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Assessment of Water Quality Index and Heavy Metal Contents of Underground Water Sources in Doma Local Government Area, Nasarawa State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors.The author YM designed the research plan for this study. Author ODO performed the analysis and wrote the first draft of the manuscript. Authors SM, ATO and DA supervised the study and analysed the data. All the authors managed the literature search. All authors read and approved the final manuscript.

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ABSTRACT

Water quality index and heavy metal contents of underground water sources in Doma Local Government Area, Nasarawa State, Nigeria was assessed to ascertain the suitability of the water for domestic purpose. Physicochemical parameters; temperature, turbidity, TDS, TSS, pH, EC, total hardness, alkalinity, chloride, nitrate and sulphates in the water samples were determined using standard methods of analysis. The water quality index (WQI) was also evaluated using known standard method. The heavy metal contents were determined using atomic absorption spectrophotometric method. The results of the physicochemical analyses shows that in borehole and hand dug well water, the respective mean values were temperature (27.11±0.45 and 27.41±0.55 °C), turbidity (1.51±0.54 and 2.56±1.04 NTU), TDS (230.00±87.75 and 358.67±91.46 mg/dm^3), TSS (3.64±1.25 and 4.17±4.17 mg/dm^3), pH (5.63±0.69 and 6.60±0.95), EC 277.16 and 296.29±26.52 µS/cm), total hardness (90.00±15.55 and 125.13±16.33 mg/dm^3), alkalinity (8.87±.083 and 9.24±1.08 mg/dm^3), chloride (20.59±14.62 and 21.22±10.13 mg/dm^3, nitrate

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(0.024±0.04 and 0.01±0.01 mg/dm^3) and sulphates (1.05±0.74 and 2.09±0.45 mg/dm^3). It was revealed that all the physicochemical parameters for both borehole and hand dug well water had values that were within the standard permissible values recommended by regulatory bodies, NSDWQ and WHO except for the pH of the borehole water which was not within the recommended range and which showed the water to be slightly acidic and which could attributable to the nature of the host rocks. WQI for borehole and hand dug well water were 29.65 and 27.38 respectively with the implication that both water sources presented good water quality for drinking based on the water quality index and water quality status. The results of the heavy metal analyses shows that in borehole and hand dug well water, the respective mean values were Cd (0.003±0.002 and 0.010±0.002 mg/dm^3), Cr (0.187±0.075 and 0.19±0.070 mg/dm^3), Cu (0.040±0.010 and 0.804±0.805 mg/dm^3), Fe (0.500±0.330 and 0.916±0.543 mg/dm^3), Pb (0.010±0.010 and 0.015±0.007 mg/dm^3) and Zn (0.290±0.120 and 0.072±0.072 mg/dm^3). The results shows that Cd, Cu, Pb and Zn for both borehole and hand dug well water had mean values that were within the standard permissible values recommended by NSDWQ and WHO while Cr and Fe had mean values that were higher and which can be attributed to anthropogenic activities close to the water sources. It is recommended the groundwater in these selected communities be monitored regularly and that there is the need for the water to be treated before use because of those parameters that are off the standards to avoid associated health risks.

Keywords: Physicochemical parameters; water; heavy metals; groundwater.

1. INTRODUCTION

Water is one of the indispensable resources available to living organisms, hence the existence of life generally, would not have been possible on planet earth without water. Over the years there have been an increase in the demand for potable water due “rapid growth in population”, accelerated pace of industrialization as well as urbanization [1]. This demand for water has led to the use of water from underground sources not only because of its widespread occurrence and availability but also due to its supposedly constituent good quality which makes it ideal supply of drinking water [2]. The supply of freshwater to Nigerian has been inadequate and has compelled inhabitants in some communities to resort to the supply of water for domestic purpose from underground water sources [3]. People have been using underground water as source of drinking water and even in the present days, it has been reported that more than half of the population of the world depends on groundwater for survival [1].

Underground water has long been considered as one of the purest form of water available in nature. It meets the overall demands for water by rural people [4]. This was considered as the main source of water for human activities including drinking in the rural areas, even some urban areas of developing countries [5]. However, the large scale industrial growth has caused serious concerns regarding the susceptibility of underground water to contamination as a result of indiscriminate discharge of wastes that have not been treated. Water contaminants present in such wastes eventually gets into rainwater which percolates into the groundwater and if the water gets to the aquifer systems the quality of underground water becomes degraded [4]. Contaminants also get into underground water sources through seepage from municipal landfills, septic tank effluents and even from runoff.

Dumping of wastes indiscriminately as well as lack of treatment facilities for wastes could be of very serious concern in communities that depend on underground water sources for survival since it could pose potential water pollution problems [6]. However, it is very important that information on the quality of water is available to aid in planning of developmental projects, even the establishment of settlements since water is said to influence the inhabitable conditions of a given location. When underground water is contaminated, its quality is affected and it cannot be restored easily [7]. Therefore, it is of utmost importance that the quality of underground water sources is protected by controlling sources of contamination to prevent health challenges that are associated with water pollution [8].

