

# Physicochemical Analysis of Ground Water of Selected Areas of Dass and Ganjuwa Local Government Areas, Bauchi State, Nigeria

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**Abstract** Ground water samples were collected from different locations within a radius of 25 km of Dass and Ganjuwa Local Government Areas (**DG-LGAs** here after referred to respectively), Bauchi State, Nigeria. These water samples from 10 sampling points of Bauchi were analyzed for their physicochemical characteristics. Laboratory analyses on samples were performed for pH, Colour, Odour, Hardness, Chloride, Alkalinity, Total Dissolved Solids (**TDS**) and others. On comparing the results against drinking water quality standards laid by Nigerian Standard for Drinking Water Quality Maximum permissible level (**NSDWQ**) and World Health Organization (**WHO**), it was found that some of the samples were non-potable for human consumption due to high concentrations of some of the parameters determined. An attempt was made to find whether or not the quality of ground water in the areas of study suitable for human consumption.

**Keywords:** hand-dug well, borehole, physicochemical study, pollution study, drinking water

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## 1. Introduction

The quality of ground water depends on various chemical constituents and their concentration, which are mostly derived from the geological data of the particular region. Ground water occurs in weathered portion, along the joints and fractures of the rocks. In fact, industrial waste and the municipal solid waste have emerged as one of the leading causes of pollution of surface and ground water. In many parts of Nigeria, available water is rendered non-potable because of the presence of excess heavy metals. It is now universally acknowledged by water and medical experts that the greatest risk associated with the ingestion of water is the microbial risk due to water contamination by human and/or animal feces [1]. In 2000, lack of access to safe water remained a problem for over a billion people worldwide, and inadequate sanitation services affected at least 2.4 billion people [2,3]. Poor water quality, sanitation and hygiene account for some 1.7 million deaths a year worldwide, mainly through infectious diarrhea [4]. Diarrheal diseases, which are frequently transmitted by contaminated water is a leading cause of morbidity and mortality among children under 5 years of age in developing countries. Estimates of annual total mortality from diarrheal disease range from 2.5 to 3.5 million and more than 80% are among children under 5 years of age [5]. Global morbidity is estimated at 4 billion

episodes per year, of which 30 % (1.2 billion episodes/year) are related to contaminated water [6].

Lack of access to safe water is strongly correlated with poverty, and the provision of safe drinking water is considered to be a fundamental step in a community's transition out of poverty [7]. Villages in Dass and Ganjuwa LGAs are characterized by different types of basement complex formations. At present there is no major industry in and around the study area, yet household waste water and garbage (municipal sewage) are directly discharged into the area. The water supply for human consumption is often directly sourced from ground water without biochemical treatment and the level of pollution has become a cause for major concern. The water used for drinking purposes should be free from toxic elements, living and non-living organisms and excessive amount of minerals that may be harmful to health. Keeping this in focus, the quality aspects of ground water in villages around Dass and Ganjuwa LGAs were analyzed for general water quality.

## 2. Materials and Methods

### 2.1. Sampling Sites

The water sample sites were selected from important water sources for domestic and livestock uses. These

include 2 hand dug wells (W1 & W2) and 3 boreholes (BH1-3) water samples from villages in Dass Local Government Area (DLGA) and 5 boreholes (BH4-8) water samples from villages in Ganjuwa Local Government Area (GLGA), Bauchi State, Nigeria. Samples were collected for quality monitoring and assessment. At each sample site, latitude, longitude and altitude were determined with a 12 channel Etrex GPS.

## 2.2. Sample Collection

Water samples from the selected sites were collected in March 2012 in 0.75 dm<sup>3</sup> pre-cleaned and capped polyethylene bottles. The samples after collection were immediately placed in dark boxes and processed within 6 hrs of collection to minimize photochemical effects.

## 2.3. Physico-chemical Analysis

The samples were analyzed for major physical and chemical water quality parameters like temperature, pH, Electrical conductivity (EC), Total Dissolved solids (TDS), total hardness (TH), Ca<sup>2+</sup>, Mg<sup>2+</sup>, as per the Assessment of Ground Water Quality method described in "Standard methods for the examination of water and wastewater of American Public Health Association [8]. The parameters present in the water sample calculated by using various methods [9,10]. The water samples temperatures, pH, electrical conductivity and TDS were determined at the point of sampling using a portable hand-held DC-powered Hanna HI 88129 digital thermometer with a glass sensor. The total hardness, total alkalinity, the concentrations of the chloride, nitrite, nitrate, sulphate, phosphate and other chemical parameters were estimated by the standard methods of water and waste water [11,12] using the Hach DR 2000 direct reading spectrophotometer.

