EFFECT OF ENVIRONMENTAL CONDITION ON THE QUALITY OF WATER FROM HAND DUG WELL WITHIN BAUCHI METROPOLIS

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Abstract

The research aimed at investigating the quality of water from Hand dug wells (HDWs) from selected areas within Bauchi metropolis, Nigeria for the Physical, Chemical and Bacteriological parameters. Names of the areas selected are; Gwallagwa, Tura, Bakaro, Jaja, Nassarawa, D/Tanshi, Makama and Doya. Ten water Samples were collected from hand dug Wells in the aforementioned areas. The study used standard laboratory techniques for the water quality analysis and the results were evaluated based on the benchmark standards of the World Health Organisation (WHO) and Nigerian Standard of Drinking Water Quality (NSDWQ). A random sampling method was used to select 10 HDWs for the water quality analysis. Excel 2007 software was used for data analysis and the results were presented in Tables and Graph. The results of water quality from HDWs were found to fall within or below or in excess of the safety limits of drinkable water based on the benchmark standard set by the WHO and the NSDWQ. The concentration of the following parameters

Keywords: water quality analysis, parameters, drinking water, hand dug wells, Bauchi Nigeria.

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were examined to assess the quality of the water : PH(3.39-7.96 mg/l), Temperature(29.8-32.2^{o}c), TDS(500-1170.5 mg/l), Colour(40% clear), Odour(Offensive), Total hardness (119-217 mg/l), Turbidity(0.4-6.9 mg/l), Chloride(172-423 mg/l), Calcium(96-312 mg/l), Magnesium (34-256 mg/l), Iron(0.06-0.14 mg/l), EC(1000-2341 mg/l), Nitrate(63.9-80.7 mg/l), Nitrite(0.0132-4.95 mg/l), Flouride(0.06-2.6 mg/l), Sodium (0.111-1.8 mg/l), Copper(0.15-1.78 mg/l), Phosphate (40.31-73.4 mg/l),Total coliform (0-1 Cfu), and Faecal Coliform (0-4 Cfu).Thesult of the analysis revealed that the quality of water from HDWs in the selected areas within Bauchi metropolis were not suitable for drinking due to high concentration of the contaminants.The study recommended regular monitoring of ground water quality and a further research to determine the sources of ground water pollution in the study area.

Introduction

Survival of living things solemnly depends on water (Alvarez, 2019). A limited resource that needs sustainable management. Globally, the sustainable development goal for every society depends on factors such as public health, food security, industrial growth, livelihood and economic development (Hosni, 2020). These cannot be achieved without quality water. The quality and quantity of water resource worldwide is a subject of ongoing concern (Jagaba,2019). Thus, knowledge of the impact of pollution sources on water resources is essential in environmental water studies and monitoring programs are being increasingly used due to an increase in water pollution incidents (Onyekwelu, 2021). Evaluation of water quality is complicated because water pollution is caused by both natural and human factors (Alam,2021). Human

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factors such as the release of effluents from human waste, chemical discharges, pesticides, fertilizers. Natural factors to include; temporal changes in the hydrologic cycle, the origin and constitution of the recharged water. Water pollution is a threat to human health, economic development, and social prosperity (Phan, 2019).

Water is very important to the human body. Every one of your cells, organs and tissues use water to help with temperature regulation, keeping hydrated and maintaining bodily functions (Sánchez, 2021). In addition, water acts as a lubricant and cushions your joints. Drinking water is great for your overall health. According to the center for disease control said everyone should drink water daily. Drinking water is very good for your heart (CDC, 2019). Your heart is working continually to pump 2,000 gallons of blood throughout your body a day (Ayodele, 2019). By drinking water and keeping hydrated, you are helping your heart do its job. Your heart is able to pump blood more easily when hydrated (consuming more water than you are losing) and allows the rest of the muscles in your body to work much better. Water naturally has zero calories, therefore, substituting water for soda or juice can reduce your caloric intake. Switching out one 20 oz. sugary beverage for water reduces your caloric intake by 240 calories (Abubakar,2020).

Water is an inorganic, transparent, tasteless, odorless, and nearly colorless chemical substance, which is the main constituent of Earth's hydrosphere and the fluids of all known living organisms (in which it acts as a solvent). It is vital for all known forms of life, even though it provides no calories or organic nutrients. Its chemical formula is H_2O, meaning that each of its molecules contains one oxygen and two hydrogen atoms, connected by covalent bonds. Two hydrogen atoms are attached to one oxygen atom at an angle of 104.45°.

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"Water" is the name of the liquid state of H_2O at standard ambient temperature and pressure. It forms precipitation in the form of rain and aerosols in the form of fog. Clouds are formed from suspended droplets of water and ice, its solid state. When finely divided, crystalline ice may precipitate in the form of snow. The gaseous state of water is steam or water vapor. (Jambolancium, 2021).

Jambolancium (2021).He further said Water plays an important role in the world economy. Approximately 70% of the freshwater used by humans goes to agriculture. Fishing in salt and fresh water bodies is a major source of food for many parts of the world. Much of the long- distance trade of commodities (such as oil, natural gas, and manufactured products) is transported by boats through seas, rivers, lakes, and canals. Large quantities of water, ice, and steam are used for cooling and heating, in industry and homes. Water is an excellent solvent for a wide variety of substances both mineral and organic; as such it is widely used in industrial processes, and in cooking and washing. Water, ice and snow are also central to many sports and other forms of entertainment, such as swimming, pleasure boating, boat racing, surfing, sport fishing, diving, ice skating and skiing.