Water quality indicates the relationship between the hydrological properties which are physical, chemical, biological as well as microbiological properties of water bodies. Therefore, analysis done to ascertain the quality of water is dependent on the physical, chemical, biological and microbiological properties of water that are indicative of the abiotic and biotic status of the given water ecosystem [9]. Water Quality Index (WQI) is evaluated by taking aggregates of the products of parameter qualities and the unit weights divided by aggregate of the unit weight. It provides a nominal number that represents the overall water quality at a certain location and time based on water quality parameters.

Another very serious concern over the quality of underground water sources is contamination by heavy metals. Heavy metals (for example lead, cadmium, chromium, copper, iron and a few others) in water refers to the heavy, dense, metallic elements or metalloids that occur in trace levels, and have potential for toxicity. Heavy metals have received particular concern over the years considering strong toxicity of heavy metals even at low concentrations [10]. They exist in water in colloidal, particulate and dissolved phases [11] with their occurrence in water bodies being either of natural origin (e.g. eroded minerals within sediments, leaching of ore deposits and volcanism extruded products) or of an anthropogenic origin (which include solid waste disposal, industrial and domestic effluents, harbor channel dredging, ore mineral processing, smelting and a few others) [10]. The other source from where underground water receives heavy metals is from the runoff that comes from agricultural farmlands where fertilizers and agrochemicals blended with these heavy metals have been used severally. These metals are not biodegradable, can bio-accumulate and persist for longtime. The runoff will carry these metals as dissolved ion in water and either percolate or flow into underground water sources [12]. Water is one the ways these metals get in contact with humans with the associated health risks like cancer, kidney dysfunction and other internal organs, gastrointestinal as well as neurological disorder with a host others [13].

Several research works have been done on the quality of underground water sources in different parts of Nigeria because of the importance of these sources of water to the citizenry that inhibit those places. These include the study on groundwater sources around Kashere and its environs [14], comparative study of the level of heavy metals in water from boreholes and hand dug wells within and around Lafia metropolis [15]. In western Nigeria, a similar research work was done on underground water source in Itaogbolu area of Ondo [12]. Also in the North Eastern Nigeria, particularly in Wukari town there was a research work on the water quality index of well water [16].

The study area is Doma Local Government Area of Nasarawa State. Like most communities in some developing countries including Nigeria, the provision of potable water is the sole business of the government and in most cases its supply is either epileptic or it is completely not available. The study area falls in this category and therefore, for meaningful living, the populace in the communities in this local government area resorted to underground water as their main source of potable water supply. There was therefore the need for this research work so as to evaluate the quality of underground water sources in the study area in terms of water quality index and the heavy metal contents to ascertain the suitability of the water for domestic purpose.

2. MATERIALS AND METHODS

2.1 Study Area

The study area is Doma Local Government Area of Nasarawa State, Nigeria with Its headquarters in the town of Doma and it is located on latitude 08° 66’’- 08° 72’’ North of the equator and longitude 07° 64’’- 07° 69’’ East of the Greenwich meridian. Doma Local Government Area is in Nasarawa South Senatorial District alongside Lafia, Awe, Keana and Obi Local Government Areas. Doma Local Government Area also forms a Federal Constituency alongside Awe and Keana Local Government Areas. The local government area is bounded to the north by Lafia Local Government Area, to the east by Obi and Keana Local Government Areas and Benue State, to the south again by Benue State, and to the west by Nasarawa Local Government Area.

It is located in the middle belt of Nigeria. In this region, there are two main seasons. The wet season from April to October and dry season from November to March. The average annual rainfall distribution in the area ranges from 100 mm–1200 mm while the minimum and maximum temperatures are 18.5 °C and 35 °C respectively and the topography of the area, particularly the relief of study area ranges between 49.5 m and 793.5 m above sea level [17]. Nasarawa State has a long history of mining. Deposition of minerals is controlled principally by geology. The study area has an under laying rocks of Cretaceous sandstone of Lafia formation that stretches down. This Lafia sandstone is highly ferroginized with intercalation of coal seams [32]. The major occupation of the populace in the study area is farming for men while the women are engaged in trading [17]. The farming activities heavily involves the use of fertilizers and agrochemicals. These fertilizers and agrochemicals are normally blended with heavy metals that will eventually be found in the environment [33].

Doma Local Government Area covers an area of 2,714 km² and had a population of 139,607 by 2006 census. The area is made up of different ethnic groups each with a distinct cultural heritage; with the predominant tribe being Alago while minority tribes include Eggon, Agatu and Hausa [17].

In the study area, functional water supply system is only available in the administrative headquarters of the local government area which is Doma town. The residents in other settlements of local government area lives on individual and Government owned boreholes and deep hand dug wells as potable water supply sources (groundwater sources). The communities used for this research work were, Yelwa, Igbabo and Doka in Doka ward, Aragye and Brumbrum in Alagye ward, Idadu and Agbashi in Agbashi ward, Rukubi and Akpanaja ward all in Doma Local Government Area.

