolved oxygen, total hardness and chromium hexavalent exceeded WHO standards in the rainy season. Spatial distribution of EC, chloride, nitrate and chromium hexavalent in the dry and rainy season indicated that the sources of these contaminants result from point sources such as house hold solid wastes, sewage effluents and wastewater. The overall water quality index (WQI) value in the dry season was 96.4 which indicate good water quality. The overall WQI value in the rainy season was 138.5 which indicate poor water quality. The high value of WQI has been found to be mainly from chloride, nitrate, dissolved oxygen, chromium hexavalent and EC. The source of these contaminants is attributed to anthropogenic origin. The study revealed that the water quality is unfit for human consumption without treatment.

Key words: Groundwater quality, Jimeta-Yola area, water quality index, chemical parameters.

INTRODUCTION

The assessment of groundwater quality status is important for socio-economic development of any region of the world. The determination of groundwater quality for human consumption is important for the well being of the ever increasing population. Good quality water will ensure the sustainability of socio-economic development, as the government priority is shifted to other sectors of the economy, rather than channeling the resources towards combating outbreaks of water borne diseases due to consumption of contaminated groundwater. Groundwater quality depends, to some extent, on its chemical composition (Wadie and Abduljalil, 2010) which may be modified by natural and anthropogenic sources. Rapid urbanization, especially in developing countries like Nigeria, has affected the availability and quality of groundwater due to waste disposal practice, especially in urban areas. Once groundwater is contaminated, its quality cannot be restored by stopping the pollutants from source (Ramakrishnaiah et al., 2009). As groundwater has a huge potential to ensure future demand for water, it is important that human activities on the surface do not negatively affect the precious resource (Sarukkalige, 2009). Poor environmental management creates havoc on the water supply, hygiene and exacerbating public health (Okoro et al., 2009). Tay and Kortatsi (2008) emphasize on the importance of groundwater globally as a source for human consumption and changes in quality with subsequent contamination can, undoubtedly, affect human health. Groundwater quality is mainly controlled by the range and type of human influence as well as geochemical, physical and biological processes occurring in the ground (Zaporozec, 1981; Carter et al., 1987). It therefore becomes imperative to regularly monitor the quality of the water and device ways to perfect it (Yisa and Jimoh, 2010).

Water quality index (WQI) is one of the most effective

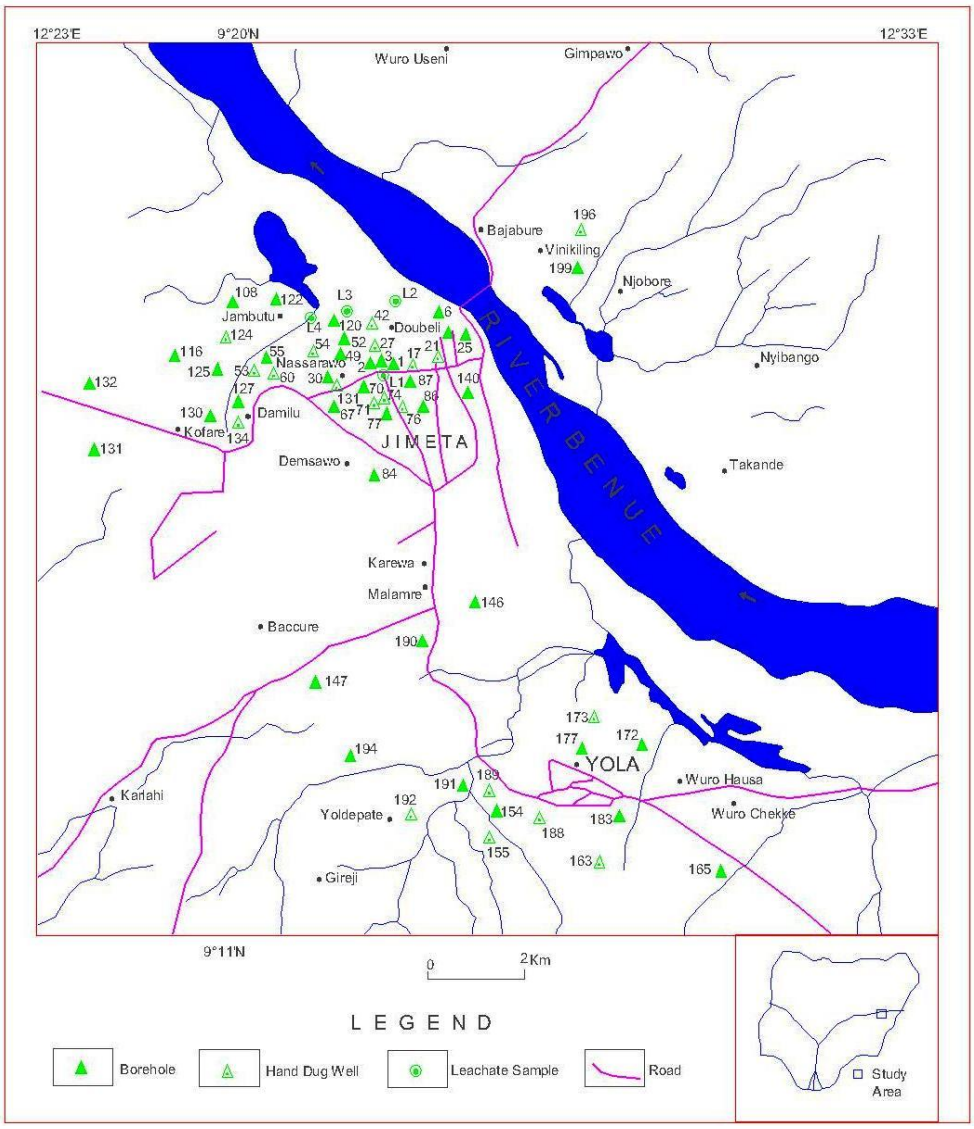

Figure 1. Map showing access routes and sampling points.

tools to communicate information on the quality of water to the concerned citizens and policy makers (Ramakrishnaiah et al., 2009; Yisa and Jimoh, 2010). It, thus, becomes an important parameter for the assessment and management of groundwater. Water quality index (WQI) is defined as a rating reflecting the composite influence of different water quality parameters. WQI is calculated from the point of view of the suitability of groundwater for human consumption (Ramakrishnaiah et al., 2009). The objective of the present work is to provide information on the physical and chemical properties of groundwater in Jimeta-Yola area in order to appreciate the impacts of indiscriminate waste disposal practice on the quality of groundwater and to discuss its suitability for human consumption from the water quality index values.