## 2.4. Microbiological Analysis

All the samples for microbiological analysis were collected separately in sterile containers from the selected sites. The standard collection procedure of Cruickshank (1965) was adopted [13].

Membrane filter technique method was employed for all microbiological analysis. A 100 ml volume of the water sample was filtered through a membrane with pore size (0.45 mm) small enough to retain the indicator bacteria to be counted. The membrane was incubated on the selective differential to allow the bacteria to grow. Colonies were recognized by their colour, morphology and number.

### 2.4.1. Test for *Clostridium Perfringens* (Differential Reinforced Clostridial Media)

For *Clostridium* test, all vegetative cells were killed by heating respectively the water samples at 75°C for 10 min and then subjected to anaerobic incubation using anaerobic jar.

The *Clostridium perfringens* differential reinforced Clostridium media (DRCM) contains cystine which permits the growth of anaerobic Clostridia and a combination of sodium thiosulphate and ferric citrate to reveal only growth of sulphite reducing bacteria by the production of black precipitate of ferrous sulphite.

### 2.4.2. Biochemical Test

Gram positive, pleomorphic rods about 3-8 x 0.10 µm with rods.

### 2.4.3. Test for Thermotolerant *E. Coli* on Mac Conkey Agar (MCA)

The water samples were subjected to anaerobic incubation using an anaerobic jar.

MCA media were used which contains lactose and bile salt. Thermotolerant *E. coli* ferments lactose and hence changes the colour of the colonies to reddish-pink colouration due to neutral red indicator producing acid and gas.

### 2.4.4. Biochemical Tests

*E.coli* was confirmed using the IMVIC test. *E. coli* is indole and methyl red positive but Voges Prausker and citrate negative.

## 3. Results and Discussion

The locations of the 10 ground water sampling sites are presented under Table 1.

Table 1. Location and altitude of water sampling sites

S/N	SAMPLE SITE	LOCATION	ALTITUDE (m)
1	Unguwan Danlawal 4004	09°99822' N 09°51665' E	606
2	Unguwan Barde 906	09°9973' N 09°51821' E	595
3	Unguwan Galadima	09°97204' N 09°40872' E	652
4	Yelwan Durr	09°97952' N 09°40912' E	642
5	Darussalam	10°03810' N 09°57319' E	604
6	Kunki	10°54271' N 09°84890' E	610
7	Yali	10°53147' N 09°85162' E	505
8	Barkayan Fulani	10°51739' N 09°88616' E	600
9	Kampanin Garkuwa	10°50447' N 09°90240' E	607
10	Rudu Yausa	10°46143' N 09°84440' E	575

A total of 10 ground water samples from 2 hand-dug wells and boreholes, used by the inhabitants of Dass and Ganjuwa villages as well as their animals were collected for water quality monitoring and assessment in March, 2012. The data revealed that there were considerable variations in the examined samples from different sources with respect to their chemical characteristics. The results indicated that the quality of water considerably varies from location to location.

The water sampling sites, locations and altitudes are shown in Table 1.

Anguwan Galadima water point (C) was observed to be at the highest elevation, 652 m above sea level, followed by Yelwan Durr water point (D, 642 m) all located in Dass LGA, while Yali water point (G) located in Ganjuwa LGA is at the lowest elevation, 505 m above sea level.

The physicochemical parameters examined for each of the water points are presented under Table 2 and Table 3. These parameters are discussed below.

