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Evaluation of Some Physicochemical Parameters in Borehole and Well Water in Tafawa Balewa, Bauchi State, Nigeria

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ABSTRACT: This study evaluated the physicochemical parameters of borehole and well water in Tafawa Balewa, Bauchi State, Nigeria using appropriate standard methods. Results for borehole water showed EC values ranging from 4.14 µS/cm (Rafin Gimba borehole) to 7.59 µS/cm (Dungah borehole), while well water EC ranged from 4.62 µS/cm (Rafin Gimba well) to 7.72 µS/cm (Maryam well). Borehole water pH values ranged between 7.10 and 7.50 and those for well water ranged from 6.90 to 7.50, all within the NSDWQ (Nigerian Standard for Water Quality) and WHO (World Health Organization) acceptable range of 6.5 – 8.5. However, TDS values for borehole water (up to 4,634 mg/dm^3) and well water (up to 4,710 mg/dm^3) exceeded the NSDWQ limit of 500 mg/dm^3, potentially indicating salinity risks. Turbidity values for both borehole and well water (up to 16.00 NTU and 15.00 NTU respectively) surpassed the maximum standard of 5.00 NTU, suggesting possible microbial contamination. Despite variations in TSS and TH, most values are within permissible limits, except for some locations with elevated hardness exceeding 150 mg/dm^3 standard. These findings highlight the need for regular monitoring and treatment of water sources in the study area to ensure compliance with drinking water quality standards.

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Water, chemically represented as H_2O, is a ubiquitous and indispensable molecule found throughout the world. It is a molecule of profound significance, not only for its role as the foundation of life, but also for its unique chemical and physical properties (Kendy *et al.*, 2010). Water is one of the most important compounds of the ecosystem and all living organisms on earth need water for their survival and growth. It is also used for drinking, cooking, agricultural activities and industrial activities; transportation and recreation are among the most vital uses of water (Simpi *et al*., 2011). Access to safe and clean water is a fundamental necessity for human health and sustainable development. Globally, millions of people, particularly in rural areas, rely on groundwater sources such as boreholes and wells, for their daily water needs (Akinbile *et al.,* 2020). The quality of groundwater is influenced by a range of physicochemical factors such as pH, temperature, total dissolved solids (TDS), total hardness (TH),

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TSS and turbidity. These parameters are crucial in determining the suitability for consumption, agricultural and industrial purposes. The permissible pH range of drinking water is 6.5 – 8.5, while TDS values should not exceed 1,000 mg/dm^3 to ensure safety and palatability (WHO, 2022). Despite these benchmarks, water quality assessments are often neglected in rural communities, leading to potential public health challenges. Nigeria faces significant challenges in ensuring safe drinking water for its growing population, especially in rural areas like Tafawa Balewa in Bauchi State. Groundwater, sourced from boreholes and wells, is the primary water supply for the majority of residents in this region. Unfortunately, these sources are vulnerable to contamination from both natural and anthropogenic activities. Studies in similar rural settings in Nigeria highlighted the presence of contaminants, with some physicochemical parameters exceeding WHO standards (WHO, 2022). Elevated TDS values ranging from 1,200 to 2,800 mg/dm^3 in groundwater samples from southwestern Nigeria, attributing the high values to geological formations and agricultural runoff (Akinbile *et al.*, 2020). The geology and hydrology of Tafawa Balewa play a critical role in shaping the quality of groundwater. The area is characterized by sedimentary rock formations, which influence the mineral content of water through processes such as leaching and dissolution. Seasonal variations in rainfall further exacerbate water quality fluctuations, with heavy rains increasing the risk of surface runoff and the introduction of contaminants into boreholes and wells. Bala and Yakubu (2020) highlighted that areas with similar geological features in northern Nigeria often show significant seasonal variation in physicochemical properties, particularly turbidity and dissolved oxygen levels. In addition to natural factors, anthropogenic activities significantly impact water quality in Tafawa Balewa. The widespread use of chemical fertilizers and pesticides in agriculture contributes to the infiltration of nitrates, phosphates and other harmful substances into groundwater. Similarly, improper waste disposal and the lack of sanitation facilities in rural areas heighten the risk of microbial and chemical contamination. For example, Eze *et al*. (2019) documented elevated nitrate levels in well water from agricultural regions of central Nigeria, with concentrations exceeding the WHO limit of 50 mg/dm^3. These findings highlight the urgent need for water quality assessments in agricultural communities to prevent adverse health effects. Waterborne diseases remain a pressing concern in many rural areas in Nigeria, where contaminated water sources are common. High turbidity levels, for instance, can reduce the effectiveness of disinfection processes, allowing pathogens to thrive. Elevated TDS values, on the other hand, may lead to long-term health issues, including kidney dysfunction and cardiovascular diseases. A study by Musa *et al*. (2021) found a strong correlation between poor water quality and the prevalence of waterborne illnesses in northern Nigerian communities, underscoring the critical role of regular water quality monitoring in public health. The availability of safe and clean drinking water is a fundamental requirement for public health and well-being. In Tafawa Balewa, the quality of water from boreholes and wells have not really been ascertained, there are concerns regarding the quality of water from boreholes and wells due to variations in physicochemical parameters resulting in several health issues such as typhoid and other water related health ailments. Hence, the objective of this paper is to determine some physicochemical parameters in borehole and well water in Tafawa Balewa, Bauchi State, Nigeria.