DESCRIPTION OF THE STUDY AREA

The study area, Jimeta-Yola; is located within latitudes 9°11'N to 9°20'N and longitudes 12°23'E to 12°33'E and covers an area of about 305 km^2 (Figure 1). The area has a mean annual rainfall of 919 mm, and means monthly minimum temperature of 19°C and maximum temperature of 37.9°C. The mean monthly temperature is 28.5°C (Ishaku, 2007). The area is characterized by broadly flat topography with gentle undulations and hill ranges (Ishaku, 1995), and is largely drained by the Benue River.

The population of the area is about 325, 925 (Census, 2006). The major occupation of the people is agriculture and small- scale industries such as Bajabure Nima foam, polyplastic industry and Adama beverages occur in the

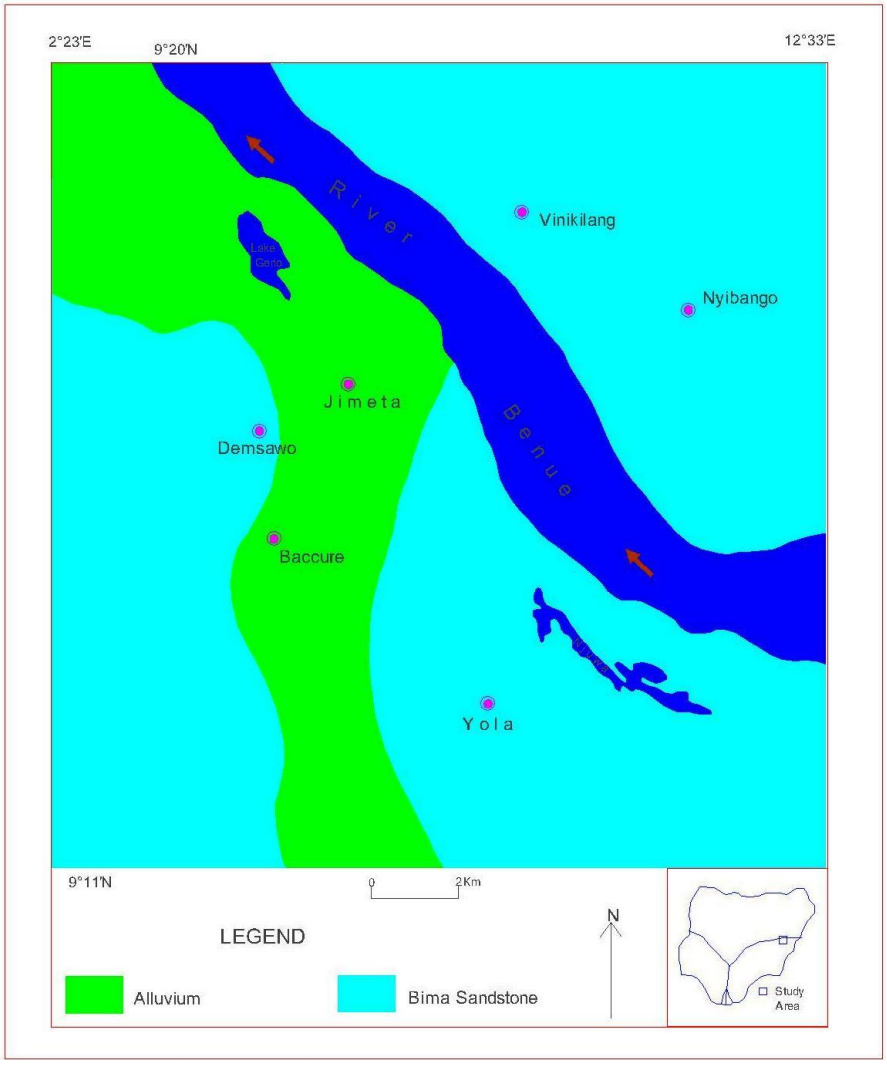

Figure 2. Geological map of the study area.

area. Small-scale metallurgical works, numerous water sachet activities and traditional textile factories occur in the area. Water supply to the people is from surface water through water treatment plants and groundwater is obtained through boreholes and hand-dug wells. The waste disposal practiced in the area is through open dump for solid wastes, pit latrines, and septic tank for human wastes (Yenika et al., 2003). House hold solid wastes are largely dumped along the flood plains of the Benue River which borders the Yola-Mubi bye-pass. Other refuse dumpsites are located in the densely populated areas of the metropolis and close to water sources especially in Luggere area and behind the LCCN Church along Ilorin/Bauchi Street. There is also water sources located in Mechanics Work shop and at the edge of the major drainage that empties waste water to the Benue River. The growth in population has affected the land use pattern, which has subsequently affected the quality of the water resource (Adekeye and Ishaku, 2004). The type of waste disposal practiced in the area may have environmental implications in terms of the groundwater quality degradation thus, affecting suitability of the groundwater as a source for human consumption. Consequently, reported cases of waterborne diseases such as: typhoid, amoebiasis, dysentery, viral hepatitis, schistomiasis and cholera have been on increase in the area (Ishaku and Ezeigbo, 2010).

GEOLOGY OF THE AREA

The study area is underlain by the Albian-Aptian Bima sandstone and recent river alluvium (Figure 2). The Bima sandstone is the oldest formation in the Upper Benue trough and unconformably overlies the basement complex. The detailed description of the Bima sandstone

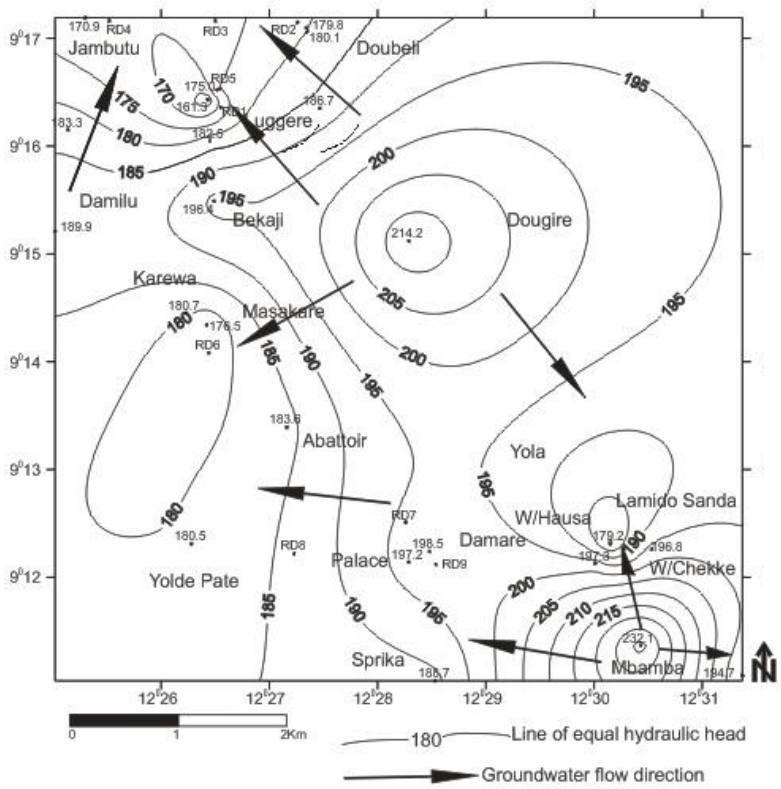

Figure 3. Hydraulic head distribution in the dry season.

