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ASSESSMENT OF WELL AND BOREHOLE WATER QUALITY IN BALI TOWN, BALI LOCAL GOVERNMENT AREA, TARABA STATE

BY

Isah A. S.[1]
aminuisahsuleiman6@gmail.com

And

Mohammed A. T.[2]
abubakarmtela@gmail.com
[1,2]Department of Civil Engineering, Federal Polytechnic Bali, Taraba State, Nigeria.

Abstract

This study assessed the quality of well and borehole water in Bali Town, located in Bali Local Government Area of Taraba State, Nigeria, by analyzing their physicochemical and bacteriological characteristics. Water samples were collected from twenty different locations, comprising ten hand-dug wells and ten boreholes across the town. Physicochemical analysis of the well water samples showed that parameters such as electrical conductivity, ammoniacal nitrogen, nitrate, total suspended solids, total dissolved solids, and total solids ranged from 31–56 µS/cm, 0.36–4.6 mg/L, 10–35 mg/L, 200–407 mg/L, 10–22 mg/L, and 210–427 mg/L, respectively. These values were within the permissible limits set by the World Health Organization (WHO, 2017) and the Nigerian Standard for Drinking Water Quality (NSDWQ, 2015). For borehole water samples, parameters such as dissolved oxygen, nitrate, ammoniacal nitrogen, total hardness, electrical conductivity, total potassium, total suspended solids, total dissolved solids, and total solids ranged from 8–19 mg/L, 0.32–0.56 mg/L, 22–45 mg/L, 112–220 µS/cm, 5.2–9.1 mg/L, 190–500 mg/L, 9–34 mg/L, and 206–514 mg/L, respectively. These also fell within WHO and NSDWQ standards. However, some well water samples exceeded acceptable limits for certain parameters. Turbidity (7–13 NTU) and total hardness (182–308 mg/L) surpassed the maximum allowable thresholds. Additionally, two samples from Anguwan Adamu and Sabon Layi had pH values above the recommended limits. Elevated potassium levels were detected in samples from Anguwan Adamu and Anguwan Idi, while dissolved oxygen levels exceeded standards in samples from Daniya, Anguwan Idi, Anguwan Musa, and Anguwan Jibawa. Similarly, in borehole water samples, turbidity levels exceeded the permissible limit in samples from Anguwan Sa'adu, Anguwan Idi, and Anguwan Jibawa. Potassium concentrations were above the threshold in samples from Anguwan Adamu and Daniya, and dissolved oxygen levels exceeded limits in samples from Anguwan Adamu, Anguwan Sa'adu, and Daniya. Bacteriological analysis revealed the presence of faecal coliforms (3–13 cfu/100 mL) and total coliforms (14–116 cfu/100 mL) in well water samples, indicating contamination likely due to poor sanitation, hygiene, and agricultural runoff. These elevated microbial levels pose serious risks to water safety for both drinking and agricultural use. The findings underscore the urgent need for targeted interventions, including the establishment of water treatment facilities, community education

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on the dangers of poor sanitation and hygiene, and the promotion of sustainable agricultural practices and public awareness on water pollution risks.

Keywords: Water quality, Physicochemical and Bacteriological Parameters, Surface and Groundwater, Water sanitation and Hygiene, Nigeria Standard for Drinking Water Quality (NSDWQ)

INTRODUCTION

Water is one of the most essential and irreplaceable resources for sustaining life. Both its quantity and quality have a direct impact on the proper functioning of the human body, which consists of approximately 75% water by weight. Given its critical role in human health and survival, alongside the growing importance of sustainable water resource management, it is imperative to manage this finite resource efficiently to ensure an adequate supply of water that meets acceptable quality standards. As the global population continues to grow, the demand for clean and safe water increases correspondingly. Maintaining water quality is not only vital for human health but also for the overall well-being of ecosystems and all living organisms.

A well is an excavation or structure created in the ground through digging, driving, or drilling to access groundwater. It represents one of the oldest and most commonly used methods for obtaining water from underground aquifers (Abubakar & Ibrahim, 2016). In Bali Metropolis, well water serves as the primary source of drinking water for the majority of the population, with approximately 94% relying on it for daily use (Naziru & Abdulkarim, 2023).