2.2 Sample Collection, Treatment and Preservation

Samples were taken from boreholes and hand dug wells in Yelwa, Igbabo and Doka in Doka ward, Aragye and Brumbrum in Alagye ward, Idadu and Agbashi in Agbashi ward, Rukubi and Akpanaja ward all in Doma Local Government Area. Water samples were collected twice a month at interval of two weeks, the day and time varied to account for the cyclic intermittent variations that may occur at the collection source. Sampling was done in the month of March (dry season) 2019. Well water samples were collected using a fetcher and borehole water samples were collected directly from the taps. The samples were all collected in clean 2.0 dm^3 white polyethylene stopper containers which had been soaked overnight in dilute HNO_3 solution, 0.1 M before washing finally with soap solution, firstly rinsed with distilled water, then deionized water and filled with deionized water to the sampling points. The containers were emptied at the sampling points and rinsed severally with the samples to be collected and eventually, the collection of samples, and the containers covered (air tight) immediately. Preservations of the samples were carried out as prescribed by APHA [18]. The samples were then transported to the laboratory and properly stored prior to analysis [19].

2.3 Analyses of Water Samples

2.3.1 Physicochemical analysis of water samples

Temperature, pH, electrical conductivity, turbidity total dissolved solids (TDS) were determined in situ using mercury bulb thermometer calibrated in degree Celsius, pH meter JENWAY–430, conductivity meter JENWAY–430, turbidity meter by Leyte Medical Equipment Company Limited, China (SGZ 200BS Turbidity Meter) and a TDS meter JENWAY– 430 respectively [18]. Other parameters such as total suspended solids was determined by gravimetric method, total hardness by EDTA titrimetric method and alkalinity, chloride, sulphate, nitrate and phosphate ion, were determined by methods prescribed by AOAC, 1990 and adopted by Ademoroti [19]. All the chemicals used for this research were of analytical grade obtained from BDH (British Drug House, London).

2.3.2 Water quality index

The weighted arithmetic index method described in a research publication by and others [20] was used for the evaluation of the water quality index (WQI). The quality rating was evaluated as follows;

$$q_n = \frac{100\,[V_n - V_{10}]}{[S_n - V_{10}]} \quad (1)$$

Where: q_n = Quality rating for nth water quality parameter, V_n = Estimated value of the nth water quality parameters of collected samples, S_n = Standard permissible value of the nth water quality parameter and V_{10} = Ideal value of the nth water quality parameter impure water.

This ideal value of the nth water quality parameter of impure water is 0 for all other parameters except the pH and dissolved oxygen which have 7 and 14.6 mg/dm^3. When the reciprocal of the standard permissible value, S is considered the value obtained represents the unit weight, W [20]. Water Quality Index, WQI is calculated by taking aggregates of the products