were provided by Carter et al. (1963), Allix (1983), Popoff et al. (1986), Popoff (1988) and Guiraud (1990a, 1991a) into B1, B2 and B3 known as the Bima group. The outcrops of the Bima group belong to the Bima 2 and 3 in the Yola arm (Braide, 1992). The Bima sandstone (B2) varies from fine to coarse grained (Allix, 1983), and the deposits were regarded as of proximal braided river origin (Guirand, 1990a, 1990b, 1991a) in (Zaborski, 1998). The Bima sandstone (B2) is widely distributed, and is characterized by trough and tabular cross-bedding. The sandstone ranges from 100 to 500 m thick. The upper Bima sandstone (B3) is fairly homogenous, relatively mature, and fine to coarse-grained sandstone, characterized by tabular cross-bedding, convolute bedding and overturned cross-bedding (Zaborski et al., 1997). The thickness ranged from 500 to 1500 m. Lithologically, the Bima sandstone consists of feldspathic sandstone, grits, pebble beds and clay intercalations in some places (Eduvie, 2000). Borehole litholgic logs in the area reveal the presence of lateritic soils, sandstones, clays, mudstone, siltstones and ironstones (Ishaku and Ezeigbo, 2000). The Bima sandstone occurs in the Southwestern, southeastern and northeastern parts of the study area (Figure 2). The river alluvium (recent) belongs to the quaternary age and is found along the main course of the Benue River, and extends towards the northeast and southern parts of the study area (Figure 2). The river alluvium consists of poorly sorted sands, clays, siltstones and pebbly sand (Ishaku and Ezeigbo, 2000; Yenika et al., 2003).

The hydraulic head distribution in both the dry season and rainy season periods (Figures 3 and 4) did not reveal variation in the direction of groundwater flow. Figures 3 and 4 indicate that regional groundwater flow occurs from the recharge zone in Dougire area and flows towards the northwestern and southeastern parts of the study area. Another recharge zone occurs in Mbamba area in the southern corner of Yola, and flows towards the Northern, western and eastern parts of Yola. The major discharge areas cover Luggere-Jambutu area, Karewa-Yolde Pate and Wuro Hausa-Lamido Sanda areas.

MATERIALS AND METHODS

Water samples were collected from the hand-dug wells, boreholes, and leachates beneath refuse dumps in the dry and rainy season periods in the study area. The results were used for the assessment of water quality and to evaluate seasonal variations. Before the collection, the sample containers were rinsed two to three times in the field using the representative groundwater samples according to Rajkumar et al. (2010). Water samples were collected from the discharge of existing hand-dug wells and boreholes according to Chilton (1992) method. Locations of the monitoring wells were determined using the global positioning system (GPS). The field parameters such as: pH, EC and TDS

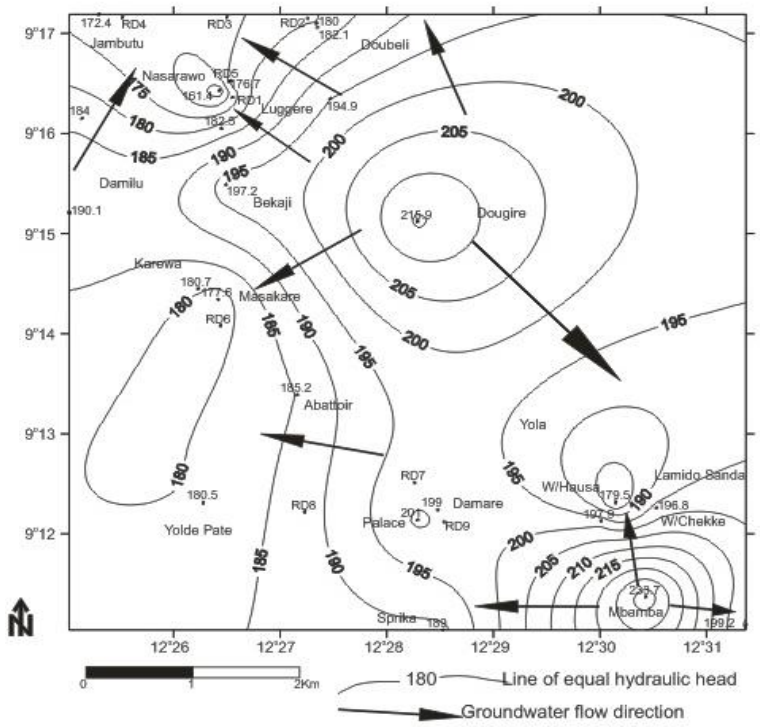

Figure 4. Hydraulic head distribution in the rainy season.

were measured in the field using the potable HANNA pH meter (Model HI 28129) and TDS/conductivity meter (HACH KIT) (Model 44600-00). The sampling points were strategically located to quantify the impacts of the dumpsites on the water sources close to the dumpsites. Sampling from boreholes located along the drainage network was also carried out to define the impacts of waste water on groundwater quality degradation. Other samples were collected from densely populated areas where most residents use pit latrines in order to understand the contribution of sewage on groundwater quality. Water samples were also collected in areas where waste disposal is organized to serve as base line water quality. Based on the locations of the sampling points, the type of sampling technique is random sampling. The water samples were analyzed chemically using spectrophotometer (Model 2010, USA), atomic absorption spectrophotometer (AAS) (model PYE UNICAM SP 9) and titrimetric method according to USEPA (1974), APHA (1980) and Sexana (1990).

The statistical analysis was carried out for correlation using SPSS 15.0 and the water quality index (WQI) was calculated in three stages. In stage 1, each of the 16 parameters has been assigned a weight (w_i) according to its relative importance in the overall quality of water for drinking purposes. The maximum weight of 5 has been assigned to the parameter nitrate due to its importance in water quality assessment. Magnesium is given the minimum weight of 1 which indicates that, it may not be deleterious. In stage 2, the relative weight (W_i) is computed from the following equation:

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \quad (1)$$

Where, W_i is the relative weight, w_i is the weight of each parameter and n is the number of parameters. Stage 3, a quality rating scale (q_i) for each parameter is assigned by dividing its concentration in each groundwater sample by its respective standard according to the guidelines by WHO and the result multiplied by 100:

$$q_i = (C_i / S_i) \times 100 \quad (2)$$

Where, q_i is the quality rating, C_i is the concentration of each parameter in each water sample, and S_i is the WHO drinking water standard for each parameter.

