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ASSESSMENT OF THE PHYSICAL, CHEMICAL AND MICROBIAL CONCENTRATION LEVELS IN WATER FROM HAND DUG WELLS IN WAILOMAYO WARD OF MAKURDI TOWN, BENUE STATE, NIGERIA

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ABSTRACT

The study assessed the physical, chemical and microbial concentration levels in Water from Hand-Dug Wells from Hand Dug Wells in Wailomayo Ward of Makurdi Town, Benue State, Nigeria. *Ten hand dug wells were sampled in three locations of Wurukum namely, Logo, Akpehe and Angwan Jukum. Results from the tested parameters of temperature, total dissolved solids (TDS), electrical conductivity (EC), turbidity, suspended solids (SS), Power of Hydrogen (pH), iron (Fe), nitrate (NO_3), nitrite (NO_2), biochemical oxygen demand (BOD) and E coli were subjected to Pearson's Product-Moment Correlation Analysis to generate correlation matrix which was used to identify inter-relationships among the parameters; and also to infer the potential sources of pollution affecting the water from hand dug wells. Correlation coefficients ranged from −1 to +1; where positive values indicated a direct association between parameters, and negative values denoted inverse relationship. Thus, the results revealed that TDS and EC (r = 0.78), suspended solids (SS) and iron (Fe) (r = 0.90), nitrate and nitrite (r =0.67), Iron and nitrate (r = 0.71) temperature and BOD (r = 0.57) had positive correlations while suspended solids and BOD (r = −0.62 had negative correlation. E. coli exhibited moderate positive correlations with suspended solids (r = 0.39) and nitrate (r= 0.26). The study concluded that all the sampled wells had one form of contamination or the other due to both geological and anthropogenic influences. It was therefore recommended that Government should live up to its responsibility of providing basic*

amenities to its teeming citizens, Public Health Education and Community Engagement should be put in place to train residents on basic knowledge of treating their water before consumption and also Government should re-introduce health monitoring and inspections to guarantee sanitary condition of hand dug wells.

1. INTRODUCTION

Access to safe and potable water remains a critical public health and development concern, particularly in developing countries where a significant proportion of the population relies on groundwater sources such as hand-dug wells. Water is indispensable to human survival and socio-economic development, yet its quality is often compromised by physical, chemical and microbial contaminants (UNESCO, 2013). In Nigeria, limited access to piped water supply has compelled many households to depend on groundwater, especially through hand-dug wells, for domestic and agricultural uses (World Bank, 2022; GSS, 2014). Although groundwater is generally perceived as safer than surface water due to natural filtration processes (Ukpong, 2013; Odoh & Jidauna, 2013), it is not immune to contamination.

The quality of water from hand-dug wells is determined by its physical (e.g., temperature, turbidity, colour), chemical (e.g., pH, dissolved solids, heavy metals, nitrates) and microbial (e.g., total coliforms, faecal coliforms, pathogenic bacteria) characteristics. Variations in these parameters are influenced by aquifer lithology, depth of wells, proximity to pollution sources, and anthropogenic activities such as waste disposal, agricultural runoff and urbanization (Okoro et al., 2009; Omole, 2013). Contamination of groundwater poses significant health risks, as consumption of polluted water is closely linked to waterborne diseases including cholera, typhoid fever and dysentery (Gleick, 2002; Ocheri et al., 2012). According to UNICEF/World Health Organization (2011), millions of people globally still rely on unsafe drinking water sources, heightening their vulnerability to microbial and chemical hazards.

In urban centres such as Makurdi, inadequate public water supply has intensified dependence on hand-dug wells, raising concerns about their safety and suitability for human consumption (Shittu, 2015; Tse & Adamu, 2021). Despite their affordability and accessibility, hand-dug wells are particularly susceptible to contamination due to shallow depth, poor construction practices and close proximity to septic tanks, refuse dumps and other pollution sources (WaterAid, 2023).

Therefore, systematic assessment of the physical, chemical and microbial concentration levels in water from hand-dug wells is essential to determine compliance with established drinking water standards and to safeguard public health. Such evaluation provides empirical evidence necessary for informed water resource management and intervention strategies in affected communities.

2 STUDY AREA

Makurdi town is located in Benue state of Nigeria between latitude 07^{0} $30^{!}$ North and 08^{0} $00^{!}$ North of the equator and Longitude 08^{0} $00^{!}$ East and 09^{0} $00^{!}$ East of the Greenwich Meridian. The town covers a radius of 16 km^2 with an area of about 800 km^2 (Bureau of Land and Survey, 2019). The town is bounded by Guma local Government Area in the North and North East, Gwer-East in the South, Gwer-West in the west and Nasarawa State in the North West. Makurdi town is a major link between the Northern and Southern part of Nigeria. The river Benue which is the second largest river in the country bisects the town into two parts of North and South banks. Makurdi town plays the double role of being a state headquarters and at the same time a local government headquarters. These amongst many factors, attract people to the town because as an urban centre, it is expected to have all necessary social amenities promotes modern living standards. These include pipe borne water supply, good sanitation and waste disposal system, electricity and so on.

The Town has several drainage channels. These channels include river Benue, which bisects the town into South and north banks, and its tributaries including Urudu, Demekpe, Kereke and Mu and the smaller ones include Idye and Dyeghe (Shabu, Fate, &Ukula, 2021).

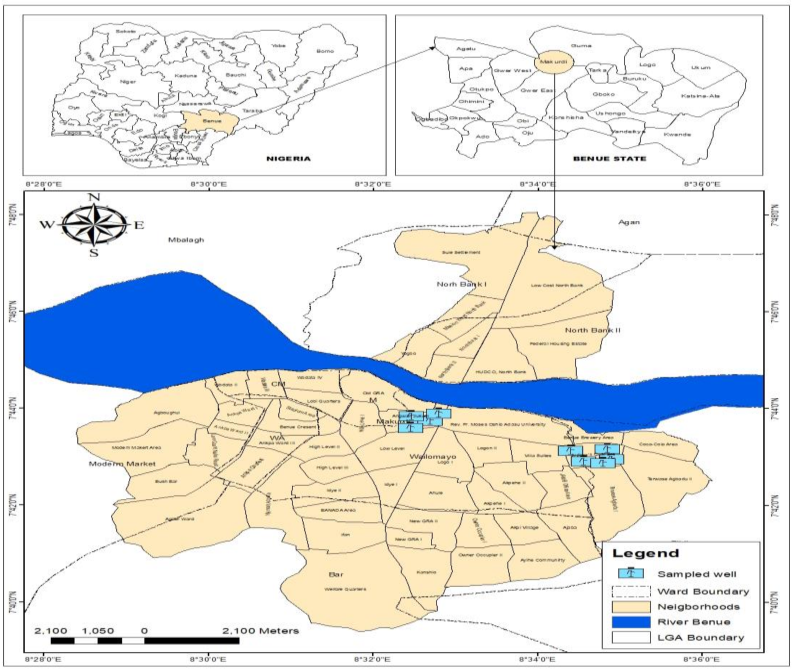

Figure 1: Map of Makurdi town showing sampling points.

