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Original Article

Physico-chemical parameters of drinking water sources in Chanchaga Local Government Area, Minna, Niger State

[1]Abubakar, A.N., [2]Eniolorunda, M. F. [2]Bala, J. D. and [2]Ilyasu, U. S.

[1]Department of Biochemistry, School of Life Sciences, Federal University of Technology, PMB 65, Minna, Niger State, Nigeria.
[2]Department of Microbiology, School of Life Sciences, Federal University of Technology, PMB 65, Minna, Niger State, Nigeria.

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ABSTRACT

Safe drinking water is a fundamental need, yet access to it by millions worldwide- including a significant portion of Nigeria's population continue to struggle with inadequate water quality. This study determines the drinking water quality in Chanchaga Local Government Area, Niger State, evaluating the following water sources: tap water, well water, sachet water and household stored water. Eighty samples were collected across 11 wards and analyzed for the following physicochemical parameters: pH, turbidity, conductivity, total dissolved solid, total suspended solids, water hardness and residual chlorine levels and results were compared with the Nigerian Standards for Drinking Water Quality guidelines. Findings revealed that while most sources met acceptable pH standards, some, particularly borehole samples, showed elevated levels due to potential contamination. High conductivity values in well water and elevated turbidity in many samples suggest the presence of dissolved ions and particulate matter, posing potential health risks. Water hardness also frequently exceeded safe limits, indicating substantial concentrations of minerals like calcium and magnesium. Notably, sachet water generally conformed to safety standards, likely reflecting effective processing practices. These results emphasize the urgent need for improved water management, treatment practices and community engagement to ensure safe water access. Enhancing water quality in this area could significantly reduce health risks and support overall community well-being.

Keywords: Chanchaga – Nigeria, Drinking water, Hardness, Nigerian Standard for Drinking Water Quality (NSDWQ), Potable water

***Corresponding author: niwoye.asmau@ futminna.edu.ng +2348037302979**

INTRODUCTION

The most essential natural resources needed by every living thing is water [1], and to have safe drinking water is a human right and need for every individual; man, woman and child [2]. Water is basically classified into surface water and ground water. Surface water refers to rivers, streams, lakes, oceans, ponds and wetland while ground water is present below the earth's surface where it is stored in porous soils and rocks [3]. It is used for drinking, bathing, production of food and also recreational purposes.

A report by World Health Organization stated that having potable water is essential in breaking the cycle of poverty because it improves people's health, strength to work and ability to function. Sadly, over 884 million people live without safe drinking water around the world [4]. Nigeria ranks as the eighth most populous country in the world, with a population exceeding 180 million. Unfortunately, less than 30% of this population has access to safe drinking water and reliable water sources. Consequently, Nigeria is among the nations struggling with unsafe water supplies. The poor quality of available drinking water contributes to the prevalence of waterborne illnesses among many Nigerians [5].

The World Health Organization (WHO) defined safe drinking water as water that does not present any significant risk to health over a lifetime of consumption, including different sensitivities that may occur between life stages. Safe drinking water must be aesthetically acceptable and does not contain pathogenic agents and dangerous chemical substances [6] [7] [8]. Despite its importance, however, when it is not available, it becomes the major cause of high morbidity and mortality rates as a result of its limitations in access and quality [9][10]. A myriad of chemical substances and physical properties of water needs to be considered in order to ascertain the safety of water for consumption [11]. The presence of inorganic salts like zinc, iron, copper and manganese in water may cause odour, but it may affect the taste when they are present in high concentration [12]. Activities of humans often cause water pollution thus making the water unfit for use.

[13][14] submitted that agricultural processes involving the use of fertilizers, herbicides and pesticides produce toxic substances that are transported as effluents into water sources and these pollute water bodies. Similarly, effluents from textile industries contain organic dyes with different ions which can alter the composition of water when introduced into it [15]. When surface and ground water are contaminated, the presence of poisonous ions is evident. However, some of these ions may combine with other compounds to form insoluble compounds which can seriously harm the body when ingested [16].

Water quality is a vital factor that significantly influences the biodiversity of aquatic systems. It serves as the medium that supports all the essential needs of fish, including breathing, feeding, reproduction, and growth. High water quality is crucial for the success of freshwater fisheries; when water conditions are favorable, fish survival, growth, and reproduction can reach optimal levels. In contrast, poor water quality can markedly reduce fish production or even render it impossible for fish to thrive [17].