For computing the WQI, the SI is first determine for each parameter, which is then used to determine the WQI as indicated by the following equation

$$SI = W_i \times q_i \quad (3)$$

$$WQI = \sum SI_i \quad (4)$$

SI_i is the subindex of ith parameter; q_i is the rating based on concentration of ith parameter and n is the number of parameters.

RESULTS AND DISCUSSION

Dry season

The results of the physical and chemical parameters are correlated with WHO standards (Table 1) to evaluate the suitability of the groundwater for human consumption.

The values of the physical parameters in the dry season (Table 1) indicate that pH ranges from 6 to 8.5

Table 1. Summary of physical and chemical parameters in the dry season.

Parameters	Minimum	Maximum	Mean	Std. Deviation	WHO, 1998
Na	1.00	240.00	55.7500	62.94822	200
K	1.00	64.00	17.9838	18.87239	200
Ca	1.00	300.50	40.9595	57.96771	75*
Mg	0.20	98.00	11.9973	19.50372	50
Cl	2.40	1730.00	269.3611	454.89954	250
HCO3	19.50	563.60	166.5108	149.91948	500
SO4	1.00	122.00	27.2059	27.33715	250
NO3	3.10	238.80	59.9194	45.45252	40-70
DO	17.60	37.00	22.8135	4.21045	5.0
COD	0.00	8.90	1.9027	1.88363	10.0
Cr	0.00	0.11	0.0162	0.02100	0.05
Fe	0.00	5.60	0.3559	0.90707	200
TH	5.00	640.00	168.5135	150.72908	1.0
pH	6.00	8.50	7.0973	0.67966	6.5-9.2
TDS	40.00	1000.00	368.3784	309.87913	500
EC	80.00	1990.00	723.5135	602.39437	500

*(WHO, 1993).

with an average of 7.1. The mean pH value is within WHO acceptable limit. TDS and EC range from 40 to 1000 mg/l and 80 to 1990 µS/cm with mean values of 368.4 mg/l and 723.5 µS/cm, respectively. The mean EC value is above WHO recommended limit. The high EC mean value could be attributed to addition of leachable salts through the prevailing anthropogenic activities in the area. For example, Figure 5 reveal a major EC plume at RD2 having EC value of 2820 µS/cm, and the surrounding wells reveal values of 1790 and 350 µS/cm, respectively. Another plume having EC value of 1990 µS/cm occurs between RD3 and RD4. Also, a plume having EC value of 2010 µS/cm occurs around the Jambutu area. The area is characterized by indiscriminate waste disposal practice such as household solid wastes and most residents use pit latrines. In Luggere area, a major plume having EC value of 4310 µS/cm occurs at RD1 dumpsite. The high EC value is attributed to the contribution of leachable salts from the dumpsite. At Yelwa ward, a plume having EC value of 1910 µS/cm was observed in a hand-dug well bordering the drainage network that empties waste water to the Benue River, consequently, the waste water is responsible for the elevated EC value. In the southern part of Yola, a major plume having EC value of 1500 µS/cm occurs between RD7 and RD9 dumpsites. The high EC value could be attributed to the contribution of leachable salts from the dumpsites. Another plume having an EC value of 1430 µS/cm occurs around Lamido Sanda area. The high EC value could be attributed to inflow of contaminated groundwater probably due to sewage effluent and indiscriminate waste disposal practice. The plume lies within the discharge area as indicated by Figures 3 and 4. The results of the cations indicate that Na and K concentrations vary from 1 to 240 mg/l and 1 to 64 mg/l with mean values of 55.8 and 18 mg/l, respectively. Ca^{2+} and Mg^{2+} vary from 1 to 300.5 mg/l and 0.20 to 98 mg/l with mean values of 41 l and 12 mg/l, respectively. All the mean values of the cations are below WHO desirable limits. The values of the anions reveal Cl^- values ranging from 2.4 to 1730 mg/l with mean value of 269.4 mg/l. The mean value is above WHO recommended limit. High chloride concentration can occur near sewage, irrigation drains, waste outlets (Yisa and Jimoh, 2010). In the study area, sources of chloride include sewage effluents from pit latrines, house hold solid wastes and waste water along drainages. For example, Figure 6 indicates that the major chloride plumes are associated with the dumpsites and areas that are characterized by uncontrolled waste disposal practice. RD1 and RD3 reveal chloride concentrations of 404 and 380 mg/l, thus confirming the source of chloride resulting from the dumpsites into groundwater. Another area of high chloride concentration is the Jambutu area where a plume reveals chloride concentration of 230 mg/l. This high concentration is also associated with sewage effluent and indiscriminate house hold solid waste disposal practice. In the southern part of Yola, a major chloride plume occurs around Lamido Sanda area with chloride concentration of 1730 mg/l. The high chloride concentration could be attributed to inflow of contaminated groundwater as the area lies within the discharge area as confirms by Figures 3 and 4. Another chloride plume having chloride concentration of 1680 mg/l occurs between RD7 and RD9 which also demonstrates the influence of the dumpsites on the

