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Assessment of Hand-Dug Wells Water Quality in Apeinumbu Community of Yandev, Gboko Local Government Area, Benue State, Nigeria: Implications for Public Health

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ABSTRACT

Understanding groundwater especially hand-dug well water quality in rural communities is a matter of utmost importance for ensuring public health and sustainable development. This study therefore investigated water quality of hand-dug wells and its implication for public health in the Apeinumbu Community of Yandev, Gboko Local Government Area, Benue State, Nigeria, focusing on physical, chemical, biological, and microbiological parameters. Water samples were taken from three locations across the study area, namely: Kumbur's Residence, NKST Pastor's Residence and Divine Mercy Neighborhood. The water samples were subject to standard laboratory analysis at Greater Makurdi Water Works Laboratory, Makurdi. Tables and bar charts were used for statistical analysis and compared with National Standard for Drinking Water Quality (NSDWQ) and WHO standards. The result shows that a pH values of 6.20, 6.00 and 6.45 at Kumbur's Residence, NKST Pastor's Residence, and Divine Mercy Neighborhood which are below the recommended standards, indicating increased acidity. Deviations were also observed in color, suspended solids, and turbidity levels, with some exceeding the WHO standards. Iron concentrations in Divine Mercy (1.09mg/l) surpassed permissible limits, while nitrite levels exceeded guidelines in NKST Pastor's Residence and Devine Mercy. Dissolved Oxygen levels were slightly below standards, and Biological Oxygen Demand indicated organic pollution. Coliform counts at NKST Pastor's Residence (17 cfu/100L) and Devine Mercy Neighborhood (32 cfu/100L) exceeded acceptable limits. The study concludes that water from these wells, particularly in Devine Mercy and NKST Pastor's Residence, poses health risks due to deviations from recommended standards. The acidic nature, chemical contaminants, and microbial contamination, as indicated by coliform counts, underscore potential health hazards for residents relying on these wells. Recommendations include avoiding untreated water consumption, implementing urgent water treatment measures, conducting community awareness programmes, and regular monitoring of water quality. Strict adherence to microbiological standards is crucial for public health, especially in areas with high coliform contamination. These findings emphasize the importance of addressing water quality concerns in the Yandev community to safeguard the health of its residents.

Key Words: Water quality, hand-dug wells, public health, physicochemical and biological

INTRODUCTION

Groundwater quality assessment is a crucial process to evaluate the suitability of groundwater for various uses, such as drinking, irrigation, industrial, and environmental purposes (United States Environmental

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Protection Agency- EPA, 2021, 2023). It involves the analysis of physical, chemical, and biological parameters to determine the level of contamination and the potential risks associated with its use (WHO, 2017; United States Environmental Protection Agency- EPA, 2023). Hand-dug wells are a vital natural resource that provides a significant portion of the world's drinking water supply. Ensuring its quality is of utmost importance to safeguard human health and the environment.

On the other hand, waterborne diseases remain a significant global public health concern, posing a substantial threat to populations across the world. These diseases are primarily caused by the consumption of contaminated water, resulting in a range of illnesses that can vary from mild gastrointestinal discomfort to severe, life-threatening conditions (Smith, Fewtrell and Bartram, 2018). Contaminated water sources, often tainted by microorganisms such as bacteria, viruses, and parasites, are the principal culprits behind waterborne diseases. The transmission of these pathogens occurs through various routes, including ingestion, contact, or inhalation of contaminated water or water-related materials. Common examples of waterborne diseases include cholera, typhoid fever, hepatitis A, giardiasis, and cryptosporidiosis, among others (Prüss-Ustün, Wolf, Bartram, Clasen, Cumming, Freeman, *et al,* 2014; EPA, 2023). Assessing the prevalence of waterborne diseases therefore, is of paramount importance to public health officials, researchers, and policy-makers, as it aids in understanding the scope of the problem, identifying risk factors, and designing effective interventions to mitigate their impact.

Shallow or hand-dug well water, is a vital source of freshwater for millions of people worldwide, particularly in rural and remote communities of most developing countries including Apeinumbu Community of Yandev, Gboko Local Government Area, Benue State, Nigeria. Wells, like boreholes, are commonly used to extract groundwater for various purposes, including drinking, agriculture, and industrial activities. However, the quality of water from wells can be compromised by a range of factors such as geological, hydrological, and anthropogenic factors, leading to potential health risks and the prevalence of water-borne diseases (Fawell & Nieuwenhuijsen, 2003; Iwar, Utsev and Hassan, 2021). This suggests that, naturally occurring contaminants such as heavy metals, arsenic, fluoride, and nitrate can leach into water from rocks and soils.

The prevalence of water-borne diseases due to poor well water quality has been documented in various studies. For instance, a study conducted by Smith et al. (2018), in rural communities of some developing countries including Nigeria, found a strong correlation between bacterial contamination of well water and cases of diarrheal diseases. Similarly, research by Li et al. (2020) demonstrated a significant link between high levels of arsenic in well water and increased risk of arsenicosis, a chronic condition caused by long-term exposure to arsenic.

Meanwhile, access to clean and safe drinking water is a fundamental human right, essential for maintaining public health and well-being. However, in the Apeinumbu community of Yandev, Gboko Local Government Area (LGA), Benue State, the primary source of water for domestic and agricultural purposes is groundwater, especially from wells, though surface water source such as stream is equally important. Concerns have been raised by the local community regarding the quality of well water and its potential correlation with the prevalence of waterborne diseases in the community which underscores the need for this study. Moreover, from the available literature (Ali, et al 2022; Owuna, 2023; Ocheri and Ode, 2022; Mile, Jande and Dagba, 2012), more emphasis has been put on quality of water sources (streams/rivers and hand-dug wells in urban areas.

Spatially, limited attention has been given to investigating the quality of water from hand-dug well in rural communities in Benue State, Nigeria including Apeinumbu community. In the last five years, waterborne diseases, such as diarrhea, cholera, and other gastrointestinal infections tend to be prevalent in Apeinumbu

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which may be connected to the quality of water the inhabitants consume, with hand-dug wells as the major source of water for drinking and other domestic uses. Hence, the need for a comprehensive study to determine the exact extent of contamination of water from these wells with focus on water quality parameters such as pH, turbidity, total dissolved solids, heavy metal content, and microbial contamination which may impact the safety of the water for human consumption and other uses. Understanding the extent of contamination of water from wells is crucial for developing effective mitigation strategies against water-related diseases and help improve the community's water quality and public health.

In light of these, the study is designed to address the gap in knowledge by assessing physicochemical and bacteriological quality of hand-dug well water in Apeinumbu community and its implications for public health.

MATERIALS AND METHODS

Study Area

Apeinumbu Community is found in Yandev Coubcil ward of Gboko local government area of Benue state, Nigeria. It is located on 7° 30' 57" N and 9° 25' 30" E. Yandev Council Ward is bordered by Tarka LGA to the north, Ipav and Mbayton council wards of Gboko LGA to the south and west. The notable landmarks in the area include the Dangote Cement plant and the Gboko polytechnic (Figure 1).

The geology of the area is dominated by sandstone sedimentary formations. Shale covers low-lying places such as Nguebi and Yandev axis. The area's soils are tropical ferruginous soils made up of hydrographics and lithosols. The parent materials formed by slope and climate are reflected in the soils. Because of the sandy quality of the topsoil, infiltration is simple, which explains why shallow wells are used in the region. The first aquifer is unconfined, with precipitation infiltration providing a water supply through a porous sandy environment. The second aquifer also referred to as the semi-confined has the formation of highly consolidated and geologically made of shale's intercalated with sandstones of coarse grains exhibiting larger pores. The study area generally has an undulating relief with few important geographic features. The noticeable uplands in the area are "Gboko and Mkar Hills" made up of lateritic mesas which serves as the source of streams in the area with an elevation of between 120m-200m above the sea level (Iorkua, Jika and Ayoosu, 2018).