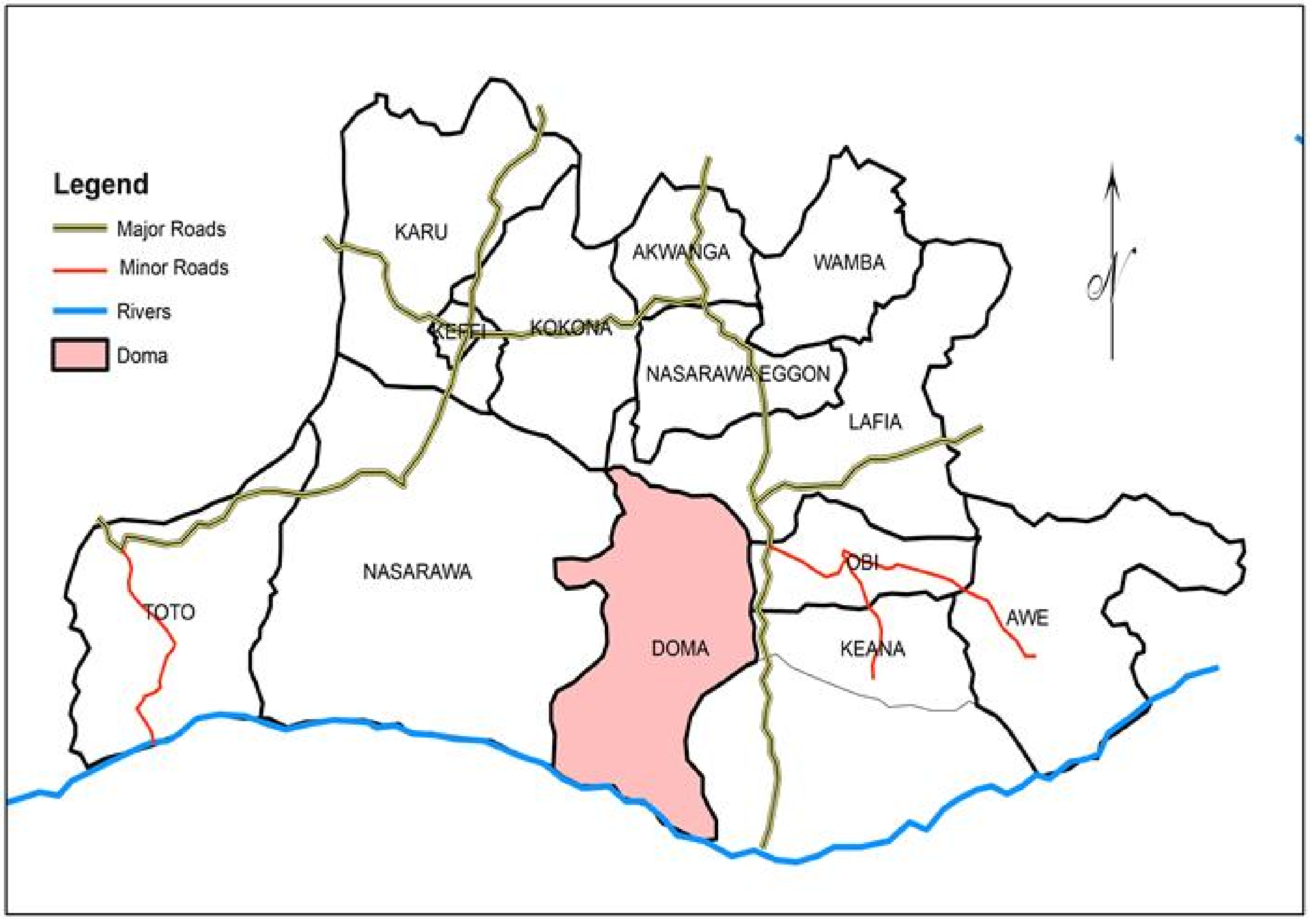

Fig. 1. Map of Nasarawa State showing the study area, Doma local government area

of determined parameter qualities and the unit weights divided by aggregate of the unit weight as shown in the equation (2) below:

$$WQI = \frac{\sum q_n W_n}{\sum W_n} \quad (2)$$

Where: q_n = Quality rating for nth water quality parameter, W_n = Unit weight

2.4 Determination of Heavy Metals in Water Samples

The following heavy metals; copper, cadmium, chromium, iron, lead and zinc were analyzed by the use of atomic absorption spectrometer (AAS ICE 3000 AA02134104 v1:30).

2.5 Statistical Analysis

The data obtained from this research work was subjected to statistical evaluations. Statistical parameters evaluated were grand mean, standard deviation and coefficient of variation.

3. RESULTS AND DISCUSSION

3.1 Physicochemical Parameters

Table 1 shows the sampling locations and Tables 2 and 3 shows the mean values of the various physicochemical parameters assessed from the different sampling locations for borehole water samples and hand dug well water samples respectively. Table 4 shows the comparison between mean values for borehole water samples and hand dug well water samples as well as the standards from different regulatory bodies, locally and internationally.

The mean value for temperature of water from the borehole and hand dug well were 27.11±0.45 and 27.41±0.55 °C respectively. Temperature values are dependent on the climatic condition of a geographical area and the period of the year. Higher temperatures in underground water sources could cause changes in the physical, chemical and microbiological quality of the water. All the values for temperature in this present study are lower than the range values of 28.8 – 29.2 °C of temperature for underground water quality from selected areas in Ado Ekiti [21] but the values higher than the mean value of 24.40°C of temperature for water from traditional hand dug wells in Awka [22]. The temperature values from this research work are within the limits recommended by regulatory bodies, NSDWQ and WHO.

Turbidity had mean values of 1.51±0.54 and 2.56±1.04 NTU for borehole and well water samples respectively. Turbidity is due to the presence of colloidal particles that could be coming from clay silt during wet season as water percolates down the different layers. The value from the borehole is within the range values of 0.42 – 1.88 NTU of turbidity for water from some selected boreholes in Gwagwalada, FCT, Abuja [23] but the value from the well water is higher than this reported range. However, the values from both borehole and well are all lower than the recommended maximum permissible limit.

The mean values of total dissolved solids (TDS) were 230.00±87.75 and 358.67±91.46 mg/dm^3 for borehole and well water samples respectively while the respective mean values for total suspended solids (TSS) were 3.64±1.25 and 4.17±4.17 mg/dm^3 for borehole and well water samples. The TDS mean values are within the range of values 6.80 – 630.00 mg/dm^3 and the TSS mean values are lower than the range values 120.00 – 980.00 mg/dm^3 for water from traditional hand dug well in Awka [22]. TDS in water plays a very important role to decide its suitability for domestic use. The TDS and TSS mean values from this research work are lower compared to the recommended standards from the different regulatory bodies.

pH mean values were 5.63±0.69 and 6.60±0.90 for borehole and well water samples respectively. pH of water is of very vital importance as it determines the acidic or alkaline nature of water and eventually its suitability for domestic or industrial use. The pH mean values recorded are slightly acidic. This could be attributed the activities around the underground water sources and the nature of host rocks (ferroginized sandstone with intercalation of coal seams which could lower pH of groundwater) [32] in the study area. The mean pH values for borehole water samples is more acidic, not within the standard values recommended by regulatory bodies but that of the well water samples is within the recommended range.