Compared to piped water, wells and boreholes are generally more vulnerable to contamination (Tole, 2019). This issue is particularly severe and widespread in developing countries, where unchecked industrial growth, inadequate monitoring infrastructure, and weak or absent environmental regulations exacerbate the problem (Ntengwe, 2018). The presence of contaminants exceeding the acceptable limits set by the World Health Organization (WHO) has been linked to the spread of various waterborne diseases, including typhoid fever, dysentery, gastrointestinal infections, and infectious hepatitis (Jiang, 2020). These risks underscore the importance of regularly monitoring chemical contaminant levels in both hand-dug wells and boreholes. The rapid growth of human populations and the expansion of urban land use have significantly increased the demand for water. As a result, alternative sources such as groundwater are increasingly being exploited through the drilling of hand-dug wells and boreholes, as observed in the study area.

Water quality is the physical, chemical and biological state of water in relation to its uses. Water quality should be assessed on the characteristics of the water relative to the beneficial uses of the water (Jidauna et al., 2017). Evaluation of these qualities is mainly to compare the concentration of key elements with the standards set by the World Health Organization and other sister organizations to ascertain the potability of the water, for human consumption.

Contaminated water and inadequate sanitation have emerged as significant global challenges, posing substantial threats to public health and burdening communities with the transmission of various diseases. Developing nations, in particular, face obstacles in accessing safe drinking water and maintaining proper sanitation infrastructure, exacerbating the problem. Bali town, situated in the Bali Local Government area of Taraba State, Nigeria, exemplifies a community grappling with these ongoing challenges. Compounding the issue is the contamination of surface water from agricultural activities and other human interventions, highlighting the urgent need for effective control measures. Therefore, this study aims to

evaluate well and borehole water quality in Bali town, Bali local government Area of Taraba state focusing specifically on the physico-chemical and bacteriological characteristics.

STUDY AREA

Bali Town is located at latitude 8° 9' 19.48" North and longitude 10° 58' 6.71" East (GPS). It covers an area of approximately 1,436 km² (554 square miles) and had a population of 105,687 according to the 2006 census National Population Census (NPC, 2006). The inhabitants are predominantly engaged in farming. Bali serves as a significant economic hub due to its vibrant food crop market, which is well connected to other parts of Taraba State and the country at large. Geographically, Bali Town is situated along the upper course of the Taraba River, approximately 150 km from Jalingo. Its strategic location within the watershed of the Benue River further enhances its importance in the region.