The study area is drained by several streams and rivers, including Kontien, Ahungwa, Ambor, Ngo, Nguembi and the head stream of River Konshisha (Nyagba, 1995). The most significant water bodies are two streams - Ahungwa and Oratsor. The 'Ahungwa' Stream is impounded to create a dam for use at the cement factory. The study area is characterized by a dendritic drainage pattern, basically that of the surface drainage systems. It is drained by smaller streams.

The study area experiences tropical wet and dry climate (Koppen's Aw). The dry and wet seasons are the two primary seasons. The average temperature in the area is 28^0C, with an average relative humidity ranging from 60-90% during the wet season. The rainy season runs from April to October, with rainfall ranging from 900 to 1200 mm, with the greatest rain falling in June and September and decreasing as latitude increases.

In terms of natural resources base and economic activities**,** mineral deposit such as limestone, granite, barite, and alluvia clay abound in in the area. Farming is the main source of income for the residents, with the area known for producing large quantities of crops like as tomatoes, pepper, rice, yam, maize, and cassava. A number of periodic markets are located in the area, where residents buy and sell a range of commodities.

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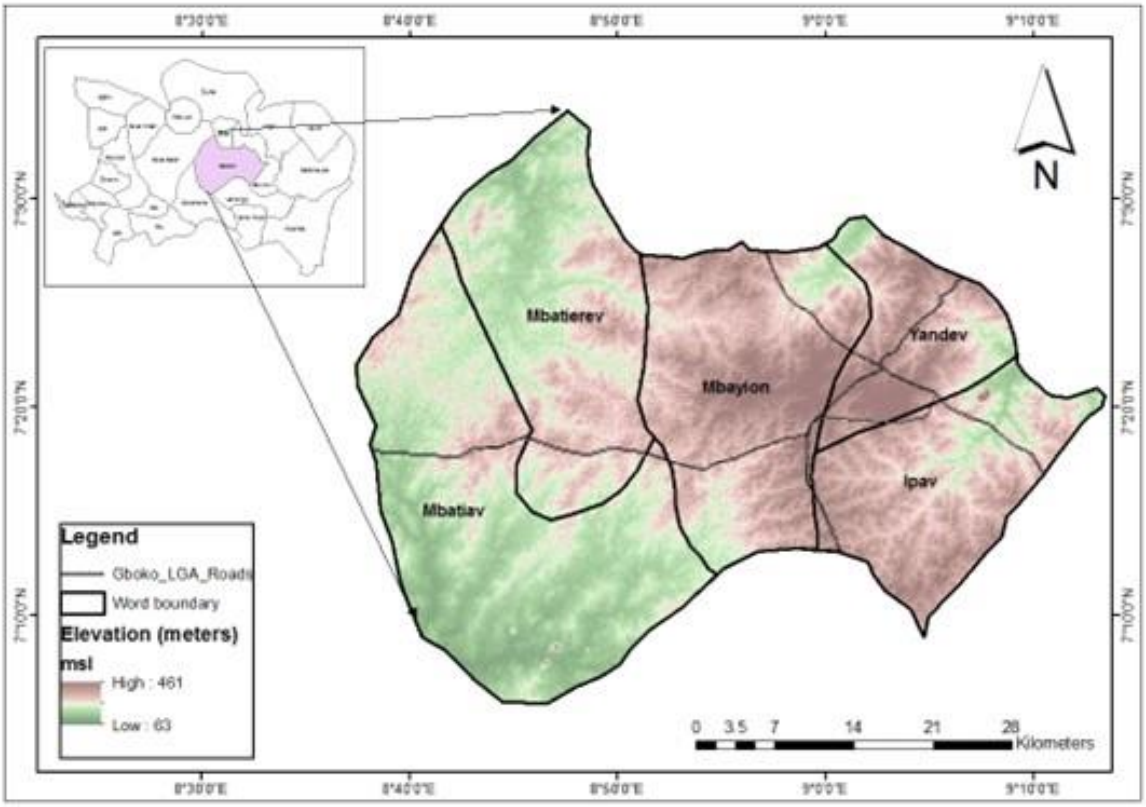

Figure 1: Gboko Local Government Area Showing Council Wards (Study Area)

Methods

The study purposively sampled three (3) hand-dug wells at the distance ranging from 2-3km apart across the study area. Purposive sampling methods was preferred in order to ensure even spatial cover of the study area. The wells are located at Kumbur's Residence, NKST Pastor's Residence and Divine Mercy Neighborhood. Though these well are located at individual residence, they are accessed by other households (over 10-20 households) within these localities, thereby making wells the major water points in the study area.

The water quality parameters selected for use in the study are presented in Table 1. The criteria for the selection of these parameters included potential health risk associated with these parameters.

Table 1: Water quality parameters

S/No	Parameter	Method of analysis	Unit of measurement	Maximum permitted limit (WHO/NSDWQ)
1	Turbidity	Turbidity Meter	NTU	5
2	pH	pH Meter	-	6.5-8.5
3	Colour		TCU	15
4	Suspended Solid	Filtration and drying	Mg/l	6

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5	Chloride	Titration	Mg/l	200-250
6	Nitrite	Spectrometry	Mg/l	50
7	Iron	Atomic Absorption Spectrometry	Mg/l	0.3
8	Dissolved Oxygen	Titrations	Mg/l	6
9	Biological Oxygen Demand (BOD)	Titrations	Mg/l	50
16	Total coliform	Surface viable count	Cfu/100L	0

Source: Water quality parameters compiled by the researcher, 2023

The water samples were collected from the sampled hand-dug wells in the study area using sterilized 1 litre plastic containers. The water samples were preserved with ice packs in a light proof insulated box to ensure rapid cooling so as to minimize chemical reactions and microbial growth in the samples. The ice packs encased in sealed containers to prevent them from contaminating the samples. Prior to packaging, the samples were chilled below 10^0C but not frozen and transported under iced condition within 24 hours to the laboratory for analysis of the selected physicochemical and bacteriological parameters. The water samples were subject to standard laboratory analysis at Greater Makurdi Water Works Laboratory, Makurdi and statistically analysed using tables and bar charts. The collection of water samples followed the steps outlined here:

1. 1 litre sterilized containers were obtained from the laboratory in surplus number to give allowance for replacement of any one that may be contaminated in the course of wrong handling. The containers were kept in a light-proof case to prevent them from coming in contact with contaminated surfaces. The sterile bottles remained closed until the time of taking the samples.

2. The fetcher containers were cleaned thoroughly using a clean cloth to remove any dust, dirt, and strainers which may harbour bacteria. These are potential sources to contaminate the samples.

3. The wells water thereafter was fetched carefully and ensure that the water sampled is a true representative of the water quality from the source.

4. The sample collector after washing his hands thoroughly with the water to be sampled, was also rinsed the containers with the water before collecting the actual sample. Then the bottle cap was carefully be removed to ensure that the inside of the container and cap do not come in contact with any contaminant.