MATERIALS AND METHODS

Description of the Study Area: Tafawa Balewa metropolis until recently was the Local Government Capital of Tafawa Balewa LGA of Bauchi State. Its geographical coordinates are 9^o 45’ 30” North 9^o 33’ 26”. It is located in the southern part of Bauchi State. It shares boundaries with Bogoro and Dass Local Governments of the State. Mean daily maximum temperature ranges from 27 °C to 29 °C between July and August and 37.6 °C in March and April same as in Bauchi metropolis (Mohammed, 2018). The sunshine hour’s ranges from 5.1 hours in July to about 8.9 hours in November. October to February usually recorded the longest sunshine hours in Bauchi. The study was conducted in five settlements of the study area: Dungah, Tudun Wada, Maryam, Rafin Gimba and the Tafawa Balewa River.

Sampling and Sample Collection: A random sampling method was adopted and well labelled. A total of 24 water samples were collected, 3 in boreholes and 3 in well each at Dungah, Tudun Wada, Maryam and Rafin Gimba. The water samples were collected in 750 cm^3 plastic containers, the bottles were pre-washed with 20 % of HNO_3 followed by distilled water except for the determination of Hg, where borosilicate glass bottles were used to minimize Hg lost and contamination as reported by Badamsi *et al.* (2021a). While sampling, the bottles were filled with water from each sampling site and filtered. Few drops of 65.00 % of HNO_3 was added to bring the pH of the water samples below 2.00, to minimize precipitation and adsorption onto the container walls as adopted by Badamasi *et al.* (2021b). The samples were placed in an ice-box and transported to the laboratory for further analyses. All the samples were labelled with appropriate codes DB = Dungah borehole, DW = Dungah well, MB = Maryam borehole, MW = Maryam well, RB = Rafin Gimba borehole and RW = Rafin Gimba well.