Source: GIS Laboratory, MOAUM, 2025

MakurdiTown is located in the Benue Valley, experiences a tropical, seasonally wet and dry climate (Wladimir Koppen's Aw), with distinct wet (April–October) and dry (November–March) seasons. The wet season brings rainfall ranging from 1000–2000 mm annually, peaking in August/September (221 mm on average). The town's climate is influenced by the South-West Monsoon (SWM) and North-East Monsoon (NEM), while the Inter-tropical Discontinuity (ITD) and local topography also affect rainfall patterns (Tyubee, 2004). The mean rainy season lasts 182 days, and temperatures vary between 26°C in December and 31°C in March/April. Humidity ranges from 43% in January to 81% in July/August, with high temperatures and humidity causing thermal stress during the dry season (Tyubee, 2005).

The geology of Makurdi Townis dominated by sedimentary formations, primarily sandstone, which underlies most of the town and contributes to its fertile soils (Abaa, 2004). These well-drained soils support urban parks and green spaces, enhancing the town's aesthetic and ecological quality. However, urbanization has led to the loss of much of Makurdi's natural vegetation, replaced by fruit trees and ornamental plants, though parks still play a crucial role in preserving greenery and offering shaded, cooler spaces that mitigate the effects of urban heat islands and improve residents' well-being.

Makurdi Town faces challenges with flooding due to its low-lying terrain and poor drainage systems, particularly in flood-prone areas like Wadata and Wurukum. The town is situated near River Benue, which frequently overflows during the rainy season, exacerbating flooding risks. Urban parks integrated with green infrastructure can help manage stormwater, reduce flooding, and offer safe outdoor spaces for recreation and mental restoration (Udo, 1970).

Makurdi town, according to the National Population Commission 1991 has a total population of 151515 persons, while, Makurdi LGA has a population of 300377 people with a population density of about 376 persons per square Kilometre (National Bureau of Statistics, 2017) and an annual growth rate of 3.0 %. Therefore, using the projection formula given below, we can ascertain the current population in the town.

$Pt = P_0 (1+ r/100)^t$

Where P_0 = known population = 151515 persons

I = Constant (i)

R = Rate of Growth (3.0)

T = Time (1991-2021) = 31years

Present population of Makurdi = 378,800 people (NBS, 2017)

The population mostly comprises the Tivs as the dominant ethnic group. Other ethnic groups include Idomas, Igedes, Igalas, Igbos, Etulos, Jukuns, and Hausas. The composition of different ethnic groups in Makurdi town can be attributed chiefly to the function of migration as it is a commercial and administrative function.

The settlement pattern in Makurdi town can be best described as nucleated settlement (Tyubee, 2008), within the urban districts such as Wadata, Wurukum, Low level, Kanshio, North bank, Madikpo, New GRA, Federal Housing and Logo while places at the periphery can be seen as dispersed such as Agan, Fiidi, Mbalagh and Bar ward.

Makurdi town being the state capital is an urban Centre characterised by complex division of labour. The socio-economic activities in the town include; civil service duties, welding, tailoring, carpentry, motor mechanics, building and construction work, fishing (by the Jukuns), sand excavation in the river, block industries, furniture making, restaurants, road transport business, filling stations, trading, those selling in the various markets within the town. The socio-economic base of Makurdi comprises several markets. These include Modern Market, which is the biggest market. Other markets include Wurukum, High level, Wadata and North bank and Makurdi international market located along Abu King Shuluwa road. Poultry is gradually assuming important dimension occasioned by the increase in population and demand.

3 MATERIALS AND METHODS

3.1 Research Design

A combination of field observation, measurement and experimentation design approaches were utilised for the study.

3.2 Data Needs/ Data Requirement

The research used water samples from hand dug wells located within Logo, Akpehe and Agwan Jukun and compared these with the permissible limits of drinking water quality by the Nigerian Standard for Drinking Water Quality (NSDWQ, 2017) as basis for determining the suitability or otherwise for human consumption from the individual wells. Table 3.1 below shows the list of the sampled parameters and their health impact as set out by the Standard Organisation of Nigerian’s Nigerian Standard for Drinking Water Quality (SON, 2017).

Table 3.1: NSDWQ, 2007, 2015, 2017 (Source: Mshelia and Mbaya, 2024; Martins and Idowu, 2020)

Physico-Chemical and Microbial Parameters of Water	NSDWQ	Health Impact
Ph	6.5-8.5	Corrosion control
Turbidity	5NTU	Protects pathogens and reduce disinfection efficacy
Odour	Unobjectionable	None
Taste	Unobjectionable	None
Electrical Conductivity	1000 mS/cm	Indicates mineral content
Total dissolved solids	500mg/l	Affects taste and scaling
Iron	0.3mg/l	
Nitrate (NO3	50 mg/l	Cyanosis and asphyxia (blue-baby syndrome) in infants under three (3) months.
Nitrite (NO2)	0.2mg/l	Cyanosis and asphyxia (blue-baby syndrome) in infants under three (3) months.
E-coli	0max	Faecal contamination
Temperature (^{0}C)	27-28	Should not exceed 25–30°C for acceptability
BOD		**Indicates organic pollution and microbial load**

3.3 Data Sources

Primary data were obtained through field measurements of hand-dug well locations using GPS and laboratory analysis of water samples for physical, chemical, and microbial properties. Secondary data were sourced from maps, academic literature, institutional GIS records, relevant agencies, and national drinking water quality guidelines.

3.4 Study Population

The study population for the study comprised ten hand dug-wells which were randomly sampled to provide information for assessment at Logo, Akpehe and AngwanJukun all in Wurukum area of Makurdi Metropolis. Particular cognizance was taken about functionality of wells.