5. While filling the bottle, the sampler will hold the bottle near the base, as it was filled to shoulder level.

6. Sufficient head space up to 1% of the container volume was left for aeration and mixing.

7. After sampling, the bottle was carefully recapped immediately.

8. The samples were labeled immediately according to the sampling locations of the hand-dug wells as WS1-WS3. WS mean water sample.

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RESULTS AND DISCUSSION

Concentration Level of Physical Water Quality Parameters

The result of the concentration levels of physical water quality parameters is presented in Figures 2–4 and Table 2. The physical water quality parameters investigated are pH, colour, suspended solid, and turbidity.

pH Concentration

The result of pH concentration in water samples of hand-dug wells is presented in Figure 2 and Table 2. The result indicates pH concentration of 6.20, 6.00 and 6.45 at Kumbur's Residence, NKST Pastor's Residence and Divine Mercy neighbourhood. The mean pH concentration in the study area stood at 6.22. This result suggests that all the pH values in the study area were below the NSDWQ and WHO standard of 6.5- 8.5 pH value for drinking water. This implies that hand-dug water in the study area is more acidic than required for drinking water and other domestic uses. The high pH values in hand-dug wells can be attributed the underlying rocks which are large limestone and sandstone. This can cause leaching of alkaline minerals such as calcium carbonate or magnesium hydroxide from these underlying soil and rock formations into the groundwater, or from the intrusion of surface water containing dissolved carbonates or hydroxides into the wells.

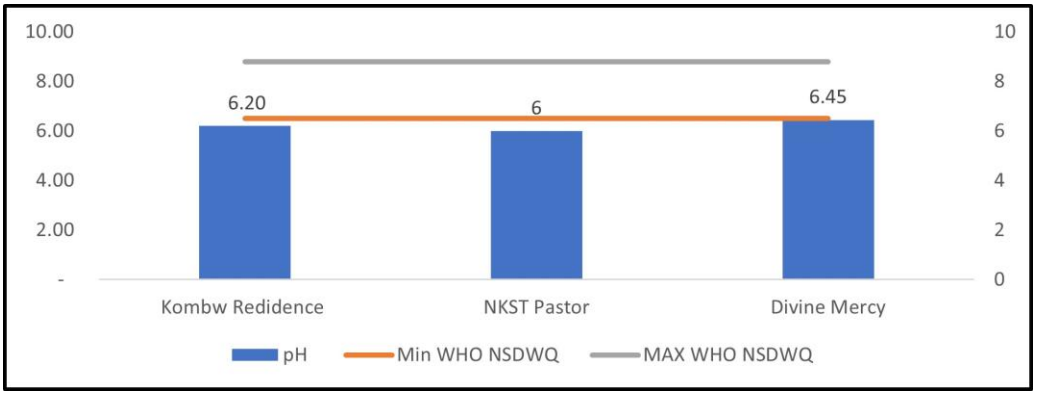

Figure 2: pH level Concentration

Table 2: Physical Water Quality Parameters of Hand-dug Wells

Parameter/Location	Kumbur's Residence	NKST Pastor's Residence	Divine Mercy Neighbourhood	NSDWQ	WHO
pH	6.20	6	6.45	6.5-8.8	6.5-8.8
Colour (TCU)	2	46	370	15	15
Suspended Solid (mg/l	6	13	73	6	6
Turbidity (NTU)	3.75	10.51	47.9	5	5

Source: Researcher's Field Work

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The pH value of hand-dug well water is a crucial parameter that can significantly impact its suitability for drinking and its potential health implications. The pH scale measures the acidity or alkalinity of a solution, with values below 7 indicating acidity, and values above 7 indicating alkalinity. A pH range of 6.0-6.45 for hand-dug well water in the study area falls slightly on the acidic side of the scale. The World Health Organization (WHO) recommends a pH range for drinking water between 6.5 and 8.5. This guideline is established to ensure that water is neither too acidic nor too alkaline, as extreme values can have adverse effects on human health. This suggests that the observed slightly acidic concentration of hand-hug well water in the study area has a number of implications for drinking and health. For instance, water with a pH below 7 tends to be acidic, and acidic water can be corrosive. This acidity may lead to the leaching of metals such as copper, iron, and lead from pipes, which can contaminate the water. Prolonged exposure to such metals can have detrimental health effects, especially on the nervous and circulatory systems.

Slightly acidic water may affect the absorption of certain essential minerals and nutrients in the body. While the impact may be minimal within the specified pH range, it is essential to consider the overall diet and nutritional intake of individuals relying on such water sources. Extremely low pH values can lead to water that is not only corrosive but may also cause respiratory irritation when inhaled as steam or vapor during activities such as showering. This is more relevant for values significantly below 6.0. This result is consistent with those of Jagaba, Kutty, Hayder, Baloo, Abubakar, Ghaleb, Lawal, Noor, Umaru and Almahbashi (2020) who reported that pH values of hand-dug well water samples at Rafin Zurfi, Bauchi State, Nigeria are adequate some study locations according to NSDWQ, while some study locations exceeded the WHO permissible limits.

Colour Concentration

The result of the colour level of the sampled hand-dug wells is presented in Figure 3 and Table. The result shows 2 TCU value for well water at Kumbur's Residence, while NKST Pastor's Residence and Divine Mercy neighbourhood are 46 TCU and 370 TCU, which are clearly above the NSDWQ and WHO tolerance limit of 6 TCU. On the other hand, well water in and around Kumbur's Residence is slightly below the NSDWQ and Who standard. This suggests that wellsc at Kumbur's Residence are better protected.

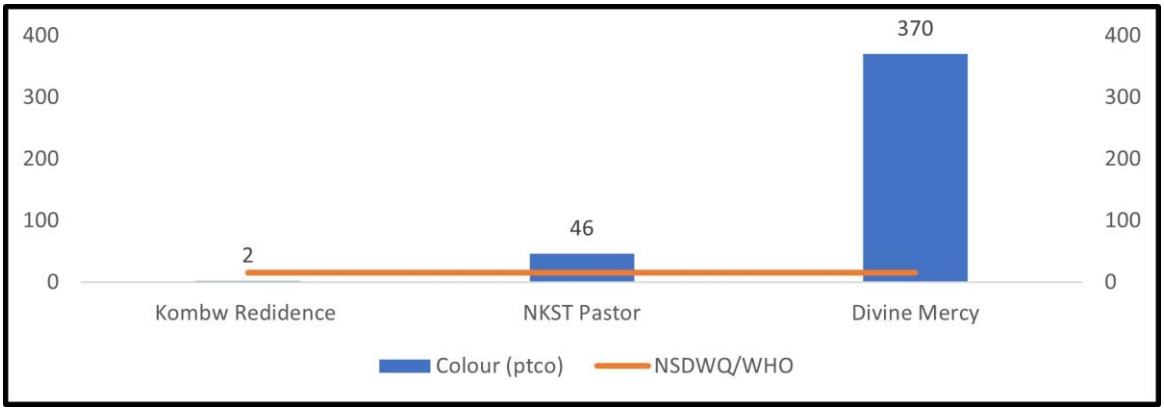

Figure 3: Colour Concentration

The water colour values measured in Tintometer (TCU) at different locations have significant implications for drinking water, other domestic uses, and health when compared to the Nigerian Standard for Drinking Water Quality (NSDWQ) and the World Health Organization (WHO) standard of 15 TCU. For instance, the water colour values of 2 TCU at Kumbur's Residence falls within the NSDWQ/WHO standard of 15 TCU, suggesting that the water may be suitable for drinking without significant aesthetic concerns related to colour, 46 TCU at NKST Pastors Residence may slightly raise concerns. However, the water at Divine

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Mercy Neighbourhood with a high color value of 370 TCU significantly exceeds the recommended standards, indicating potential aesthetic issues. High water color may affect the palatability of the water, influencing consumer acceptance. Furthermore, water with elevated color values, such as 370 TCU at Divine Mercy Neighbourhood, may pose challenges for other domestic uses like cooking, cleaning, and laundry. High colour levels can affect the appearance of dishes, laundry, and surfaces, and may lead to dissatisfaction among users. On health implications, while high water colour itself is not directly associated with adverse health effects, it can serve as an indicator of other water quality issues. Elevated colour levels may suggest the presence of organic matter, dissolved substances, or microbial contaminants that could impact health indirectly.