Water quality around the globe faces significant threats from various sources of pollution, including sewage and domestic waste, industrial discharges, agricultural runoff, fertilizers, toxic metals, and detergents. Additionally, groundwater can be contaminated by microorganisms. The presence of these pollutants has detrimental effects on ecosystems. For instance, human exposure to elevated levels of heavy metals in water can lead to serious health concerns such as blood disorders, kidney damage, and neurological issues [3]. This study aims to investigate the physicochemical parameters of drinking water sources in Chanchaga Local Government Area, Minna, Niger State.

MATERIALS AND METHODS

Description of the Study Area

Chanchaga Local Government is one of the twenty-five (25) Local Government Areas in Niger State with its headquarters in Minna, the state capital. It lies between latitude $9^0$35'00" to $9^0$41'00" and longitude $6^0$25'00" to $6^0$37'00". It covers an area of 72 km^2 with total population of 201,429 people [21]. It is made up of 11 wards; Limawa 'a', Limawa 'b', Makera, Minna central, Minna south, Nasarawa 'a', Nasarawa 'b', Nasarawa 'c', SabonGari, Tudun Wada north and Tudun Wada south. The mean maximum temperature remains high throughout the year, hovering about 32^{0}C, particularly between March and June, while the lowest temperature occurs usually between the months of December and January during the harmattan period [18]. Figure 1 is a map of Niger state showing the twenty-five (25) Local Governments Areas and Figure 2 shows the map of Chanchaga Local Government Area indicating sampling points excluding sachet water samples that were purchased directly from vendors.

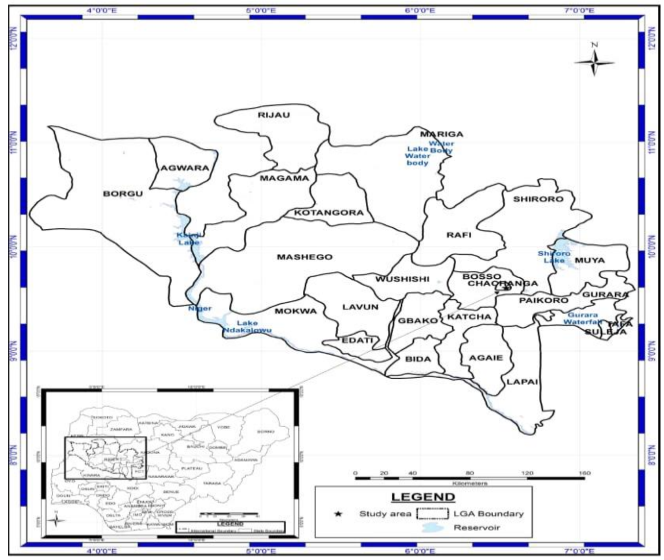

Figure 1 Map of Niger State showing study area

Source: Department of Geography, FUT Minna.

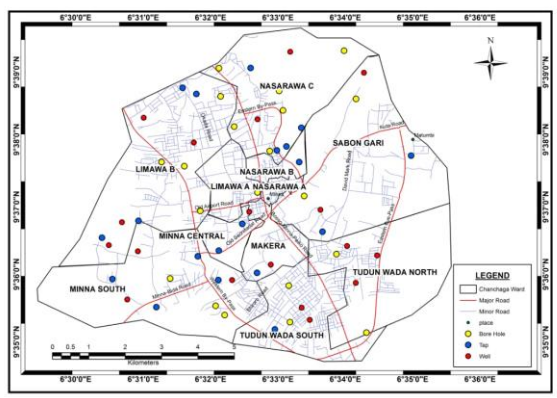

Figure 2 Map of Study Area Showing Sampling Points

Source: Department of Geography, FUT Minna.

Sampling

Drinking water sources that were sampled include: Tap water, well water, packaged sachet water and household stored water. The selection of the regions where the drinking water sources were sampled was based on the availability of the different sources, the frequency of their use and being depended by the large population of the people that resides there.

Sample Collection and Processing

Water samples were collected aseptically using 250mL sterile sampling containers. In collecting water sample from the borehole and tap, the mouth and the outer parts of the borehole and taps were sterilized with the flame of a cigarette lighter, it was allowed to cool by running the water for about 1 minute before water collection. At the point of collection, the containers were rinsed three times with the borehole and tap water sample prior to collection [19] [20]. All of the collected water samples were immediately transported to the laboratory and stored in the refrigerator at 4°C in the laboratory. Water source sampling from wells involved drawing water using a bucket and taking 250mL into a sterile container [19] [21]. This was considered to be more representative of what is actually being consumed by the household. The bottles were properly corked and transported to the laboratory while sachet water samples were purchased from roadside vendors.

Sample Size

A total of 80 samples were collected and analyzed in the study area. They are 20 wells, 20 public taps/pipe borne water, 20 household water sources and 20 different brands of sachet water. These samples were randomly collected from the 11 wards that comprise the study area.