3.5 Sample size and Sampling procedure

3.5.1 Sample Size

The study purposively sampled ten (10) hand-dug wells across the identified locations of Logo (2), Akpehe (4) and Angwan Jukun (4) all within the Wailomayo Ward of Makurdi town which was the study area. Purposive sampling method was preferred to ensure even spatial coverage of the study area. Purposive sampling, also known as judgmental or selective sampling, was used to deliberately select sampling locations based on specific criteria, such as location within the study area and functionality of wells.

3.6 Field Based Analysis

The colour, odour, temperature and taste were determined in the residential areas or sites using their various instruments.

Laboratory Analysis

Elements	instruments
(pH) Determination	pH Meter
Colour determination	Tintometer
Taste and Odour Determination	Osmoscope
Turbidity Determination	Nephelometer
Temperature Determination	Thermometer
Electrical Conductivity Determination	Water Sensors
Total Dissolved Solids (TDS)	TDS Meter
Potassium Determination	flam photometer
E. coli	AquaBiois
Biochemical Oxygen Demand (BOD)	Calibration

3.8 Water Samples Collection

Water samples were collected from the ten (10) hand dug wells in the study area of Wailomayo in the Month of June, 2025. The justification of this period of sampling was just the researcher’s discretion. The following materials were used at the course of field studies:

i. Ten 1 litre sterilized containers

ii. Hand held Global Positioning System (GPS) machine for taking coordinates of sampled well for the purpose of use in map.

iii. 100-meter measuring tape

iv. Notebook for recording

v. Thermometer for temperature recording so as to avoid exposure to sunlight and prevent microbial growths.

vi. Container to store water samples after collection

3.9 Methods of data analysis

The water quality samples was subjected to standard laboratory analysis at Greater Makurdi Water Works Laboratory, Makurdi while quantitative data generated from the field-study were analyzed using tables and bar charts.

The Pearson's Product-Moment Correlation Coefficient (r) was used to determine factors that influence the quality of water from hand dug wells in the study area. Pearson's product moment's correlation coefficient is the most commonly used formula to measure the strength and direction of a linear relationship between two continuous variables: It is represented by the formula:

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

Where**:**

r – correlation coefficient

n – number of paired observations

x – values of the first variable

y – values of the second variable

$\sum x$ – sum of all x-values

$\sum y$ – sum of all y-values

$\sum xy$ – sum of the products of paired x and y values

$\sum \mathbf{x^2}$ – sum of squared x-values

$\sum \mathbf{y^2}$ – sum of squared y-values

4 RESULTS AND DISCUSSION

4.1 Physico –Chemical and Microbial Parameters of Hand- Dug Wells

Samples obtained from hand dug wells in the study areas were subjected to laboratory analysis for physic-chemical and bacteriological/ microbial parameters. Results obtained were compared with the Nigerian Standard for Drinking Water Quality Guidelines by the Standard Organisation of Nigeria (SON, 2017). The guidelines contain mandatory limits concerning constituents and contaminants of water that are known to be hazardous to health and/or give rise to complaints from consumers (NIS, 2007). Physical parameters tested for were taste, odour, temperature, total dissolved solids (TDS), electrical conductivity (EC), turbidity and suspended solids. Power of Hydrogen (pH), Iron (Fe), Nitrate (NO_3) and Nitrite

(NO_2) and Biochemical Oxygen Demand (BOD) were tested to know chemical parameters' concentration levels while E-coli was tested for bacteriological/ microbial contamination. Parameters of taste and odour were found to be objectionable meaning that these variables are dependent on individuals and local factors, including the quality of the water to which the community is accustomed and a variety of social, environmental and cultural considerations (WHO, 2022).

Table 4.1: Summary of Results of Physico-Chemical and Microbial parameters tested for

PARAMETER	**Unit**	**WELLS**										**NSDWQ**
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
PHYSICAL												
Temperature	°C	31.4	32	32	31.3	31.5	32	31.5	31.7	31.3	31.6	25 °C
Total Dissolved Solids (TDS)	mg/L	544	622	559	713	334	640	678	195	458	879	500
Electrical Conductivity (EC)	µS/cm	998	1320	905	1444	857	797	883	1430	814	1220	1000
Turbidity	NTU	4	3.27	4.3	3.95	3.04	3.98	3.95	3.26	4.39	5	5
Suspended Solids	mg/L	8	1	7	13	17	10	12	1	13	31	30
B. CHEMICAL												
Ph		6.8	7.6	7.8	7.4	6.8	7.2	7.9	7.2	7.2	7.6	6.5-8.5
Iron (Fe)	mg/L	0.22	0.18	1.01	0.55	1.23	0.67	0.76	0.18	0.11	2	0.3
Nitrate (NO3)	mg/L	32	29.5	41.5	33.9	41.4	43.2	50.6	57	30.2	56	50
Nitrite (NO2)	mg/L	0.01	0.09	0.34	0.09	0.07	0.66	0.54	0.12	0.75	0.79	0.2
Biochemical Oxygen Demand (BOD)	mg/L	4.5	8.4	9.3	2.6	3.8	2.5	3	6.9	4.9	3	<5
C BIOLOGICAL/ MICROBIAL												
E- Coli	**CFU /100 m/L**	**9**	**0**	**0**	**0**	**2**	**0**	**5**	**6**	**0**	**10**	**0**

Source: Field work 2025

4.2 Descriptive Statistics of Tested Parameters

Descriptive statistics of tested parameters in the study area analysed the minimum and maximum values, mean, standard deviation (SD) as well as the Co-efficient of Variation (CV). The reason for analysis of the CV of water from the hand-dug wells is to measure the relative variability or precision of variability or precision of a measurement, allowing for a standardized comparison of different datasets or regardless of their mean values.

Table 4.2 Descriptive Statistics of the Tested Parameters in the Study Area.

