FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 6 No. 1, March, 2022, pp 358 - 367
DOI: https://doi.org/10.33003/fjs-2022-0601-907

INVESTIGATION OF GROUNDWATER CONTAMINATION IN SOME SELECTED AREAS OF BOGORO AND ENVIRONS, NORTH-EAST NIGERIA

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ABSTRACT

The quality of drinking water in some selected areas of Bogoro and its Environs in Bauchi State, Nigeria, were investigated in order to assure a continuous supply of clean and safe drinking water for public health protection and analyze the spatiotemporal variation of groundwater quality in the area. A rigorous physical and chemical study of drinking water samples was conducted in some residential and commercial areas. For each water sample collected during dry and wet seasons, a variety of physical characteristics such as pH, turbidity, conductivity, total dissolved solids (TDS), and chemical parameters such as Ca, Na, K, $SO^2{}_4$, $PO^2{}_4$, F, Cl, Cu, Mg, Fe, and Mn were analyzed. The resulting values for each parameter were compared to the World Health Organization's (WHO) and European Union (EU) standards. The values of each parameter were found to be within the permissible limits with the exception of Turbidity with an average value of 7.55mg/L, Fluoride (0.52mg/L), Iron 0.69mg/L which were above the permissible limit. The implications of ingestion of these contaminants include Gastro-Intestinal distress, liver or kidney damage with some other health implications. However, in order to assess the total water quality of water in the area, it's necessary to analyze other potential water contaminations, such as heavy metals, microbiological and radioactive elements, and human body fluids. Based on these findings, it's recommended that Public health institutions should intensify awareness and enlightenment campaigns to water users on procedures and water treatment techniques.

Keywords: European Union; Groundwater; Mean value; Water Quality Test; WHO

INTRODUCTION

Water is vital to human health and well-being. Humans today have access to safe drinking water as a basic right. Around 780 million people lack access to clean, safe water, and 2.5 billion people lack appropriate sanitation. As a result, water-related diseases and disasters kill approximately 6–8 million people each year (Azrina *et al.*, 2011; United Nations, 2013; WHO, 2011). As a result, in many regions of the world, water quality regulation is a top-priority governmental agenda (World Health Organization (WHO), 2011). Water used in household supplies is usually referred to as domestic water in today's globe. This water is treated to make it safe to drink and use for other purposes. The taste, odor, color, and concentration of organic and inorganic particles in water define its quality and fitness for usage (Dissmayer, 2000).Contaminants in water can have an impact on water quality and, as a result, human health. Geological conditions, industrial and agricultural operations, and water treatment plants are all potential sources of water contamination. Microorganisms, inorganics, organics, radionuclides, and disinfectants are different types of pollutants (Nollet, 2000). In comparison to organic chemicals, inorganic compounds hold a greater percentage of pollutants in drinking water (Azrina *et al.*, 2011). Heavy metals in mineral form make up a portion of inorganics. Heavy metals build up in human organs and the neurological system, interfering with normal processes. Heavy metals like lead (Pb), arsenic (As), magnesium (Mg), nickel (Ni), copper (Cu), and zinc (Zn) have gotten a lot of attention in recent years because they cause health concerns (WHO, 2011). Furthermore, traces of metals such as cadmium (Cd) and chromium (Cr) have been linked to cardiovascular disorders, kidney issues, neurocognitive impairments, and cancer, according to epidemiological research (DeZuana, 1997). Pb is known to slow infants' physical and mental development, whereas As and mercury (Hg) can cause significant poisoning with skin pathology and cancer, as well as subsequent kidney and liver damage (WHO, 2011, Fawel, 1993). Hg and inorganic Hg compounds are categorized as group 3 carcinogens by the International Agency for Research on Cancer (IARC, 1993, Jin *et al*, 2010). Furthermore, in many places of the world, such as the United States, Canada, Germany, Norway, Greece, and Finland, the presence of hazardous and radioactive elements like uranium in groundwater is a severe problem. Chemical toxicity is considerable, and it has deadly effects on the human skeleton and kidneys (Katsoyiannis and Zouboulis, 2013, Tuzen and Soylak, 2006).

To analyze water pollutants, a number of scientific processes and instruments have been developed (Dissmayer, 2000). The study of several parameters such as pH, turbidity, conductivity, total suspended solids (TSS), total dissolved solids (TDS), and chemical parameters are all part of these procedures. If the levels of these parameters exceed the safe limits specified by the World Health Organization (WHO) and other regulatory agencies, they can have an impact on the quality of drinking water (WHO, 2011). As a result, researchers and government agencies around the world have been investigating the quality of drinking water on a regular basis (IARC, 1993, Jin *et al*, 2010, Katsoyiannis and Zouboulis, 2013, Tuzen and Soylak, 2006, Heydari and Bidgoli, 2012).

Bogoro is one of Bauchi's most well-known, historical, and mining areas. Minerals and mining activities were well-known in the Local Government. There is no information on the quality of drinking water or potential causes of pollution in scholarly works of literatures. Because new institutions are flocking to the area, it is critical to assess the local government's drinking water quality in order to ensure safe drinking water for local inhabitants and throngs of students. The purpose of this research was to assess the drinking water quality of boreholes, wells, and streams in some parts of Bogoro Local Government, Bauchi State, Nigeria. Water samples were taken from various residential and commercial locations within the research region for a complete physical and chemical investigation. Each water sample was tested for pH, turbidity, conductivity, total dissolved solids (TDS), and chemical characteristics such as Ca, Na, K, SO^2_4, PO^2_4, F, Cl, Cu, Mg, Fe, and Mn. The results of each parameter were compared to WHO guidelines and standards (WHO, 2011) as well as national and international standards such as the (EU, 2011).