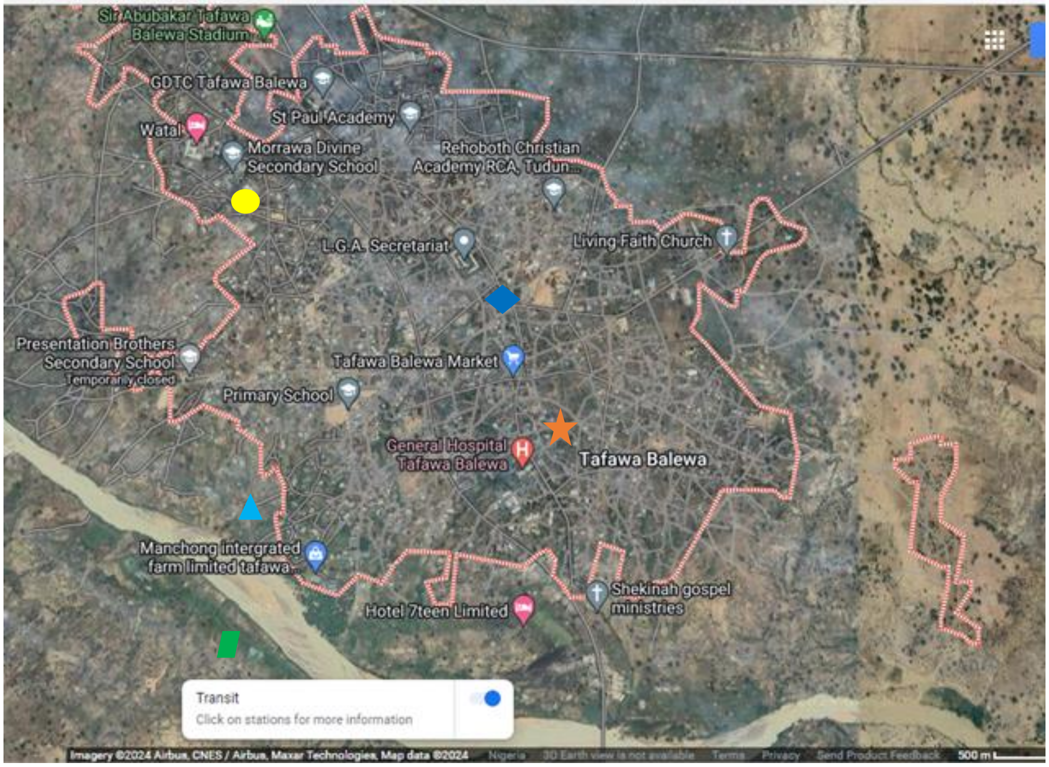

Fig.1: The Google Satellite View of Tafawa Balewa Metropolis
Source: Google map
Keys

Dungah Maryam Rafin Gimba Tudun Wada River

Determination of physicochemical parameters: The pH of water sample was measured using a hand held electrical pH meter and was determined at the point of sample collection. The temperature of the water sample was determined using a handheld mercury filled thermometer. The temperature was also measured and recorded at the point of sample collection. Total Dissolved Solid (TDS) was determined using a four in one Hanna Total dissolved solid, pH, Electrical Conductivity and temperature meter with model number HI9813-5 based on the method reported by Ademoroti (1996). Turbidity of the water was determined using a multi-programmed HACH DR/890 Colorimeter kit, expressed in whole number as Nephelometric turbidity unit (NTU) as described by other workers (Dinrifo *et al.*, 2010; Essien and Olisah, 2010). Electrical conductivity was determined using a four in one Hanna Total dissolved solid, pH, Electrical Conductivity and temperature meter with model number HI9813-5 based on the method reported by Ademoroti (1996). Total suspended solids (TSS) also known as non-filterable solids (NFS) was determined based on the methods adopted by Mackereth *et al.* (1989) and Ademoroti (1996). The total hardness of the water in the studied locations were determined titrimetrically using 0.01 mol/dm^3 ethylenediaminetetraacetic acid (EDTA) and ammonium buffer (pH 10.00) for each 50.00 cm^3 water sample. The total hardness was then calculated using the formula measured in mg/cm^3:

$$Total\ Hardness = \frac{V_b * 1000}{V_s} \quad (1)$$

Where Vs = Volume of sample; Vb = Volume of EDTA

Quality control and statistical analysis: All analyses were performed in triplicate. Blank determinations were carried out to correct any background contamination from reagents, filter papers or other systemic sources of error. Statistical analyses were conduct using Microsoft excel 2016 version and SPSS 23.0 (SPSS Inc., Chicago, USA). Analysis of variance (ANOVA) was used to test whether or not significant differences exist between water sources (Borehole, well and river). Statistical significance was considered at 95 % confidence level.

RESULTS AND DISCUSSION

Levels of Selected Physicochemical Parameters: Tables 1 and 2 show the levels of selected physicochemical parameters investigated in borehole and well water respectively in Tafawa Balewa, Bauchi State, Nigeria.