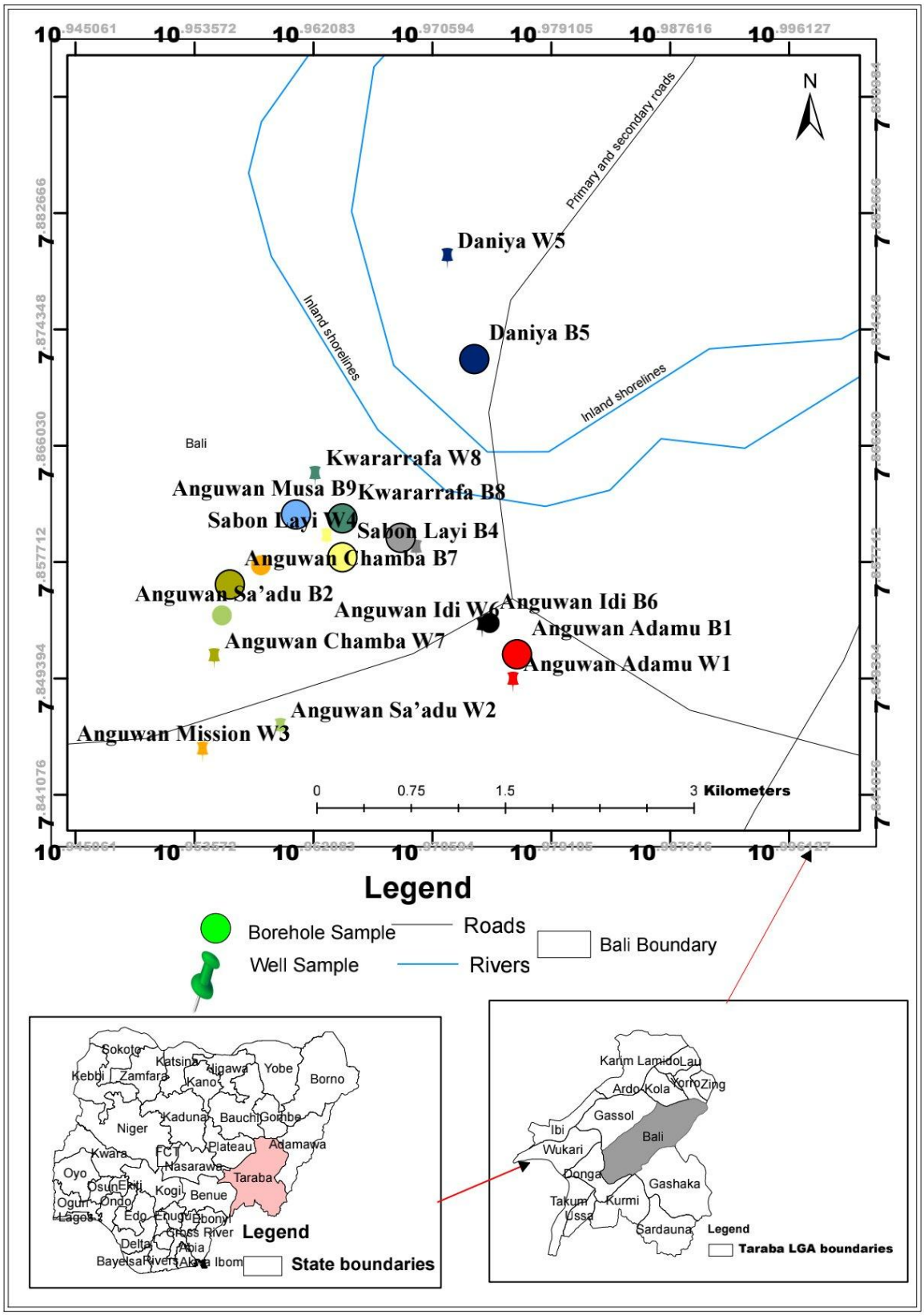


Figure 1: Map of the Study Area (Source: Google Map 2025).

MATERIALS AND METHODS

MATERIALS

The following materials and equipment were used for sample collection and analysis:

. Plastic sample bottles 2000mL and 1000mL.

b. Wagtech Palintest test kit. (Potalab^{+} XA (PTW10010 XA), A Halma company).

c. HACH Hardness test kit. (Model: HA-71A, Veraldo water quality).

d. Conductivity meter. (Model: HI98305, Hanna instruments portable conductivity/TDS meter).

e. DO meter. (Model: HI9146 (Portable dissolved oxygen meter), Hanna instruments).

f. Lovibond turbidity water test. (Model: 2000/T- Portable turbidity meter, Lovibond tintometer group).

g. pH Meter. (Model: HI98107 (Portable pH meter, Hanna instruments)

h. TDS Meter. (Model: HI98305, Hanna instruments portable conductivity/TDS meter).

i. Titrimetric apparatus: burette, measuring cylinder, stirring rod, beaker, test tube, etc.

j. Membrane filtration: membrane filter, filter holder, incubator, agar medium, etc.

k. Gravimetric apparatus: weighing balance, oven, filter paper, etc.

l. Reagent: nitrate test powder, nitrate test tablet, nitricol tablet, ammonia No. 1 and No. 2 tablets, phosphate No. 1 LR and No. 2 LR tablets, hardness 1 buffer solution and hardness 2 indicator solution, EDTA, potassium K tablet, etc.

m. Distilled water.

n. Clinical hand gloves.