Potable water is water that is safe to drink or use for food preparation. The amount of drinking water required to maintain good health varies, and depends on physical activity level, age, health-related issues, and environmental conditions. For those who work in a hot climate, up to 16 litres a day may be required. Typically in developed countries, tap water meets drinking water quality standards, even though only a small proportion is actually consumed or used in food preparation. Other typical uses include washing, toilets, and irrigation. Greywater may also be used for toilets or irrigation. Its use for irrigation however may be associated with risks. Water may also be unacceptable due to levels of toxins or

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suspended solids. The amount of drinking water required per day is variable. It depends on physical activity, age, health, and environmental conditions. In the United States, the reference daily intake (RDI) for total water is 3.7 litres (130 imp fl oz; 130 US fl oz) per day for human males older than 18, and 2.7 litres (0.59 imp gal; 0.71 US gal) per day for human females older than 18 which includes drinking water, water in beverages, and water contained in food. The European Food Safety Authority recommends 2.0 litres (70 imp fl oz; 68 US fl oz) per day for adult women and 2.5 litres (88 imp fl oz; 85 US fl oz) per day for adult men. An individual's thirst provides a better guide for how much water they require rather than a specific, fixed quantity. Americans, on average, drink one litre (35 imp fl oz; 34 US fl oz) of water a day and 95% drink less than three litres (110 imp fl oz; 100 US fl oz) per day. Physical exercise and heat exposure cause loss of water and therefore may induce thirst and greater water intake. Physically active individuals in hot climates may have total daily water needs of 6 litres (210 imp fl oz; 200 US fl oz) or more. (BASWB/TP/037, 2019).

Nigeria is so rich in water resources that many of its 36 states are named after rivers. In addition to surface water found in nearly every part of the country, there's also plenty stored in the ground. The country has 215 cubic kilometres a year of available surface water. This is a lot higher than many African countries, particularly those in the southern and northern regions of the continent. South Africa, for example, has about 49 cubic kilometres a year. But this isn't the case. In fact, only 19% of Nigeria's population has access to safe drinking water. Although 67% of people have basic water supply, access is uneven. In cities, 82% of people have a basic supply. In rural areas, only 54% do. Wealth also distorts access. About 80% of wealthy Nigerians have access to at least a basic water supply, in comparison to only 48% of poor Nigerians. The lack of

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accessible, reliable and safe drinking water, together with poor sanitation and hygiene, is estimated to cost Nigeria about USD$1.3 billion in access time, loss due to premature death, productive time lost and health care costs (BASWB/TP/037, 2019).

Why is this happening in a country with abundant water resources? Nigeria suffers from "economic water scarcity" – the inability to properly manage, use and protect water resources for socioeconomic development and environmental sustainability. Nigeria aims to provide water that meets the standards set out by the World Health Organisation. In practice, poor regulatory, legal and institutional frameworks prevent this. It's no surprise that potentially toxic concentrations of metals have been reported in Nigeria's drinking water. Another major problem is that the country has adopted a "control and command" approach to water resource management. It focuses on engineering physical infrastructure and excludes other perspectives. This means that authorities managing water don't sufficiently engage with the people using it. Infrastructure in communities tends to collapse when users aren't involved in planning or running it. There has also been little coordination between federal, state and local government agencies (Buck, et al., 2021). New research shows that water management needs different approaches. These include broader stakeholder involvement, collaboration between sectors, more attention to the human dimensions of management, and recognition of the economic, social, ecological and cultural values of water.

South Africa provides a legal example that Nigeria can learn from. The South African National Water Act provides for the basic rights of humans and the environment. The first prescribes the minimum amount and quality of water required for domestic activities and hygiene, to which everyone is entitled. The latter prescribes the minimum amount and quality of water to which the environment is entitled to maintain and

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protect ecosystems. The Act also expects ordinary citizens to have a say in the water sector. In Europe, the European Commission Water Framework Directive also provides for broader stakeholder involvement in the management of water resources (Birch, et al., 2019).

Provision of portable water for drinking and domestic purpose which is essential to public health and wellbeing is a source of concerned in Bauchi metropolis, in which most of its populace, especially the rural dwellers depend on the hand dug wells for the source of water for drinking and domestic activities. Most of these wells are dug near source of pollution like pit latrine, drainage, septic tanks soak ways and barn yards. When rain water reaches the ground it dissolve some of these mineral and organic substance capable of causing disease and adverse physiological effect to human and animal which result in committing a lot resource for the treatment of water related diseases. The yearning aspiration of Bauchi state government is the provision of potable and safe water. Thus the aim of the research is to study the effect of environmental condition on quality of water from hand dug well within Bauchi Metropolis.