Parameter	**Unit**	**ND**	**Min**	**Max**	**Mean**	**SD**	**Co-efficient of Variation.**	**NSDWQ Permissible Limits**
Test	-	10						
Odour	-	10						
Temperature	^{0}C	10	31.3	32.0	31.65	0.18	O.57	25℃
Total dissolved (TDS)	mg/L	10	544	915	729.5	92.75	12.71	500
Electrical conductivity	µS/cm	10	814	1444	1129.0	157.5	13.95	1000
Turbidity	NTU	10	3.04	5.0	4.02	0.49	12.19	5
Suspended solids	mg/L-	10	1	17	9.0	4.0	44.44	30
pH	-	10	6.8	6.9	6.85	0.03	0.44	6.5- 8.5
Iron(fe)	mg/L	10	0.11	1.23	0.67	0.28	41.79`	0.3
Nitrate (NO_3)	mg/L	10	30.2	56.0	43.1	6.45	14.97	50
Nitrite (NO_2)	mg/L	10	0.01	0.79	0.40	0.20	50.00	0.2
Biochemical oxygen demand (BOD)	mg/L	10	2.5	8.4	5.45	1.48	27.61	<5
E-coil	**Cfu/100m/L**	**10**	**0**	**10**	**5.0**	**2.5**	**50.00**	**0**

Source: Researcher's fieldwork, 2025

Formula for mean $= \frac{\text{min} + \text{max}}{2}$

Formula for standard deviation (SD)$=\frac{\text{max} - \text{min}}{4}$

Formula for Coefficient of Variation (CV)

$\text{CV}(\%) = \frac{\text{SD}}{\text{mean}} \text{X}100$

Table 4.2 discusses the descriptive statistics for tested parameters of sampled hand-dug wells in the study area. The results show that minimum value of temperature was 31.3^{0}C while the maximum value was 32^0C. Mean value is 31.65^0C while Standard Deviation was 0.18 and the Co-efficient of Variation was 0.57. The minimum for TDS is 544mg/L while the maximum value was 915mg/L and the mean value was 729.5mg/L. The SD value was 92.75 while the CV was 12.71. The descriptive statistics for EC showed that the minimum value was 814µS/cm and the maximum value was 1444µS/cm with mean of 1129.0µS/cm. The SD was 157.5 while the CV was 13.95. Turbidity had a minimum value of 3.04NTU and maximum of 5.0NTU with mean being 4.02NTU. The SD value was 0.49 while CV was 12.19. Suspended Solids parameter (SS) was 1mg/L minimum; 17mg/L maximum and mean value of 9.0mg/L. The SD value was 4.0 and the CV was 44.44.

Power of Hydrogen (pH) had a minimum value of 6.8 and a maximum of 6.9. The mean value was 6.85, SD of 0.03 and CV of 0.44. The minimum value for Iron (Fe) was 0.11mg/L, maximum value 1.23mg/L while the mean was 0.67. The standard deviation was 0.28 and the co-efficient of variation was 41.79. Nitrate values were 30.2mg/L (minimum), 56.0mg/L (maximum), 43.1 (mean), 6.45 (standard deviation) and 14.97 (co-efficient of variation. The values for Nitrite were minimum (0.01), maximum (0.79), mean (0.40), standard deviation (0.20) and co-efficient of variation (50.0). Biochemical Oxygen Demand (BOD) had a minimum value of 2.5mg/L, maximum of 8.4mg/L and mean of 5.45; the standard deviation value was 1.48 and the co-efficient variation of 50. The variables for E-coli show that the minimum value was 0cfu/100mL while the maximum was 10cfu/100mL. The mean was 5.0 and the standard deviation value was 2.5 with co-efficient variation of 50.

4.3 Comparative Analysis of Physico-Chemical Water Quality Parameters with Nigerian Standard for Drinking Water Quality Guidelines:

The assessment utilized eleven major parameters of physical (temperature, total dissolved solids, electrical conductivity, turbidity and suspended solids), chemical (pH, Iron, Nitrate and Nitrite) and biological/microbial (E-coli) respectively.

4.4.1 Temperature

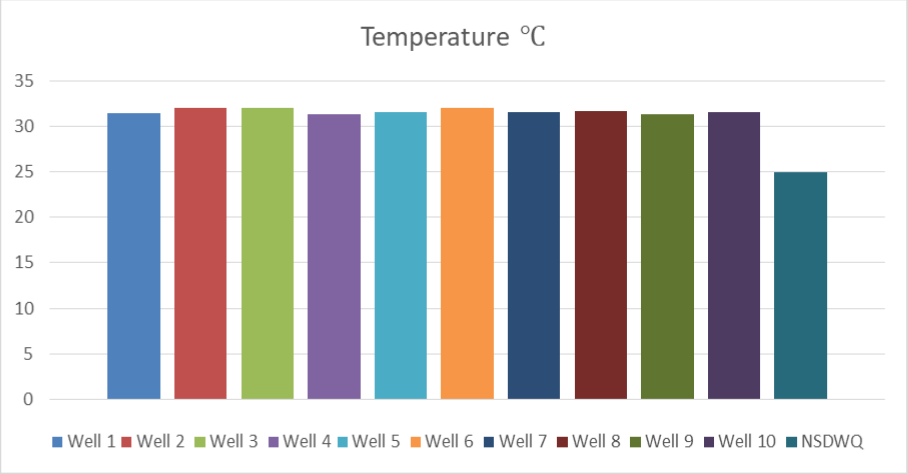

Figure 4.1 Temperatures of Sampled Wells.

The results from sampled hand dug wells revealed that all the wells have temperatures above the NSDWQ permissible limit of 25°C. The findings from the individual wells as shown on Table 4.1 shows that well 9 has the lowest temperature of 31.3°C, while wells 3 and 6 have the highest temperature of 32°C. The implication of this finding is that water from all the wells is warm. Warm water is considered less palatable when compared to cool water (at the acceptable permissible limit) as higher temperature in water have impact on the acceptability of a number of other inorganic constituents and chemical contaminants that may affect taste. This finding agrees with the results by WHO (2022) and NSDWQ (SON, 2017) which notes that high water temperature enhances the growth of microorganisms and may increase problems related to taste, odour, colour and corrosion.