o. Water samples: surface and groundwater

METHOD OF SAMPLE COLLECTION

Water samples were collected from 20 locations within Bali Town, Bali Local Government Area, comprising ten hand–dug wells and ten boreholes. The samples were collected in sterilized bottles, with 2000 mL allocated for physicochemical analysis and 1000 mL for bacteriological analysis. Following standard procedures outlined by the American Public Health Association (APHA, 2017), the samples were promptly transported to the laboratory for analysis. Each bottle was clearly labeled with its corresponding source location, as detailed in Table 1. A comprehensive analysis was conducted to evaluate various physicochemical and bacteriological parameters. Nitrate, ammoniacal nitrogen, total nitrogen, total phosphorus, and total potassium were analyzed using the Wagtech Palintest kit. Total hardness was determined with the Hach hardness test kit. Electrical conductivity, dissolved oxygen, turbidity, and pH were measured using a conductivity meter, DO meter, Lovibond turbidimeter, and pH meter, respectively. Total dissolved solids (TDS) were measured using a TDS meter, while total suspended solids (TSS) were determined through the gravimetric method. Total solids (TS) were calculated as the sum of TDS and TSS. Bacteriological analysis for faecal and total coliforms was performed using the membrane filtration method.

Table 1: Water Samples, Location, and Sources

S/N	Surface Water Samples	Ground Water Samples	Sample location
1.	W1	B1	Anguwan Adamu
2.	W2	B2	Anguwan Sa'adu
3.	W3	B3	Anguwan Mission
4.	W4	B4	Sabon Layi
5.	W5	B5	Daniya
6.	W6	B6	Anguwan Idi
7.	W7	B7	Anguwan Chamba
8.	W8	B8	Kwararrafa
9.	W9	B9	Anguwan Musa
10.	W10	B10	Anguwan Jibawa

RESULTS AND DISCUSSIONS

The results of the physicochemical and bacteriological analyses of well and borehole water samples collected from various locations within Bali Town, Bali Local Government Area, Taraba State, Nigeria, are presented in Table 2. The findings indicate notable variations in water quality across the sampled sites. These results were evaluated against the drinking water quality standards set by the World Health Organization (WHO, 2017) and the Nigerian Standards for Drinking Water Quality (NSDWQ, 2015).

Table 2: Results of the Physicochemical and Bacteriological Analysis of Well Water

		WELLWATER SAMPLES										
S/N	**PARAMETERS**	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W7**	**W8**	**W9**	**W10**	**MEAN**
1.	Turbidity (NTU)	7	7	9	13	12	8	8	7	11	12	9.4
2.	$_{p}$Hs	5.5	6.7	6.8	5.5	5.8	5.7	6.8	6.9	5.7	5.6	6.1
3.	TSS (mg/L)	200	400	400	200	200	205	407	404	210	215	284.1
4.	TDS (mg/L)	10	22	16	15	17	10	20	18	16	18	16.2
5.	TS (mg/L)	210	422	416	215	217	215	427	422	226	233	300.3
6.	Nitrate (mg/L)	18	28	18	10	35	16	15	25	20	35	22
7.	Ammoniacal Nitrogen (mg/L)	0.41	0.63	0.36	0.72	1.4	3.3	2.4	0.8	4.6	4.2	1.9
8.	Total Nitrogen (mg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
9.	Total Phosphorus (mg/L)	0.6	0.8	1.4	1.6	2.3	0.7	0.9	1.1	1.2	1.4	1.2
10.	Total Hardness (mg/L CaCO3)	274	274	308	188	184	272	272	306	200	182	246
11.	EC (µS/cm)	39	56	43	31	34	38	54	42	32	33	40.2
12.	Total Potassium (mg/L)	18	6	7	9	8	16	7	6	8	9	9.4
13.	Dissolved Oxygen (mg/L)	8.3	8	10.3	7.5	5.4	6.4	7.8	9.8	5.6	6.6	7.6
14.	Faecal Coliform (cfu/100mL)	5	3	16	10	12	7	4	14	9	13	9.3
15.	Total Coliform (cfu/100mL)	14	14	114	112	116	12	13	111	110	108	72.4

EC = Electrical Conductivity. ND= Not Detected.