Table 2. Well Water Quality Analysis

S/N	PARAMETERS	W1	W2	NSDWQ* MPL
1	Temperature (°C)	26.7±0.3	28.6±0.3	-
2	pH	7.0±0.01	7.26±0.02	6.5- 8.5
3	Appearance	Unobj	Unobj	Unobj
4	Taste	Unobj	Obj	Unobj
5	Odour	Unobj	Unobj	Unobj
6	Turbidity(NTU)	2.0±0.0	2.0±0.0	5
7	Electrical Conductivity (µS/cm)	720.7±8.5	728±3.0	1000
8	TDS(mg/L)	361.7±2.5	364.7±1.5	500
9	Total Hardness ( as CaCo <sub>3</sub> ) mg/dm <sup>3</sup>	710.0±0.0	675.7±0.58	150
10	Total Alkalinity(as CaCo <sub>3</sub> ) mg/dm <sup>3</sup>	127.7±0.58	153.7±0.58	100
11	Chloride, Cl <sup>-</sup> ( mg/dm <sup>3</sup> )	224.±0.0	272.0±0.0	250
12	Nitrite, No <sub>2</sub> <sup>-</sup> ( mg/dm <sup>3</sup> )	0.01±0.01	0.3±0.0	0.2
13	Nitrate, No <sub>3</sub> <sup>-</sup> ( mg/dm <sup>3</sup> )	44.6±0.55	40.7±0.0	50
14	Sulphate, So <sub>4</sub> <sup>-</sup> ( mg/dm <sup>3</sup> )	0.0	150.0±0.0	200
15	Fluoride, F <sup>-</sup> ( mg/dm <sup>3</sup> )	0.7±0.01	0.7±1.36	1.5
16	Cyanide, CN <sup>-</sup> ( mg/dm <sup>3</sup> )	0.0	0.0	0.001
17	Phosphate, PO <sub>4</sub> <sup>3-</sup> (mg/dm <sup>3</sup> )	0.7±0.0	0.3±0.0	-
18	Calcium, Ca <sup>2+</sup> (mg/dm <sup>3</sup> )	176.0±0.0	279.0±0.0	75
19	Magnesium, Mg <sup>2+</sup> (mg/dm <sup>3</sup> )	15.7±0.0	18.3±0.0	0.2
20	Total Iron, Fe <sup>2+</sup> ( mg/dm <sup>3</sup> )	5.6±0.01	0.0	0.3
21	Copper, Cu <sup>2+</sup> ( mg/dm <sup>3</sup> )	4.2±0.01	5.3±0.0	1
22	Zinc, Zn <sup>2+</sup> ( mg/dm <sup>3</sup> )	0.3±0.01	0.5±0.01	5
23	Manganese, Mn <sup>2+</sup> ( mg/dm <sup>3</sup> )	0.0	0.0	0.05
24	Lead, Pb <sup>2+</sup> ( mg/dm <sup>3</sup> )	0.0	0.0	0.001
25	Arsenic, As (mg/dm <sup>3</sup> )	0.0	0.0	0.001
26	Barium, Ba <sup>2+</sup> ( mg/dm <sup>3</sup> )	0.0	0.02±0.01	0.05
27	Total Coli form (cfu/100ml)	233.0±20.0	586.7±63.5	0
28	Faecal Coli form (cfu/100ml)	88.7±9.5	200.0±3.0	0

NSDWQ\*MPL: Nigerian Standard for Drinking Water Quality Maximum permissible level