4.4.2 Total Dissolved Solids (TDS)

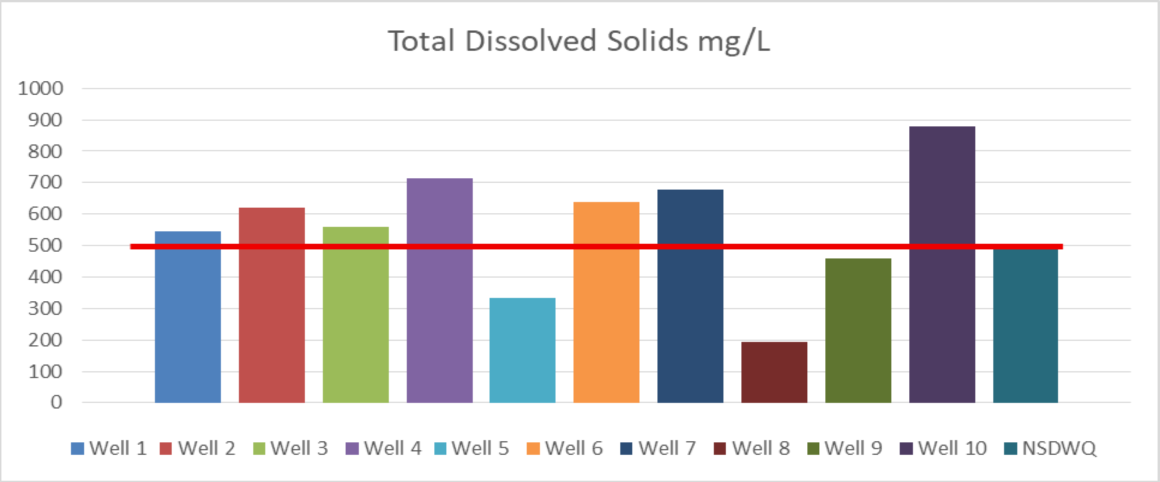

Figure 4:2 Total Dissolved Solids (TDS) in Sampled Hand Dug Wells.

The analysed values for TDS as shown in Figure 4.2 reveals that only wells 5, 8 and 9 fell within the stipulated NSDWQ guideline of 500mg/L. TDS is used as an indication of the presence of a broad array of chemical contaminants like calcium, phosphate, nitrates, sodium, magnesium, potassium and chloride (Martins and Idowu, 2020). High TDS levels as observed in seven (7 out of the ten (10) sampled wells is an indication of hard water, which can cause scale build-up in pipes, valves, and filters, reducing performance and adding to system maintenance costs. TDS is highly toxic with the presence of abnormal pH, high turbidity, or reduced oxygen. However, water from the wells with values below the acceptable limit are all safe for drinking on the basis of TDS as supported by the NSDWQ standard as total dissolved solids are one of the key aspects and one of the physical standards of measuring the potability of drinking water. This finding agrees with the work of Eze&Eze (2018)as well as Magashi (2025).

4.4.3 Electrical Conductivity Concentration

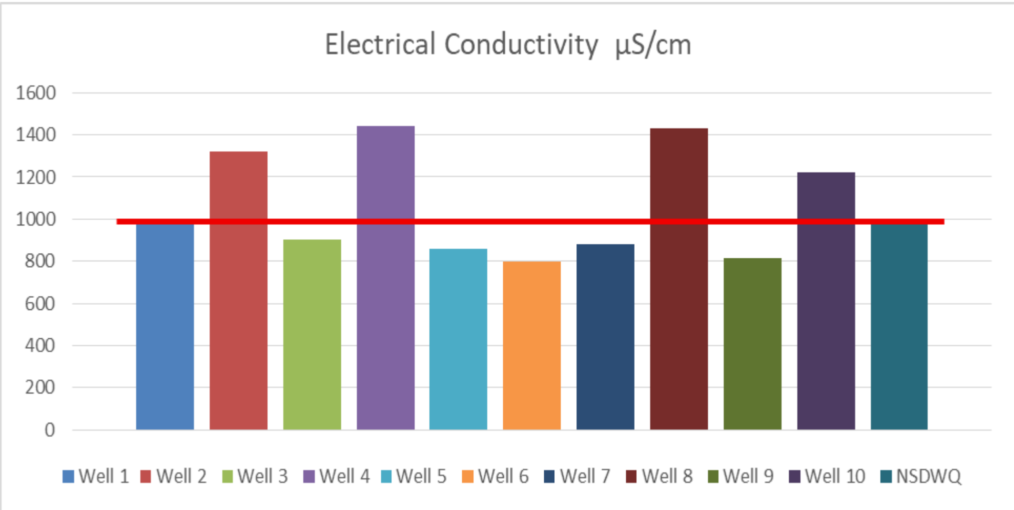

Figure 4.3 Concentration Levels of Electrical Conductivity.

The result for electrical conductivity concentration reveals that wells 2, 4 8 and 10 recorded values above the EC permissible limit by NSDWQ of 1000µS/cm with1320µS/cm, 1444µS/cm,1430µS/cm, and 1220µS/cm respectively. Electrical conductivity in drinking water is the ability of water to conduct electricity as a result of the concentration of dissolved salts and ions. Higher electrical conductivity in water implies more dissolved ions and other materials present. This means that the wells with values above the permissible limit of the NSDWQ value have higher tendency of electrical conductivity being more contaminated. This result agrees with the work of Gnimadi (2024).

4.4.4 Turbidity

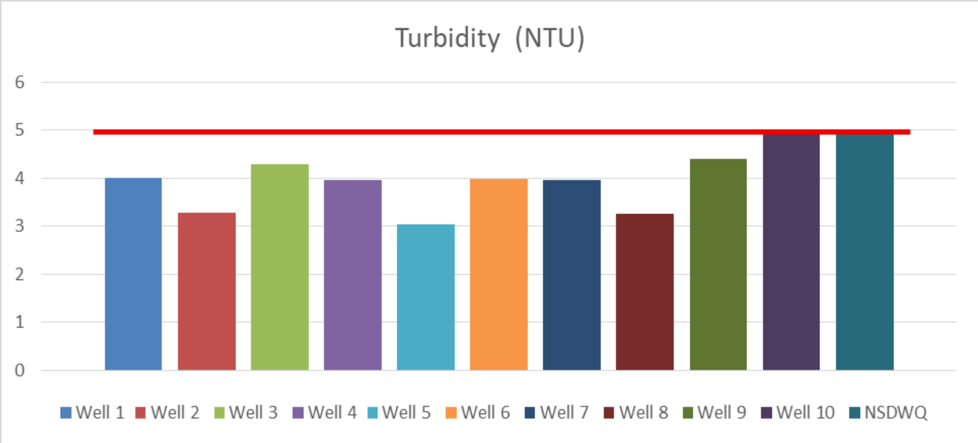

Figure 4.4: Concentration Levels of Turbidity.

Turbidity has to do with the cloudiness of water (APHA, 2005) caused by clay, silt, organic materials, plankton and other particulate matters (Alley, 2007). It is measure of the ability of light to pass through water.