Table 3: Comparison of Physicochemical and Bacteriological Parameters of Well Water with WHO and NSDWQ

WELLWATER SAMPLES							
S/N	**PARAMETERS**	**Min**	**Max**	**Mean**	**Permissible Limits as per the Standards**		**Samples Exceeding Permissible Limits**
					WHO (2017)	**NSDWQ (2015)**	
1.	Turbidity (NTU)	7	13	9.4	Max. 5	Max. 5	All the samples
2.	pH	5.5	6.9	6.1	6.5 – 8.5	6.5 – 8.5	W1 and W4
3.	TSS (mg/L)	200	407	284.1	500	500	None of the samples
4.	TDS (mg/L)	10	22	16.2	500	500	None of the samples
5.	TS (mg/L)	210	427	300.3	1000	1000	None of the sample
6.	Nitrate (mg/L)	10	35	22	10	50	None of the samples
7.	Ammoniacal Nitrogen (mg/L)	0.36	4.6	1.9	5	0.5	None of the samples
8.	Total Nitrogen (mg/L)	-	-	ND	-	-	ND
9.	Total Phosphorus (mg/L)	0.6	1.6	1.2	-	-	
10.	Total Hardness (mg/L CaCO3)	182	308	246	100	150	All the samples
11.	EC (µS/cm)	31	56	40.2	1000	1000	None of the samples
12.	Total Potassium (mg/L)	6	18	9.4	10	-	W1 and W6
13.	Dissolved Oxygen (mg/L)	5.4	10.3	8.3	Min 7.5	Min 7.5	W5, W6, W9 W10
14.	Faecal Coliform (cfu/100mL)	3	13	9.3	0	0	All samples
15.	Total Coliform (cfu/100mL)	14	116	72.4	10	10	All samples

Table 4: Results of the Physicochemical and Bacteriological Analysis of Borehole Water

BOREHOLE WATER SAMPLES											
S/N	**PARAMETERS**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**	**MEAN**
1.	Turbidity (NTU)	0.1	5.4	1.2	1.3	0.1	5.3	0.4	2.1	0.4	5.8	2.2
2.	pH	6.2	6.74	6.72	6.6	6.1	8.5	6.5	8.5	8.2	6.5	7.1
3.	TSS (mg/L)	195	190	300	240	360	380	460	420	500	480	352.5
4.	TDS (mg/L)	12	16	24	18	26	9	30	34	14	22	20.5
5.	TS (mg/L)	207	206	324	258	386	389	490	454	514	502	373
6.	Nitrate (mg/L)	14	10	19	8	17	13	9	18	19	9	13.6
7.	Ammoniacal Nitrogen (mg/L)	0.44	0.36	0.32	0.56	0.46	0.42	0.33	0.34	0.54	0.47	3.79
8.	Total Nitrogen (mg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
9.	Total Phosphorus (mg/L)	1.4	0.6	0.4	1.2	1.3	1.2	0.7	0.6	1.1	1.2	0.97
10.	Total Hardness (mg/L CaCO3)	24	22	37	42	32	45	35	25	24	35	32.1
11.	EC (µS/cm)	149	112	473	123	173	150	180	315	310	220	220.5
12.	Total Potassium (mg/L)	9.1	5.2	8.1	7.8	6.7	4.8	6.2	5.7	4.6	8.4	6.7
13.	Dissolved Oxygen (mg/L)	6.1	6.3	7.8	7.5	7.2	8.2	9.4	10.1	10.6	9.3	8.3
14.	Faecal Coliform (cfu/100mL)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

15.	Total Coliform (cfu/100mL)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

EC = Electrical Conductivity.

Table 5: Comparison of Physicochemical and Bacteriological Parameters of Borehole Water with WHO and NSDWQ