The water at Kumbur's Residence and NKST Pastors Residence complies with the NSDWQ/WHO standard, indicating that these sources meet the recommended guidelines for water colour. Residents in these areas may have access to water that meets basic aesthetic standards. In Divine Mercy Neighbourhood, the high colour value raises concerns about compliance with the established standards. The water colour values at the mentioned locations have direct implications for the suitability of water for drinking and other domestic uses. The deviations from the NSDWQ/WHO standards, particularly in Divine Mercy Neighbourhood, warrant immediate attention to ensure the safety and satisfaction of the residents in terms of water quality.

Suspended Solid

The result of the concentration level of suspended solid in hand-dug well in the study area is presented in Figure 4 and Table 2. The result indicates suspended solid concentrations of 6 mg/l, 13 mg/l and 73 mg/1 at Kumbur's Residence, NKST Pastor's Residence and Divine Mercy neighbourhood. This result suggests that suspended solid significantly exceeded the NSDWQ and WHO standard of 6.00mg/l.

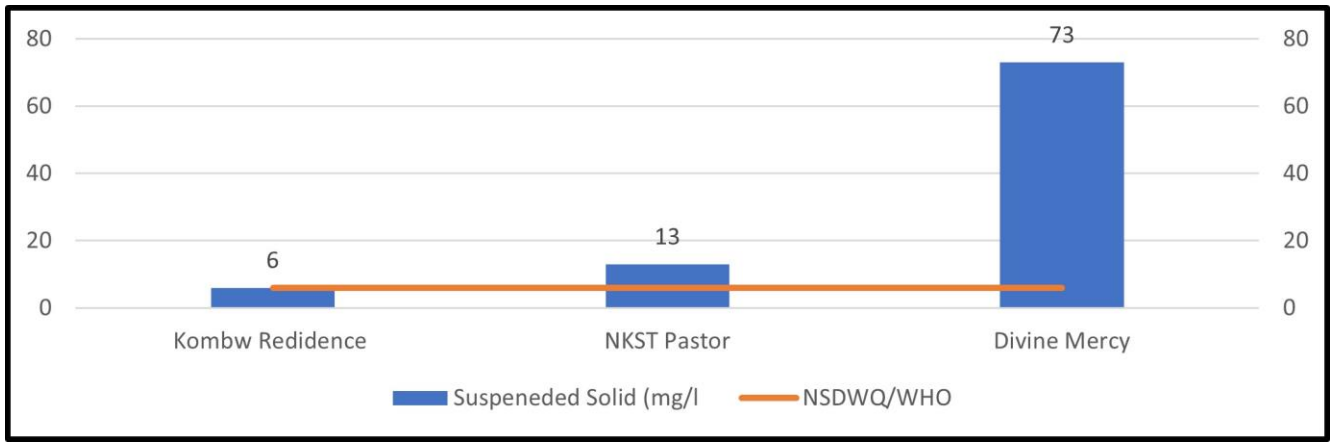

Figure 4: Suspended Solid Concentration in Hand-dug Wells

Suspended solid values in hand-dug wells at different locations can have significant consequences for drinking water quality, other domestic uses, and public health. For instance, the suspended solid values exceeding the NSDWQ/WHO standard of 6 mg/l at NKST Pastors Residence (13 mg/l) and especially at Divine Mercy Neighbourhood (73 mg/l) indicate potential contamination of the water sources. Suspended solids may include particles such as silt, clay, and organic matter, which can affect the taste, odor, and overall quality of the water. Consuming water with high suspended solid levels poses a risk to human health, as it may contain harmful pathogens and pollutants. Also, high levels of suspended solids in water can impact the suitability for various domestic uses. For instance, water with elevated solid content may cause issues in laundry, bathing, and cooking. Suspended solids can interfere with soap and detergent

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effectiveness, leaving residue on clothes and dishes. Additionally, cloudy water may be aesthetically displeasing and impact the overall usability of the water for daily household activities.

On public health concerns, high levels of suspended solids in drinking water can have adverse health effects. These particles may carry pathogens, bacteria, and other contaminants that can cause waterborne diseases, leading to gastrointestinal issues, infections, and other health problems. Vulnerable populations, such as children, the elderly, and individuals with weakened immune systems, are particularly at risk.

Turbidity

The result of the analysis of turbidity in well water in the study area is presented in Figure 5 and Table 2. The result indicates that turbidity in the study area ranged from 3.75-47.9 NTU. The turbidity level of 10.51 and 47.9 NTU exceeded NSDWQ and WHO standard of 5 NTU, while turbidity of 3.75 NTU in hand-dug wells at Kumbur's Residence fall below the standards.

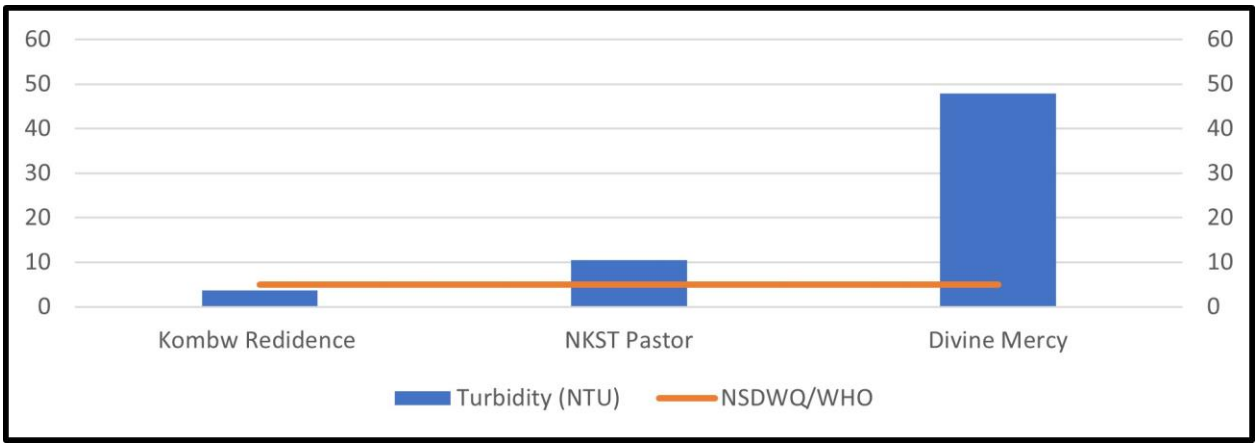

Figure 5: Turbidity level of Hand-dug wells

The turbidity values of hand-dug wells in various locations such as Kumbur's Residence (3.75 NTU), NKST Pastors Residence (10.51 NTU), and Divine Mercy Neighbourhood (47.9 NTU) are crucial indicators of water quality. The National Standard for Drinking Water Quality (NSDWQ) and the World Health Organization (WHO) recommend a turbidity level of 5 NTU or less for drinking water. The turbidity level at Kumbur's Residence is well below the NSDWQ/WHO standard, indicating relatively clear water. This suggests that the water from this well is suitable for drinking and other domestic uses. Low turbidity values are associated with improved aesthetics, as clear water is more visually appealing. From a health perspective, the low turbidity indicates a lower risk of waterborne diseases, contributing to the overall well-being of the community.