Physicochemical analysis of samples

Physicochemical parameter study is very vital to get exact idea about the quality of water and results can be compared with standard values of drinking water quality guidelines. Recommended methods of American Public Health Association [22] were employed for examination of physicochemical parameters of water samples. Samples were analyzed for pH, turbidity, total hardness, temperature, Electric Conductivity (EC), Total Suspended Solid (TSS), Total dissolved solid (TDS) and Residual chlorine.

pH

A pH meter model 3320 JENWAY (electronic) was initially standardized using buffer solutions (4 and 9). The electrode was rinsed with distilled water, inserted into the water sample, and then the reading was taken [14].

Electric conductivity (EC)

The conductivity of the water samples was determined using a conductivity meter (DOSJ-308A). A volume of 100 mL of distilled water was poured into one beaker, while 100 mL of the water sample was poured into a separate beaker. The conductivity meter was switched on, and its sensor rod was first dipped into the distilled water to standardize the readings. The sensor was then immersed in the beaker containing the water sample, and the conductivity readings were recorded in microSiemens per centimeter (µS/cm). After each measurement, the electrode was rinsed to ensure accurate results for subsequent tests [3].

Turbidity

A two-part calibrated turbidity tube was used, with calibrations from 5-25 turbidity units. The joined tubes were held over a white paper, while slowly pouring the water sample into the tube until the black cross at the bottom is no longer visible. At this point the reading was taken from the side of the tube as the turbidity value of the water sample [2].

Total suspended solids (TSS)

A 100 ml water sample was thoroughly mixed and then measured into a beaker. The sample was filtered using a pre-weighed Whatman filter paper (No. 42). The residue collected on the filter paper was dried in an oven at a temperature of 103°C to 105°C for 30 to 40 minutes. After drying, the filter paper with the residue was cooled and weighed using Equation 1.

Equation 1: Total suspended solid (TSS) = $\frac{W2}{W1} \times 1000$

Where W1 =weight of filter paper

W2 = weight of filter paper + residue [17].

Total dissolved solids (TDS)

A clean and dry evaporating dish was weighed. Then, 100 mL of the water sample was filtered through filter paper, and the filtrate was collected in the evaporating dish. The sample evaporated using a hot water bath. Once all the water had evaporated, the weight of the evaporating dish was recorded, and then it was allowed to cool in a desiccator. The weight of the evaporating dish after cooling was noted, and the difference was calculated using Equation 2.

Equation 2: TDS (g/L) $= \frac{W2}{W1} \times 100$

Where TDS = total dissolved solid, A= final weight of evaporating dish (g), B = initial weight of evaporating dish (g), and V= volume of sample taken (mL) [14].

Residual chlorine

Residual chlorine of samples was determined by taking 25ml of samples and DPD total chlorine was added. Using 0.00564 N Ferrous Ethylene-diammonium Sulphate (FES) cartridge, it was titrated with 0.00564N FES to a colourless end point. After which RC was calculated using equation 2 as described by APHA, [22];

Equation 3: RC $= \frac{Digital\ reading}{100} mg/Litre$

Water hardness

Total hardness was analyzed by titrating a 50 mL water sample with a standard solution of Ethylenediaminetetraacetic acid (EDTA). Drops of EDTA were added at pH 10 using the Eriochrome Black T indicator until the solution changed to a sky-blue color. The hardness was calculated by multiplying the average number of EDTA drops used for the sample by a calibration factor of 20 [17].

Temperature

A mercury-in-glass thermometer (range of 50°C) was used to measure the atmospheric temperature at each station. The thermometer was allowed to stabilize for 2 minutes before recording the reading in degrees Celsius (°C).

RESULTS

Table 1 shows the mean values for physicochemical parameters of well water. From the results, the pH of well water sampled ranged from 6.47 – 8.01 while turbidity values ranged from 5.0- 9.0 NTU. Well water had high total dissolved solid across the 20 sampled sources with well 6 having 1152.01mg/L.