The results for turbidity reveals that values obtained from nine sampled hand dug wells fall below the NSDWQ permissible limit of 5NTU while value from one well is the same as the permissible limit. Gnimadi et al (2024) reports that turbidity is one of the most recognizable indicators of sedimentary particles in water, which not only diminishes the aesthetics of water bodies but also inhibits the growth of algae crucial for ecosystem balance. The presence of turbidity in high concentration in all the wells (since no well has less than 3.04NTU) means that water from the wells will not be aesthetically appealing and also, clarity will be reduced. This result may also be due to the time of sampling which was in the rainy season. This finding agrees with the works of Magashi et al (2025), Ogiji (2025) and Gnimadi et al (2024).

4.4.5 Suspended Solids

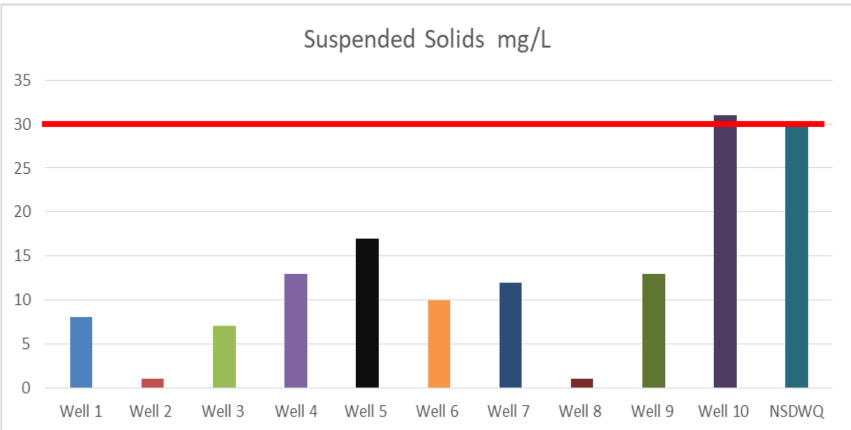

Figure 4.5 Concentration levels of Suspended Solids.

The result for suspended solids is shown in Figure 4.5. Suspended solids from well 1-9 fell within the permissible limit of 30mg/L. however, the value for well 10 is slightly above the NSDWQ acceptable value at 31mg/L. Suspended solids are small solid particles such as soil, sand and/ or organic matter that have not yet dissolved in water. Like turbidity, suspended solids impede water clarity and render water aesthetically unappealing. The results obtained from water samples from hand dug wells in the study area could be as a result of underlying rock structure (sedimentary rocks) and/ or anthropogenic activities around the wells.

4.4.6. Power of Hydrogen (pH)

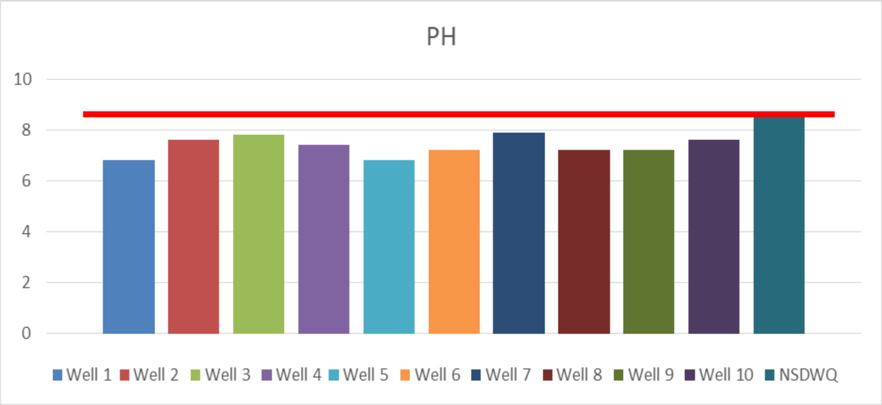

Figure 4.6: Concentration Levels of pH.

Figure 4.6 is the result for power of Hydrogen (pH). The permissible limit for pH as stipulated by the Standard Organisation of Nigeria (SON, 2015) for drinking water quality in Nigeria ranges from 6.5 to 8.5. However, the results obtained from the sampled hand dug wells ranged from 6.8-7.9, indicating that they all fall within the acceptable limits of the guidelines. The implication of this parameter is that water from all the wells is fit for human consumption using pH as a criterion

4.7 Iron (Fe).

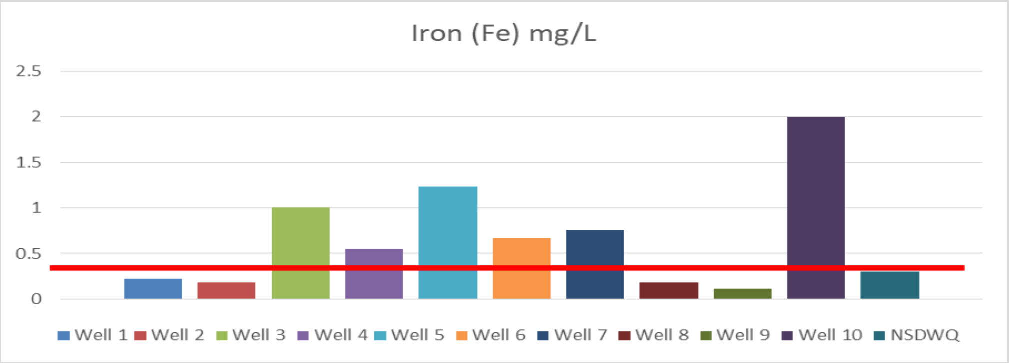

Figure 4.7 Concentrations Levels of Iron. (Fe)

The result in Figure 4.7 reveals that values of iron concentrations in the sampled hand dug wells range from 0.11 - 2. o0 mg/L. This is against the NSDWQ stipulated expectation of 0.3mg/L as shown on Table 4.1. The lowest value of 0.11mg/L was recorded in well 1 while well 10 had the highest value of 2.0mg/L. According to Martins &Idowu (2020), Iron is found in water bodies as a result of its abundant presence in the Earth's crusts as well as through anthropogenic activities around due to pH and oxidation potential of water. However, in sub-surface water like hand dug wells the presence of Iron in elevated quantities in ground water is as a result of the absence of atmospheric oxidative conditions as well as contact with Iron bearing minerals. Iron does not necessarily have harmful effect on water quality but because its presence leads to the formation of ferric oxides, this can precipitate and cause orange stains on settling surface (SON, 2007). Since the formation of ferric oxides makes Iron-laden waters objectionable, it follows that even though only wells 1,2,8, and 9 have values below the NSDWQ Guidelines, water from hand dug wells 3,4,5,6,7 and 10 may still be considered objectionable and agrees with WHO (2017), SON, (2015) and Martins and Idowu (2020).