However, the turbidity level at NKST Pastors Residence slightly exceeds the recommended standard of 5 NTU. While it may still be considered acceptable for drinking according to some guidelines, the elevated turbidity suggests an increased presence of suspended particles in the water. These particles may include sediment, microorganisms, or other contaminants that could affect both the water's taste and safety. In the same vein, the turbidity value at Divine Mercy Neighbourhood significantly exceeds the NSDWQ/WHO standard. Such high turbidity levels indicate a substantial presence of suspended particles, potentially including pathogens, sediment, and pollutants. This poses a significant risk to health, as waterborne diseases are more likely to thrive in water with elevated turbidity. Residents in this area should avoid using this water for drinking or other domestic purposes without proper treatment. Again, Jagaba et al., (2020) reports that turbidity, Total hardness, TSS, EC, BOD, Ca, SO_4, Cl, Cu and Zn measurements were all within permissible

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limits of WHO, which is partly consistent with the findings of this study.

Chemical Parameters of Hand-Dug wells

The study analysed the following chemical water quality parameters of hand-dug wells in the study area. They are iron, nitrite and chloride. The result is presented in Figures 6 - 8 and Table 3.

Table 3: Chemical Water Quality Parameters of Hand-dug Wells

Parameter/Location	Kumbur's Residence	NKST Pastor's Residence	Divine Mercy Neighbourhood	NSDWQ	WHO
Iron (mg/l)	0.09	0.23	1.09	0.3	0.3
Nitrite (mg/l)	0.0281	0.259	0.346	0.2	0.2
chloride (mg/l)	70.9	113.4	156.01	250	200

Source: Researcher's Field Work

Iron concentration level

The result of the concentration level of iron in the sampled hand-dug wells is presented in Figure 6 and Table 3. The result shows that wells at Divine Mercy neighbourhood have the highest iron concentration of 1.09mg/l, which exceeded NSDWQ and WHO tolerance value of 0.3mg/l. The iron concentration of 0.09 and 0.23 were found in hand-dug wells water at Kumbur's and NKST Pastor's Residences respectively. These values are slightly below the NSDWQ and WHO standards of 0.3mg/l. The iron (fe) values in hand-dug wells at various locations have implications for drinking water, other domestic uses, and public health when compared to the Nigerian Standard for Drinking Water Quality (NSDWQ) and the World Health Organization (WHO) standard of 0.3 mg/l.

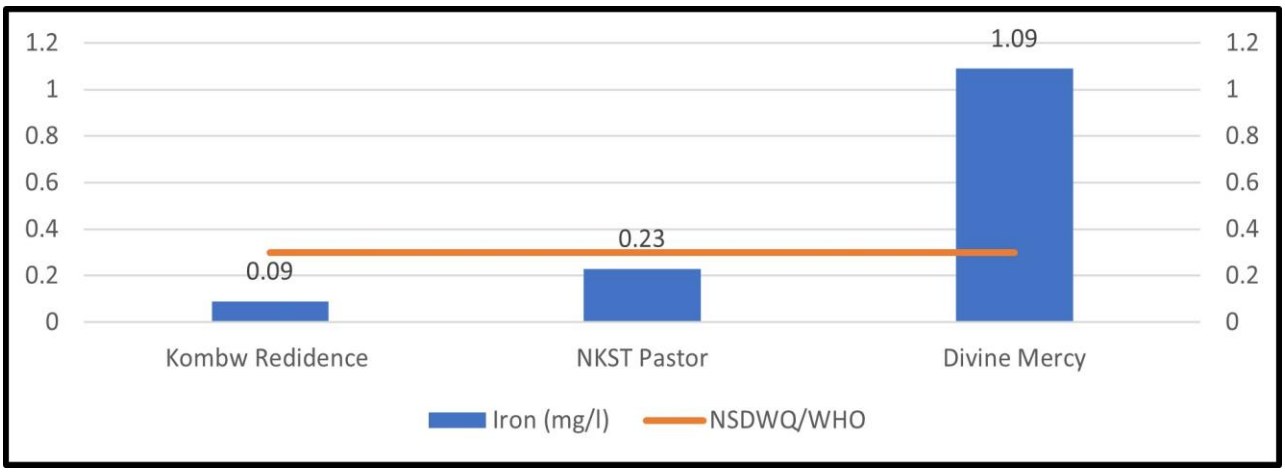

Figure 6: Iron concentration in Hand-dug Wells

This iron concentration falls well below the NSDWQ/WHO standard of 0.3 mg/l, indicating that the water from the hand-dug well at Kumbur's Residence is safe for drinking and other domestic uses. Low iron levels are generally desirable as they prevent issues such as taste and odor problems, staining of clothes and

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fixtures, and potential health concerns. The iron concentration at NKST Pastors Residence is slightly elevated but still below the NSDWQ/WHO standard. While it may not pose an immediate health risk, monitoring the trend is important to prevent a gradual increase over time. The iron concentration at Divine Mercy Neighbourhood is significantly higher than the recommended standards. Such elevated levels could lead to aesthetic issues like staining and an unpleasant taste in the water. At the short-run high iron concentration in water may not impact on human health negatively, however, prolonged consumption of water with high iron content may have health implications, including gastrointestinal distress and other related health concerns.

Nitrite Concentration Level

The result of the level of concentration of nitrite in the hand-dig wells is presented in Figure 7 and Table 3. The result shows nitrite concentration of 0.0281mg/l, 0.259 mg/l and 0.346mg/l at Kumbur's Residence, NKST Pastor's Residence and Divine Mercy neighbourhood respectively. All the value exceeded NSDWQ and WHO tolerance limit of 0.2 mg/l except for well water at Kumbur's Residence that falls below the acceptable limit.