Table 1 Mean Value for Physicochemical Analyses of Well Water Sample in Study Area

Samples	pH	Temp (^{0}C)	Conductivity (µs/Mol)	TSS (mg/L)	TDS (mg/L)	Total Hardness (mg/L)	Turbidity (NTU)
W1	6.57	24	710	362.11	438.11	145.00	7.0
W2	6.68	25	500	485.20	320.04	140.00	7.0
W3	6.94	24	330	385.11	438.11	90.00	7.0
W4	7.02	24	250	635.28	160.09	90.00	9.0
W5	6.92	24	300	245.82	192.01	80.09	7.0
W6	7.39	26	1800	528.21	1152.01	250.00	8.0
W7	7.81	24	1710	681.80	1094.40	240.99	8.0
W8	7.20	25	1630	421.26	1043.20	255.62	8.0
W9	8.01	25	800	731.25	512.00	165.09	9.0
W10	7.20	25	1100	225.21	704.05	135.40	5.0
W11	6.91	24	890	720.24	603.00	169.03	8.0
W12	7.24	24	930	626.01	819.00	171.23	8.0
W13	7.26	24	1100	211.09	712.00	200.17	7.0
W14	6.63	26	1540	119.09	1026.40	231.30	9.0
W15	6.70	24	410	219.09	284.10	129.52	7.0
W16	6.47	24	650	410.00	312.07	192.00	8.0
W17	6.65	25	720	440.00	411.13	140.32	7.0
W18	7.88	25	700	432.00	360.22	120.09	7.0
W19	7.90	24	900	560.07	804.16	136.07	8.0
W20	6.95	24	1050	700.00	112.30	90.00	8.0

Key: W: well water

Table 2 shows the mean values for physicochemical parameters for borehole water. The pH had a range of 7.11 to 8.65 while two borehole samples had high conductivity values. The result showed that borehole water had turbidity levels ranging from 1.0 – 9.0 NTU.

Table 2 Mean Value for Physicochemical Analyses of Bore hole Water from Study Area

Samples	pH	Temp (^{0}C)	Conductivity (µs/Mol)	TSS (mg/L)	TDS (mg/L)	Total Hardness (mg/L)	Turbidity (NTU)
BH1	7.13	25	140	105.00	890.29	125.06	1.0
BH2	7.61	25	520	114.30	341.82	265.93	4.0
BH3	7.53	25	110	93.21	74.81	135.00	2.0
BH4	7.56	26	120	61.40	75.24	130.00	4.0
BH5	7.67	25	100	75.83	60.88	105.32	5.0
BH6	8.60	25	1100	63.25	703.21	500.06	6.0
BH7	8.65	24	1	38.41	0.64	60.38	3.0
BH8	8.40	25	790	101.83	508.21	370.11	5.0
BH9	8.60	24	1700	93.21	1088.00	550.04	5.0
BH10	8.45	25	580	84.75	362.80	345.26	9.0
BH11	8.43	25	200	80.21	83.05	185.20	2.0
BH12	8.47	25	260	81.06	83.44	192.64	5.0
BH13	7.54	25	410	112.08	101.09	235.11	5.0
BH14	7.59	26	130	61.44	78.20	138.75	4.0
BH15	7.66	25	210	80.90	83.00	183.50	4.0
BH16	7.60	24	260	81.11	83.44	192.00	3.0
BH17	7.11	25	100	75.70	60.29	135.33	6.0
BH18	7.38	25	500	114.36	311.08	262.04	6.0
BH19	8.57	24	200	80.40	83.00	185.44	1.0

BH20	7.67	24	150	76.53	79.46	141.23	5.0

Key: BH: Borehole water

Table 3 shows the mean values for physicochemical parameters for tap water samples. The residual chlorine values ranged from 0.08 – 3.50 mg/L while the values for total suspended solids ranged from 118.00 – 1001.11 mg/L. From the results, tap water had total hardness that ranged from 126.77 to 408.94 mg/L.

Table 3 Mean Value for Physicochemical Analysis of Tap Water from Study Area

Sample	pH	Temp. (^{0}C)	Cond. (µs/Mol)	TSS (mg/L)	TDS (mg/L)	T hardness (mg/L)	Turbidity (NTU)	Residual chlorine (mg/L)
T1	7.90	25	110	309.81	70.40	135.00	6.0	2.13
T2	7.95	24	210	382.61	134.63	195.21	6.0	2.13
T3	8.30	24	540	394.62	341.60	335.26	8.0	0.71
T4	7.86	24	1100	529.40	704.13	408.11	6.0	1.13
T5	7.91	24	370	310.00	144.08	196.70	6.0	2.24
T6	7.92	25	250	390.73	139.20	192.82	7.0	2.45
T7	7.85	25	550	401.88	389.09	310.26	7.0	0.73
T8	7.64	24	160	205.00	1171.10	137.00	5.0	0.06
T9	7.87	24	170	324.25	70.80	135.21	5.0	2.86
T10	8.40	24	240	390.00	138.64	189.77	5.0	2.11
T11	8.32	24	210	388.46	137.11	192.02	6.0	3.50
T12	8.44	24	320	396.23	140.33	197.41	6.0	3.60
T13	8.53	25	1410	340.19	1143.18	411.96	6.0	0.08
T14	7.95	24	600	125.00	56.51	128.91	7.0	2.77
T15	8.30	24	300	118.36	52.65	128.11	7.0	3.00
T16	7.90	24	140	160.93	72.74	133.67	7.0	2.08
T17	7.56	25	200	118.00	52.10	126.77	6.0	3.13
T18	7.01	25	460	306.62	274.34	200.08	5.0	0.73
T19	7.11	24	930	1001.11	609.11	358.51	6.0	0.19
T20	7.63	25	1200	670.01	1120.03	408.94	6.0	0.16