Electrical conductivity (EC) of water is dependent on temperature and it indirectly measures the salinity of water [24]. Electrical conductivity had mean values of 277.16±79.99 and 296.29±26.52 µS/cm for borehole and well water samples respectively. These values are higher than the mean value of EC for borehole

Table 1. Sampling locations in Doma LGA, Nasarawa State, Nigeria indicating sample numbers

Location	Borehole water sample	Hand dug well water sample
Yelwa, Igbabo and Doka	SB1	SW8
Idadu	SB2	SW9
Agbashi	SB3	SW10
Rukubi	SB4	SW11
Akpanaja	SB5	SW12
Brumbrum	SB6	SW13
Aragye	SB7	SW14

Table 2. Mean values of the physicochemical parameters in borehole water samples from Doma LGA

Parameters	Location							Mean	SD	CV (%)
	SB1	SB2	SB3	SB4	SB5	SB6	SB7			
Temperature (°C)	26.70	26.90	27.00	28.10	27.10	26.95	27.00	27.11	0.45	1.68
Turbidity (NTU)	1.20	1.11	1.50	1.10	1.15	2.50	2.00	1.51	0.54	36.05
Total Dissolved Solids (mg/dm^3)	210.00	70.00	300.00	350.00	210.00	250.00	220.00	230.00	87.75	38.15
Total Suspended Solids (mg/dm^3)	3.50	2.50	2.00	3.00	4.50	5.50	4.50	3.64	1.25	34.28
pH	5.40	6.00	6.50	6.00	4.50	5.00	6.00	5.63	0.69	12.34
Electrical Conductivity (µS/cm)	415.00	275.10	185.00	350.00	225.00	225.00	265.00	277.16	79.99	28.86
Total Hardness (mg/dm^3)	90.00	100.00	85.00	95.00	60.00	110.00	90.00	90.00	15.55	17.27
Alkalinity (mg/dm^3)	8.90	8.95	7.80	9.00	10.10	7.85	9.50	8.87	0.83	9.34
Chloride (mg/dm^3)	49.63	14.18	15.85	10.00	14.85	30.50	9.10	20.59	14.62	71.01
Nitrate (mg/dm^3)	0.006	0.12	0.009	0.008	0.007	0.009	0.009	0.024	0.04	176.45
Sulphate (mg/dm^3)	0.05	0.07	1.45	1.55	2.00	1.15	1.05	1.05	0.74	0.71

SD =Standard Deviation, Coefficient of Variation

Table 3. Mean values of the physicochemical parameters in hand dug well water samples from Doma LGA

Parameters	Location							Mean	SD	CV (%)
	SW8	SW9	SW10	SW11	SW12	SW13	SW14			
Temperature (°C)	27.65	26.85	27.00	28.10	28.15	27.00	27.10	27.41	0.55	2.01
Turbidity (NTU)	1.75	2.50	3.00	4.10	1.95	1.15	3.50	2.56	1.04	40.49
Total Dissolved Solids (mg/dm^3)	540.15	305.00	295.00	410.00	320.00	280.00	360.55	358.67	91.46	25.50
Total Suspended Solids (mg/dm^3)	3.25	4.50	5.45	6.75	3.00	2.15	4.10	4.17	1.57	37.53
pH	5.10	6.15	7.50	7.85	6.00	6.50	7.10	6.60	0.95	14.43
Electrical Conductivity (µS/cm)	320.00	304.00	310.00	250.00	320.00	270.00	300.00	296.29	26.52	8.95
Total Hardness (mg/dm^3)	115.00	110.00	105.00	130.00	125.90	140.00	150.00	125.13	16.33	13.05
Alkalinity (mg/dm^3)	10.95	9.85	8.00	9.00	9.90	7.95	9.00	9.24	1.08	11.74
Chloride (mg/dm^3)	40.00	12.65	10.15	16.75	18.00	25.00	26.00	21.22	10.13	47.75
Nitrate (mg/dm^3)	.007	0.006	0.009	0.018	0.021	0.025	0.009	0.01	0.01	56.09
Sulphate (mg/dm^3)	2.01	2.05	2.75	1.55	2.25	1.55	2.50	2.09	0.45	21.53

SD =Standard Deviation, Co-efficient of Variation

Table 4. Comparison between mean values of physicochemical parameters of underground water sources from Doma LGA