Table 3. Borehole Water Quality Analysis

S/N	PARAMETERS	BH1	BH2	BH3	BH4	BH5	BH6	BH7	BH8	NSDWQ* MPL
1	Temperature(0c)	29.8±0.1	28.6±0.2	29.8±0.1	29.3±0.2	29.4±0.1	29.0±0.2	28.7±0.1	27.7±0.2	-
2	pH	6.8±0.01	7.3±0.03	6.5±0.02	7.3±0.01	7.0±0.01	7.3±0.11	7.0±0.01	7.2±0.02	6.5- 8.5
3	Appearance	Unobj	Unobj	Unobj	Unobj	Unobj	Unobj	Unobj	Unobj	Unobj
4	Taste	Unobj	Unobj	Obj	Unobj	Obj	Obj	Obj	Unobj	Unobj
5	Odour	Unobj	Unobj	Unobj	Unobj	Unobj	Unobj	Unobj	Unobj	Unobj
6	Turbidity (NTU)	1.0±0.0	1.0±0.0	1.0±0.0	1.0±0.0	1.0±0.0	1.0±0.0	2.0±0.0	2.0±0.0	5
7	Electrical Conductivity (µS/cm)	227±1.0	352±0.0	139±1.0	285±1.0	409.7±2.5	397.±0.57	433±1.0	241±1.0	1000
8	TDS(mg/L)	113.7±0.58	176.0±0.0	69.7±0.58	142.7±0.58	204.7±1.5	198.7±0.58	216.7±0.58	120.7±0.58	500
9	Total Hardness ( as CaCo <sub>3</sub> ) mg/dm <sup>3</sup>	126.0±0.0	211±1.0	80.7±0.58	190.0±0.0	296.0±0.0	264.7±0.58	315.0±0.0	127.7±2.5	150
10	Total Alkalinity(as CaCo <sub>3</sub> ) mg/dm <sup>3</sup>	87.7±0.45	197.7±0.58	80.7±0.58	144.0±0.0	205.0±1.0	225.7±0.58	103.7±0.58	84.0±0.0	100
11	Chloride, Cl <sup>-</sup> ( mg/dm <sup>3</sup> )	29.0±0.0	31.3±0.30	21.0±0.0	26.0±0.0	48.9±0.0	31.1±0.10	60.0±0.06	35.0±0.0	250
12	Nitrite, No <sub>2</sub> <sup>-</sup> ( mg/dm <sup>3</sup> )	0.07±0.0	0.04±0.0	0.02±0.0	0.2±0.01	0.02±0.0	0.05±0.01	0.07±0.0	0.02±0.0	0.2
13	Nitrate, No <sub>3</sub> <sup>-</sup> ( mg/dm <sup>3</sup> )	19.8±0.0	38.5±0.0	6.6±0.02	34.2±0.06	4.4±0.01	12.1±0.06	49.8±0.25	7.7±0.0	50
14	Sulphate, So <sub>4</sub> <sup>-</sup> ( mg/dm <sup>3</sup> )	22.5±0.0	22.4±0.06	5.0±0.01	25.5±0.05	65.0.0±0.0	60.3±10.11	88.3±0.75	23.0±0.5	200
15	Fluoride, F <sup>-</sup> ( mg/dm <sup>3</sup> )	0.4±0.0	0.54±0.0	0.2±0.0	0.5±0.01	0.4±6.80	0.4±0.0	0.7±0.0	0.3±0.0	1.5
16	Cyanide, CN <sup>-</sup> ( mg/dm <sup>3</sup> )	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.001
17	Phosphate, PO <sub>4</sub> <sup>3-</sup> (mg/dm <sup>3</sup> )	0.2±0.01	0.3±0.01	0.1±0.01	1.9±0.01	1.8±0.0	1.5±0.05	1.7±0.03	1.2±0.01	-
18	Calcium, Ca <sup>2+</sup> (mg/dm <sup>3</sup> )	48.4±0.06	83.6±0.06	30.2±0.06	77.5±0.5	132.0±0.0	103.7±0.6	126.0±0.0	84.5±0.3	75
19	Magnesium, Mg <sup>2+</sup> (mg/dm <sup>3</sup> )	3.67±0.0	2.9±0.01	4.88±0.0	3.66±0.0	6.1±0.01	7.3±0.0	8.6±0.0	55.8±0.0	0.2
20	Total Iron, Fe <sup>2+</sup> ( mg/dm <sup>3</sup> )	0.0	0.4±0.01	2.5±0.0	0.4±0.01	0.1±0.01	0.1±0.0	0.3±0.0	1.2±0.06	0.3
21	Copper, Cu <sup>2+</sup> ( mg/dm <sup>3</sup> )	0.4±0.01	0.3±0.0	0.3±0.0	0.3±0.01	0.2±0.01	0.3±0.0	0.2±0.01	0.2±0.01	1
22	Zinc, Zn <sup>2+</sup> ( mg/dm <sup>3</sup> )	0.04±0.0	0.1±0.0	0.1±0.0	0.2±0.01	0.5±0.0	0.8±0.01	0.2±0.0	0.4±0.01	5
23	Manganese, Mn <sup>2+</sup> (mg/dm <sup>3</sup> )	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.05
24	Lead, Pb <sup>2+</sup> ( mg/dm <sup>3</sup> )	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.001
25	Arsenic, As (mg/dm <sup>3</sup> )	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.001
26	Barium, Ba <sup>2+</sup> ( mg/dm <sup>3</sup> )	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.05
27	Total Coli form (cfu/100ml)	6.0±0.0	144.0±12.0	0.0	151.7±13.5	184.0±8.0	121.7±0.60	10.0±0.0	4.0±0.0	0
28	Faecal Coli form (cfu/100ml)	0.0	0.0	0.0	0.0	20.7±2.52	6.7±2.31	0.0	0.0	0

NSDWQ\*MPL: Nigerian Standard for Drinking Water Quality Maximum permissible level

**Odour:** It is evident from the Tables that the water samples possess some perceived odour that was not quantified in this study. The occurrence of odour was probably associated with the presence of inorganic or organic contaminants in water. Related to taste, a strong odour from water for consumption will obviously cause revulsion or rejection on the part of the consumer. Its cause is normally dissolved volatile organic compounds small concentrations of which may have great organoleptic effects.

W2, BH3, 5, 6 & 7 water samples had objectionable taste. As with odour, taste is a parameter which can lead to severe consumer reaction which may necessitate the condemnation of water supply. While astringent tastes can be caused by the presence of excessive amounts of metals or dissolved salts, there are often other more serious problems which arise in such cases (e.g. physiological effects). Purely organoleptic taste problems arise most commonly from algae and from phenols after chlorination. Decaying algal masses can release to the water trace organic compounds (including phenolic types), which produce offensive tastes after chlorination treatment [14]. These water points have often been subjected to such treatments to mitigate any potential health hazards. In practice, in the great majority of cases, taste is assessed by an individual analyst and is described subjectively. Thus taste of water sample objectionable to one person may not be to another and vice versa [14].