Key: T= Tap

Results for the mean values for physicochemical parameters for sachet water shows that while the residual chlorine values ranged from 0.32- 4.25 mg/L, sachet water had relatively low total dissolved solids, with the highest value recorded being 145.28 mg/L.

Table 4 Mean Value for Physicochemical Analysis of Sachet Water in from Study Area

Sample	pH	Temp. (^{0}C)	Cond. (µs/Mol)	TSS (mg/L)	TDS (mg/L)	T hardness (mg/L)	Turbidity (NTU)	Residual chlorine (mg/L)
Sw1	8.21	25	1	15.35	0.72	67.04	4.0	0.71
Sw2	8.20	26	40	14.90	25.60	145.28	2.0	0.71
Sw3	8.30	25	90	10.20	51.25	130.11	2.0	2.84
Sw4	8.36	24	80	18.35	58.30	100.63	4.0	4.25
Sw5	8.09	25	100	15.55	65.21	135.20	6.0	1.38
Sw6	8.32	25	50	16.20	32.80	50.90	2.0	0.35
Sw7	8.27	25	80	21.85	51.20	90.30	4.0	0.35
Sw8	8.34	24	30	15.43	25.40	100.32	2.0	0.45
Sw9	8.06	24	20	14.79	23.06	128.74	2.0	0.71
Sw10	8.24	24	2	18.01	0.86	120.66	2.0	0.71
Sw11	8.23	25	20	11.74	23.56	98.76	3.0	2.14
Sw12	8.09	24	50	15.56	31.94	90.00	2.0	2.36
Sw13	7.53	25	30	11.45	25.38	115.04	2.0	3.25
Sw14	7.04	24	30	12.62	25.36	123.60	2.0	2.84
Sw15	7.89	24	70	20.09	53.10	120.70	2.0	1.79
Sw16	8.11	24	10	13.44	20.76	96.44	2.0	0.65
Sw17	8.40	24	100	17.09	63.06	93.27	2.0	1.63
Sw18	8.30	24	120	12.08	68.43	124.73	2.0	1.66
Sw19	8.38	24	100	14.36	63.10	74.74	2.0	1.43
Sw20	7.52	24	60	16.00	32.64	80.09	2.0	0.32

Key Sw= sachet water

The results for mean physicochemical parameters of drinking water in Chanchaga Local Government Area shows that there was no significant difference between the mean values for pH of borehole, sachet and tap waters, and all samples were within the permissible limits by drinking water standard guidelines. There was significant difference between borehole water and well water values. Results for water hardness showed significant difference among all drinking water samples with borehole water having the highest mean value at 221.92 mg/L, while sachet water had the least mean value at 104.33 mg/L and it is the only water source that conformed to the drinking water guidelines

Samples	pH	Temp (^{0}C)	Conductivity (µS/cm)	TDS (mg/L)	TSS (mg/L)	Hardness (mg/L)	Turbidity (NTU)	Residual chlorine (mg/L)
BOREHOLE WATER	7.91±0.119b (7.11-8.65)	24.85±0.13a (24-26)	392.55±99.66a (1.00-1700)	258±69.26b (0.64-1088)	84±4.39b (38-114)	221.92±28.92c (60-550)	4.25±0.43b (1-9)	_
WELL WATER	7.12±0.106a (6.47-8.01)	24.50±0.14a (24-26)	901±105.14b (250-1800)	591±69.24c (160-1152)	430±47.67c (112-804)	158.57±12.31b (80-256)	7.60±0.21c (5-9)	_

SACHET WATER	8.09±0.07 8b (7.04-8.40)	24.45±0.1 4a (24-26)	180.50±38. 34a (10-700)	37±4.63a (0.72-68.43)	15.30±0.65a (10.2-21.9)	104.33±5.54 a (51-145)	2.55±0.2 5a (2-6)	1.53±0.25a (0.32-4,25)
TAP WATER	7.92±0.08 9b (7.08-8.45)	24.50±0.1 6a (24-26)	304.50±26. 42a (110-540)	38±4.53a (0.73-58.43)	338.23±10. 54a (208.2-394.6)	184.49±16.4 9bc (114-335)	6.90±0.2 6c (5-9)	2.41±0.13b (0.71-3.55)
NSDWQ	6.5-8.5	Ambient	1000	1000	25	150	5.0	_
WHO	6.5-8.5	40	400	1000	_	_	5.0	5