4.4.8 Nitrate (NO_3)

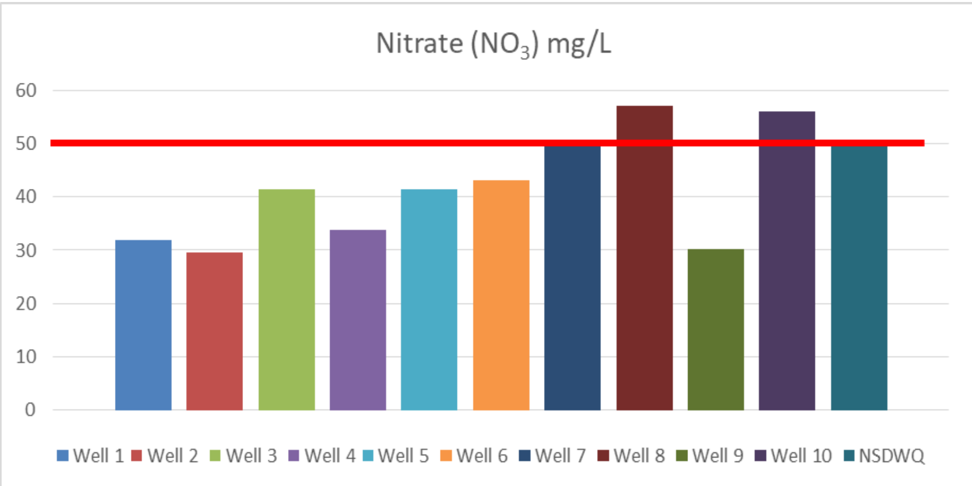

Figure 4.8: Concentration Levels of Nitrate. (NO_3)

Although there are differences in the values of the Nitrate (NO_3) from results obtained, the general results show that all the values for this parameter fall within the permissible limit of 50mg/L with the exception of wells 8 and 10 which recorded values of 57mg/L and 56mg/L respectively. Nitrate is naturally injected into groundwater through the chemical weathering of rock minerals and other organic constituents in the soil environment (Magashi et al, 2025). Nitrate can penetrate into groundwater through soil layers (Eze and Eze, 2018); also, pollution around hand dug wells can also lead to introduction of Nitrate into groundwater. Nitrate stimulates the growth of plankton and algae. However, if algae grow too wildly, oxygen levels, will be reduced to toxic nitrates in the human intestine. This especially affects babies through their intestines. Many babies have been seriously poisoned by hand dug well water containing high levels of nitrate-nitrogen (causing 'blue baby disease'). This agrees with works of Martins and Idowu (2020) and Gnimadi (2024) and Eze and Eze (2018).

4.4.9 Nitrite (NO_2)

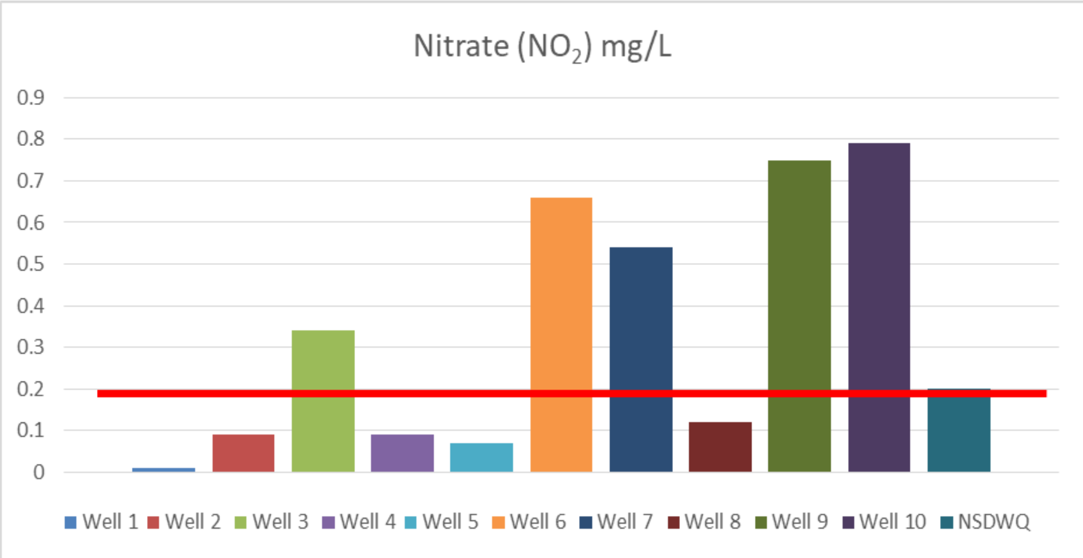

Figure 4.9 Concentration Levels of Nitrite.

The result for Nitrite concentration levels in sampled wells reveals differences in values with five wells recording values above the stipulated NSDWQ guidelines of 0.2mg/L and five wells recording values below the permissible level. Nitrite pollution in groundwater is as a result of animal waste run-offs from dairies and feedlots, excessive use of fertilizers or seepage of human sewage from private and public systems. The presence of nitrite in varying levels in the sampled wells could be as a result of location in close proximity to latrines and soakaways/ and/or dumpsites. Health implication of consuming water with high nitrite levels is the risk of 'blue baby syndrome' or methemogloinaemia as it easily affects the intestinal tracts of babies.