METHODOLOGY

Study Area

Bauchi State (Hausa: *Jihar Bauchi*) takes its name from the historic town of Bauchi, which also serves as the capital city and is located in the North East of Nigeria. The state was formed in 1976 when the former North-Eastern State was broken up. It originally included the area now in Gombe State, which became a distinct state in 1996. Bauchi State occupies a total land area of 49,119 km^2 (18,965 sq mi) representing about 5.3% of Nigeria's total land mass and is located between latitudes 9° 3' and 12° 3' north and longitudes 8° 50' and 11° east.

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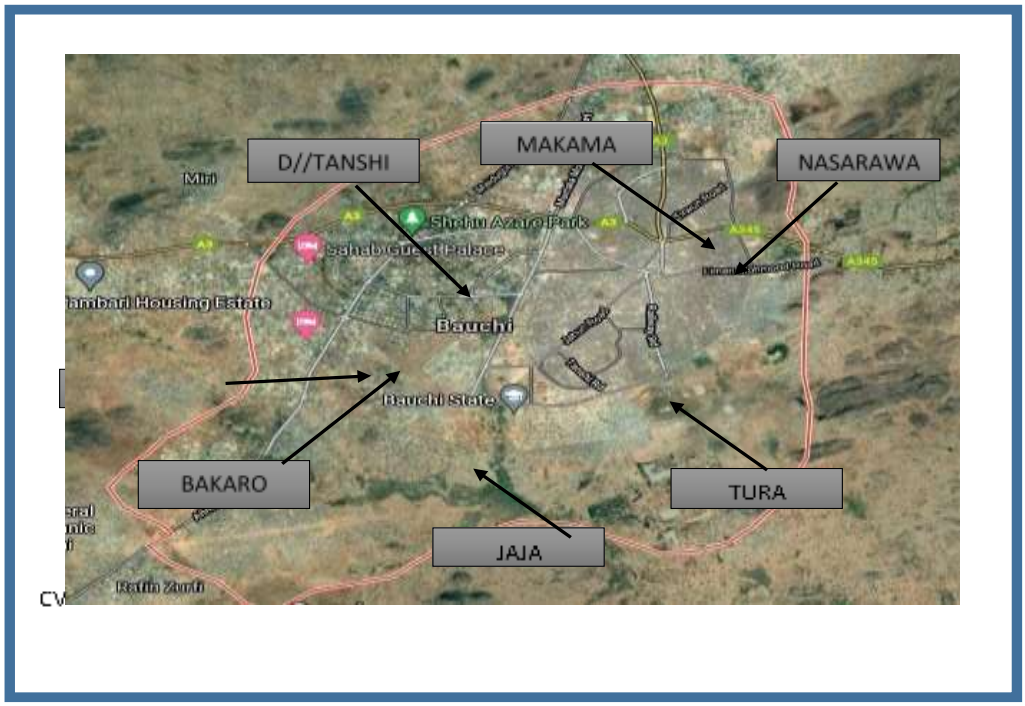
Map of Bauchi metropolis showing the location



Water Sampling

Water sampling followed by analysis in the laboratory is common to monitor specific pollutants such as trace organic and inorganic chemicals (pesticides, hydrocarbons, toxic metals) and pathogens like Esherichia coli bacteria (Environmental and pollution science Third Edition, 2019). Monitoring of ground water chemistry and purification efficacy, water sampling and analysis for selected organic contaminants, water chemistry is performed at selected Wells. Sampling water for subsequent microbial analysis is somewhat easier than sampling soils for a variety of reasons. First, because water tends to be more homogeneous than soils, there is less point- to- point variability between two samples collected within the same vicinity. Second,it is often physically easier to pump and hoselines (James

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G.,2020). Thus known volumes of water can be collected for known depths with relative ease. Amounts of water collected depends on the sample being evaluated, but can vary from 100ml for potable drinking water collected from water utilities to 1000l for groundwater samples (G. Speight, 2020). Sampling strategy is also less complicated for water samples. In many cases, because water is mobile, a set number of bulk samples are simply collected from the same point at various time intervals (James G., 2020). Such a strategy would be useful, for example, in sampling a well water for a drinking water treatment plant.

Although collection of a water sample is relatively easy, processing the sample before microbial analysis can be more difficult. Water samples should be cooled to 40^{0}c as soon as possible after collection and analyzed for bacteria. Depending on the type of microbial analysis that will be performed, samples can also be frozen. Microbial populations in water samples change much more rapidly than those in soil samples.

Sample Collection

In order to get the most accurate results, sample needed to be collected properly. In collecting the samples for physical and chemical examination, the following requirements was satisfied:-

- Samples were collected, stored, and dispatched in suitable sterilized bottles.
- Great care was taken during sampling to prevent contamination of the samples being collected.
- In order to prevent any significant change in the composition of collected sample prior to it's analysis, the samples was collected properly and dispatched as soon as possible.
- DE chlorination was practiced when the sampled water contained chlorine residual to stop the bactericidal effects of chlorine. Sodium

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this sulphate was an acceptable DE chlorinating agent, added before sterilization of bottles.

- Air space was left in the bottle to allow for mixture of the sample

The bottle was opened only at the time of filling. The bottle held at the base, was filled without rinsing, stopper and foil was replaced and secured, avoiding any accidental contamination by human and transportation means.