Superscripts with the same letters in each column are not significantly different (*P>0.05*) , **World Health Organization, (2011). *Nigerian Standard for Drinking Water Quality, (2007)

DISCUSSION

The importance and effects of water to health and the well-being of man, animal and the entire nation cannot be overestimated, as one of the natural resources which is necessary for existence and survival of all human being is potable water [23]. A careful look at table 4.5 shows that mean pH values of water samples ranged from 6.47 – 8.65. Most water samples had pH slightly above 7.0 which suggests a tendency for slight alkalinity of water samples; however, all water samples were between the range stipulated by NSDWQ and WHO (6.5 – 8.5) except for a borehole sample which had 8.65. This slight deviation may be due to the presence of a greater number of organic matter or alkaline substances. Results from this work revealed that the pH of sampled sachet water ranged from 7.04 -8.40. A more acidic pH was reported by [24], with a range of 6.5-8.5 for pH of sachet water samples. The electric conductivity (EC) (which is the degree of electric current transmission due to the ionic concentration) of water samples ranged from 1.0000µS/cm-180000µS/cm. Well water samples had high results for electric conductivity with results ranging from 330- > 1700 00µS/cm. A similar result was recorded by [25] who reported a high value for EC (256.00µS/cm to 1488.00µS/cm) in well water samples, a report which is in contrast to the results of [26] that reported a low EC for hand dug well. The variation in these results may be as a result of different physical features of the well sampled e.g. presence of protective covering and concrete internal ringing that can prevent the well water from external particles. This study showed that sampled borehole water had an EC range from 0100µS/cm to >160000µS/cm. This result is in contrast with that of [24] who recorded lower EC between 21.50 - 224 µS/cm in sampled borehole water. The higher conductivity value in this study indicates that there are more chemicals dissolved in the water. A total of 30 water samples tested had electric conductivity values above the World Health Organization standard value of 400.0000µS/cm for potable water but most were in line with [6] guideline of a maximum EC of 100000µS/cm. However, all sachet water sampled complied with the stipulated standard for drinking water guideline as results ranged from 1-10000µS/cm. Samples with values of electric conductivity higher than the standard are usually as a result of an excessive concentration of dissolved ionic solids within the water samples. It should be noted that pure water is naturally a poor conductor of electricity and heat. The temperature of all water samples ranged from 24^0C - 26^0C, this result corresponds to that of [18] that reported similar result from studied tap, hand dug well and borehole water sources. Turbidity which is the measure of clarity of water samples ranged from 1NTU to 9NTU. Forty (40) water samples, most from the well water samples had turbidity level above the stipulated standard of 5.00 NTU for potable water. Only a sample of sachet water failed to meet the standard limit for turbidity in drinking water with turbidity of 6.0 NTU. More often than not, turbidity is brought about by the presence of colloidal matter and/or suspended particles in water. Results from the value of the total suspended solids (TSS) which are particles that are larger than 2 microns found in water column revealed that most water samples fall short of the required standard value as set by NSDWQ of 25mg/L. The values of TSS from samples ranged from 10.20 mg/L to 804 mg/L. the result showed that all sachet water conformed with the set standard for drinking water guideline with range from 10.20 mg/L to 20.09 mg/L. The high value of TSS in majority of water samples may be attributed to the presence of high inorganic materials in water samples, however organic materials from decomposing materials can also contribute to the concentration of TSS in water samples. The results for total dissolved solids (TDS) in water samples range from 0.64 mg/L to 1152 mg/L. TDS are a leading cause of turbidity in drinking water. TDS measures the total organic and inorganic materials present in water samples. These solids are primarily minerals, salts and organic matters that can be a general indicator of water quality. Eight (8) samples from the study area failed to meet the NSDWQ and WHO stipulated maximum of 1000 mg/L TDS for potable water.