elevated chloride concentration. Bicarbonate and sulphate range from 19.5 to 563.6 mg/l and 1 to 122 mg/l with mean values of 166.5 and 27.2 mg/l, respectively. The mean values of bicarbonate and sulphate are below WHO recommended limits. Nitrate concentrations vary from 3.1 to 238.8 mg/l with mean value of 59.9 mg/l. The mean value is above the desirable limit, and therefore indicates potential risk due to nitrate. High nitrate concentration in drinking water is deleterious especially to babies. It is known that high nitrate concentration in drinking water causes methaemoglobinemia (Efe et al., 2005). It has also been suggested that chronic exposure to high levels of nitrate in drinking water may have adverse effects on the cardiovascular system (Adelana and Olasehehinde, 2003). Bowman (1994) stated that increased concentration of nitrate often cause blood disorders. The source of nitrate in the study area is anthropogenic in origin and is related to point sources. For example, Figure 7 reveals a major nitrate plume having concentration of 238.8 mg/l in Yelwa ward. The high nitrate concentration is influenced by waste water in the drainage network. Another nitrate plume having concentration of 169.2 mg/l occurs between RD3 and RD4 dumpsites while RD2 reveal a nitrate plume having concentration of 101.9 mg/l. The elevated concentrations of nitrate could have been derived from the dumpsites. Around RD3, concentrations of nitrate were obtained as 89.9 and 81.5 mg/l which increase to 169.2 mg/l between RD3 and RD4. This increase could be attributed to inflow of contaminated groundwater as the plume lies within the discharge area as revealed by Figures 3 and 4. At RD1 in Luggere area, nitrate plume having concentration of 150 mg/l occurs and represents contribution of leachates from the dumpsites. Jambutu area reveal nitrate plume having concentration of 132 mg/l, and this decreases to 108.1 mg/l towards Damilu area. The high concentrations of nitrate in these areas represent the influence of sewage effluents and house hold solid wastes from the residential areas. In the southern part of the study area, nitrate plume having concentration of 102 mg/l lies between RD7 and RD9, and another plume having concentration of 88.5 mg/l occurs down gradient of RD8. These high concentrations of nitrate are attributed to point sources of pollution resulting from the dumpsites. Dissolved oxygen (DO) and chemical oxygen demand (COD) values range from 17.6 to 37 mg/l and 0 to 8.9 mg/l with mean values of 22.8 and 1.9 mg/l. The mean value of DO has exceeded WHO standard limit. Highly oxygenated water could cause the oxidation of ammonium ion to nitrate. The values of chromium hexavalent, Fe^{2+} and total hardness range from 0 to 0.1 mg/l, 0 to 0.4 mg/l and 5 to 168.5 mg/l. Cr^{+6} from Figure 8 indicates a major plume occurring at Tafida area in the southeastern part of Yola. The plume has a concentration of 0.11 mg/l and lies within the discharge area as revealed by Figures 3 and 4. In flow of contaminated groundwater is responsible for the elevated concentration of Cr^{+6}. Another Cr^{+6} plume having concentration of 0.06 mg/l could be due to the influence of the dumpsites occurring at RD7 and RD9 along groundwater flow direction as indicated by Figures 3 and 4. A plume of Cr^{+6} having concentration of 0.06 mg/l also occur at the discharge area between the Cemetery and Lamido Sanda area. This plume could have been influenced by inflow of contaminated groundwater. In the northern part of the study area, a plume of Cr^{+6} having concentration of 0.05 mg/l occurs between RD3 and RD4, the dumpsites could have been the source of Cr^{+6}. All the mean values are below WHO recommended limits. From the mean values of the chemical parameters in the dry season, EC, chloride, nitrate and dissolved oxygen exceeded WHO recommended limit. The sources of these contaminants could be linked to anthropogenic sources. In the dry season, the mean values of the cations are in the order of abundance as $Na^{+} > Ca^{2+} > K^{+} > Mg^{2+}$ and anions as $Cl^{-} > HCO_3^{-} > NO_3^{-} > SO_4^{2-}$

Rainy season

From Table 2, the values of the physical parameters indicate the pH ranges from 5.4 to 8.3 with an average of 7.0 while EC and TDS range from 80 to 2140 mg/l and 40 to 1070 mg/l with mean values of 708.6 µS/cm and 348.1 mg/l, respectively. The mean value of EC exceeded WHO recommended limit. Ec is an index representing total concentration of soluble salts in water (Purandara et al., 2003). The high mean value of EC could be associated with leachable salts following the dissolution of waste materials in the rainy season. For example Figure 9 reveals a major EC plume at Jambutu area having EC value of 3500 µS/cm. The plume reveals higher value than the dry season value which could be attributed to the release of leachable salts from the dissolution of waste materials and sewage effluents in the rainy season. Another EC plume having value of 2050 µS/cm was recorded at RD1 dumpsite in Luggere area, indicating higher value over the dry season period. At RD2 and around RD3 EC plumes reveal EC values of 1740 and 1760 µS/cm lower than the dry season period. At RD2, the plume has higher value in the dry season, and around RD3 there was high EC value in the rainy season. The low value in the rainy season at RD2 could be attributed to dilution effect. In the southern part of the study area, the EC plume occurring between RD7 and RD9 reveal EC value of 1340 µS/cm lower than the dry season value. The low EC value could be attributed to dilution effect. The plume occurring between the Cemetery and Lamido Sanda area indicates EC value of 1300 µS/cm lower than the dry season value. This is a clear indication of dilution effect in the rainy season. The concentrations of sodium and potassium range from 4 to 420 mg/l and 1 to 72 mg/l, and mean values were 151 and 21.3 mg/l, respectively. Calcium and magnesium range from 3.4 to 88.4 mg/l and 0.3 to 30.2 mg/l, and

Table 2. Summary of physical and chemical parameters in the rainy season.

Parameter	Minimum	Maximum	Mean	Std. deviation
Na	4.00	420.00	150.9722	129.06975
K	1.00	72.00	21.2838	19.69755
Ca	3.40	88.40	38.5973	20.83475
Mg	0.30	30.20	13.3139	8.09777
Cl	14.20	5375.00	464.9405	931.42778
HCO3	12.20	780.80	234.9622	207.53761
SO4	2.00	146.00	47.4324	43.32278
NO3	4.90	224.10	62.0514	52.39785
DO	11.80	105.60	20.7622	14.59266
COD	0.00	9.70	5.5216	2.49712
Cr	0.01	1.20	0.1959	0.32628
TH	5.00	680.00	236.8919	173.75490
Fe	0.00	1.20	0.2868	0.21587
pH	5.40	8.30	6.9892	0.74528
EC	80.00	2140.00	708.6486	545.58919
TDS	40.00	1070.00	348.1081	274.57885