Method –

i. ***Analytical Determination of Physical Parameters:-*** Results of water physical parameter analysis are usually expressed in parts per million (PPM) by weight, this also correspond to milligram per litre (mg/l).

ii. ***Determination of chemical parameters***

iii. ***Determination of Microbiological Organism.***

RESULT AND DISCUSSION

In this study the concentration of water from hand dug well quality parameters within Bauchi metropolis of some selected location were investigated and results were shown in table and also presented graphically. The discussions of results are hereby presented below.

Physical Parameters

Sample Code	Sample	lateral Dista	PARAMETERS Tempera	TD	PH	Colou	Odou
A	Gwalla	14m	31.6^{o}C	662	5.0	clear	**fre**
B	Gwalla	8m	32.2^{o}C	90	4.8	clear	**earthy**
C	Tura	7m	31.9^{o}C	896	3.3	cloud	**fre**
D	Bakaro	6m	31.5^{o}C	946	3.9	cloud	**fishy**

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E	Jaja	1m	32.0^{o}C	1170.	4.4	cloud	**fishy**
F	Nasarra	7m	31.9^{o}C	90	4.57	cloud	**fishy**
G	D/Tanshi	2m	32.1^{o}C	1051	5.19	cloudy	**musty**
H	Makama	8m	29.8^{o}C.	910.	6.7	clear	**earthy**
I	Doya	6m	30.4^{o}C	958	7.9	clou	**musty**
J	**Doya**	**21m**	**30.0^{o}C**	**500**	**7.8**	**clear**	**free**

Table 1

Chemical Parametetrs

Sample Code	Sample Location	lateral Distance	PARAMETERS (mg/l) Total Hardness	Turbidity	Iron	EC	Nitrate	Nitrite
A	Gwallaoa	14m	179	6.9	0.08	1324	79.8	0.1683
B	Gwallaoa	8m	193	6.2	0.07	1817	77.4	0.1625
C	Tura	7m	134	6.0	0.12	1792	78.5	4.95
D	Bakaro	6m	128	1.9	0.12	1892	68.7	0.0363
E	Jaia	1m	162	0.4.	0.14	2341	80.7	0.0132
F	Nasarrawa	7m	173	4.2	0.12	1801	78.3	0.0462
G	D/Tanshi	2m	119	5.3	0.14	2102	74.3	0.231
H	Makama	8m	198	5.7	0.09	1821	69.6	0.9636
I	Dova	6m	201	3.2	0.13	1917	78.5	0.0452
J	Doya	21m	217	5.2	0.06	1000	63.9	0.0463

Table 2

Sample code	Sample Location	lateral Distance	PARAMETERS Copper	Phosphate	Potassium	Sodium	Fluoride	Chloride
A	Gwallaoa	14m	0.22	5.50	62.5.	0.285	0.1	193
B	Gwallaoa	8m	0.235	15.73	54.6	0.301	0.23	236
C	Tura	7m	0.15	7.46	52.5	0.321	0.26	251
D	Bakaro	6m	0.47	4.04	50	0.501	0.31	287
E	Jaia	1m	1.78	46.32	40.31	1.80	2.6	423
F	Nasarrawa	7m	0.26	7.53	51.5	0.348	0.28	268
G	D/Tanshi	2m	1.63	44.21	41.2	1.52	2.3	386
H	Makama	8m	0.253	17.23	53.5	0.311	0.25	241
I	Dova	6m	0.32	4.06	51	0.498	0.33	293
J	Dova	21m	0.36	3.01	73.4	0.111	0.36	172

Table 3

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Sample Code	Sample Location	lateral Distance	PARAMETERS Magnesium Hardness
A	Gwallaga	14m	39
B	Gwallaga	8m	119
C	Tura	7m	132
D	Bakaro	6m	148
E	Jaia	1m	256
F	Nasarraw	7m	123
G	D/Tanshi	2m	221
H	Makama	8m	112
I	Dova	6m	142
J	Dova	21m	34

Bacteriological Parametetrs

Sample code	Sample **Location**	Lateral **Distance**	**Total Coliform**	PARAMETERS **Faecal coliform**
A	Gwallaga	14m	0	0
B	Gwallaga	8m	0	1
C	Tura	7m	0	2
D	Bakaro	6m	0	3
E	Jaja	1m	0	4
F	Nasarrawa	7m	0	2
G	D/Tanshi	2m	1	4
H	Makama	8m	1	3
I	Doya	6m	1	4
J	**Doya**	**21m**	**0**	**0**

Table 4

Temperature

The temperature of the water from the hand dug well in the villages ranges from 29.8 to 32.2^{O}C, although, both NSDWQ and WHO have not define