Table 1: Levels of Physicochemical Parameters in Borehole Water of Tafawa Balewa

Parameters	DB	MB	RB	TB	NSDWQ (2015)	WHO (2022)
EC (µS/cm)	$7.59^{a} \pm 0.01$	$6.81^{c} \pm 0.01$	$4.14^{d} \pm 0.01$	$7.17^{b} \pm 0.03$	1000	1500
pH	$7.10^{d} \pm 0.06$	$7.20^{b} \pm 0.06$	$7.50^{a} \pm 0.00$	$7.20^{b} \pm 0.00$	6.5 – 8.5	6.5 – 8.5
Temperature (°C)	$35^{a} \pm 0.00$	$34^{a} \pm 0.00$	$35^{a} \pm 0.00$	$35^{a} \pm 0.00$	Ambient	Ambient
TDS (mg/dm^3)	$3687^{a} \pm 136.39$	$4634^{b} \pm 10.54$	$1232^{d} \pm 10.02$	$3563^{c} \pm 38.02$	500	-
TH (mg/dm^3)	$266.70^{a} \pm 11.55$	$203.30^{c} \pm 20.82$	$90.00^{d} \pm 0.00$	$233.30^{b} \pm 11.55$	150	500
TSS (mg/dm^3)	$0.010^{b} \pm 0.001$	$0.012^{a} \pm 0.001$	$0.009^{c} \pm 0.001$	$0.002^{d} \pm 0.001$	-	-
Turbidity (NTU)	$12.00^{b} \pm 2.89$	$11.00^{c} \pm 0.58$	$07.00^{d} \pm 0.73$	$16.00^{a} \pm 1.53$	5.00	5.00

Values are mean ± standard deviation (n = 3). DB = Dungah borehole, MB = Maryam borehole, RB = Rafin Gimba borehole, TB = Tudun Wada borehole, NSDWQ = Nigerian standard for drinking water quality, WHO = World health organization, EC = Electrical Conductivity, TDS = Total Dissolved Solids, TH = Total Hardness and TSS = Total Suspended Solid. Values on the same row with the same superscript letters are significantly the same ($p \geq 0.05$), while those on the same row with different superscript letters are significantly different ($p \leq 0.05$) as revealed by one-way ANOVA and Least Significant Difference tests.

Table 2: Concentration of Physicochemical Parameters in Well Water of Tafawa Balewa

Parameters	DW	MW	RW	TW	NSDWQ (2015)	WHO (2022)
EC (µS/cm)	$6.90^{b} \pm 0.00$	$7.72^{a} \pm 0.01$	$4.62^{d} \pm 0.01$	$5.17^{c} \pm 0.01$	1000	1500
pH	$7.20^{c} \pm 0.15$	$6.90^{d} \pm 0.06$	$7.50^{a} \pm 0.06$	$7.40^{b} \pm 0.00$	6.5 – 8.5	6.5 – 8.5
Temperature (°C)	$35^{a} \pm 0.58$	$35^{a} \pm 0.58$	$35^{a} \pm 0.58$	$35^{a} \pm 0.58$	Ambient	Ambient
TDS (mg/dm^3)	$3759^{b} \pm 19.01$	$4710^{a} \pm 45.40$	$1497^{c} \pm 2.31$	$1441^{d} \pm 1.15$	500	-
TH (mg/dm^3)	$200.00^{b} \pm 20.00$	$216.70^{a} \pm 15.28$	$40.00^{d} \pm 0.00$	$60.00^{c} \pm 0.00$	150	500
TSS (mg/dm^3)	$0.053^{a} \pm 0.001$	$0.012^{c} \pm 0.001$	$0.011^{d} \pm 0.001$	$0.012^{c} \pm 0.001$	-	-
Turbidity (NTU)	$11.00^{c} \pm 1.53$	$13.00^{b} \pm 0.00$	$08.00^{d} \pm 0.58$	$15.00^{a} \pm 0.58$	5.00	5.00

Values are mean ± standard deviation (n = 3). DW = Dungah well, MW = Maryam well, RW = Rafin Gimba well, TW = Tudun Wada well, NSDWQ = Nigerian standard for drinking water quality, WHO = World health organization, EC = Electrical Conductivity, TDS = Total Dissolved Solids, TH = Total Hardness and TSS = Total Suspended Solid. Values on the same row with the same superscript letters are significantly the same ($p \geq 0.05$), while those on the same row with different superscript letters are significantly different ($p \leq 0.05$) as revealed by one-way ANOVA and Least Significant Difference tests.