mean values were 38.6 and 13.3 mg/l. The mean values of the cations are below WHO recommended limits. The concentrations of chloride, bicarbonate and sulphate range from 14.2 to 5375 mg/l, 12.2 to 780.8 mg/l and 2 to 146 mg/l, with mean values of 464.9, 235 and 47.4 mg/l, respectively. Among the anions, the mean chloride value is above the recommended limit of WHO. Figure 10 indicates a major chloride plume occurring at concentration of 5375 mg/l at RD2 in Doubeli area and 4355mg/l in Jambutu area. The high concentration of chloride in these areas is related to the dissolution of house hold solid wastes and sewage effluent following the use of pit latrines by most residents. Figure 10 further reveals a chloride plume in the southern part of the study area between RD7 and RD9 having concentration of 1300 mg/l which clearly indicates chloride contamination from the dumpsites. The chloride concentration of 1300 mg/l is lower than the dry season value which further suggests the effect of dilution. Another effect of dilution is manifested in Lamido Sanda area where a chloride plume revealed concentration of 1265 mg/l lower than the dry season value. Nitrate concentrations vary from 4.9 to 224.1 mg/l with an average of 62.1 mg/l. The mean value is above the WHO recommended limit. Figure 11 indicates a major nitrate plume occurring at a concentration of 224.1 mg/l around the Lamido Sanda area. The high concentration of nitrate is attributed to inflow of contaminated groundwater due to sewage effluents and dissolution of waste materials from house hold solid wastes. The plume lies in the discharge area as indicated on Figures 3 and 4. The next nitrate plume in order of concentration occurs at RD3 having concentration of 150 mg/l and the surrounding wells reveal concentrations of 94, 71.3 and 51 mg/l, respectively. This is a clear contribution of nitrate from the dumpsite in the degradation of groundwater quality. At Jambutu area, nitrate plume revealed concentration of 105.4 mg/l lower than the dry season period which could be attributed to dilution effect and denitrification process. The effect of dilution and denitrification process also occurred in Yelwa area where nitrate plume revealed concentration of 238.8 mg/l and decreases to 4.9 mg/l in the rainy season. DO and COD values range from 11.8 to 105.6 mg/l and 0 to 9.7 mg/l, with averages of 20.8 and 5.5 mg/l, respectively. The mean value of DO is above WHO standard limit. Chromium hexavalent, total hardness and iron range from 0.01 to 1.2 mg/l, 5 to 680 mg/l and 0 to 1.2 mg/l, with mean values of 0.2, 236.9 and 0.3 mg/l. The mean value of chromium hexavalent and total hardness exceeded WHO recommended limit. The high mean value of chromium hexavalent constitutes health hazard. For example, Figure 12 indicates a major Cr^{+6} plumes occurring at concentrations of 1.12 mg/l around Malamre area, 1.02 mg/l around Clerks Quarters and 1.2 mg/l at Demsawo area. Ishaku and Ezeigbo (2010) discovered that anthropogenic activities are responsible for Cr^{+6} contamination of groundwater in the area. Chromium hexavalent is known to be carcinogenic (Edet and Okereke, 2001; Otukune and Biukwu , 2005). The mean values of the chemical parameters indicate that chloride, nitrate, dissolved oxygen, total hardness and chromium hexavalent exceeded WHO recommended limits in the rainy season which could be attributed to the dissolution of waste materials. The cations were in order of abundance as $Na^{+} > Ca^{2+} > K^{+} > Mg^{2+}$ while anions were in the order of abundance as $Cl^{-} > HCO_3^{-} > NO_3^{-} > SO_4^{2-}$

Correlation analysis between the chemical parameters in the dry season (Table 3) indicate high positive

Table 3. Correlation of chemical parameters in the dry season in the study area.

	Na	K	Ca	Mg	Cl	HCO_3	SO_4	NO3	DO	COD	Cr	Fe	TH	pH	TDS	EC
Na	1															
K	0.616(**)	1														
Ca	0.536(**)	0.485(**)	1													
Mg	0.387(*)	0.603(**)	0.795(**)	1												
Cl	0.292	0.460(**)	0.176	0.206	1											
HCO_3	0.486(**)	0.454(**)	0.397(*)	0.432(**)	0.115	1										
SO_4	0.575(**)	0.619(**)	0.427(*)	0.432(*)	0.585(**)	0.418(*)	1									
NO3	0.568(**)	0.239	0.116	0.136	0.041	0.205	0.253	1								
DO	0.240	0.011	0.293	0.014	0.095	-0.109	0.271	0.012	1							
COD	-0.031	-0.095	-0.072	-0.079	0.241	-0.200	-0.051	0.074	0.131	1						
Cr	-0.160	0.010	-0.098	-0.019	0.399(*)	-0.052	0.050	-0.127	0.103	0.174	1					
Fe	-0.152	-0.156	-0.086	-0.125	-0.003	-0.081	0.173	-0.248	0.230	-0.005	0.144	1				
TH	0.626(**)	0.786(**)	0.401(*)	0.504(**)	0.221	0.546(**)	0.486(**)	0.511(**)	0.053	0.033	-0.029	-0.167	1			
pH	0.523(**)	0.358(*)	0.375(*)	0.251	0.004	0.607(**)	0.265	0.341(*)	0.098	-0.175	0.100	-0.083	0.473(**)	1		
TDS	0.848(**)	0.799(**)	0.589(**)	0.594(**)	0.339(*)	0.561(**)	0.601(**)	0.590(**)	0.184	0.026	-0.063	-0.125	0.835(**)	0.520(**)	1	
EC	0.753(**)	0.713(**)	0.416(*)	0.410(*)	0.331(*)	0.488(**)	0.508(**)	0.527(**)	0.199	0.053	-0.091	-0.132	0.787(**)	0.510(**)	0.867(**)	1

**Correlation is significant at the 0.01 level, * correlation is significant at the 0.05 level.

correlation between Mg^{2+}-Ca^{2+} (r = 0.80), TH, K^+ and TDS (r = 0.77 to 0.84), TDS, Na^+ and K^+ (r = 0.80 to 0.85) and EC, Na^+, K^+ and Fe^{2+} (r = 0.71 to 0.79). In the rainy season, correlation (Table 4) between the chemical parameters indicates high positive correlation as follows: K^+, Na^+, Mg^{2+}, HCO_3^- and TH (r = 0.73 to 0.85), EC, Na^+, K^+, HCO_3^- and TH (r = 0.78 to 0.93) and TDS, Na^+, K^+, Mg^{2+}, HCO_3^-, TH and EC (r = 0.83 to 0.98). The high positive correlation between the chemical parameters is an indication of common source.

The WQI values computed for the study area in the dry season and rainy season are presented in Tables 5 and 6. The computed WQI values for the dry season (Table 5) indicate that the overall WQI was 96.4. According to Ramakrishnaiah et al. (2009), WQI <50 is excellent; 50 to 100 is good water; 100 to 200 poor water; 200 to 300 is classified as very poor water and WQI >300 indicates that water is unsuitable for drinking. By the aforementioned standards, the overall WQI indicates water of good quality. The overall WQI computed for the rainy season was 138.5 and indicates poor water (Table 6). The high value of WQI has been found to be mainly from chloride, nitrate, dissolved oxygen, chromium hexavalent and EC. The source of these contaminants is attributed to anthropogenic sources such as sewage effluents, house hold solid wastes and waste water. The mean values of these contaminants also exceeded WHO standards as revealed previously with the exception of total hardness.

Conclusion

The following conclusions can be derived from this study:

1. The groundwater quality is contaminated in the dry season due to high concentrations of EC, chloride, nitrate and dissolved oxygen and chloride, nitrate, dissolved oxygen, total hardness and chromium hexavalent in the rainy season. The mean concentrations of these parameters exceeded WHO recommended standards.
2. Spatial distribution of EC, chloride, nitrate and chromium hexavalent in the dry and rainy season indicated that the sources of these contaminants result from point sources such as: house hold solid wastes, sewage effluents and waste water.

Table 4. Correlation of chemical parameters in the rainy season in the study area.