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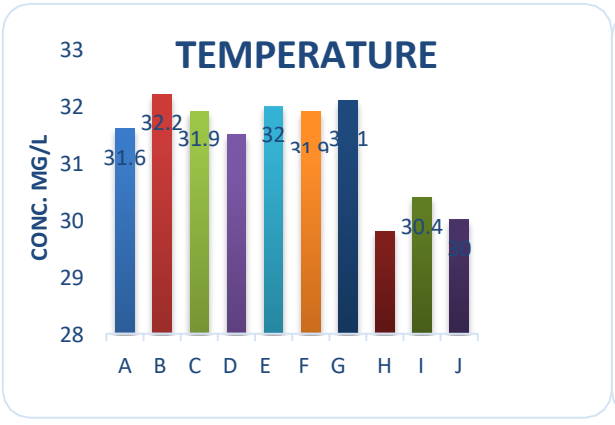
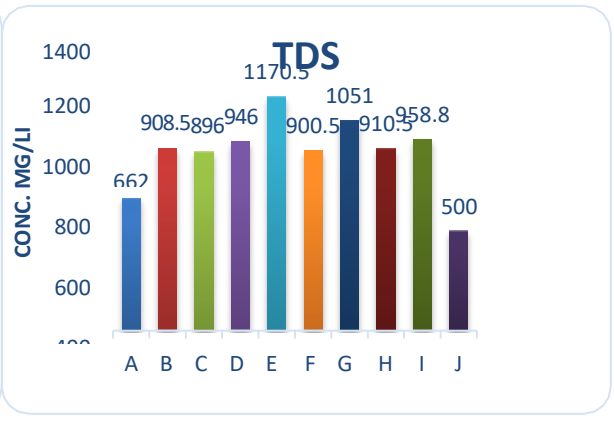
temperature values for drinking water, all the values exceeded the normal room temperature of 22°C. This can be acceptable because it could be due to the weather condition of the area at the period of sample collection.

Total Dissolved Solids (Tds)

The WHO standard recommended a value of 1500mg/l as safe water for drinking; but the NDSWQ recommended maximum limit of 500mg/l of water as safe drinking in Nigeria, therefore the only water samples with TDS values below 500mg/l were considered safe for drinking. From the result of analysis the TDS concentration of the groundwater/water from hand dug Wells in the villages ranges from 500 to 1170.5mg/l, This means that the TDS values in some sample were below the maximum limits while some others were above the maximum limit of 500mg/l recommended by NSDWQ. The high TDS values in the study area might be a result of pollution through leaching from Pit latrines into the hand dug wells due to the un-protective nature of the hand dug wells.

Graphical Presentation





PH

The PH of the groundwater or water from hand dug Wells in the selected villages within Bauchi ranges from 3.39 to 7.96, considering the PH values

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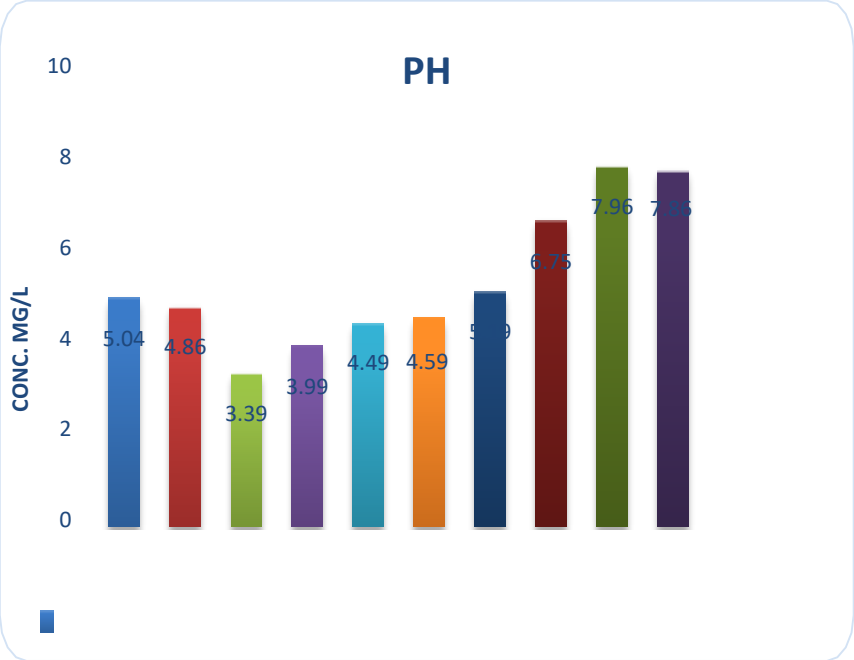
gotten from most of the areas, the water is not to recommendable for drinking. According to NSDWQ the maximum permissible limit of PH ranges from 6.5 to 8.5.



	A	B	C	D	E	F	G	H	I	J
P	5.0	4.8	3.3	3.9	4.4	4.5	5.1	6.7	7.9	7.8

Colour

Colour in water is a reflection of the presence of suspended matter. The greater is the suspended matter in water the greater will be the colour. However, colour often arises naturally due to the presence of colloidal particles such as Iron/Manganese in water.But the apparent colour of all the waters tested from the selected areas within Bauchi metropolis were contaminated with both organic and inorganic waste and therefore will pose the lives of the consumers to serious health hazard. According to **WHO** standard and **NSDWQ,** waters which obtained their colour from natural organic matter usually pose no health hazard.

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Odour

Odour in water is caused mainly by the presence of organic substances. Some odours are indicative of increased biological activity, otherwise may result from industrial pollution. From the observation during the analysis for water odour, it was observed that all the waters were not odour free and is not advisable for drinking.