Levels of Selected Physicochemical Parameters in borehole of Tafawa Balewa: The electrical conductivity (EC) of borehole water in Tafawa Balewa ranged from 4.14 µS/cm in Rafin Gimba borehole to 7.59 µS/cm in Dungah borehole, with intermediate values of 6.81 µS/cm and 7.17 µS/cm recorded in Maryam and Tudun Wada boreholes, respectively (Table 1). These values are significantly lower than those reported by Osakwe and Ifebi (2014), who observed EC values ranging from 52.80 µS/cm to 89.40 µS/cm in borehole water from Delta State, Nigeria and Egbuna *et al*. (2021), who recorded values of 30.00 – 80.00 µS/cm in southeastern Nigeria. The observed variations in EC values between this study and the literature could be attributed to differences in geological formations, levels of anthropogenic activities and the extent of mineral dissolution. The EC values obtained in this study are well below the permissible limits of 1,000 µS/cm stipulated by the Nigerian Standard for Drinking Water Quality (NSDWQ, 2015) and 1,500 µS/cm recommended by the World Health Organization (WHO, 2022). These low EC values indicate minimal ionic content, suggesting that borehole water in Tafawa Balewa is low in salinity and safe for human consumption with respect to electrical conductivity. This also reflects the reduced impact of industrial or agricultural pollution on the water sources.

The pH values of borehole water in Tafawa Balewa, as presented in Table 1, ranged from 7.10 in Dungah borehole to 7.50 in Rafin Gimba borehole, with intermediate values of 7.20 recorded in both Maryam and Tudun Wada boreholes. These values are consistent with the findings of Egbuna *et al*. (2021), who reported pH values ranging from 7.00 to 7.60 in borehole water samples from Anambra State, Nigeria. However, they contrast with the slightly acidic pH values of 6.20 to 6.90 reported by Musa and Tijjani (2020) in northern Nigeria, a difference likely attributed to variations in geological formations and anthropogenic activities such as agricultural runoff, which may introduce acidic or basic compounds into groundwater. The pH values obtained in this study fall within the acceptable range of 6.5 – 8.5 specified by the Nigerian Standard for Drinking Water Quality (NSDWQ, 2015) and the World Health Organization (WHO, 2022). This compliance suggests that the borehole water in Tafawa Balewa is suitable for consumption, posing no risks associated with acidity or alkalinity.

The temperature of borehole water in Tafawa Balewa, as shown in Table 1, was consistently measured at 35 °C across all sampling locations. This result is comparable to typical groundwater temperatures in tropical regions, where climatic conditions influence subsurface water systems. Musa and Tijjani (2020) reported groundwater temperatures ranging from 34 °C to 36 °C in northern Nigeria, attributing this to shallow aquifer depths and limited thermal insulation from the soil. Similarly, Egbuna *et al*. (2021) found groundwater temperatures of 33 °C to 35 °C in southeastern Nigeria. Although neither the NSDWQ nor WHO specifies a temperature standard for drinking water, elevated temperatures can influence water's palatability and the solubility of gases, potentially leading to changes in taste and odor.

The TDS values for borehole water ranged from 1,232 mg/dm^3 in Rafin Gimba borehole to 4,634 mg/dm^3 in Maryam borehole, with intermediate values of 3,563 mg/dm^3 and 3,687 mg/dm^3 recorded in Tudun Wada and Dungah boreholes, respectively. These values significantly exceed those reported by Egbuna *et al*. (2021), who documented TDS levels of 350 – 800 mg/dm^3 in borehole water from southeastern Nigeria and Omoniyi *et al*. (2019), who observed values ranging from 500 – 1,200 mg/dm^3 in groundwater in southwestern Nigeria. Elevated TDS levels in this study could result from geological factors, including the dissolution of minerals from sedimentary rocks, as well as anthropogenic inputs such as agricultural runoff. The observed TDS values also exceed the NSDWQ limit of 500 mg/dm^3, although WHO does not specify a maximum TDS guideline. High TDS levels may affect water taste and pose risks of kidney-related health issues when consumed over a long period.

The total hardness of borehole water ranged from 90.00 mg/dm^3 in Rafin Gimba borehole to 266.70 mg/dm^3 in Dungah borehole, with intermediate values of 203.30 mg/dm^3 and 233.30 mg/dm^3 in Maryam and Tudun Wada boreholes, respectively. These results align with findings by Musa and Tijjani (2020), who reported TH levels of 80 – 300 mg/dm^3 in borehole water from northern Nigeria and Osakwe and Ifebi (2014), who observed hardness levels between 100 and 250 mg/dm^3 in boreholes in Delta State, Nigeria. The elevated hardness levels in this study, particularly in Dungah and Tudun Wada, exceed the NSDWQ permissible limit of 150 mg/dm^3, although they fall well below the WHO guideline of 500 mg/dm^3. Hardness in water is influenced by dissolved calcium and magnesium ions, with variations often tied to local geology. High hardness levels may lead to scaling in appliances and reduced soap efficiency.