Location of the Study Area

The study area is Boi, Bogoro local government area, of Bauchi State, North-East, Nigeria. It covers a total land area of about 121km^2 and extends between latitude 9° 31′ 00″ N to 9° 37′ 00″ N North of the equator and 9° 30′ 00″ E to 9° 36′ 00″ E East of the Greenwich meridian, on the scale of 1:50,000 Tafawa Balewa sheet 170SW, Federal Survey of Nigeria 1976 (Figure.1.) and is accessible through the Bauchi - Kabwir major road and through tarred, untarred roads that link the various villages, settlements and towns together (Figure 1.). The climate of the study area is typical of the Sudan Savannah type with the climatic season of wet and dry seasons. The wet season is characterized by high storms and it varies from year to year. The dry season is long-lasting for about six months of the rainy season, from October to April, followed by five months of the rainy season, from May to September with the highest recorded rainfall in August (Iloeje, 1989). Generally, the area is devoid of a thick forest but consists of grasses, shrubs, and scattered trees. Shrubs however form the dominant vegetation.

The area is situated on gently undulating terrains. The topographic elevation varies from 2250 (ft) to 2550 (ft), the high relief of the North East region of the study area is occupied by the hilly tract of Lusa (Figure 1.). The drainage pattern of the study area is mainly dendritic - (tree-like branching). This indicates a South and South East flow direction within the study area (Figure1.).

The distribution of groundwater within an area is originally controlled by some geological factors which include: lithology, texture, and structures within the rocks, as well as climatic elements such as rainfall, temperature, rainfall, and wind. The ability of some crystalline rocks to store, transmit and yield water chiefly depends on some factors which include: the extent of openness and continuity of the fractures and the degree to which fractures are hydraulically connected. To understand the groundwater potential of the study area, surface water of the area must be considered and looked into. Drainage of the study area is dominantly by surface streams which are mainly dendritic (Figure 2.). River Lere that flows through Boi is the major river that borders the study area, these streams retain surface flow only for short period after the rainy season. The youthfulness of the drainage and the normal topography preclude surface conservation schemes of any appreciable magnitude (Carter *et al.,* 1963).

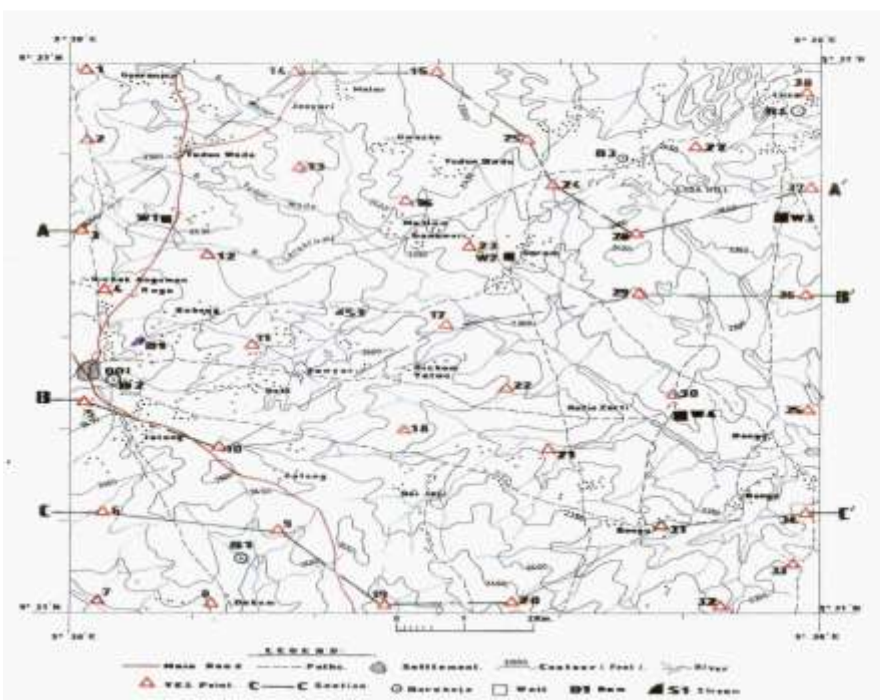

Figure 1**:** Topographical Map of the Study Area showing sample points (After Federal Survey of Nigeria Topo Sht. 170sw of 1976)