Total Hardness

Hardness refers to the total concentration of calcium and magnesium in water; it is also a measure of the capacity of water to precipitate soap. Soap is precipitated mainly by calcium and magnesium present in polyvalent cation and they are often in complex forms frequently with organic constituents (Jayalakshmi, et al., 2019). Hard water is generally associated with formation of scales in boilers, heaters, hot water pipes and on utensils. Hard water also prevents formation of leather until excessive soap is consumed. Total Hardness is composed of two components:- temporary and permanent Hardness. **NSDWQ** recommends total hardness as 150mg/l. In the study areas, total hardness ranges from 128 to 217mg/l which indicates the degree of pollution ranging from soft to extremely hard

Turbidity

The turbidity measures the degree to which the water loses its transparency due to the presence of suspended particles. Turbidity affects the acceptability of water for drinking and also its demand for other uses. Turbidity is often determined by measuring the amount of light scattered by the particulate matter in the water using a nephelometer. The maximum allowable limit for turbidity is 5NTU (NSDWQ). The turbidity in

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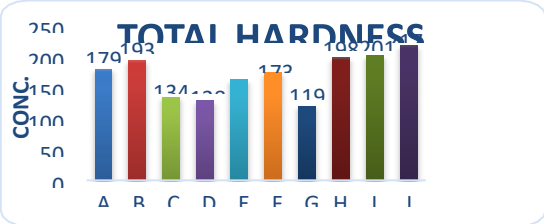
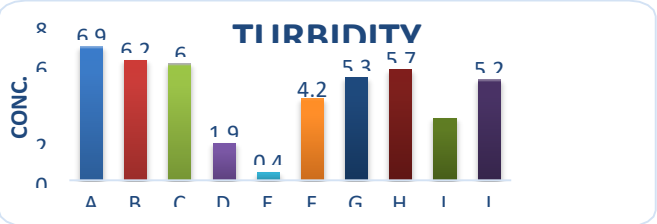
the study areas ranges from 3.2 to 6.7 NTU. And high turbidity was found in few of the areas.





Iron

Iron in the groundwater is normally present in the soluble ferrous (Fe2+) form. It is easily oxidized to the insoluble ferric (Fe) state upon exposure to air. Underground water normally contains Fe2+ due to insufficient oxygen in the aquifer. Groundwater containing iron in soluble form (ferrous) is usually clear and colourless when drawn. Upon contact with the air, they slowly cloud and finally deposit a yellowish to reddish brown precipitate of ferric hydroxide. Iron containing waters stain porcelain fixture and laundry. Iron bacteria (crenothrix and gellionella) utilize ferrous iron as an energy source and precipitate ferric hydroxide. In iron-bearing waters, the growth of iron bacteria may cause pipe clogging. NSDWQ limit iron to 0.3mg/l. The total iron concentration of well water in the selected areas ranges from 0.06 to 0.14, which is within the recommended limits.

Electrical Conductivity (Ec)

This measures ability of water to conduct electric current which is mostly influenced by dissolved salts such as sodium chloride and potassium chloride. Pure water is not a good conductor of electric current. Increase in concentrations enhances the electrical Conductivity of water. Generally, the amount of Dissolved Solids in water determines the

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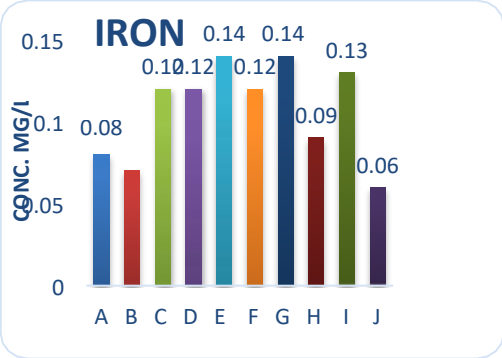
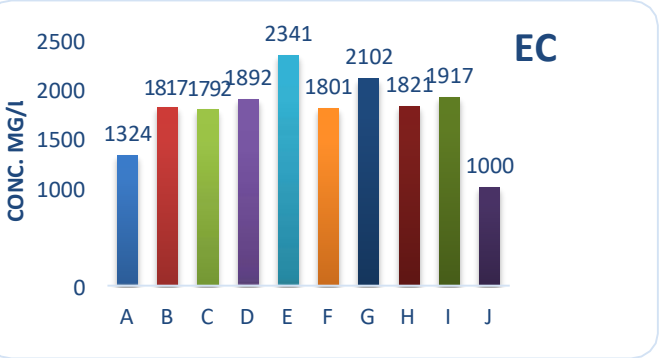
electrical Conductivity. **NSDWQ** allows maximum permissible limit of EC in drinking water as 1000mg/l. The EC concentration of the water in the study areas ranges from 1000 to 2341mg/l, which is beyond the recommended limit.





Copper

Copper is an essential element in human metabolism, and its deficiency results in a variety of clinical disorders, including nutritional anemia particularly in infants. It can also cause stomach and intestinal distress, liver and kidney damage, anemia in high doses. It also impacts an adverse taste and significant staining to clothes and fixtures. **NSDWQ** limits copper to 2mg/l. The Copper concentration of the well water in the villages ranges from 0.15 to 1.78mg/l which is beyond the recommended limit.