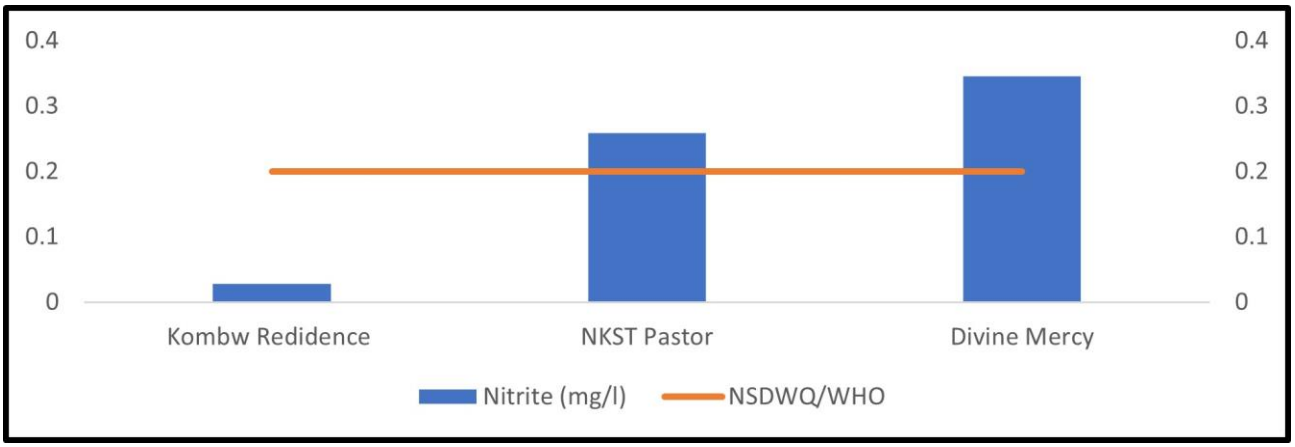

Figure 7: Nitrite Concentration in Hand-dug Wells

The Nitrite values observed in hand-dug wells at various locations have implications for drinking water, other domestic uses, and health. To assess these implications, it's important to compare the measured Nitrite concentrations with the Nigerian Standard for Drinking Water Quality (NSDWQ) and the World Health Organization (WHO) standard, both of which set a limit of 0.2 mg/l for Nitrites in drinking water. Elevated Nitrite levels in drinking water can pose serious health risks, particularly to infants. Nitrites can react with hemoglobin in the blood, forming methemoglobin, which reduces the blood's oxygen-carrying capacity. This condition is known as methemoglobinemia or "blue baby syndrome," and it can be life-threatening if not addressed promptly.

High Nitrite levels in water can also have adverse effects on other domestic uses. For instance, using water with elevated Nitrite concentrations for cooking may result in the ingestion of these contaminants, which can be harmful over time. Additionally, water with high Nitrite content may affect the taste and odor of food and beverages prepared with it, impacting overall food quality.

Beyond the immediate risks associated with drinking water, prolonged exposure to elevated Nitrite levels can lead to various health issues. These may include gastrointestinal problems, respiratory issues, and potential developmental problems in children. The presence of Nitrites in water sources should be promptly addressed to mitigate the long-term health risks associated with chronic exposure.

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Chloride Concentration

The result of the concentration of chloride in the hand-dug wells in the study area is presented in Figure 8. The result shows chloride concentration of 70.9mg/L, 113.4mg/l and 156.01mg/1 at Kumbur's residence, NKST Pastor's Residence and Divine Mercy neighbourhood respectively.

The chloride values of 70.9 mg/l at Kumbur's Residence, 113.4 mg/l at NKST Pastors Residence, and 156.01 mg/l at Divine Mercy Neighbourhood suggest varying levels of chloride contamination in hand-dug wells in these locations. Assessing these values in relation to the Nigerian Standard for Drinking Water Quality (NSDWQ) and World Health Organization (WHO) standards is crucial to understand the potential implications for drinking water safety, other domestic uses, and overall public health.

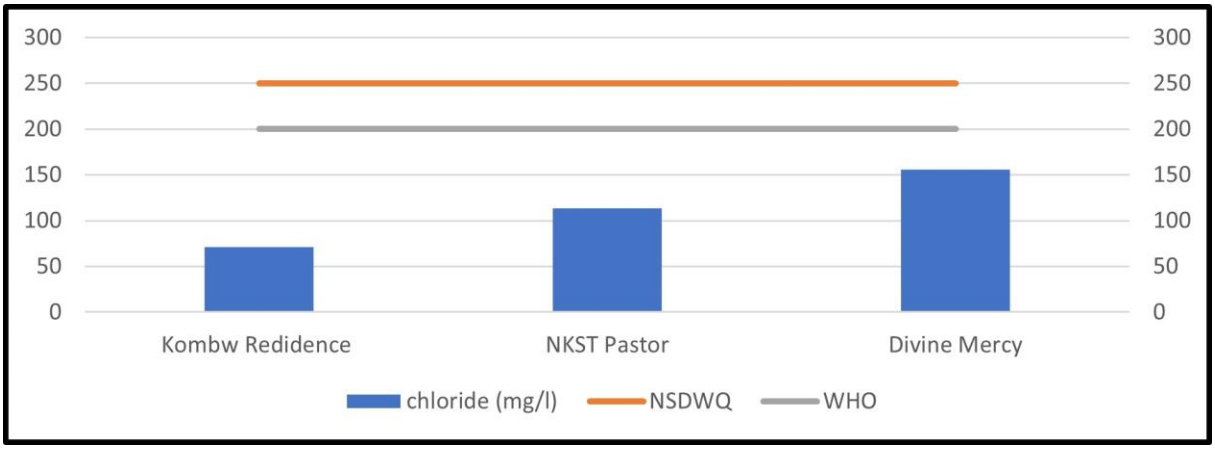

Figure 8: Chloride Concentration in Hand-dug Wells

According to the NSDWQ and WHO standards, the permissible limit for chloride in drinking water is set at 250 mg/l and 200 mg/l, respectively. The chloride values observed in Kumbur's Residence (70.9 mg/l) fall below both standards, indicating that the water is within acceptable limits for chloride content for drinking purposes. NKST Pastors Residence (113.4 mg/l) also falls below the NSDWQ and WHO standards, though it is closer to the upper limit. This may raise concerns about potential future increases in chloride levels. Divine Mercy Neighbourhood (156.01 mg/l) still falls below the standard; however, it is significantly higher than other location, indicating a potential health risk associated with drinking water from this source.

Beyond drinking, water is used for various domestic purposes, including cooking, bathing, and cleaning. While the chloride levels in Kumbur's Residence and NKST Pastors Residence are within acceptable limits, the elevated levels in Divine Mercy Neighbourhood may impact the suitability of water for these domestic uses. High chloride concentrations can impart undesirable taste to water and may contribute to corrosion of plumbing and appliances, affecting the overall quality of water for domestic applications.

Elevated chloride levels, especially exceeding established standards, can have health implications. Chronic exposure to high chloride levels in drinking water may lead to adverse health effects such as hypertension and cardiovascular issues. Communities relying on water sources with chloride concentrations above recommended levels, may face increased health risks. Continuous exposure to such water may necessitate mitigation measures or the identification of alternative water sources.

Biological and microbiological water Quality Parameters of Hand-Bug Wells

The following biological and microbial water quality parameters of hand-dug wells were assessed in the

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study area. They are dissolved solid (DO), Biological oxygen demand (BoD) and total coliform. The result is presented in Figures 9-11 and Table 4.

Table 4: Biological and microbiological Water Quality Parameters of Hand-dug Wells

Parameter/Location	Kumbur's Residence	NKST Pastor's Residence	Divine Mercy Neighbourhood	NSDWQ	WHO
Dissolved Oxygen (DO) (mg/l)	4.9	5.1	5.6	6	6
Biological Oxygen Demand (BoD) (mg/l)	28	40	47	50	50
Total Coliform (CFU/100mL)	0	17	32	10	10

Source: Researcher's Field Work

Dissolved Oxygen (DO) Concentration

The result of the concentration of dissolved oxygen (DO) is presented in Figure 9 and Table 4. The result indicates DO concentration of 4.9mg/l, 5.1 mg/l and 5.6 mg/l at Kombor Residence, NKST Pastor's Residence and Divine Mercy neighbourhood respectively. The Dissolved Oxygen (DO) values in hand-dug wells play a crucial role in assessing water quality for drinking, domestic use, and its potential impact on human health. The Dissolved Oxygen values of 4.9 mg/l at Kumbur's Residence, 5.1 mg/l at NKST Pastor's Residence, and 5.6 mg/l at Divine Mercy Neighborhood are slightly below the Nigerian Standard for Drinking Water Quality (NSDWQ) and World Health Organization (WHO) standard of 6.00 mg/l.