The TSS values for borehole water ranged from 0.002 mg/dm^3 in Tudun Wada borehole to 0.012 mg/dm^3 in Maryam borehole, with 0.009 mg/dm^3 and 0.010 mg/dm^3 observed in Rafin Gimba and Dungah boreholes, respectively. These values are lower than those reported by Egbuna *et al*. (2021), who documented TSS levels ranging from 0.05 – 0.12 mg/dm^3 in borehole water samples and Bala and Yakubu (2020), who observed similar values of 0.03 – 0.08 mg/dm^3 in groundwater in northern Nigeria. The low TSS levels in this study could result from natural filtration processes in the sedimentary rock formations of Tafawa Balewa, which restrict the entry of particulate matter into aquifers. While neither the NSDWQ nor WHO provides a standard for TSS, low levels indicate better water clarity and reduced risks of clogging in distribution systems.

The turbidity of borehole water ranged from 7.00 NTU in Rafin Gimba borehole to 16.00 NTU in Tudun Wada borehole, with values of 11.00 NTU and 12.00 NTU recorded in Maryam and Dungah boreholes, respectively. These values are higher than those reported by Osakwe and Ifebi (2014), who documented turbidity levels of 3.00 – 8.00 NTU in borehole water from Delta State, Nigeria, but are comparable to the findings of Musa and Tijjani (2020), who recorded turbidity values of 8.00 – 20.00 NTU in northern Nigeria. The high turbidity levels in this study likely result from surface runoff, poor wellhead protection and infiltration of particulate matter. Notably, all the turbidity values exceed the NSDWQ and WHO standards of 5.00 NTU, indicating the potential presence of microbial contaminants. Elevated turbidity suggests the need for treatment before consumption to mitigate health risks.

Levels of Selected Physicochemical Parameters in Well of Tafawa Balewa: The electrical conductivity (EC) of well water in Tafawa Balewa ranged from 4.62 µS/cm in Rafin Gimba well to 7.72 µS/cm in Maryam well, with intermediate values of 5.17 µS/cm and 6.90 µS/cm recorded in Tudun Wada and

Dungah wells, respectively (Table 2). These values are much lower than those reported by Bala and Yakubu (2020), who documented EC values ranging from 45.00 µS/cm to 120.00 µS/cm in well water from northern Nigeria. Similarly, Egbuna *et al*. (2021) observed EC values of 30.00 – 80.00 µS/cm in southeastern Nigeria. The lower EC values observed in this study may reflect minimal dissolved ionic species, likely due to limited anthropogenic activities and the influence of sedimentary rock formations, which yield water with reduced mineral content. Notably, the EC values in this study are well within the permissible limits of 1,000 µS/cm set by the NSDWQ (2015) and 1,500 µS/cm recommended by WHO (2022). This suggests that the well water sources in Tafawa Balewa are low in salinity and safe for consumption with respect to electrical conductivity.

The pH values of well water in Tafawa Balewa ranged from 6.90 in Maryam well to 7.50 in Rafin Gimba well, with intermediate values of 7.20 and 7.40 observed in Dungah and Tudun Wada wells, respectively (Table 2). These results align with findings by Omoniyi *et al*. (2019), who reported pH values of 6.80 – 7.60 in well water from southwestern Nigeria. However, they contrast slightly with the slightly acidic pH values of 6.50 – 7.00 reported by Musa and Tijjani (2020) in northern Nigeria, likely due to regional differences in geological formations and water table depths. The observed pH values in this study fall within the acceptable range of 6.5 – 8.5 stipulated by both the NSDWQ (2015) and WHO (2022), indicating that the well water is neutral to slightly alkaline and suitable for consumption. This neutral pH also minimizes the risks of corrosion and scaling in water distribution systems, making the water safer for domestic and industrial use.

The temperature of well water in Tafawa Balewa was consistently recorded at 35°C across all sampling locations, as shown in Table 2. This value aligns with findings by Bala and Yakubu (2020), who reported well water temperatures ranging from 34°C to 36°C in northern Nigeria. Similarly, Egbuna *et al*. (2021) observed temperatures of 33°C to 35°C in well water samples from southeastern Nigeria, attributing such elevated values to the shallow nature of aquifers in tropical regions and the influence of ambient temperatures. While the NSDWQ and WHO do not provide specific guidelines for water temperature, high temperatures may influence water's taste and odor, as well as reduce the solubility of oxygen, potentially affecting its overall quality.