Parameters	Borehole water	Hand dug well water	Recommended standards	
			[13]	[29]
Temperature (°C)	27.11±0.45	27.41±0.55	27.00 – 29.00	Ambient
Turbidity (NTU)	1.51±0.54	2.56±1.04	5.00	5.00
Total Dissolved Solids (mg/dm^3)	230.00±87.75	358.67±91.46	1000.00	500.00
Total Suspended Solids (mg/dm^3)	3.64±1.25	4.17±4.17	-	25.00
pH	5.63±0.69	6.60±0.95	6.50 – 8.50	6.50 – 8.50
Electrical Conductivity (µS/cm)	277.16±79.99	296.29±26.52	1400.00	1000.00
Total Hardness (mg/dm^3)	90.00±15.55	125.13±16.33	600.00	150.00
Alkalinity (mg/dm^3)	8.87±0.83	9.24±1.08	200.00	-
Chloride (mg/dm^3)	20.59±14.62	21.22±10.13	200.00	250.00
Nitrate (mg/dm^3)	0.024±0.04	0.01±0.01	10.00	50.00
Sulphate (mg/dm^3)	1.05±0.74	2.09±0.45	400.00	100.00

and well water samples from Okene Local Government Area in both dry and wet seasons which was 1.00 μS/cm [25]. The mean conductivity values for both borehole and well water samples are within the recommended standard values.

Calcium and magnesium are primarily responsible for the presence of hardness in water. Underground water may be categorized based on hardness values; <75 mg/dm^3 (soft), 75 -150 mg/dm^3 (moderately soft), 150 -300 mg/dm^3 (hard) and >300 mg/dm^3 (very hard) and hard water for scum with soap and could also cause scale deposits in pipes [23]. The mean total hardness for borehole and well water were 90.00±15.55 and 125.13±16.33 mg/dm^3. The mean value of total hardness is lower but that of the well water samples is higher than the range values, 92.6±5.3 – 116.8±4.8 mg/dm^3 for total hardness of water from selected groundwater sources in Ado Ekiti [21]. Mean values of total hardness from this research work are all lower than the recommended standard values.

Alkalinity is fundamentally due to the carbonate, bicarbonate as well as hydroxide contents of water. Alkalinity in borehole and well water samples were 8.87±0.83 and 9.24±1.08 mg/dm^3. These mean values are higher compared to the mean values of alkalinity in borehole and well water from Wukari, determined on collection which is 8.00 mg/dm^3 [16]. The alkalinity values in borehole and well water samples are all lower than the standard values.

The mean value of chloride in borehole and well water samples were 20.59±14.62 and 21.22±10.13 mg/dm^3 respectively. Chloride in water originates from natural sources (chloride containing rocks), sewage and industrial effluents and runoff during rainy season. The mean values from this work are lower than the mean value of 130.64 mg/dm^3 for well water from Itaogbolu area of Ondo State [12]. The chloride contents in water from borehole and well water are far below the recommended standard values.

Nitrate had mean values of 0.024±0.04 and 0.01±0.01 mg/dm^3 in borehole and well water samples respectively. Nitrate in water is primarily dependent on nitrification activities of microorganisms. Nitrates generally are contributed to water through discharge of sewage, industrial effluents and runoff from agricultural fields [26]. The mean nitrate values in this work are lower than the range values of 1.74±0.66 – 2.81±1.41 mg/dm^3 for nitrate in groundwater in Keta South, Ghana for both dry and wet seasons [27]. The mean values of nitrate in both borehole and well water samples are below the recommended permissible limits by regulatory bodies.

The mean values of sulphate in borehole and well water samples were 1.05±0.74 and 2.09±045 mg/dm^3 respectively. Sulphate in water comes from natural sources such as dissolution of sulphate minerals, gypsum; sulfide minerals, pyrite as well as anthropogenic sources such as mining, drainage and farmlands where agrochemicals and fertilizers have been used. The mean values of sulphate from this work are lower than the mean value of 74.55 mg/dm^3 for well water from Itaogbolu area of Ondo [12]. The sulphate contents in water from borehole and well water are far below the recommended standard values.

Table 5 shows the water quality index and water quality status while Tables 6 and 7 shows the water quality index of borehole water in Doma Local Government Area and water quality index of hand dug well water in Doma Local Government Area respectively. The respective WQI values for borehole and hand dug well water samples in Doma Local Government Area were 29.65 and 27.38. These values were calculated based on the standard values provided by NSDWQ for parameters analyzed. The implication therefore, is that both water sources presented good water quality for drinking based on the water quality index and water quality status presented on Table 5.

The *coefficient of variation* represents the ratio of the standard deviation to the mean, and it is a useful measure of relative variability for comparing the degree of *variation* from one *data* series to another, even if the means are very different from one another. For borehole water the most varied parameter is nitrate, 176.45% and the least varied parameter is sulphate, 0.71% whereas for the hand dug well the highest coefficient of variation was for nitrate, 56.09% and the lowest was for temperature, 2.01%.

The values of the physicochemical parameters of borehole water samples are generally lower than those of the hand dug well water samples. This could be attributed to fact that boreholes are normally covered and in most cases wells are not properly covered and there could be settling of dust in hand dug well and the inflow of runoff during rainy season and all these can affect the water quality parameters.