Phosphate

Phosphate is one of the principal causes of eutrophication in natural waters. Serious water quality problems have resulted from uncontrolled algae and aquatic plant blooms in lakes and reservoirs that contain phosphorus in excess of 0.05mg/l. Phosphorus is an essential element to health. A deficiency in phosphorus may result in body weakness, bone

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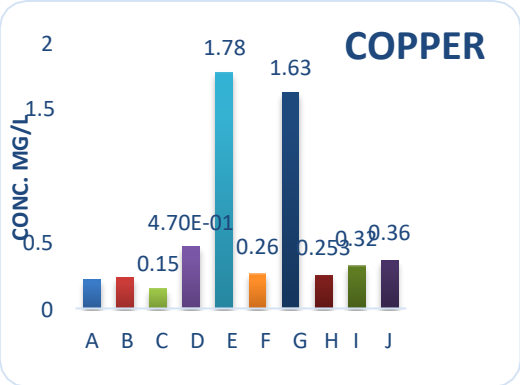
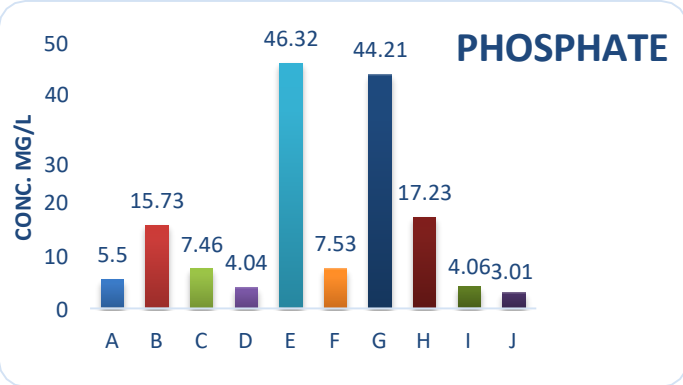
pain and ticket. Suggested adult daily intake for phosphorus is 800mg; the actual intake through diet is 1500mg/l. Phosphorus contribution from water is insignificant and **NSDWQ** does not regulate it. In the study areas, the phosphate ranges from 3.01 to 46.32mg/l.





Chloride

Chlorides are usually found in the form of salts of sodium, potassium, and calcium (NaCl, KCl, and $CaCl_2$). The concern with chlorides in water is more to do with quality of taste than with health. The maximum permissible limit recommended by WHO standard is 200 and that of NSDWQ is 502. The value of chloride gotten from the analysis of the water from hand dug Wells in the study areas ranges from 172 to 423mg/l. Comparing these values to the **WHO** standard, the water is not safe for drinking but to the **NSDWQ**, it is safe for drinking.

Flouride

Fluoride content in drinking water is of great concern because its concentration in optimum value is beneficial to human health while concentration in excess has negative impact on health. It has been established that fluoride of concentration in values between 1.00 mg/l and 1.5mg/l (**WHO** and **NSDWQ**) is of optimum benefit because it can

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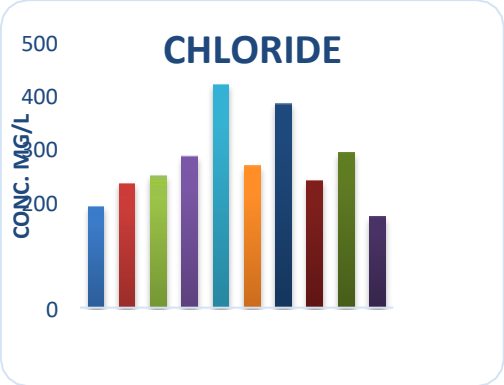
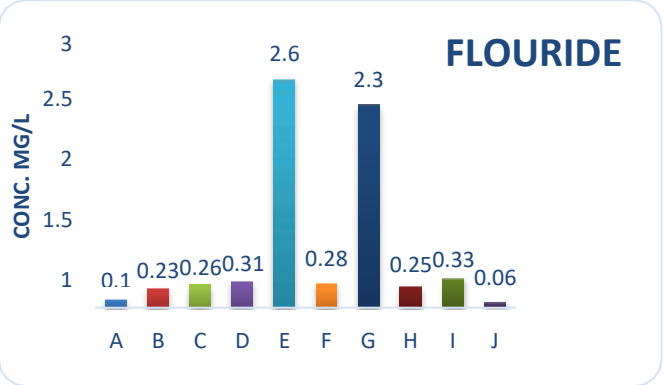
prevent tooth cavities, especially among children and the consumption of water with fluoride exceeding this limit can cause dental and skeletal fluorosis. The results of the analysis of fluoride content in most of the water samples are either less than 1mg/l or in excess of 1.5mg/l, which in both instances fall outside the optimum range for safe human consumption. Only the water samples from sample A, B, C, D, F,H, I, and J have a fluoride content that Fall within the recommended safety limits of 1mg/l and 1.5mg/l by the **WHO** and **NSDWQ** and are considered safe for drinking in terms of fluoride concentration.