The TDS values for well water in Tafawa Balewa ranged from 1,441 mg/dm^3 in Tudun Wada well to 4,710 mg/dm^3 in Maryam well, with intermediate values of 1,497 mg/dm^3 and 3,759 mg/dm^3 observed in Rafin Gimba and Dungah wells, respectively. These values significantly exceed those reported by Omoniyi *et al*. (2019), who documented TDS levels of 500 – 1,200 mg/dm^3 in well water from southwestern Nigeria. The variations in TDS levels can be linked to the dissolution of minerals from sedimentary rocks and anthropogenic activities such as agricultural runoff, which introduces ions into the water. Notably, the observed TDS values exceed the NSDWQ limit of 500 mg/dm^3, suggesting potential issues with taste and long-term health risks. WHO does not specify a limit but recommends values below 1,000 mg/dm^3 for palatability.

The total hardness of well water ranged from 40.00 mg/dm^3 in Rafin Gimba well to 216.70 mg/dm^3 in Maryam well, with intermediate values of 60.00 mg/dm^3 and 200.00 mg/dm^3 in Tudun Wada and Dungah wells, respectively. These results are consistent with the findings of Musa and Tijjani (2020), who observed TH levels between 50 – 250 mg/dm^3 in well water from northern Nigeria. However, the values exceed the NSDWQ limit of 150 mg/dm^3 in some wells but are within the WHO guideline of 500 mg/dm^3. Elevated hardness levels, caused by dissolved calcium and magnesium ions, can lead to scaling in pipes and household appliances, as well as affect the efficiency of soap.

The TSS values for well water ranged from 0.011 mg/dm^3 in Rafin Gimba well to 0.053 mg/dm^3 in Dungah well, with intermediate values of 0.012 mg/dm^3 recorded in Maryam and Tudun Wada wells. These values are higher than those reported by Bala and Yakubu (2020), who observed TSS levels ranging from 0.01 to 0.03 mg/dm^3 in well water from northern Nigeria. The slightly elevated TSS levels in this study may reflect surface runoff and sediment infiltration into the wells due to insufficient protective measures. Although neither the NSDWQ nor WHO specifies a limit for TSS, low values indicate clearer water and reduced risks of clogging or contamination by particulates.

The turbidity of well water ranged from 8.00 NTU in Rafin Gimba well to 15.00 NTU in Tudun Wada well, with values of 11.00 NTU and 13.00 NTU observed in Dungah and Maryam wells, respectively. These values are consistent with the findings of Omoniyi *et al*. (2019), who reported turbidity levels of 8.00 – 18.00 NTU in well water from southwestern Nigeria, but exceed the NSDWQ and WHO standards of 5.00 NTU. The high turbidity values suggest the presence of suspended particles and possible microbial contamination, potentially resulting from poor wellhead protection and surface runoff. Elevated turbidity levels pose risks to human health if the water is consumed untreated and highlight the need for filtration or sedimentation treatments *before use.*

Data analyses: The experimental values were subjected to standard error of the mean (a measure of precision) and One-Way Analysis of Variance with F-critical of 4.07 for a 3, 8 degree of freedom as shown in Table 1 and 2. Experimental values that were statistically different ($p < 0.05$) were further subjected to the Least Significant Difference test (LSD) with a view to determine where the significant difference lies.

Conclusion: This study successfully assessed the physicochemical parameters of borehole and well water in Tafawa Balewa, revealing that while electrical conductivity and pH values complied with NSDWQ (2015) and WHO (2022) standards, turbidity, total dissolved solids and total hardness exceeded permissible limits in some locations. To address these challenges, regular monitoring is recommended alongside the implementation of effective treatment methods such as sedimentation, filtration and disinfection to reduce turbidity and microbial risks. Public awareness campaigns on wellhead protection and runoff prevention are crucial, while the government and relevant agencies should ensure access to affordable water treatment facilities in the study location. Collaborative efforts involving local authorities, health organizations and water management experts are essential for ensuring sustainable access to safe and potable water for residents of Tafawa Balewa.

Declaration of conflict of interest: The authors declare no conflict of interest in this work.

Data Availability Statement: Data are available upon request from the first author or corresponding author or any of the other authors.

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