**pH:** Three water supply points (W1, BH5, and BH7) are basically neutral with a pH of  $7.0 \pm 0.01$ ; four water points (W2, BH2, BH4, BH6 and BH8) are generally weakly alkaline; and the remaining two are weakly acidic. Comparing these with the NSDWQ standards, the pH levels of the water supply points investigated are within the permissible range of 6.5 – 8.5. All the underground water samples are characterized by either a weakly acidic or weakly basic pH and are within the maximum permissible pH level (6.5-8.5) of NSDWQ. The water supply point (BH3) with the lowest pH of 6.5 may be attributed to the discharge of acidic products into this source by the agricultural and domestic activities. This is supported by the fact that studies have shown that 98 % of all world ground water are dominated by calcium and bicarbonate ions due to lime stone weathering in the catchments and underground water beds [10]. Extreme pH values can affect the palatability of water. Most biochemical reactions are sensitive to variation of pH. For most of such reactions as well as for human beings, pH value 7.0 is considered as best and ideal. In the present study pH value of the water samples varied in a narrow range within the permissible limits in all sources. Hydrogen ion concentrations govern the behaviour of several other important parameters of water quality such as ammonia toxicity, chlorine disinfection efficiency and the solubility of metal ions that may be catalyzed by  $H^+$  ions.

**Electrical conductance (EC):** The mobility of ions in solution can be seen to be closely related with the total alkalinity. This is not surprising as the flow of water would be proportional to the concentration of the hydroxide ion (alkalinity) in the water. The EC values were found higher at two water supply points (W1 and W2) with values of 721 and 728  $\mu S/cm$  respectively. These water supply points are located within the densely

populated villages in Dass. Hence the relatively higher values may be associated to concentrated dissolved salts as a result of human activities. Very low electrical conductivity was found at all the other sampling points. In this study, the electrical conductance was generally lower than the MPL (1000  $\mu S/cm$ ) of NSDWQ in all the water samples. The conductance is related to the ionic content of the water sample which is in turn a function of the dissolved (ionisable) solids. This property is related to the hardness of water because the more dissolved ions (such as  $Ca^{2+}$ ,  $Mg^{2+}$ ,  $SO_4^{2-}$  etc) that are present in a water sample, the more would be its conductance and hence its hardness. Conductivity is an invaluable indicator of the range into which hardness and alkalinity values are likely to fall, and also of the order of the dissolved solid contents of the water. Total dissolved solids and conductivity can be used to delineate each other. Conductivity is proportional to the dissolved solids. Both showed analogous trend in all the sites [10].

**TDS:** The results of this analysis recorded TDS values below 500  $mg/dm^3$  for all water samples which are all below the NSDWQ, MPL of 1000  $mg/dm^3$ . The highest TDS values were observed for the W1 and W2, which are about 360  $mg/dm^3$  while the lowest value,  $69.7 \pm 0.58$   $mg/dm^3$  was recorded for BH3. No further studies were conducted to ascertain the variation of the values for the boreholes studied. However the relatively higher values for the wells may be related to their exposure to air and environmental pollutants. It is known that where TDS are high, the water may be "saline" and the applicable parameter is "Salinity" [14].

**Turbidity (NTU):** The origin of turbidity may be clay particles, sewage solids, silt and sand washings, organic and biological sludges or some other factors. Direct health effects depend on the precise composition of the turbidity-causing materials, but there may be other implications [14]. Turbidity in water arises from the presence of very finely divided solids which are not filterable by routine methods. The existence of turbidity in water will affect its acceptability to consumers. The particles forming the turbidity may also interfere with the water treatment techniques and in the case of the disinfection process the consequences could be grave. As turbidity can be caused by sewage matter in water there is a risk that pathogenic organisms could be shielded by the turbidity particles and hence escape the action of the disinfectant [14]. The NTU found were all below the 5 units. In fact they were generally either 1 or 2 units which mean the water supply from the boreholes and wells are acceptable as far as NTU are concerned.

**Chloride:** Chloride exists in all natural waters; the concentrations varying very widely and reaching a maximum in sea water (up to 35,000  $mg/dm^3$  Cl). In fresh waters, the sources include soil and rock formations, sea spray and waste discharges. Sewage contains large amounts of chloride, as do some industrial effluents. Chloride does not pose a health hazard to humans and the principal consideration is in relation to palatability. In Table 2 and Table 3, the concentrations of the chloride in all the water samples were below the NSDWQ\*MPL (250  $mg/dm^3$ ) except W2 ( $272.0 \pm 0.0$   $mg/dm^3$ ). At levels above 250  $mg/dm^3$  Cl; water will begin to taste salty and will become increasingly objectionable as the concentration rises further, hence the objectionable taste recorded. High