Calcium Hardness

Calcium is an element that is found naturally in abundance within the earth's crust. It is also an important and abundant element in the human body. Adequate intake of calcium is essential for normal growth and good health. Calcium is the most important element causing hardness in water. Water samples from HDW in the selected areas within Bauchi metropolis showed values for calcium concentration are above maximum permitted limit of 314mg/l recommended by **NSDWQ** and **WHO**. The presence of

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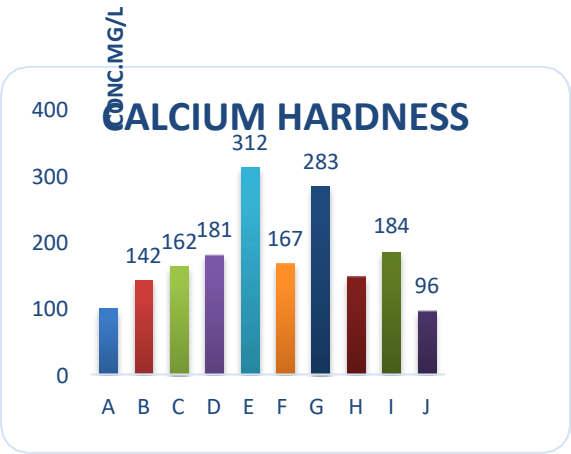
excess calcium in water causes temporary hardness, but it can be removed easily by boiling.

Magnesium Hardness

Magnesium is essential for proper functioning of living organisms and found in minerals dolomite, magnetite etc. Human body contains about 25kg of Magnesium (60% in bones and 40% in muscles and tissues). According to NSDWQ the permissible limit of Magnesium in water should be 150mg/l. In the study areas magnesium concentration ranges from 34 to 256mg/l. considering the result gotten in most of the areas, the water is safe for drinking. Only few of the areas have a magnesium value exceeding the given standard.





Bacteriological Analysis

Coliform bacteria are described by grouping based on their common origin or characteristics, as either Total or Faecal Coliforms. The Total group includes Faecal Coliform bacteria such as Escherichia coli (E coli) and other Coliform bacteria that are naturally found in the soil. Faecal Coliform bacteria exist in the intestines of human beings and animals and are released through waste discharges into the soil (WHO, 2003).

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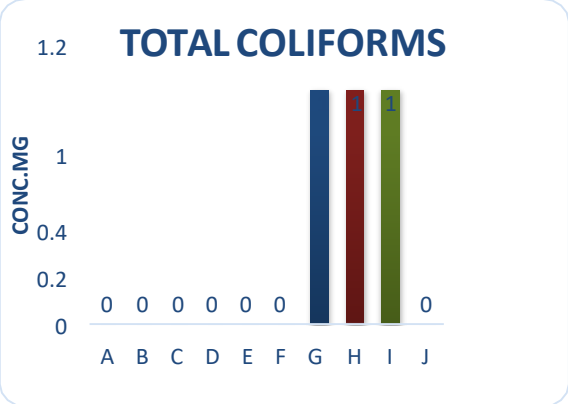
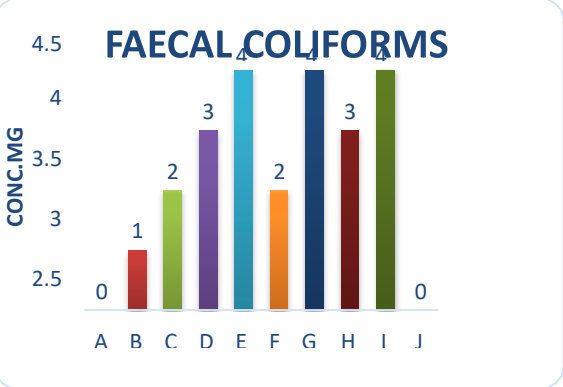
Coliform bacteria are used as indicators of as water quality because their presence in drinking water may indicate a possible presence of harmful, disease causing organisms. Their detection in drinking water is also relatively simple and economical. The bacteriological analysis of water samples showed that all the HDW contained Coliform bacteria mostly with concentrations above the maximum limits recommended by both NSDWQ and WHO. According to the WHO standards no Coliform should be detected at all in any 100ml of drinking water. However, the NSDWQ recommend 10cfu/100ml as the maximum permissible limits for the total coliform concentration for safe drinking water quality in Nigeria. Therefore, the results of water samples from 17/20 (85%) of HDW are with values above 10cfu/100ml which are not safe for drinking while water samples from 3 HDW (namely: HDW 13, 15 and 18) which showed values below 10cfu/100ml were considered safe for drinking based on the NSDWQ standard.





CONCLUSION

The results of the analysis showed a variation in water quality parameters. In some parameters, the water samples from hand dug wells in selected areas within Bauchi metropolis are within safety limits while in many parameters the water quality either falls below or exceed the standards

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set by the national standard for drinking water quality (NSDWQ) and the World Health Organisation (WHO). Therefore, the study concluded that water from HDWs within selected areas of Bauchi metropolis are not safe for drinking and the water should be treated before drinking.

RECOMMENDATIONS

The study recommended regular assessment of ground water quality and a further research to determine the sources of ground water pollution in the selected areas within Bauchi metropolis in order to design measures for improving water quality in HDWs in the study area. In addition to the above mentioned measures, it is essential that knowledge about the method of sanitary risk assessment of hand-dug wells and other groundwater sources be disseminated and made known to the public. In this regard, the establishment of National On-site Sanitation Study Bureau would be a great development. Awareness programmes to enlighten the public should also be carried out on a regular basis.

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