Table 5. Water quality index and water quality status [28]

Water quality index	Water quality status
0 – 25	Excellent water quality
26 – 50	Good water quality
51 – 75	Poor water quality
76 – 100	Very poor water quality
>100	Unsuitable for drinking

3.2 Heavy Metals

Tables 8 and 9, shows the mean values of various heavy metal concentrations determined for the different sampling locations for borehole water samples and hand dug well water samples respectively. Table 10, shows the comparison between mean values for borehole water samples and hand dug well water samples as well as the standards from different regulatory bodies, locally and internationally for metals in water. The mean concentration of cadmium in borehole and hand dug well water samples were 0.003±0.002 and 0.01±0.002 mg/dm^3 respectively. These values are lower compared to the values of 0.07 and 0.09 mg/dm^3 for water from borehole and hand dug well respectively from around Kashere and its environs, Upper Benue Trough, Northeastern Nigeria [14]. The value for the mean concentrations of cadmium from this research work are all within the standard limits recommended by the regulatory bodies. Chromium had 0.187±0.075 and 0.19±0.070 mg/dm^3 as the mean concentrations in borehole and hand dug well water respectively. These values are higher than the range concentration values from ND (not detectable) to 0.2 mg/dm^3 in water from wells in Itaogbolu area of Ondo State, Nigeria [12]. These mean concentrations from the present study are higher than standard value recommended for chromium in drinking water, and this could be attributed to surface contamination originating from anthropogenic sources particularly from waste dumps that are close to the groundwater sources. Chromium in water above the recommended permissible maximum could cause cancer [29].

The mean concentrations of copper were 0.040±0.010 and 0.804±0.805 mg/dm^3 in water from borehole and hand dug well respectively. The concentration of the metal in the well water is higher than its concentration in the borehole water and this could be attributed to nature of host rocks around the well because copper is a metal that exists in the environment, as a mineral in rocks and soil. Mean copper concentration for the borehole water is lower, and that of the hand dug well is higher than the range values of 0.07±0.01 to 0.23±0.02 mg/dm^3 for copper in underground water in selected areas of Ado Ekiti [21]. Mean concentration from the present study are all lower than the recommended standard values. Iron had mean concentrations of 0.500±0.33 and 0.916±0.543 mg/dm^3 in borehole and hand dug well water respectively. These values are higher than the mean concentration of 0.100 mg/dm^3 for iron in hand dug well water from selected land uses in Wukari town [30]. The mean concentrations of iron from this study are higher than the recommended standard values by WHO and NSDWQ. The presence of iron in groundwater is a direct result of its natural existence in underground rock formations and precipitation water that infiltrates through these formations. The elevated level of iron in the groundwater sources in the study area could be attributed to the underlying rock, highly ferroginized sandstone. As the water moves through the rocks, some iron dissolves and accumulates in the aquifers which serve as a source for groundwater.

The mean concentrations of lead in borehole and hand dug well water respectively were 0.01±0.010 and 0.015±0.007 mg/dm^3. These mean values are lower than the range of values of 0.043±0.075 – 0.077±0.133 mg/dm^3 for lead in borehole water from Enyigba community in Abakaliki [31]. The values from this study are within the range of standard values recommended by the regulatory bodies. The concentrations of zinc in the borehole and hand dug well water were 0.29±0.12 and 0.072±0.072 mg/dm^3 respectively. Mean concentration of zinc in borehole water is higher than the range concentration of 0.02 – 0.17 mg/dm^3 in ground water sources from selected areas in Mubi Local Government Area, Adamawa State [34]. Mean concentrations from both the borehole and hand dug well are all within the recommended standards. Concentrations of metals in the hand dug well water were generally higher than the ones of the borehole water. There were also variations in the metal concentrations in both borehole and hand dug well water from one location to another, and all these could be attributed to geological distribution of minerals from one location to the other and anthropogenic activities in the study area. Variations like this was reported for groundwater sources in Itaogbolu area of Ondo State, Nigeria [12].

Table 6. Quality index of borehole water in Dome LGA

S/N	Parameters	Mean	Standard permissible level[29]	Ideal value	Unit weight (Wn)	Quality rating Qn	Qn×Wn
1	Turbidity (NTU)	1.51	5.00	0	0.2	30.20	6.04
2	Total Dissolved Solids (mg/dm^3)	230.00	500.00	0	0.002	46.00	0.092
3	Total Suspended Solids (mg/dm^3)	3.64	25.00	0	0.04	14.56	0.5824
4	pH	5.63	8.50	7	0.118	130.48	15.39664
5	Electrical Conductivity (µS/cm)	277.16	1000.00	0	0.001	27.72	0.02772
6	Total Hardness (mg/dm^3)	90.00	150.00	0	0.0067	60.00	0.402
7	Chloride (mg/dm^3)	20.59	250.00	0	0.004	8.24	0.03296
8	Nitrate (mg/dm^3)	0.024	50.00	0	0.02	0.05	0.001
9	Sulphate (mg/dm^3)	1.05	100.00	0	0.01	1.05	0.0105
					∑Wn **=** 0.7617		∑QW = 22.5852