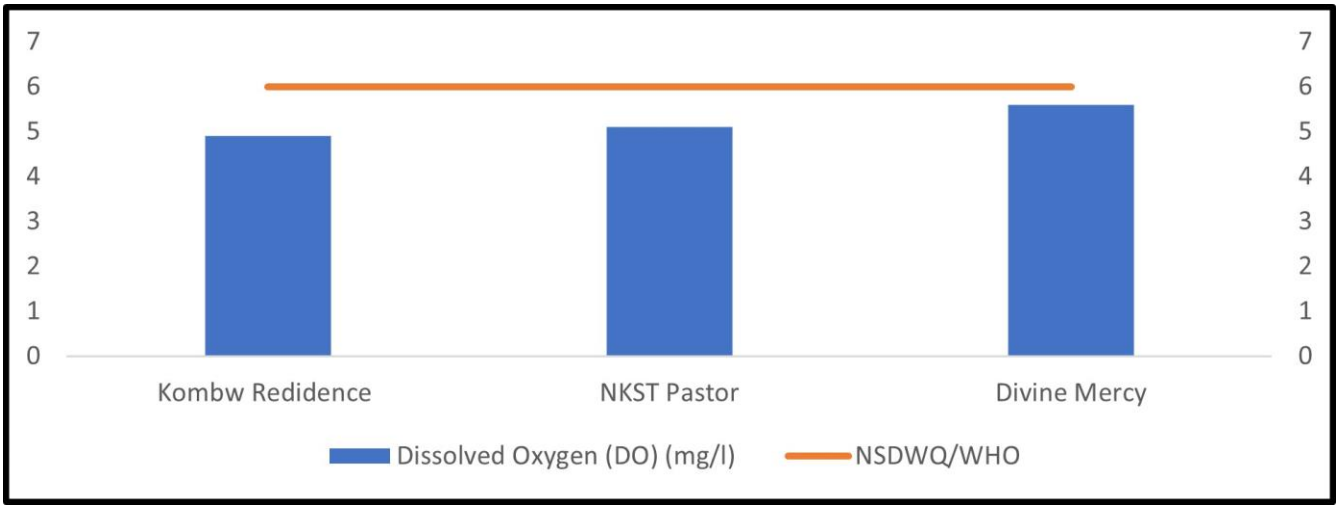

Figure 9: Dissolved Oxygen (DO) concentration

The implications of these values to different aspects such as drinking, other domestic uses, and public health in general. The DO values observed in the mentioned wells are close to the recommended standards, indicating relatively good water quality. However, any deviation from the recommended standards raises concerns about potential contaminants. Lower DO levels can affect the taste and odor of water. While the current values are acceptable, continuous monitoring is essential to ensure that water quality remains within the acceptable range. Also, hand-dug wells are often primary sources of water for domestic purposes.

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Adequate DO levels are crucial for sustaining aquatic life and preventing the growth of harmful bacteria and pathogens. Although the recorded values are slightly below the standard, they are still within an acceptable range for general domestic use.

Dissolved Oxygen is a key parameter in assessing the aerobic conditions of water. Inadequate DO levels may indicate the presence of pollutants or contaminants that can potentially harm human health. While the current DO values are not alarming, it is essential to recognize that they are close to the lower limit of the recommended standards. Prolonged exposure to water with lower DO levels may increase the risk of waterborne diseases.

Biological Oxygen Demand (BoD)

The result of the level of biological oxygen der Demand (BoD) is presented in Figure 10 and Table 4. The result shows that BoD of 38 mg/l, 47 mg/l and 50 mg/l at Kumbur's Residence, NKST Pastor's Residende and Divine mercy neighbourhood respectively.

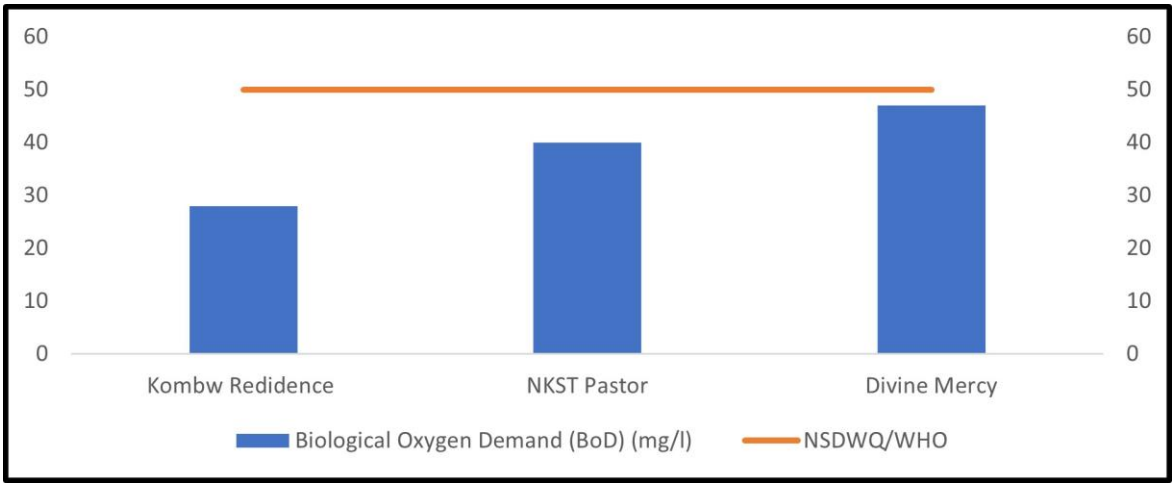

Figure 10: Biological Oxygen Demand (BoD) concentration

The Biological Oxygen Demand (BoD) values of 38 mg/l at Kumbur's Residence, 40 mg/l at NKST Pastor's Residence, and 47 mg/l at Divine Mercy Neighbourhood indicate the organic pollution levels in the hand-dug wells within these locations. These values represent the amount of dissolved oxygen required by microorganisms to break down organic matter in the water. While the NSDWQ (Nigerian Standard for Drinking Water Quality) and WHO (World Health Organization) standard for BoD in drinking water is set at 50 mg/l, the observed values in the mentioned wells are slightly below this threshold.

However, it is crucial to note that even though the BoD levels are below the standard, any presence of organic pollutants in drinking water may have implications for human health and domestic use. For instance, the BoD values, although below the standard, suggest that there is some degree of organic pollution in the water sources. Prolonged consumption of water with elevated organic content may pose health risks, such as the potential for waterborne diseases. Beyond drinking, water from these wells is likely used for various domestic purposes, including cooking, bathing, and cleaning. High organic content in water can affect the taste, odor, and color of water, making it less desirable for daily household activities. The presence of organic pollutants may lead to the growth of harmful microorganisms in the water. This can increase the risk of waterborne diseases such as diarrhea, gastroenteritis, and other waterborne infections. Vulnerable populations, such as children and the elderly, may be at a higher risk of health issues. Continuous exposure to water with elevated BoD levels may have cumulative health effects over time.

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Chronic exposure to organic pollutants can contribute to the development of health conditions and may impact the overall well-being of the community.

Total Coliform Count

The result of Coliform count is presented in Figure 11 and Table 4. The result indicates 17 cfu/100L and 32 cfu/100L at NIKST Pastor's Residence and Divine Mercy. neighbourhood respectively, while no coliform was found in hand-dug wells at Kumbur's Residence. The Coliform contamination level at NKST Pastor's Residence and Divine Mercy neighbourhoral exceeded the a NSDWQ and WHO acceptable limit of 10 cfu/100L.