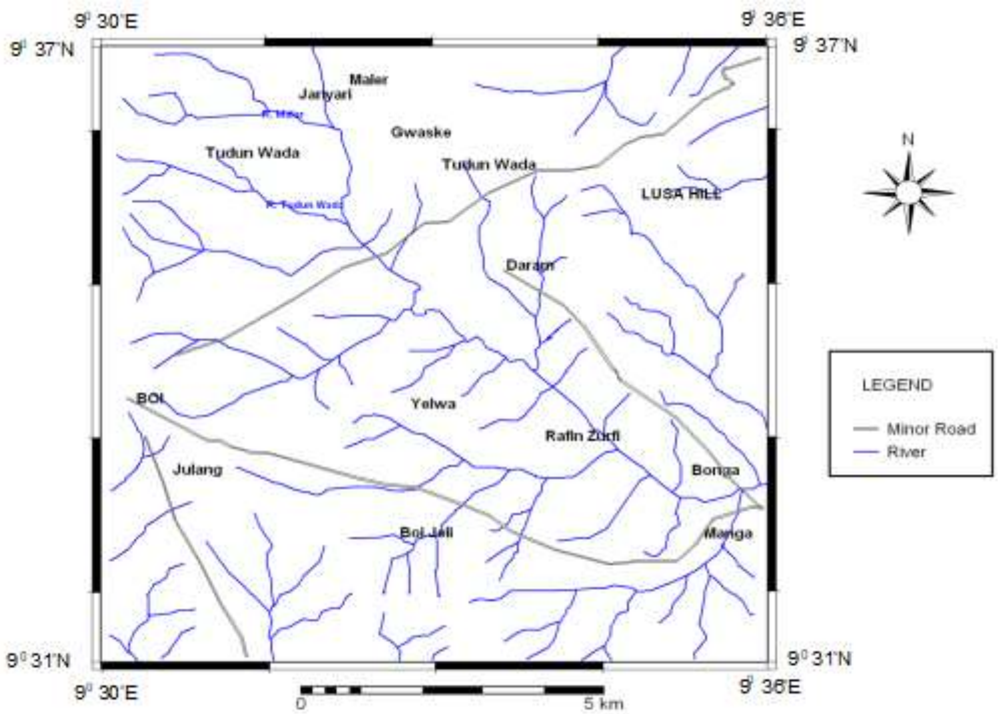

Figure 2: Drainage Pattern of the study area

Geology of Study Area
The area is on the Basement Complex of North-Eastern Nigeria (Figure 3.), which is made – up of basically crystalline rocks. The Basement Complex rocks consistessentially of rocks that are granitic in composition. In different stages of metamorphism, they occur as gneisses, migmatite, quartzite, phyllite, Schist, and pegmatite. The rocks of the study area include the Granite Gneiss and Migmatitic Gneiss believed to be Birimian in age (Oyawoye, 1970 and McCurry, 1976). They were emplaced into the Basement during Pan – African and are called Nigeria, older granite to distinguish them from the younger granites rocks. Through the process of metamorphism, migmatization, and granitization that took place, the rocks were initially largely covered into migmatites and Gneisses with some relics of original gneisses (McCurry, 1976). The study area is underlain by the following rocks of the older Granites of Precambrian to lower Paleozoic Viz: Biotite Granite, Migmatitc Gneiss, and Granite Gneiss.

Biotite Granites
Biotite granites rocks cover predominantly most of the Northwestern parts of the study area and range from medium to coarse-grained with minor variation in textures (Obaje *et al.*, 2009). The color of the biotite granite ranges from white to grey (i.e. leucocratic). Some of the biotite granites occurred as boulders (Figure 3.). At the Northeastern part of Lusa, there was also biotite granites exposure which is leucocratic and the grain sizes range from medium to coarse grain sizes as well. The biotite granite lithology terminates at Jolong and Daram in the southern part of the study area and extends Northward and Westward of the study area respectively.

Migmatite Gneiss
Migmatite gneiss covers predominantly most parts of the study area (Figure 3.), they were seen outcropping at the southern and southeastern parts of the study area. The outcrops were of low relief when compared to the biotite granites. Migmatites were foliated, there was the alignment of the light and dark minerals and the texture was medium to coarse-grained. The migmatite gneiss lithology terminates at Jolong and Daram in the Northern part and at Bonga at the Eastern part of the study area, it extent southwards of the study area. There were veins in the study area and also segregations of light-color granitic composition called leucosome, with dark-colored amphiboles and biotite-rich materials called melanosomes.

Granite Gneiss
Granite gneiss rocks cover Northeastern parts of the study area. The rocks had contact with migmatite which was transitional and generally have complete structural conformity with foliations. The term granite gneiss is generally used for a heterogeneous group of rocks, mostly which are granodioritic in composition with variable amounts of remnant streaks schlieren and larger relics bodies of original gneiss were recognizable (McCurry, 1976). The granite gneiss lithology covers the extreme Northeastern and Southeastern parts of the area and was seen at Lusa, Manga, and Bonga respectively. The rocks showan alternating color of dark and light, also yielding a structure called gneissose foliation.