	Na	K	Ca	Mg	Cl	HCO3	SO_4	NO_3	DO	COD	Cr	TH	Fe	pH	EC	TDS
Na	1															
K	0.848(**)															
Ca	0.681(**)	0.507(**)	1													
Mg	0.760(**)	0.815(**)	0.500(**)	1												
Cl	0.418(*)	0.583(**)	0.104	0.580(**)	1											
HCO_3	0.804(**)	0.612(**)	0.359(*)	0.591(**)	0.462(**)	1										
SO_4	0.459(**)	0.424(**)	0.255	0.203	0.035	0.424(**)	1									
NO_3	0.502(**)	0.655(**)	0.566(**)	0.690(**)	0.360(*)	0.124	0.185	1								
DO	0.216	0.103	0.240	0.169	0.062	0.135	0.120	0.109	1							
COD	-0.013	0.015	0.001	0.175	0.229	-0.040	-0.088	0.122	-0.070	1						
Cr	-0.119	-0.189	-0.004	-0.141	-0.138	0.087	-0.214	-0.289	-0.038	-0.112	1					
TH	0.782(**)	0.727(**)	0.455(**)	0.691(**)	0.428(**)	0.789(**)	0.470(**)	0.365(*)	-0.039	0.098	-0.110	1				
Fe	-0.239	-0.285	-0.087	-0.283	-0.076	-0.071	-0.133	-0.323	-0.084	-0.255	0.282	-0.249	1			
pH	0.486(**)	0.210	0.117	0.229	0.133	0.542(**)	0.212	-0.194	0.328(*)	-0.243	0.018	0.218	0.136	1		
EC	0.930(**)	0.901(**)	0.579(**)	0.782(**)	0.527(**)	0.783(**)	0.498(**)	0.549(**)	0.166	0.057	-0.178	0.804(**)	-0.259	0.340(*)	1	
TDS	0.958(**)	0.919(**)	0.603(**)	0.817(**)	0.544(**)	0.803(**)	0.464(**)	0.571(**)	0.170	0.030	-0.166	0.834(**)	-0.260	0.376(*)	0.981(**)	1

**Correlation is significant at the 0.01 level, * correlation is significant at the 0.05 level.

Table 5. Computed water quality index for Jimeta-Yola area in the dry season.

Chemical parameters	Standard permissible Value (s_i) (WHO, 1998)	Weight (w_i)	Relative weight (W_i)	q_i	SI
Na	200	2	0.03846	27.9	1.07
K	200	2	0.03846	9.0	0.35
Ca	75*	2	0.03846	54.7	2.10
Mg	50	1	0.01923	24.0	0.46
Cl	250	3	0.05769	107.8	6.22
HCO_3	500	3	0.05769	33.30	1.92
SO4	250	4	0.07692	10.9	0.84
NO3	40-70	5	0.09615	108.9	10.47
DO	5.0	4	0.07692	456.0	35.08
COD	10.0	4	0.07692	19.0	1.46
Cr	0.05	5	0.09615	40.0	3.85
TH	200	3	0.05769	40.0	2.31
Fe	1.0	4	0.07692	84.3	6.48

Table 5. Contd.

Ph	6.5-9.2	4	0.07692	90.5	6.96
EC	500	4	0.07692	73.7	5.67
TDS	500	4	0.07692	144.7	11.13
Total		52			96.37

*(WHO, 1993).

Table 6. Computed water quality index for Jimeta-Yola area in the rainy season.

Chemical parameters	Standard permissible Value (s_i) (WHO, 1998)	Weight (w_i)	Relative weight (W_i)	q_i	SI
Na	200	2	0.03846	75.5	2.90
K	200	2	0.03846	10.65	0.41
Ca	75*	2	0.03846	51.47	1.98
Mg	50	1	0.01923	26.6	0.51
Cl	250	3	0.05769	185.96	10.73
HCO_3	500	3	0.05769	47	2.71
SO_4	250	4	0.07692	18.96	1.46
NO_3	40-70	5	0.09615	112.91	10.86
DO	5.0	4	0.07692	416	32
COD	10.0	4	0.07692	55	4.23
Cr	0.05	5	0.09615	400	38.46
TH	200	3	0.05769	118.45	6.83
Fe	1.0	4	0.07692	30	2.31
pH	6.5-9.2	4	0.07692	89.17	6.86
EC	500	4	0.07692	141.72	10.90
TDS	500	4	0.07692	69.62	5.36
Total		**52**			138.51

*(WHO, 1993).

3. In the dry season, the cations were in the order of abundance as Na+ >Ca2+ >K+ >Mg2+ and anions as Cl- >HCO3- >NO3- >SO42- and the cations were in order of abundance as Na+ >Ca2+ >K+ >Mg2+ while anions were in the order of abundance as Cl- >HCO3- >NO3- >SO42- in the rainy season.

4. The overall WQI value computed for the groundwater in the dry season was 96.4 which indicate good quality water.

5. The overall WQI value in the rainy season was 138.5 which exceeded 100, the upper limit of drinking water. This value indicates poor water quality. The high value of WQI has been found to be mainly from chloride, nitrate, dissolved oxygen, chromium hexavalent and EC. The source of these contaminants is attributed to anthropogenic sources such as sewage effluents, house hold

solid wastes and waste water.
6. The study reveals that the water quality is unfit for human consumption without treatment.
7. Controlled waste disposal practice should be encouraged to minimize groundwater contamination.

ACKNOWLEDGEMENTS

My special thanks go to the Adamawa State Water, Yola, Department of Chemistry and Biochemistry, Federal University of Technology,
Yola for providing me with the necessary facilities to carry out the water analysis.