4.4.10 Biochemical Oxygen Demand

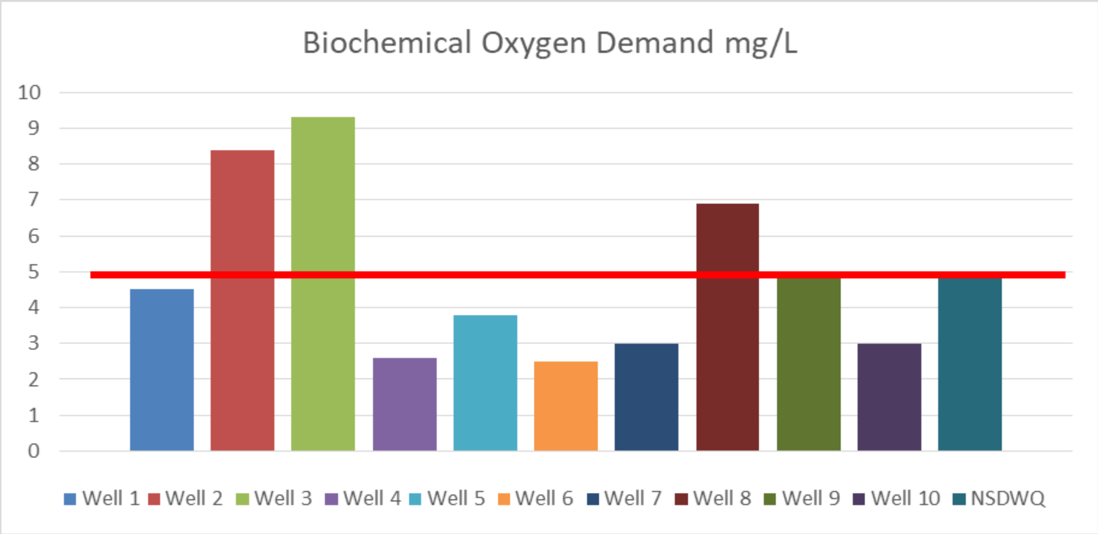

Figure 4.10 Concentration Levels of Biochemical Oxygen Demand.

The result for BOD shows that wells 2, 3, 8 and 9 have values above the permissible level of the NDSWQ which is <5mg/L. BOD in hand dug wells is a measure of organic pollution. High BOD is due to the presence of microorganisms as high bacteria count is an indication of water contamination (Akpoveta et al, 2021). Conversely, lower BOD presence indicates less contamination of water. The results for BOD show that BOD is present in all the sampled wells. The health implication of BOD (and especially high amount) is that it leads to the outbreak of water borne diseases such as dysentery, cholera and typhoid as well as potential exposure to pathogens and heavy metals carried by the organic matter.

4.4.11 E-Coli

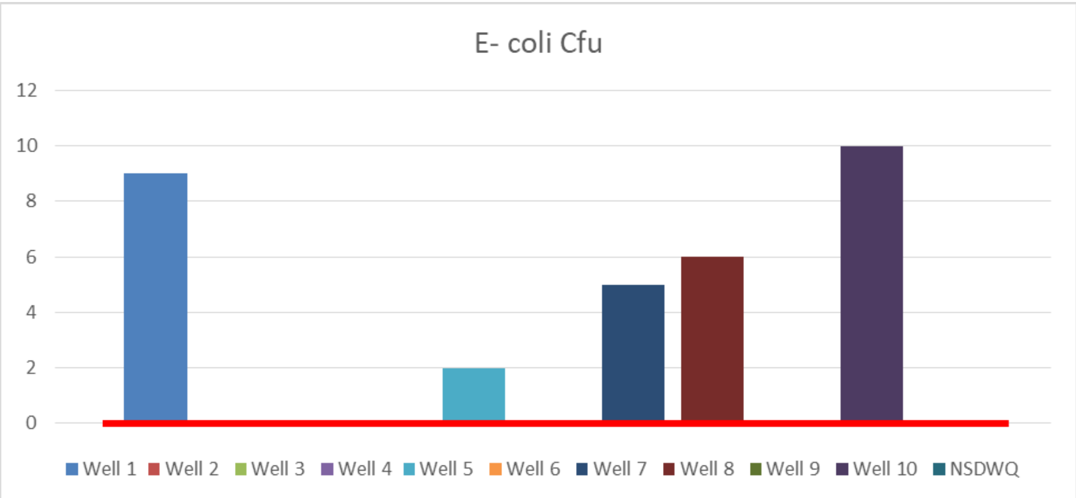

Figure 4.11 E-COLI.

Figure 4.11 shows the result for the presence of E-Coli in the hand dug wells sampled. Five of the wells, wells 1, 5, 7, 8 and 10 have e-coli presence in varying levels above the permissible guideline of 0cfu/ml by the NSDWQ. However, the other wells, 2,3,4, 6 and 9 do not have faecal presence which is the implication of e-coli contamination. While the presence of E-coli in the five wells indicates dangerous cases of microbiological contamination, the absence of this parameter in the other five wells is an indication of the fact that the wells are fit for consumption. However, of caution here is the fact that total coliform, even without E. coli still indicates a potential health risk and hints at possible integrity breaches in the water system. This finding agrees with the study by Imam et al (2025).

5. CONCLUSION

Access to potable water remains a major challenge in many parts of Makurdi, particularly in Wailomayo Ward where public water supply is inadequate. As a result, a significant proportion of residents depend on hand-dug wells for their domestic and drinking water needs. Although groundwater is often perceived as relatively safe, it is vulnerable to contamination from both geological formations and anthropogenic activities such as poor waste disposal, septic seepage, and urban runoff.This study assessed the physical, chemical and microbial concentration levels in water from hand-dug wells in Wailomayo Ward(Logo, Akpehe and AngwanJukum) to determine their suitability for human consumption. Findings revealed that several water quality parameters exceeded the permissible limits set by the Nigerian Standard for Drinking Water Quality, indicating varying degrees of contamination across the sampled wells. These results underscore the urgent need for effective government intervention, enforcement of groundwater protection policies, and implementation of appropriate water treatment measures to safeguard public health in the area.

6. RECOMMENDATIONS

1. **Provision of Safe Public Water Supply:** Government should strengthen and expand access to reliable potable water in Makurdi to reduce overdependence on hand-dug wells, which have shown varying levels of physical, chemical and microbial contamination.
2. **Routine Monitoring and Regulatory Enforcement:** Relevant health and environmental agencies should conduct regular inspection and laboratory testing of hand-dug wells to ensure compliance with the Standards Organisation of Nigeria drinking water guidelines, while enforcing proper siting, construction standards, and sanitation practices around wells.

3. **Public Health Education and Community Engagement:** Residents should be educated on safe water handling, household water treatment methods (such as boiling, filtration, and chlorination), and proper environmental sanitation to minimize the risk of waterborne diseases associated with contaminated well water.

7 CONTRIBUTION TO KNOWLEDGE

1 The study applied the Pearson's Product-Moment Correlation Coefficient (r) to establish relationships among physical, chemical and microbial parameters, thereby demonstrating how multiple water quality indicators can interact to influence overall contamination levels in hand-dug wells in Makurdi.

2 The research provides site-specific data on the major factors influencing hand-dug well contamination in Wailomayo Ward, particularly considering its low-lying terrain, thereby contributing to the existing body of knowledge on groundwater quality and management in Benue State.

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