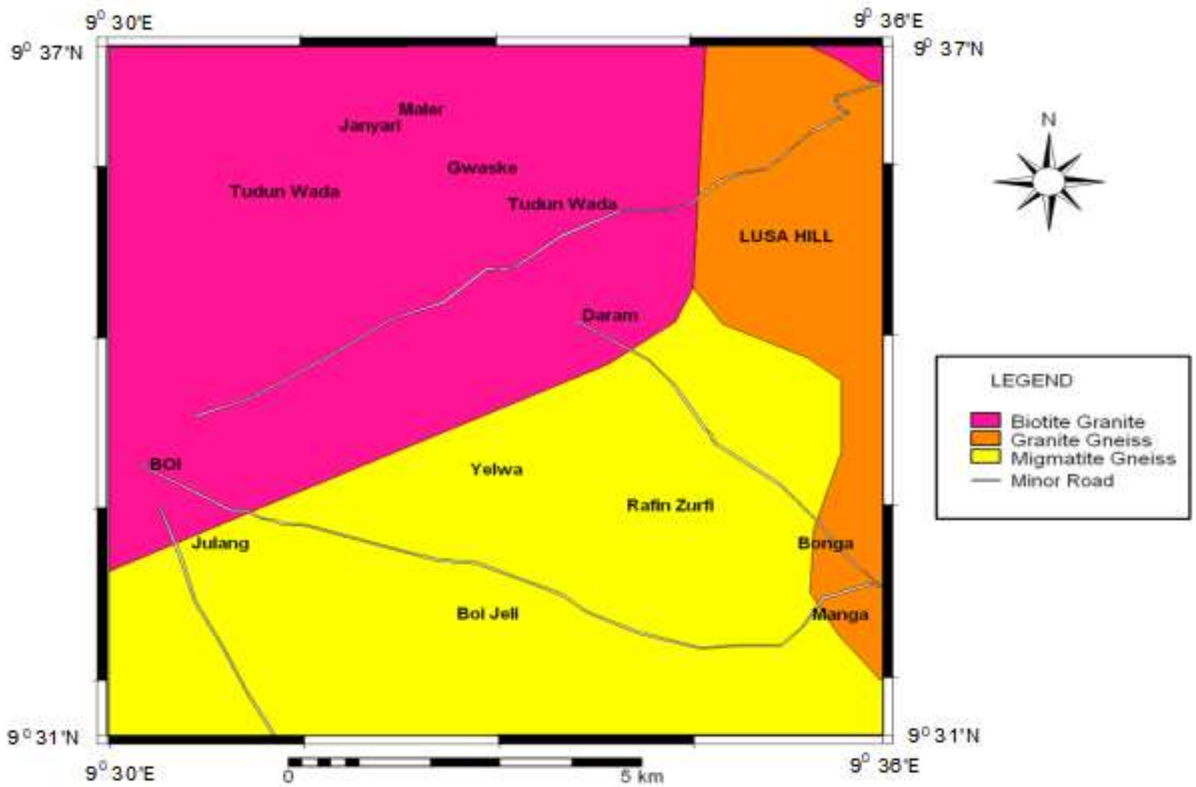

Figure 3**:** Geological map of Boi and Environs (After Geological Survey Agency 2014)

Plate I: Showing Migmatite, Gneiss exposure at Jolong

MATERIALS AND METHOD

Good representative water samples were collected randomly from selected boreholes, streams, and hand-dug wells, twice. Ten first sets of samples were collected in August corresponding to the rainy season and ten sets in March corresponding to the dry season. A total of about twenty (20) water samples were collected for this particular study. About eight (8) samples were obtained from hand-dug wells, eight (8) from boreholes, and four (4) from surface water bodies as shown in Fig.1. The entire samples were obtained in pre-washed (detergent, diluted trinitrate (v) acid ($HN0_3$), and doubly de-ionized distilled water, respectively) polyethylene bottles. Before the sample collection, the containers were rinsed three times in the field using the representative groundwater samples according to the Rajkumar *et al.,* (2010) method. The physical parameters were measured at the point of measurement on the field where total dissolved solids (TDS), electrical conductivity(EC), temperature(T^0), and $_P$H were measured in the field using the TDS/Conductivity meter (Milwaukee meter). Analytical water test tablets (photometer grade) reagents for the specific test were used for the preparation of all solutions. Water samples were analyzed using a plaintext photometer 5000 following the procedures set out in the instruction booked (Palintest, 1980). Each sample was analyzed for Fluoride (F^-), Chloride ($C1^-$), Iron (Fe^{2+}), Phosphate ($P0_4^{3-}$), Hardness ($CaCo^{3-}$), Sulphate (SO_4^{2-}), Manganese (Mn^{2+}), Copper (Cu^{2+}), Magnesium (mg^{2+}) Calcium (Ca^{2+}), Potassium(K^+), total alkalinity and total salinity. The concentrations of elements present were compared with the World Health Organization (WHO, 2011) and the European Union (EU, 2011) standard guidelines value to evaluate the portability of the water for human consumption. The mean Value test was used in carrying out the comparison. The Mean Value test is based on the estimation of the 95% upper confidence limits of the mean concentration of a contaminant (95% UCL, also referred to as US_{95}) and its use as the appropriate value to be compared with the relevant guideline value or site-specific assessment criterion. This 95% UCL is meant to provide a reasonably conservative estimate of whether the measured concentration is acceptable, considering the uncertainty and variables associated with site investigations.

The necessary calculation involves five steps (Dean, 2007) as follows:

(i) Calculate the arithmetic sample mean x

(ii) Calculate the unbiased sample standard deviations

(iii) Select an appropriate t value e.g. 95th percentile confidence limit, t the tabulated "t value" can be obtained from our figure mathematic table.

(iv) Calculate the upper 95th percentile bound of sample as $US_{95} = x + (ts\sqrt{n})$

(v) Compare the upper bound value (US_{95}) with the guideline value G.

RESULTS AND DISCUSSION

The results of the water analysis for samples collected in the rainy and dry seasons are presented in tables a and b – the concentration of each parameter varies from one sample point to the other. Then compared to WHO and EU permissible values to determine and compare the suitability and effect of continual consumption of such waters.