chloride levels may similarly render freshwater unsuitable for agricultural irrigation [14]. In this work underground water samples W1 and W2 (Table 2) showed high levels of chloride ions, 224 and  $272 \pm 0.0$  mg/dm<sup>3</sup> respectively. Only that of the latter well is above the 250 mg/dm<sup>3</sup> maximum permissible level of NSDWQ. The boreholes chloride contents range from 21-60 mg/dm<sup>3</sup> and are far below the maximum permissible level of NSDWQ. The presence of ions such as Cl<sup>-</sup>, K<sup>+</sup> etc in human fluids are required as electrolytes. So the low levels found in virtually all the water points studied means the chloride ions in the drinking water should be supplemented. The water sample points studied may be safe except the W1 and W2 because, it is a known fact that an increase of even 5 mg/dm<sup>3</sup> Cl<sup>-</sup> may give rise to suspicions of a sewage discharge [14]. This water point is located not more than 15 meters from sewages and perhaps latrine toilets.

**Nitrates:** Nitrates in soils may be from soluble nitrate compounds or from run-off from inorganic fertilizers that may leach into the wells [14]. Samples from boreholes BH1,3,5,6 & 8 showed low safe levels of nitrates when compared with the MPL of NSDWQ. Samples from wells W1 & 2 and boreholes samples BH 2,4 & 7 showed high levels of nitrates, which are however, not above the MPL of NSDWQ. This may suggest safe water for domestic and livestock use.

The levels of nitrate concentrations are of interest for various reasons. Most importantly, high nitrate levels in waters (above 11 mg/dm<sup>3</sup> N [50 mg/dm<sup>3</sup> NO<sub>3</sub><sup>-</sup>]) for drinking purposes will render them hazardous to infants as they induce the "blue baby" syndrome (methaemoglobinaemia). The nitrate itself is not a direct toxicant but is a health hazard because of its conversion to nitrite [14].

**Nitrite:** Nitrite exists normally in very low concentrations and even in waste treatment plant effluents levels are relatively low, principally because the nitrogen will tend to exist in the more reduced (ammonia) or more oxidised (nitrate) forms. Nitrite is an intermediate in the oxidation of ammonia to nitrate, such oxidation can proceed in soil, and because sewage is a rich source of ammonia, waters which show any appreciable amounts of nitrite are regarded as being of highly questionable quality. Levels in unpolluted waters are normally low, below 0.03 mg/dm<sup>3</sup> NO<sub>2</sub>. Values greater than this indicate sewage pollution [14]. The nitrite levels were generally low and below the 0.2 mg/dm<sup>3</sup> MPL of NSDWQ for water samples from W1 and BH1-8. It can be seen from Table 2 that only the water sample from well W2 that revealed a nitrite level of 0.34 mg/dm<sup>3</sup> above the MPL of NSDWQ. Thus the source may not be safe for domestic and livestock use.

**Cyanide and Fluoride:** Industrial effluents (principally electroplating) and electronic wastes are known to be the main sources of cyanide [14]. This human activity is absent in the villages surrounding these water points. Thus the low levels recorded. Cyanide is a reactive and highly toxic ion which in excessive amount will cause mortality rapidly to humans and to fish because it is strongly bonded to iron in the haemoglobin thus rendering oxygen transportation from cell to cell impossible [14]. The CN<sup>-</sup> and F<sup>-</sup> levels are observed to be below the 0.001 mg/dm<sup>3</sup> and 1.5 mg/dm<sup>3</sup> MPL respectively of NSDWQ.

Fluoride occurs naturally in quite rare instances; it arises almost exclusively from fluoridation of public water

supplies and from industrial discharges. Health studies have shown that the addition of fluoride to water supplies in levels above 0.6 mg/dm<sup>3</sup> F leads to a reduction in tooth decay in growing children and that the optimum beneficial effect occurs around 1.0 mg/dm<sup>3</sup>. At levels markedly over 1.5 mg/dm<sup>3</sup> an inverse effect occurs and mottling of teeth (or severe damage at gross levels) will arise [14]. For this reason there is a constraint on fluoride levels, the effects of which vary with temperature. The fluoride levels for the water samples under investigation are within safe limits.

**Sulphate:** The sources of sulphate in underground waters may be rocks, geological formation, and so on. Excess sulphate has a laxative effect, especially in combination with magnesium and/or sodium. Sulphates exist in nearly all natural waters, the concentrations varying according to the nature of the terrain through which they flow. They are often derived from the sulphides of heavy metals (iron, nickel, copper and lead). Iron sulphides are present in sedimentary rocks from which they can be oxidised to sulphate in humid climates; the latter may then leach into watercourses so that ground waters are often excessively high in sulphates [14]. As magnesium and sodium are present in many waters, their combination with sulphate will have an enhanced laxative effect of greater or lesser magnitude depending on concentration. The utility of water for domestic purposes will therefore be severely limited by high sulphate concentrations, hence the limit of 200 mg/dm<sup>3</sup> SO<sub>4</sub><sup>2-</sup> [14]. The sulphate contents (5.0-88.3 mg/dm<sup>3</sup>) of all the boreholes samples fall below the MPL (200 mg/dm<sup>3</sup>) of NSDWQ. Well sample, W1 showed a zero level of sulphate, while sample from W2 showed the highest level of 150 mg/dm<sup>3</sup>.