$$WQI = \frac{\sum QW}{\sum W} = \frac{22.5852}{0.76\ 17} = 29.65$$

Table 7. Quality index of hand dug well water in Dome LGA

S/N	Parameters	Mean	Standard permissible level [29]	Ideal value	Unit weight (Wn)	Quality Rating Qn	Qn×Wn
1	Turbidity (NTU)	2.56	5.00	0	0.2	51.2	10.24
2	Total Dissolved Solids (mg/dm^3)	358.67	500.00	0	0.002	71.73	0.14346
3	Total Suspended Solids (mg/dm^3)	4.17	25.00	0	0.04	16.68	0.6672
4	pH	6.60	8.50	7	0.118	77.65	9.1627
5	Electrical Conductivity (µS/cm)	296.29	1000.00	0	0.001	29.63	0.02963
6	Total Hardness (mg/dm^3)	125.13	150.00	0	0.0067	83.42	0.558914
7	Chloride (mg/dm^3)	21.22	250.00	0	0.004	8.49	0.03396
8	Nitrate (mg/dm^3)	0.01	50.00	0	0.02	0.02	0.0004
9	Sulphate (mg/dm^3)	2.09	100.00	0	0.01	2.09	0.0209
					∑Wn **=** 0.7617		∑QW = 20.8572

$$WQI = \frac{\sum QW}{\sum W} = \frac{20.8572}{0.76\ 17} = 27.38$$

Table 8. Mean concentrations of heavy metals (mg/dm^3) in borehole water samples from Doma LGA

Parameters	Location							Mean	SD	CV (100%)
	SB1	SB2	SB3	SB4	SB5	SB6	SB7			
Cd	0.003	0.006	0.005	0.001	0.002	0.003	0.004	0.003	0.002	50.12
Cr	0.12	0.26	0.13	0.29	0.13	0.13	0.25	0.187	0.075	40.31
Cu	0.04	0.05	0.06	0.03	0.02	0.04	0.02	0.040	0.01	40.28
Fe	0.09	0.13	0.73	0.82	0.24	0.69	0.82	0.500	0.33	66.27
Pb	0.018	0.013	0.010	0.006	0.007	0.015	0.025	0.010	0.01	49.56
Zn	0.26	0.31	0.35	0.25	0.51	0.21	0.15	0.290	0.12	39.84

SD =Standard Deviation, Coefficient of Variation

Table 9. Mean concentrations of heavy metals (mg/dm^3) in hand dug water samples from Doma LGA

Parameters	Location							Mean	SD	CV (100%)
	SB8	SB9	SB10	SB11	SB12	SB13	SB14			
Cd	0.003	0.002	0.007	0.007	0.005	0.007	0.008	0.010	0.002	42.73
Cr	0.10	0.13	0.13	0.25	0.23	0.20	0.30	0.19	0.07	38.56
Cu	0.81	0.74	0.77	0.85	0.81	0.80	0.85	0.804	0.040	4.97
Fe	0.08	1.81	0.89	1.35	0.75	0.69	0.84	0.916	0.543	59.34
Pb	0.020	0.017	0.016	0.006	0.007	0.015	0.025	0.015	0.007	44.70
Zn	0.019	0.036	0.026	0.024	0.065	0.215	0.120	0.072	0.072	100.16

SD =Standard Deviation, Coefficient of Variation

Table 10. Comparison between mean values of heavy metal concentrations (mg/dm^3) in underground water sources from Doma LGA

Parameters	Borehole water	Hand dug well water	Recommended standards	
			[13]	[29]
Cd	0.003±0.002	0.010±0.002	0.005	0.003
Cr	0.187±0.075	0.19±0.070	0.050	0.050
Cu	0.040±0.010	0.804±0.805	1.000	1.000
Fe	0.500±0.330	0.916±0.543	0.300	0.300
Pb	0.010±0.010	0.015±0.007	0.050	0.010
Zn	0.290±0.120	0.072±.0.072	5.000	3.000

4. CONCLUSION

The physicochemical parameters determined for borehole and hand dug well water samples; temperature, turbidity, total dissolved solids, total suspended solids, electrical conductivity, total hardness, alkalinity, chloride, nitrate, and sulphate were all within the standards permissible limit recommended by regulatory bodies. However, the mean pH for the hand dug well water was within the recommended standard values, but the pH value for the borehole is outside the range recommended standards. It shows that the water is slightly acidic. The WQI evaluated for both borehole and hand dug well water samples shows the ground water sources presented good water quality. The results of the mean metal concentrations in borehole and hand dug well water samples shows that the concentrations of Cd, Cu, Pb and Zn are within the standards permissible limit recommended by regulatory bodies while those of Cr and Fe are higher than standard values. This work helps the populace to know that using water from the groundwater sources in the study area without treatment will eventually pose some health implications.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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