Water quality evaluation: Parameters within guideline levels

The results showed that all of the samples tested were within the permissible limits prescribed by WHO and EU both in the wet and dry seasons for electrical conductivity (EC), temperature, total dissolved solids (TDS), Turbidity, Fluoride, total hardness ($CaCo_3$), Sulphate ($S0_4^{2+}$), Copper (Cu), Magnesium (Mg^{2+}), Manganese(Mn^{2+}) and Calcium (Ca^{2+}) except iron, fluoride and turbidity. Conductivity ranged between 328-987l/cm, Temperature ranged between 30 - 350ºc. The total dissolved solids range is between 162-471ppm. Turbidity range from 1.03-7.41 NTU, Total hardness varied from 22-168mg\L. Sulfate varied between 18-30mg\L. Copper ranged between 0.02-0.06mg\L. Chloride concentration range from 1.33-2.69mg/l. Fluoride overall mean value of 0.52 mg/l and concentration range of 0.09 - 0.91 mg/l. Manganese (Mn^{2+}) has mean value of 0.11 mg/l and concentration range of 0.01 - 0.19mg/l. Bicarbonate concentration varies from 11.5-11.8 mg/l and has a mean value of 11.6 mg/l. Phosphate has concentration between 0.02-0.47mg/l. Sulfate has a concentration between 18-30mg/l. pH has a concentration between 5.08-6.74mg/l. Calcium(Ca^{2+}) has concentration of 2.3-14.01mg/l. Potassium(K^+) has concentration of 0.10-0.20mg/l. Manganese has a concentration of 0.01-0.19mg/l. Sodium(Na^+) has mean concentration of 42-69mg/l. At these levels, these parameters do not rose any health impact and are within the WHO and EU guideline values. As such it will be sufficient to conclude that these parameters are unlikely to be sources of water contamination in some parts of Bogoro local government of Bauchi state North-Eastern Nigeria. On the other hand, there were incidences in which Turbidity in some samples, were having values above the permissible limits. The concentration of turbidity is far above the permissible at Ndukum, Gyara, and Daram respectively. Iron in all the samples has a concentration above the permissible limit. The concentration of iron (Fe^{2+}) vary from 0.42 - 0.83mg/l, and has mean value of 0.69 mg/l. The concentration of iron in all the samples is above the permissible limit for drinking water by WHO and EU (2011). The concentration of Total hardness at Kubong is above the permissible limit during the rainy season.

Turbidity

In this study, eight out of the 20 samples had turbidity values outside the WHO and EU guideline value of 5NTU in the rainy season, turbidity value range between 1.03- 7.41NTU. The concentration was generally less in the dry season with all the samples having turbidity values below the WHO and EU guideline levels. The source of high turbidity in some samples is most likely due to those generated as water moves through the loose soils of the area into the groundwater supply. The average concentration of turbidity in the rainy season when there is a high likelihood of mud and silt being washed into the ground and surface water will suggest the need to constantly measure this parameter, especially in the rainy season.

Iron

Similar to turbidity, the concentration of iron was generally found to be outside the guideline value of 0.3 and 0.2mg/L in both rainy and dry seasons for all the samples. It has been suggested that high rainfall is essential in increasing iron concentration in boreholes, wells and streams (Abubakar and Adekola, 2012). Rainwater as it infiltrates the soil and underlying geologic formations dissolve iron, causing it to sink into aquifers that serve as sources of groundwater for boreholes, wells and streams. Therefore, it is not surprising that iron concentration is high in all seasons.

Fluoride

The concentration of fluoride at Boi has a concentration above the permissible limit during rainy and dry seasons. A high concentration of fluoride containment in groundwater tends to be found in association with crystalline rocks containing fluoride-rich minerals, especially granite and volcanic rocks, shallow aquifers in arid areas experiencing strong evaporation, sedimentary aquifers undergoing ion exchange, and inputs of geothermal water. Fluoride has long been found to have a beneficial effect on dental health as such it is an additive in toothpaste and food. However, when present in drinking water at concentrations much above the guideline value of 1.5mg/L, long-term use can result in the development of dental fluorosis or at its worse cripping skeletal fluorosis. It is important for water managers to constantly monitor this parameter.

Water Quality in Some Parts of Bogoro Local Government

All the samples in some parts of Bogoro local government area have at least one or more incidence of water contamination revealed by analysis conducted. This is by the fact that all the samples collected have values above the permissible limit both during rainy and dry seasons. Water quality improves in the dry season.

Comparison of Concentration of Elements in the Samples with WHO and EU Standards

The mean value test provides an overall assessment of water quality in the study area. The mean value test result presented in (the table 1a & 1b) shows that the concentration of Turbidity, Fluoride, and Iron are above either The World Health Organization (WHO) or European Union (EU) Standards.