REFERENCES

Adekeye JID, Ishaku JM (2004). Groundwater contamination in shallow aquifers of Jimeta metropolis, Adamawa State, N.E. Nigeria. Zuma J. Pure Appl. Sci., 6(1): 150-159.
Adelana SMA, Olasehinde PI (2003). High nitrate in water supply in Nigeria: Implications for human health. WATER RESOURCES-Journal of the Nigerian Association of Hydrogeologists (NAH), 14: 1-11.
Allix P (1983). Environments me'sozoïques de la partie nord-orientale du fosse de la Bénoué (Nigeria). Stratigraphie, sédimentologie, evolution géodynamique. Trav. Lab. Sci. Terre, St. Jéróme, Marseille (B), 21: 1-200.
APHA (1980). Standard methods for the examination of water and waste water 15th ed. Washington, D.C. American public Health Association, p. 1134.
Bowma J (1994). 'Water is best'. Would Pindar still think so? In: Cartledge B (ed) Health and the environment. The Linacre lectures 1992-3. Oxford University Press, Oxford, pp. 85-125.
Braide SP (1992). Studies on the Sedimentation and Tectonics of the Yola arm of the Benue Trough. Facies Architecture and their Tectonic significance. J. Min. Geo., 28(1): 23-31.
Carter AD, Palmer RC, Monkhouse RA (1987). Mapping the vulnerability of groundwater to pollution from agricultural practice, particularly with respect to nitrate. **In:** Vulnerability of Soil and Groundwater to pollutants (ed. van Duijvenbooden W, Waegeningh HG). TNO Committee on Hydrological Research. The Hague, Proceedings and Imformation, 38: 333-342.
Carter JD, Barber W, Tait EA (1963). The Geology of parts of Adamawa, Bauchi and Borno Provinces in Norteastern Nigeria. Geol. Surv. Of Nig. Bull. P. 30.
Census (2006). Population of the Federal Republic of Nigeria. Adamawa State statistical Tables. National population commission final Results of population of Nigeria.
Chilton J (1992). Groundwater. Water Quality Assessment-A guide to use; sediments and water in environmental monitoring, 2nd ed. UNESCO/WHO/UNEP.
Edet AB, Okereke CS (2001). A regional study of saltwater intrusion in Southeastern Nigeria based on the analysis of geoelectrical and hydrochemical data. Environ. Geol., 40: 1278-1284.
Eduvie MO (2000). Groundwater Assessment and Development in the Bima Sandstone: A cases study of Yola-Jimeta area. WATER RESOURCES-Journal of the Nigerian Association of Hydrogeologists (NAH) 2: 31-38.
Efe SI, Ogban FE, Horsfall M Jnr, Akporhonor EE (2005). Seasonal Variations of Physico-chemical Characteristics in Water Resources Quality in Western Niger Delta Region, Nigeria. J. Appl. Sci. Environ. Mgt., 9(1): 191-195.
Guiraud M (1990a). Mécanime de formation du basin sur décrochements multiples de la Haute-Bénoué (Nigeria): faciés et géometrie des corps sédimentares. Mém. Habilitation, Univ. Montpellier, P. 445.
Guiraud M (1991a). Mécanisme de formation du basin crétacé sur décrochements multiples de la Haute-Bénoué (Nigeria). Bull. Centres Rech. Explor.-Prod. Elf-Aquitaine, 15: 11-67.
Ishaku JM (1995). The hydrogeology of Yola area and Environs in the Upper Benue River Basin. MSc. Thesis (unpublished). Department of Geology, University of Nigeria, Nsukka.
Ishaku JM (2007): Waste Disposal and Groundwater Quality in Jimeta-Yola area, Adamawa State, Nigeria. Ph.D Thesis (unpublished). Department of Geology, University of Nigeria, Nsukka.
Ishaku JM, Ezeigbo HI (2000). Water quality of Yola, northern Nigeria. WATER RESOURCES-Journal of the Nigerian Association of Hydrogeologists (NAH) 1: 39-48.
Ishaku JM, Ezeigbo HI (2010). Groundwater Quality monitoring in Jimeta-Yola area, northeastern Nigeria. WATER RESOURCES-Journal of the Nigerian Association of Hydrogeologists (NAH 20(2): 1-14.
Ishaku JM, Ezeigbo HI (2010). Seasonal Variation in Chromium hexavalent and Copper Contamination in Groundwater of Jimeta-Yola Area, Northeastern Nigeria. Global J. Geol. Sci., 8(2): 143-154.
Okoro EI, Egboka BCE, Anike OL, Onwuemesi AG (2009). Integrated water resources management of the Idemili River and Odo River drainage basins, Nigeria. Improving Integrated Surface and Groundwater Resources Management in a Vulnerable and Changing World (proc. of JS .3 at the Joint IAHS & IAH Convention, Hyderabad, India, September 2009). IAHS Publ. pp.117-122.
Otukune TV, Biukwu CO (2005). Impact of Refinery Influent on physic-chemical properties of a water body on Niger Delta. J. Applied Ecol. Environ. Res., 3: 61-72.
Popoff M (1988). Du Gondwana ă l' Atĺantique sud: les connexions du fosse de la Bénoué avec les basins du Nord Est brësilion jusqúá Í ouverture du golfe de Guinée au Crétacé inferior. J. Afr. Earth Sci., 7: 409-431.
Popoff M, Wiedmann J, De Klasz I (1986). The Upper Cretaceous and Gongila and Pindiga Formations, northern Nigeria: Subdivisions, age, stratigraphic correlations and paleogeographic Implications. Eclogae geol. Helv., 79: 343-363.
Purandara BK, Varadarajan N, Jayashree K (2003). Poll Res., 22(2): 189.
Rajkumar N, Subramani T, Elonga L (2010). Groiundwater contamination due to municipal solid waste disposal-A GIS based study in Erode city. Int. J. Environ. Sci., 1(1): 39-55.
Ramakrishnaiah CR, Sadashivaiah C, Ranganna G (2009). Assessment of Water Quality Index for Groundwater in Tumkur Taluk, Karnataka State, India. E-Journal of Chemistry, 6(2): 523-530.
Sarukkalige PR (2009). Impact of land use on groundwater quality in Western Australia. Improving Integrated Surface and Groundwater Resources Management in a Vulnerable and Changing World (proc. of JS .3 at the Joint IAHS & IAH Convention, Hyderabad, India, September 2009). IAHS Publ. pp. 136-142.
Sexana MM (1990). Environment: Water analysis, soil and air. 2nd ed. Agro Botanical Publishers (India), p. 188.
Tay C, Kortatsi B (2008). Groundwater Quality Studies: A case study of the Densu Basin, Ghana. West Afr. J. Appl. Ecol., 12.
USEPA (1974). Methods for chemical analysis of water and wastes. Technical report Office of Technology Transfer, Washington, D.C., pp. 105-106.
Wadie AST, Abduljalil GADS (2010). Assessment of hydrochemical quality of groundwater under some Urban areas within Sana'a Secretariat. Ecletica quimica. www.SCIELO.BR/EQ. 35(1): 77-84.
World Health Organization (1993). International Standards for drinking Water Quality. Geneva.1.
World Health Organization (WHO). (1998). Guide lines for drinking water 2nd Edition vol. 2 Health criteria and other information genera Switzerland; pp. 281-308.
Yenika ME, Uma KO, Obiefuna GI (2003). A case study of shallow aquifer in Jimeta-Yola metropolis, northeastern Nigeria. WATER RESOURCES-Journal of the Nigerian Association of Hydrogeologsts (NAH), 14: 84-91.
Yisa J, Jimoh T (2010). Analytical Studies on Water Quality Index of River landzu. Ame. J. Appl. Sci., 7(4): 453-458.
Zaborski P (1998). A review of the Cretaceous system in Nigeria. Afr.

Geosci., Rev., 5(4): 385-483.
Zaborski P, Ugodulunwa F, Idornigie A, Nnbo P, Ibe K (1997). Stratigraphy and Structure of the Cretaceous Gongla Basin, Northeast Nigeria. Elf exploration production, F-64018 Pau.
Zaporozec A (1981). Groundwater pollution and its sources. Geo. J., 5(5): 457-471.