Similarly, from the results, the values for total hardness of water ranged from 51 mg/L to 550 mg/L. Thirty-three (33) samples had values above stipulated standard of 150 mg/L. Generally, Water hardness is the measure of the capacity of water to react with soap and this hardness is caused by the presence of dissolved calcium and magnesium in water. Hard water requires more soap to produce lather and it often produces noticeable deposit of precipitate in containers. Water containing calcium carbonate at concentrations below 60mg/L is generally soft, 60 -120mg/L is moderately hard, 120-180mg/L, hard, and more than 180mg/L is very hard [27][28]. However, both calcium and magnesium are essential minerals and beneficial to human health in diverse respects. Inadequate intake of calcium have been associated with increased risks of osteoporosis, nephrolithiasis (kidney stone), obesity, colorectal cancer, insulin resistance, stroke, hypertension, coronary artery disease. Individuals are protected from excess intake of calcium by a tightly regulated intestinal absorption and elimination mechanism via the action of 1, 25-dihydroxyvitamin D. When calcium is absorbed in excess of need, the excess is excreted by the kidney in healthy people without renal impairment [28].

Deficiency of magnesium have been implicated in the pathogenesis of hypertension, also cardiac arrhythmias of ventricular and atrial origin have been reported in patients with hypomagnesaemia. A serious cardiac arrhythimia, Torsade de Pointes is treated with intravenous magnesium therapy. Also, oral magnesium supplementation improves insulin sensitivity and metabolic control in type 2 diabetes mellitus. On the other hand, excess intake of magnesium salts may cause a temporary adaptable change in bowel habits (diarrhea) i.e. drinking water in which both magnesium and sulfate are present at high concentrations above 250mg/L each can have laxative effects (27). From the study, most well water samples and borehole samples had very high values. The may be solely due to the presence of high concentration of carbonates and dissolved solids in the aquifers. Based on the results of residual chlorine, samples had a range between 0.32mg/L to 4.25 mg/L. Of all the 40 samples tested for residual chlorine, 22 samples (14 sachet water and 8 tap water samples) had residual chlorine value below are the stipulated minimum of 2mg/L for potable water. Chlorine in drinking water is used as disinfectant to kill microorganisms, however if in excess in drinking water, it can confer unpleasant taste to water and can dissuade people from using the supply.

CONCLUSION

Access to good quality drinking water is a matter of importance that cannot be overemphasized. Human activities, coupled with rise in population pose a great pressure on availability of safe drinking water. However, effective water quality monitoring could assist in checking how human activities affect the quality of our water and impact of the introduction of pollutants on water quality. The result of the physicochemical analysis from this study revealed that most water sampled have values within the stipulated permissible limits for drinking water quality laid down by regulatory bodies. However, most borehole water and well water had total hardness above stipulated standard and well water had high turbidity value.

RECOMMENDATIONS

1. Water quality monitoring and assessments should be a continuous process that should be encouraged
2. Appropriate treatment should be done accordingly to seasonal variation with respect to the important physicochemical parameters
3. Proper sanitation should be strictly observed around ground water sources
4. Pipes conveying tap water should be neatly laid in the earth and not in dirty drainage systems as seen in some places in the study area.

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REFERENCES

1. Job OS[1], Bala JD[1], Abubakar AN[2], Mustapha A[1], Innocent OM[3] and Friday NN[2] (2024).Nanotechnology in Water Quality: Assessment Application for Microbial Detection and Control *Mini Review* Volume 9 Issue DOI: 10.23880/oajmb16000308

2. Grönwall, J and Danert, K. (2020). Regarding groundwater and drinking water access through a human rights lens: Self-supply as a norm. *Water*, *12*(2), 419.
3. Nsi, E. W., Uwanta, E. J., Akpakpan, A. E and Ekwere, I. O. (2020). Analytical Assessment of Borehole Water in Some Local Government Areas of AkwaIbom State, South-South Nigeria. *European Scientific Journal*, *6*(13), 122-136.
4. Shultz, C. J. (2022). Macroservicing: a commentary on services as constructive engagement for sustainable peace, prosperity and well-being. *Journal of Services Marketing*, *36*(7), 877-884.
5. Eludoyin, A. O. (2021). Accessibility to safe drinking water in selected urban communities in southwest Nigeria. *Water Productivity Journal*, *1*(2), 1-10.
6. Nigerian Standard for Drinking Water Quality (2007). ICS 13.060.20 Price Group D © SON Guyton and Hall (1996). Medical physiology. 9th Edition, 357-362.
7. World Health Organization (2022). Guidelines for drinking-water quality: incorporating the first and second addenda. World Health Organization.
8. Kundu, D., Dutta, D., Joseph, A., Jana, A., Samanta, P., Bhakta, J. N and Alreshidi, M. A. (2024). Safeguarding drinking water: A brief insight on characteristics, treatments and risk assessment of contamination. *Environmental Monitoring and Assessment*, *196*(2), 180.
9. Okonkwo E.C.[a], EdidiongA. Essien [b], Evidence Akhayere [b], Muhammad A bid [a], Doga Kavaz [d], Tahir A.H. Ratlamwala. (2018).Thermal performance analysis of a parabolic trough collector using water-based green-synthesized nanofluids. *ELSEVIER Solar Energy* Volume 170; 658-670
10. Bala, J. D., Eniolorunda, M.F., Abdulraham, A. A., Adabara, N. U., Kuta, F. A., Adedeji, A. S and Agboola, R. K (2019). Bacteriological water quality assessment of stored borehole and tap water in Minna metropolis, Nigeria. *Nigerian Journal of Water Resources*, 5(1), 22- 29.
11. World Health Organization (2022). Guidelines for drinking-water quality: incorporating the first and second addenda. World Health Organization
12. Roy, S. (2022). Sources and Treatment of Taste and Odour in Water-A Review. *Water and Energy International*, *65*(7), 12-16.
13. Wato, T and Amare, M (2020). The agricultural water pollution and its minimization strategies—A review. *Journal of Resources Development and Manag*ement, *64*, 10-22.
14. Rad, S. M., Ray, A. K., and Barghi, S. (2022). Water pollution and agriculture pesticide. *Clean Technologies*, *4*(4), 1088-1102.
15. Uddin, F. (2021). Environmental hazard in textile dyeing wastewater from local textile industry. *Cellulose*, *28*(17), 10715-10739.