Table 1a: Chemical and Physical characteristics of water samples from some part of Bogoro Local Government Area in the Dry Season

Sample Location	Sample Source	Coordinates		Physical Parameters					Chemical Parameters Cations (mg/l)								Chemical Parameters Anions (mg/l)				
		Latitude(N)	Longitude(E)	Temperature (T^0)	PH	TDS (mg/l)	EC (ms/cm)	TB (NTU)	TH (mg/l)	Ca^{2+} (mg/l)	Mg^{2+} (Mg/l)	Mn^2 (mg/l)	Fe^{2+} (mg/l)	Cu^{2+} (mg/l)	Na^+ (mg/l)	K^+ (mg/l)	$SO4^{2-}$ (mg/l)	$HC0_3^-$ (mg/l)	$Po4^{2-}$ (mg/l)	F− (mg/l)	Cl− (mg/l)
Ndukum	B1	9.52325,	9.53046	35	6.74	371	545	6.78	57	6.70	0.11	0.05	**0.63**	0.01	48.9	0.17	18	11.5	0.01	0.81	1.98
Boi	B2	9.56126	9.50209	32	6.30	445	980	2.61	74	13.10	0.13	0.11	**0.72**	0.01	50.2	0.19	23	11.7	0.01	**1.55**	2.05
Kubong	S1	9.5707	9.51737	30	6.70	220	441	2.06	168	14.01	0.01	0.07	**0.73**	0.01	50.8	0.16	6	11.5	0.01	0.44	2.03
Gyara	W1	9.59085	9.51380	31	6.92	338	670	3.78	67	8.50	0.13	0.01	**0.83**	0.03	23	0.10	2	11.5	0.00	0.64	1.88
Gwaska	B3	9.60283	9.57356	30	5.83	471	987	2.71	70	12.01	0.17	0.17	**0.42**	0.01	50.8	0.14	14	11.8	0.02	0.91	1.96
Daram	W2	9.58362	9.55280	35	5.08	325	645	**7.41**	69	7.30	0.09	0.19	**0.58**	0.01	38	0.20	11	11.6	0.27	0.73	1.69
Lusa	B4	9.60998	9.59769	32	6.55	210	413	1.59	60	6.01	0.14	0.09	**0.82**	0.01	50.7	0.19	8	11.6	0.02	0.05	2.69
Lusa	W3	9.59444	9.59919	30	6.74	162	328	1.03	46	4.10	0.11	0.13	**0.81**	0.01	50.8	0.10	9	11.7	0.13	0.41	2.41
Kol	S2	9.55055	9.55000	31	6.60	233	466	1.33	27	3.93	0.06	0.11	**0.65**	0.001	55.4	0.17	20	11.6	0.01	0.90	1.33
Bonga	W4	9.55694	9.58002	32	6.45	354	707	1.08	22	2.30	0.04	0.18	**0.67**	0.001	49.2	0.18	12	11.5	0.04	0.09	2.38
Mean				31.80	6.39	312.5	618.2	3.05	57.2	7.80	0.10	0.11	**0.69**	0.015	46.78	0.16	12.3	11.6	0.06	0.52	2.04
Range				30-35	5.08-6.74	162-471	328-987	1.03-7.41	22-168	2.3-14.01	0.01-0.13	0.01-0.19	0.42-0.83	0.01-0.03	23-50.8	0.10-0.20	2-23	11.5-11.8	0.01-0.27	0.09-1.25	1.33-2.69
WHO(2011) Permissible Value (mg/l)				23-40	6.5-8.5	1000	2500	5	500	150	100	0.4	0.3	2	200	12	250	250	0.5	1.5	5
EU(2011) Permissible Value(mg/l)				23-40	6.5-8.5	1000	2500	3	150	150	100	0.2	0.2	2	200	12	250	250	0.5	1.5	5

Table 1b: Chemical and Physical characteristics of water samples from some part of Bogoro Local Government Area in the Rainy Season

Sample Location	Sample Source	Coordinates		Physical Parameters					Chemical Parameters Cations (mg/l)								Chemical Parameters Anions (mg/l)				
		Latitude(N)	Longitude(E)	Temperature (T^0)	PH	TDS (mg/l)	EC (ms/cm)	TB (NTU)	TH (mg/l)	Ca^{2+} (mg/l)	Mg^{2+} (Mg/l)	Mn^+ (mg/l)	Fe^{2+} (mg/l)	Cu^{2+} (mg/l)	Na^+ (mg/l)	K^+ (mg/l)	$SO4^{2-}$ (mg/l)	$HC0_3^-$ (mg/l)	$Po4^{2-}$ (mg/l)	F− (mg/l)	Cl− (mg/l)
Ndukum	B1	9.52325	9.53046	28.0	6.84	381	565	**8.78**	124	6.80	0.14	0.06	0.73	0.02	60.90	0.28	30	14.5	0.02	0.82	1.28
Boi	B2	9.56126	9.50209	28.2	6.50	455	1000	6.61	158	13.20	0.15	0.12	**0.82**	0.04	66.20	0.40	25	14.7	0.03	**1.60**	2.25
Kubong	D1	9.5707	9.51737	28.6	6.90	230	461	6.06	**170**	14.21	0.04	0.08	**0.83**	0.04	58.80	0.28	20	14.5	0.03	0.64	2.23
Gyara	W1	9.59085	9.51380	27.0	6.92	348	690	**8.78**	144	8.60	0.14	0.02	**0.93**	0.06	43.00	0.26	10	14.5	0.04	0.84	2.88
Gwaska	B3	9.60283	9.57356	28.2	5.93	491	1007	6.71	150	12.21	0.18	0.18	**0.52**	0.04	56.80	0.28	20	14.8	0.04	0.96	2.96
Daram	W2	9.58362	9.55280	27.8	5.18	335	665	**12.41**	148	7.40	0.19	0.20	**0.68**	0.05	42.00	0.41	20	14.6	0.47	0.93	2.69
Lusa	B4	9.60998	9.59769	28.7	6.65	220	423	4.59	130	6.31	0.16	0.09	**0.92**	0.04	62.70	0.40	18	14.6	0.04	0.06	4.69
Lusa	W3	9.59444	9.59919	27.4	6.94	172	348	4.03	102	4.20	0.17	0.14	**0.91**	0.04	62.80	0.26	20	14.7	0.23	0.61	4.41
Kol	S1	9.55055	9.55000	27.4	6.90	243	486	4.33	64	3.95	0.09	0.13	**0.75**	0.06	66.40	0.40	28	14.6	0.02	0.92	2.33
Bonga	W4	9.55694	9.58002	29.0	6.65	364	727	4.08	74	2.40	0.05	0.19	**0.77**	0.06	69.22	0.29	18	14.5	0.06	0.16	3.38
Mean				28.03	6.69	322.5	638.2	**7.55**	124.4	7.90	0.11	0.12	**0.89**	0.06	68.79	0.27	20.3	14.6	0.08	0.72	3.04
Range				27-29	5.18-6.90	172-455	328-1007	4.03-12.41	44-160	2.3-14.21	0.01-0.18	0.01-0.20	0.52-0.93	0.02-0.06	42-69.22	0.27-0.40	18-30	14.50-14.80	0.02-0.47	0.09-1.40	1.28-4.69
WHO(2011) Permissible Value (mg/l)				23-40	6.5-8.5	1000	2500	5	500	150	100	0.4	0.3	2	200	12	500	500	5	1.5	5
EU(2011) Permissible Value(mg/l)				23-40	6.5-8.5	1000	2500	3	150	150	100	0.2	0.2	2	200	12	250	250	0.5	1.5	5