		BOREHOLEWATER SAMPLES					
S/N	**PARAMETERS**	**Min**	**Max**	**Mean**	**Permissible Limits as per the Standards**		**Samples Exceeding Permissible Limits**
					WHO (2017)	**NSDWQ (2015)**	
1.	Turbidity (NTU)	0.1	5.8	2.2	Max. 5	Max. 5	B2, B6, and B10
2.	pH	6.1	8.5	7.1	6.5 – 8.5	6.5 – 8.5	B1 and B5
3.	TSS (mg/L)	190	500	352.5	500	500	None of the samples
4.	TDS (mg/L)	9	34	20.5	500	500	None of the samples
5.	TS (mg/L)	206	514	373	1000	1000	None of the samples
6.	Nitrate (mg/L)	8	19	15.3	10	50	None of the samples
7.	Ammoniacal Nitrogen (mg/L)	0.32	0.56	3.79	5	0.5	None of the samples
8.	Total Nitrogen (mg/L)	ND	ND	ND	-	-	ND
9.	Total Phosphorus (mg/L)	0.4	1.4	0.97	-	-	
10.	Total Hardness (mg/L CaCO3)	22	45	32.1	100	150	None of the samples
11.	EC (µS/cm)	112	220	220.5	1000	1000	None of the samples
12.	Total Potassium (mg/L)	5.2	9.1	6.7	10	-	None of the samples
13.	Dissolved Oxygen (mg/L)	6.1	10.6	8.3	Min 7.5	Min 7.5	B1, B2, and B5
14.	Faecal Coliform (cfu/100mL)	ND	ND	ND	0	0	ND
15.	Total Coliform (cfu/100mL)	ND	ND	ND	10	10	ND

TURBIDITY

Turbidity negatively impacts water quality by reducing clarity, increasing treatment costs, and disrupting aquatic ecosystems, including fish habitats and spawning areas. In this study, well water samples exhibited significantly higher turbidity values, ranging from 7 NTU to 13 NTU, with an average of 9.4 NTU. In comparison, borehole (groundwater) samples had turbidity levels ranging from 0.1 NTU to 5.8 NTU, with an average of 2.2 NTU, as shown in Table 2. All turbidity values recorded for well water samples exceeded the maximum allowable limit of 5 NTU set by the WHO (2017) and NSDWQ (2015) for drinking water. Among borehole samples, three samples collected from Anguwan Sa'adu, Anguwan Idi, and Anguwan Jibawaalso surpassed this threshold. Similar findings of elevated turbidity were reported by Adebola et al. (2023), Rey-Romero et al. (2020), and Adekola et al. (2015), while Oni et al. (2020) documented comparatively lower values. The elevated turbidity levels in well water are primarily attributed to intensive agricultural practices, soil erosion, sediment deposition, and the infiltration of suspended and dissolved particles via surface runoff into surrounding water sources.

pH

The pH values of well water samples ranged from 5.5 to 6.9, with an average of 6.1, while borehole water samples had pH values between 6.1 and 8.5, averaging 7.1, as presented in Table 3. Most well water samples fell within the recommended pH range of 6.5–8.5, except for two samples from Anguwan Adamu and Sabon Layi. Likewise, all borehole samples complied with the permissible limits established by WHO (2017) and NSDWQ (2015), except for two samples from Anguwan Adamu and Daniya. It is important to note that pH values below 6.5 can pose health risks, including acidosis and increased susceptibility to infections, and may also enhance the toxicity of heavy metals in water systems, as reported by Adesakin et al. (2020).

TOTAL SUSPENDED SOLIDS

Total Suspended Solids (TSS) significantly affect water clarity, light penetration, habitat quality, the transport of nutrients and contaminants, clogging of water infrastructure, and the overall aesthetic quality of water. In this study, TSS levels in well water samples ranged from 200 mg/L to 407 mg/L, with a mean of 284.1 mg/L. Borehole water samples showed TSS levels ranging from 190 mg/L to 500 mg/L, with an average of 352.5 mg/L, as presented in Table 3. Overall, well water exhibited slightly lower TSS concentrations compared to borehole water, as reflected in Tables 2 and 4. All TSS values for both well and borehole samples remained within the permissible limits established by WHO (2017) and NSDWQ (2015) for drinking water quality. Notably, Rey-Romero et al. (2020) reported comparatively lower TSS values in their study.

TOTAL DISSOLVED SOLIDS

Total Dissolved Solids (TDS) represent the concentration of dissolved minerals and salts in water. In this study, TDS levels in well water samples ranged from 10 mg/L to 22 mg/L, with a mean of 16.2 mg/L, while borehole water samples ranged from 9 mg/L to 34 mg/L, with an average of 20.5 mg/L, as shown in Table 3. Well water exhibited slightly lower TDS levels compared to borehole water, as illustrated in Tables 2 and 4. All TDS values for both well and borehole water samples were within the acceptable limits for drinking water quality recommended by WHO (2017) and NSDWQ (2015). The relatively low TDS levels in well water are likely due to dilution or limited mineral dissolution, though agricultural runoff may still contribute to the overall content. In comparison, Jidauna et al. (2017) and Adekola et al. (2015) reported higher TDS values, while Rey-Romero et al. (2020) observed lower concentrations.