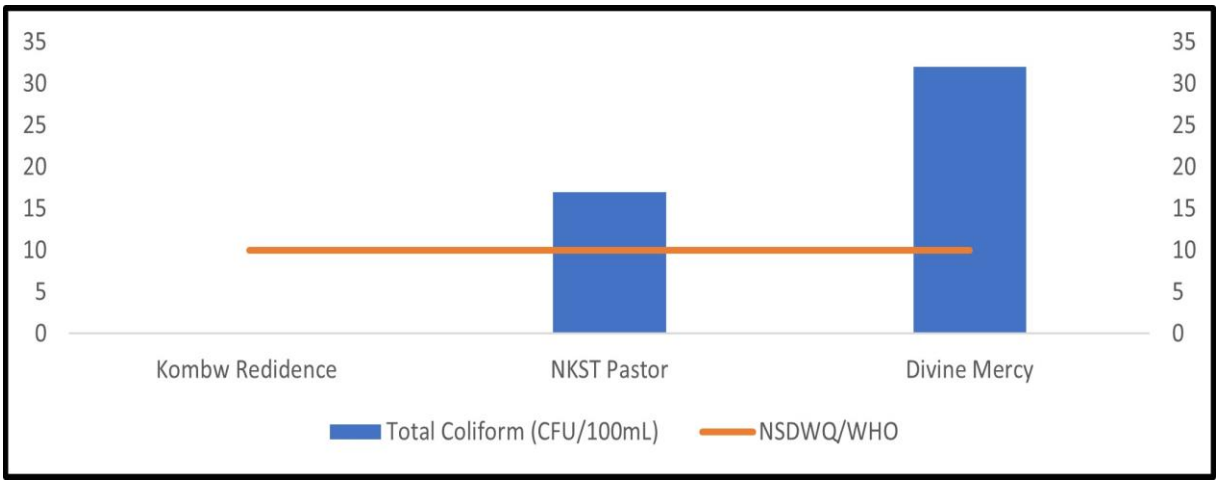

Figure 11: Total Coliform Concentration

The microbiological coliform values in hand-dug wells at various residences present important implications for drinking water quality, domestic use, and overall public health. The comparison of these values against the Nigerian Standard for Drinking Water Quality (NSDWQ) and World Health Organization (WHO) standard of 10 cfu/100L is crucial in assessing the safety of water sources. The absence of coliforms in the well water at Kumbur's Residence indicates a very low risk of fecal contamination. The water from this well meets the NSDWQ and WHO standards, making it suitable for drinking without posing a significant threat to health. Water from this well is safe for various domestic uses, including cooking and personal hygiene.

At, NKST Pastor's Residence, the coliform count of 17 cfu/100L suggests a moderate level of contamination, exceeding the recommended standards. While the contamination level is higher than the standards, it may still be considered relatively safe for drinking. However, periodic monitoring and water treatment are advisable. Caution is recommended for uses like cooking and personal hygiene, and appropriate water treatment methods should be implemented. At Divine Mercy Neighbourhood, the coliform count of 32 cfu/100L raises concerns about water safety, indicating a higher risk of fecal contamination. The water from this well exceeds both NSDWQ and WHO standards, posing a potential health risk. Immediate actions, such as water treatment or finding alternative water sources, are essential. Water from this well should not be used for domestic purposes without adequate treatment to reduce microbial contamination.

Overall, the results of hand-dug well water quality largely agree with those of Nkansah, Boadi and Badu, (2010). The author reported that the concentrations of most of the investigated parameters in the drinking water samples from Ashanti region of Ghana were within the permissible limits of the World Health

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Organization drinking water quality guidelines. Specifically their result showed variation in the investigated parameters in samples as follows: pH, 6.30–0.70; conductivity (EC), 46–682 μS/cm; PO_4^{3-}, 0.67–76.00 mg/L; F^-, 0.20–0.80 mg/L; NO_3^-, 0–0.968 mg/L; NO_2^-, 0–0.063 mg/L; SO_4^{2-}, 3.0–07.0 mg/L; Fe, 0–1.2 mg/L; Mn, 0–0.018 mg/L. Total coliform and Escherichia coli were below the minimum detection limit (MDL) of 20 MPN per 100 ml in all the samples.

Similarly, Yakubu, Bello and Diyaji, (2017) in their study of water quality assessment of hand-dug well in Sabon-Gari, Zaria, Nigeria reported high variation between the WHO standards and the obtained values from well water samples. With the exception of pH that fall within the range, the values for total hardness, total dissolved solid, DO, nitrate, chloride and conductivity fall below, while the values for temperature, BOD, bacteria count and coliform count are above the WHO standards. These findings are similar to this present study and underscores the level of contamination of hand-dug well water in most rural communities in developing countries including Nigeria.

The findings of Balarabe, Tijjani, Ahmad and Mustapha (2018) in their assessment of the water quality from hand dug wells and boreholes water in Rogo Local Government Kano State, Nigeria, showed some degree of agreement with the results of this study. They found that the mean pH ranged from 6.2 – 6.6 and temperature of the sample ranges from 24° C – 27° C. Total alkalinity ranges from 63-80mg/l, total acidity showed a great variation between the hand dug wells and borehole samples. DO concentrations of hand dug wells were less than that of boreholes and did not meet the WHO unit (5 -14 mg/l). The BOD of both boreholes and hand dug wells water sample were within the WHO standard (2 – 4 mg/l) for drinking, except borehole water sample from B4 with BOD value of 1.9. The water samples from both sources were odorless, colorless, tasteless and clear for consumption. Also, Ashafa, Saidu and Jibrin (2020) reported that all the analyzed samples in their study of physico-chemical parameters of some selected hand dug wells water in Bida Metropolis, Niger State, Nigeria fall within the allowable limit of world health organization standard and National standard for drinking water quality. Their findings indicated better water quality than the present study. They found that that PH value of the samples has the highest value of 7.56 (Alkaline), bicarbonate ranges from 0.52 mg/l to 47.94 mg/l. Chlorine ranges from 29.40 mg/l to 161.7 mg/l. The result of BOD and COD ranges from 8.00 mg/l to 17.0 mg/l and 16.0 mg/l to 56.0 mg/l respectively, it was found that turbidity test range from 0.30 NTU to 1.94 NTU. The electrical conductivity of the hand dug well water samples range from 93 ohms/cm to 1583 ohms/cm the mean average value of total dissolve solid was 186.33 mg/l and the result of calcium ranges between 3.36 mg/l to 65.60 mg/l. From the foregoing, it is evident that the location of hand-dug wells relative to waste dumpsite, pit latrine or soak away as well as its protection are critical to the overall water quality especially for drinking and other domestic uses.

CONCLUSION AND RECOMMENDATIONS

The study concludes that multiple water quality parameters of hand-dug wells deviated from recommended standards (NSDWQ and WHO), especially at Divine Mercy neighbourhood and NKST Pastor's Residence, indicating potential health implications for the residents relying on these hand-dug wells for drinking water. The presence of chemical contaminants such as iron and nitrite in the hand-dug wells is noteworthy. Similarly, the presence of coliform counts above the recommended limits in NKST Pastor's Residence and Divine Mercy Neighborhood further raises concerns about microbial contamination, emphasizing the potential health risks associated with these water sources.

Sequel to these findings, the study recommends that residents of these areas should avoid using this water for drinking purposes without proper treatment. Urgent measures should be taken by individuals, communities, and local authorities to implement appropriate water treatment methods to reduce water pollutant concentrations, especially in locations with elevated levels.

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