16. Ikeme, C. H., Dioha, I. J., Olasusi, K. A and Promise, U. C (2014). Physico-chemical analysis of selected borehole water in Umuihi town Imo state, Nigeria. *International Journal of Scientific and Engineering Research*, 5(8), 681-685.

17. Bosede, O. F., Modinot, A. O., Idowu, A. F. Akin-Obasola, B. J and Moradeyo, O. S (2024) Physico-chemical Parameters Study in Oriyanrin Lower Ogun River Water Body. *Journal of Agricultural Earth & Environmental Sciences 3 (4), 01*, *6*.

18. Waheed, G. A., Abdullahi, I., Akobundu, N. A., Ibrahim, A. A., Adekola, A. A and Tauheed, Y (2016). Evaluation of groundwater potential of Chanchaga area, Minna, North-central Nigeria. *American Journal of Innovative Research and Applied Sciences*, 2(1), 1-9. Nigeria. *European Scientific Journal*, *6*(13), 122-136.

19. Bala, J. D. (2006). Occurrence of fecal coliform in water sources in Jimeta-Yola. *Journal of Environmental Science*, *10*(2), 64-66.

20. Kihupi, S. M. C., Yohana, L., Saria, J. A and Malebo, H. M (2016). Fecal contamination of drinking water in Tanzania's commercial capital, Dar Es Salaam: Implication on health of the consumers. *Journal of public health and epidemiology*, 2(1), 1025.

21. Too, J.K., Sang, W. K., Ng'ang'a, Z. and Ngayo, M. O (2016).Faecal contamination of drinking water in Kericho District, Western Kenya: role of source and household water handling and hygiene practices. *Journal of Water and Health* 14 (4), 662-671.

22. APHA (1995). American Public Health Association, Standard Methods for the Examination of Water and Wastewater, APHA, AWWA, WEF. APHA Publication.

23. Paul, S and Lama, W. (2022). Water Use and Its Crisis in the World. In *Responsible Consumption and Production* (pp. 853-862). Cham: Springer International Publishing.

24. Temaugee, S. T., Wariebi, A and Saakorun, M. I. (2020). Seasonal variation of electrical conductivity of groundwater and its implication on the residents of Lafia municipal area, Nasarawa State, Nigeria. *International Journal of Environmental Protection and Policy*, *8*(1), 22-30.

25. Ayegbo, K. S., Ogundipe, K. E., Olimaro, G., Ajimalofin, A. D. and Akinwumi, I. I. (2021, March). Water quality of selected sachet water brands sold in Sango-Ota, Nigeria. In *IOP Conference Series: Materials Science and Engineering* (Vol. 1036, No. 1, p. 012011). IOP Publishing.

26. Pauline, E. A., Osagie, I., Razzaq, A. A., and Omoniyi, M (2018). Experimental determination of drinking water quality in Abeokuta Metropolis, South-Western Nigeria. *International Journal of Advances in Scientific Research and Engineering*, *4*(12), 241-256.

27. Akanwa, A. O and Okonkwo, A. U (2018). Challenges of water and sanitation coverage in Nigeria: Implications for best practices. *Journal of Analytical Chemistry*, 2(4), 15-27.

28. World Health Organization (2011). Guidelines for Drinking-Water Quality: 4th Edition. http://apps.who.int/iris/bitstream/10665/44584/1/ 9789241548151_eng.pdf.