**Phosphate:** Phosphorus occurs widely in plants, micro-organisms, animal wastes and so on. PO<sub>4</sub><sup>3-</sup> particularly Ca<sub>3</sub>(PO<sub>4</sub>)<sub>2</sub> are important for strong bones and teeth [15].

The significance of phosphorus is principally in regard to the phenomenon of over-enrichment of lakes and, to a lesser extent, rivers. Phosphorus gaining access to underground water bodies is perhaps unlikely. The phosphate levels range between 0.15-1.93 mg/dm<sup>3</sup> with sample from BH3 being the least and BH4 the highest.

**Copper:** This element is present naturally with iron deposits but more often its presence in waters is due to attack on copper pipes. A copper level of 2 mg/litre in drinking-water will be protective of adverse effects of copper and provides an adequate margin of safety [16,17]. However, its stringent tastes in water can be caused by levels above 1 mg/l Cu [14]. Staining of laundry and sanitary ware occurs at copper concentrations above 1 mg/litre. At levels above 2.5 mg/litre, copper imparts an undesirable bitter taste to water; at higher levels, the colour of water is also impacted [1].

In this work, Cu<sup>2+</sup> levels for samples from wells W1&2 are highest containing 4.19 and 5.25 mg/dm<sup>3</sup> respectively and are above MPL (1.0 mg/dm<sup>3</sup>) of NSDWQ. Water drawn from these wells may not be safe for domestic consumption. All the borehole water samples however, are within safe permissible limits.

The relatively high level of this metal in the well water samples may be due largely to human activities around them as supported from previous studies [14].

**Zinc:** Zinc is essential to man but if ingested in large amounts it has an emetic effect. However, the concern for

its level in water supply is not in regard to toxicity but taste, and quite high levels are permissible [14]. Principal significance of excessive amounts in water is that emetic effects occur. The zinc levels for all the samples under consideration are generally low (0.10-0.76 mg/dm<sup>3</sup>) and are below the MPL (5.0 mg/l) of NSDWQ. Zinc has natural geological occurrence and from wastes.

**Manganese:** Manganese is a widely distributed constituent of ores and rocks. Manganese has no particular toxicological connotations; the objections to manganese - like iron - are aesthetic factor [14]. A second effect of the presence of manganese much above the limits is its unacceptable taste problem [14]. Generally toxicity is not a factor, as waters with high levels of manganese will be rejected by the consumer long before any danger threshold is reached.

All the water samples showed zero levels of manganese that are low and below the MPL (0.05 mg/dm<sup>3</sup>) of NSDWQ. The zero level could be due to the sensitivity of the instrument used or total absence in the water samples investigated. No other comparative method was however used to ascertain either of these possibilities.

**Iron, (Fe<sup>2+</sup>):** Total iron means the presence of iron in its two prominent oxidation states, Fe<sup>2+</sup> and Fe<sup>3+</sup>. In this work only Fe<sup>2+</sup> was determined. As with iron, manganese is found widely in soils and is a constituent of many ground waters. It, too, may be brought into solution in reducing conditions and the excess metal will be later deposited as the water is re-aerated. The general remarks for manganese apply to iron but the staining problems with this metal may be even more severe, hence the stringent limits.

**Lead:** Leaching from ores may be the primary source in boreholes in the study areas.

The toxicity of lead is well known so that strict limits on its presence in raw and finished drinking waters must be imposed [14]. All the water samples showed zero levels of lead that are below the MPL (0.001 mg/dm<sup>3</sup>) of NSDWQ. The levels of lead in the water samples studied are low. This may suggest that the environment is free of lead and hence water samples from the wells and boreholes are safe for human consumption and their animals.

**Arsenic:** Arsenic is very widely distributed throughout the earth's crust, according to the WHO Guidelines, which state that "it is introduced into water through the

dissolution of minerals and ores, from industrial effluents, and from atmospheric deposition: concentrations in ground water in some areas are sometimes elevated as a result of erosion from natural sources. The average daily intake of inorganic arsenic in water is estimated to be similar to that from food; intake from air is negligible [14].

Arsenic is very toxic to humans, some arsenical compounds are carcinogenic, and hence there is much concern about them. There are a variety of other effects on health. The WHO states that inorganic arsenic is a documented human carcinogen, and that a relatively high incidence of skin and possibly other cancers that increase with dose and age has been observed in populations ingesting water containing high concentrations of arsenic [14]. Like Pb, and Mn, the water samples investigated contained no detectable As and may be safe for domestic use.