The health Implication of a high concentration of this element is varied ranging from the provision of nuclei for attachment and growth of pathogenic microorganisms (as a result of high turbidity), to debilitating skeletal and dental fluorosis (as a result of high Fluoride Concentration).

DISCUSSION

The geochemical results of groundwater quality in some parts of Bogoro and its environs, revealed that the order of cation concentration are: $Na^+ > Ca^{2+} > Fe^{2+} > K^+ > Mn^{2+} > Mg^{2+} > Cu^{2+}$ while the anions are in the order of $SO_4^{2-} > HCO_3^- > Cl^- > F^- > PO_4^{2-}$ and the physical parameters measured were EC > TDS > TH > T^0 > pH > TB respectively. The cations, anions, and physical parameters present in the study area where values are above the permissible limits include iron, turbidity, total hardness in some samples, and fluoride at Boi. Though iron is an essential element in human nutrition and its deficiency may result in unpaired mental development in children, reduced work performance in adults, and in severe cases anemia or unpaired oxygen delivery. A high concentration of iron could be attributed to the weathering of acidic rocks, acidic mines, water drainage, landfills leachates (Sawyer and McCarthy, 1967). A high concentration of fluoride could be due to leaching from rocks rich in fluoride. Though fluoride occurs in many common rocks forming minerals such as fluorites (CaF_2) which occurs in both igneous rocks, apatite ($Ca_5[PO_4]_3$ (Cl, F, OH), topaz ($Al_2F_2[SiO_4]$), muscovite [$KAl_2(OH, F_2)(AlSiO_3O_{10})$] and range of amphibole and mica minerals (Sawyer and McCarthy, 1967).Felsic igneous rocks which have a high concentration of SiO_2, tend to have a higher concentration of fluoride than mafic rocks. The average Fluoride content in rocks is 1000 kg^{-1} in alkali rocks, 400 kg^{-1} in intermediate rocks dropping to 100 kg^{-1}, in ultramafic rocks. When such rocks are weathered can cause a high concentration of fluoride in groundwater and these rocks types are bedrocks found in the study area. Fluorine is released as fluoride during weathering. Fluoride is an essential micro-nutrients for mammals serving to strengthen the apatite matrix of skeletal tissue and teeth. A high concentration of fluoride in water above the permissible limit may induce skeletal and dental disorder, and cause harm to kidneys, nerves, and muscles and a low concentration of fluoride in plants can cause damage in leaves and growth retardation in plants (Sawyer and McCarthy, 1967). Turbidity is the measure of relative clarity or cloudiness of water. High concentration in the study area could be caused by suspended and colloidal matter, such as clay silt, finely divided organic and inorganic matter, and other microscopic organisms (Sawyer and McCarthy, 1967). The total dissolved solids test measures the total amount of dissolved minerals in the water. The solids are iron, chlorides, sulfates, calcium, or other minerals found on the earth's surface. The dissolved minerals can produce an unpleasant taste or appearance and can contribute to scale deposits on pipe walls. Primary sources for TDS in receiving water in the study area are agricultural and residential run-off, leaching of soil, contaminations, and point source water pollution.