**Barium:** Barium is a naturally occurring mineral (e.g. in barytes). The sampling sites have no history of barite mining. According to the WHO Guidelines [14], while food is the main source of barium intake by humans, where barium occurs in drinking water supplies the latter can contribute a significant proportion of total intake.

Excessive amounts of barium can cause muscular, cardiovascular and renal damage. Although not markedly toxic, barium in excess quantities is clearly undesirable.

Apart from the water sample from well W2 that contains 0.02±0.01mg/dm<sup>3</sup> of Ba<sup>2+</sup>, the rest of the samples contain no barium at all as far as this study revealed. Hence water samples from them may be adjudged to be safe [14].

**Total coliform:** Results for total coliform are presented under Table 2 and Table 3. The total coliform counts for W1&2 samples (Table 2) were 233 and 587 cfu/100 ml respectively and are significantly high and thus may be unsafe for domestic use. The entire boreholes showed except BH3 significant total coli form counts (4-184 cfu/100 ml) that may not be ignored. Samples from wells W1 and W2 also showed high faecal coli form counts of 89 & 200 cfu/100 ml respectively (Table 2). Water samples from all the boreholes may be safe except from bore holes BH5 and BH7 which showed a low faecal coli form counts of 21 and 7 cfu/100 ml respectively (Table 3).

The results for the physicochemical, chemical and the total coliform as well as the faecal coliform parameters are shown in Table 2 and Table 3.

Table 4. Thermotolerant *E. coli* and *Clostridium perfringens* tests

Water sample	Thermotolerant <i>E. coli</i>		<i>Clostridium perfringens</i>		Remarks
	Colonies count (at 35°C after 24-48 hrs)	H <sub>2</sub> S test (at 30°C for 24-48 hrs)	Colonies count (at 35°C after 24-48 hrs)	H <sub>2</sub> S test (at 30°C for 24-48 hrs)	
W1	25	black ppt	18	black ppt	Unsafe water
W2	8	black ppt	4	black ppt	Unsafe water
BH1	0	no black ppt	0	no black ppt	Safe water
BH2	0	no black ppt	0	no black ppt	Safe water
BH3	0	no black ppt	0	no black ppt	Safe water
BH4	0	no black ppt	0	no black ppt	Safe water
BH5	0	no black ppt	0	no black ppt	Safe water
BH6	0	no black ppt	0	no black ppt	Safe water
BH7	0	no black ppt	0	no black ppt	Safe water
BH8	0	no black ppt	0	no black ppt	Safe water

From Table 3, the *E. coli* counts are 25 and 8 respectively in W1 and W2 water samples. And both showed black precipitate with  $H_2S$  (Table 4) indicating that the water from these sources is not safe for human use. Because samples from both W1 and W2 showed a large presence of *E. coli*, the inference is that heavy, recent pollution by human or animal wastes has occurred. *E. coli* is an actual bacterium that causes gastroenteritis in humans, and is abundant in human and animal feces (up to 1,000,000,000 *E. coli*'s per gram of fresh feces). The presence of *E. coli* in water always indicates potentially dangerous contamination requiring immediate attention [14].

The borehole samples all showed a total absence of *E. coli* indicating that these water sources are safe for human consumption. However, because coliforms counts not including *E. coli* are observed in some of the borehole samples, the implication is that either the pollution is recent or non-faecal in origin or remote, faecal origin such that the intestinal conformers has not survived. This was confirmed by the negative (absence of black precipitate)  $H_2S$  tests for all the boreholes samples (Table 4). The inference is that all the boreholes water sources are safe for human consumption.

#### 4. Conclusion

From the results of this study, the concentrations of most metal ions and anions are within permissible limits except the few cases discussed but the wells located at Uguwan Dan Lawal, W1 and Uguwan Barde, W2 are heavily contaminated with faecal matter. Immediate chlorination process should be embarked upon to eliminate negative impacts of water contamination. Covering the wells immediately after chlorination would also enhance the water quality. Pit or latrine toilet systems should be discouraged particularly in houses close to these water points. Seepages from sewages and soak-aways in neighbouring houses to these water points should be checked and corrected.

It may be recommended that simple, acceptable, low-cost interventions at the point-of-use (household) level that are capable of improving the microbial quality of drinking water and reduce the attendant risks may be established. A water quality intervention, in terms of household (point-of-use) treatment is known to reduce diarrhoeal illness levels. This suggests that water quality intervention may be more important than previously thought, as previous studies have suggested that such interventions are only effective where good sanitary conditions at point-of-use already exist.

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