Table 2: Mean value test of water samples

Parameters		Rainy season	Dry season	Average	EU	WHO
Turbidity (NTU)		**7.55**	2.74	**5.15**	3	5
Conductivity (*Ω*/cm)		638.2	618.2	628.2	2500	2500
Temperature (°C)		28.03	31.80	29.92	23 - 40	23 - 40
pH		6.69	6.39	6.54	6.5 - 8.5	6.5 - 8.5
TDS (PPM)		322.50	312.5	317.50	1000	1000
Sodium (Na^+)(mg/L)		68.79	46.78	57.78	200	200
Fluoride (F^-) (mg/L)		**0.72**	**0.52**	**0.62**	1.5	1.5
Chloride (Cl^-) (mg/L)		3.04	2.04	2.54	5	5
Iron (Fe^{2+}) (mg/L)		**0.89**	**0.69**	**0.79**	0.2	0.3
Phosphate(mg/L)	($PO4^{3-}$)	0.08	0.06	0.07	0.5	1.5
Hardness (mg/L)	($CaC0_3$)	124.40	57.20	90.8	150	500
Sulphate (mg/L)	($SO4^{2-}$)	20.30	12.3	16.30	100	250
Manganese (mg/L)	($Mn^{2+)}$	0.12	0.11	0.15	0.2	0.4
Copper (Cu) (mg/L)		0.06	0.15	0.11	2	2
Magnesium (mg^{2+}) (mg/L)		0.11	0.10	0.11	100	150
Calcium (Ca^{2+}) (mg/L)		7.90	7.80	7.81	150	150
Bicarbonate($HC0_3$-) (mg/L)		14.6	11.6	13.10	250	500
Potassium(K^+) (mg/L)		0.27	0.16	0.22	12	12

Bold values indicate incidences where parameters are outside guideline value

Total hardness has a mean concentration value of 57.20mg/l and is within the permissible limit by WHO and EU (2011) and has a range concentration value of 20mg/l to 80mg/l, except for the sample at Kubong which is above the permissible limit, and may be caused by dissolved polyvalent metallic ions. And also may be caused by an abundance of calcium and magnesium dissolved in water. High total hardness is found in groundwater that has come in contact with certain rocks especially the alkali feldspars which can release calcium and magnesium. The values of the total hardness indicate that the water in the area is soft water except for the sample at Kubong based on Sawyer and McCarthy's (1967) values. According to Sawyer and McCarthy (1967) hardness value of 0 - 75 mg/l is classified as soft, 75 - 150 mg/l as moderately hard, 150 - 300 mg/l as hard, and > 300 mg/l as very hard. According to Okafor (1994), water used in boilers should be soft and noncorrosive, while laundry water should be colorless and soft. Water for industrial activities should be odorless, colorless, free from suspended matter and microorganisms, and of low iron and manganese content. According to Todd (1980) water containing more than 0.2 mg/l of iron and manganese is objectionable for most industries. Salinity hazards expressed as electrical conductivity (Ec) and total dissolved solids (TDS) are also considered in the evaluation of water quality for irrigational practices (Ishaku and Matazu, 2001). The total hardness of water limits its use for domestic, industrial, and agricultural activities, Water hardness can cause scaling of pots, boilers, and irrigation pipes, it may also cause health problems to humans such as kidney failure (Ishaku *et al.*,2012). Electrical conductivity (EC) is a good measure of salinity hazard to crops. Excess salinity reduces the osmatic activity of plants and thus interferes with the absorption of water and nutrient from soil (Ishaku *et al.*, 2012).

Water quality assessment is one of the key aspects of water resources management. The result of this study, suggests that the samples from some parts of the Bogoro Local Government area are above the permissible limit by WHO and EU standards. The concentration of Fluoride, Iron, and Turbidity has an upper bound value (US_{95}) above the permissible limit as such, this calls for serious health concerns. The presence of these contaminants in boreholes, wells, and stream waters at levels exceeding guideline values has major health implications for the general public. This emphasizes the need of water managers promoting water treatment and management practices that are efficient. The use of natural supplements such as Moringa oleifera seeds as natural absorbents and antibacterial agents for purification of ground water for drinking purposes is one technique that might be useful and prove to be easily accessible, low cost, and environmentally acceptable. Moringa oleifera seed powder has the potential to be utilized as a therapy for turbidity, TDS, hardness, chlorides, alkalinity, and acidity, according to a recent study (Mangale *et al.*, 2012). Where rural and semi-urban populations living in extreme poverty are currently drinking excessively turbid and microbiologically contaminated water, this is advised for eco-friendly, nontoxic, simpler water treatment. As a result, we propose for water agencies to collaborate with local people and researchers to ensure the method's long-term viability.

CONCLUSION AND RECOMMENDATIONS

The rapid increase in population and the climatic stress responsible for intermittent rainfall have combined to limit the availability of potable water within Bogoro and environs. Acute water scarcity within the study area especially in the dry season has forced the majority of the population to rely on groundwater supplies, hence the presence of these contaminants in high concentrations in boreholes, wells, and surface water bodies from the study area is a source of serious health concern to the inhabitants of the area.

Based on the geochemical results, the following recommendations were made:

(i) Rapid promotion of efficient water treatment techniques such as the use of Moringa Oleifera seed as a natural absorbent and antimicrobial agent of purification of groundwater for drinking purposes.

(ii) Routine water quality analysis by some agencies has provided baseline information on water quality which will aid sustainable water resource management at the community base level and will develop the capacity of local health agencies to map the incidences and occurrence of water-borne diseases in the study area.

(iii) Awareness campaign creation and Integration of water quality analysis into the Primary Health Care (PHC) framework.

CONFLICT OF INTEREST

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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