TOTAL SOLIDS

Total Solids (TS) represent the combined concentration of both suspended and dissolved solids, serving as an important indicator of overall water quality. In this study, TS levels in well water samples ranged from 210 mg/L to 427 mg/L, with an average of 300.3 mg/L. Borehole water samples ranged from 206 mg/L to 514 mg/L, with a mean value of 373 mg/L, as shown in Table 3. All well and borehole water samples remained within the maximum allowable limit of 1000 mg/L, as established by WHO (2017) and NSDWQ (2015). By comparison, Rey-Romero et al. (2020) reported lower TS values in their study.

NITRATE

Nitrate concentrations in the well water samples ranged from 10 mg/L to 35 mg/L, while those in the borehole water samples varied between 8 mg/L and 19 mg/L, with well water generally exhibiting higher levels. All samples were within the Nigerian Standards for

Drinking Water Quality (NSDWQ, 2015) limit of 50 mg/L. However, only one well water sample complied with the more stringent World Health Organization (WHO, 2017) guideline of 10 mg/L, as shown in Table 3. Higher nitrate concentrations were reported in studies by Adebola et al. (2023) and Oni et al. (2020), whereas lower levels were observed in the findings of Adesakin et al. (2020), Rey-Romero et al. (2020), and Jidauna et al. (2017). Elevated nitrate levels pose serious health risks, especially to infants, and can also degrade groundwater and aquatic ecosystems by promoting eutrophication, algal blooms, and nutrient leaching.

AMMONIACAL NITROGEN

Ammonia concentrations in the well water samples ranged from 0.36 mg/L to 4.6 mg/L, while those in the borehole water samples ranged from 0.32 mg/L to 0.56 mg/L, with significantly higher levels observed in well water, as shown in Table 3. All samples from both sources were within permissible regulatory limits, indicating the absence of ammonia contamination. Comparatively lower concentrations were reported in studies by Rey-Romero et al. (2020) and Adekola et al. (2015).

TOTAL NITROGEN

Total nitrogen was not detected in any of the well water samples. Similarly, Rey-Romero et al. (2020) reported comparatively low concentrations. Total nitrogen was also absent in all borehole water samples. Although nitrogen is vital for agricultural productivity, excessive application of nitrogen-based fertilizers such as NPK and ureaalong with inefficient irrigation practices and runoff from livestockcan lead to nitrogen contamination in water bodies. This contamination poses a threat to water quality and can have harmful environmental consequences.

TOTAL PHOSPHORUS

Phosphorus is vital for both ecosystems and human activities; however, elevated concentrations can degrade water quality, trigger eutrophication, and promote harmful algal blooms. The results revealed that total phosphorus concentrations in well water samples ranged from 0.6 mg/L to 1.6 mg/L, with an average of 1.2 mg/L. In comparison, borehole water samples had phosphorus levels ranging from 0.4 mg/L to 1.4 mg/L, averaging 0.97 mg/L. Well water generally exhibited slightly higher concentrations than borehole water, as presented in Tables 2 and 4. Lower phosphorus levels were reported by Adesakin et al. (2020) and Rey-Romero et al. (2020). The elevated phosphorus concentrations observed in borehole water suggest possible contamination from agricultural runoff, likely resulting from the extensive use of inorganic fertilizers such as NPK, Single Super Phosphate (SSP), ammonium nitrate, and diammonium phosphate in the area's intensive farming practices. Effective phosphorus management is essential to ensure safe drinking water and protect aquatic ecosystems.

TOTAL HARDNESS

The results showed that total hardness in well water samples ranged from 182 mg/L to 308 mg/L, with an average of 246 mg/L, as presented in Table 2. In contrast, borehole water samples had total hardness values ranging from 22 mg/L to 45 mg/L, with an average of 32.1 mg/L, as shown in Table 4. All well water samples exceeded the World Health Organization (WHO, 2017) and Nigerian Standards for Drinking Water Quality (NSDWQ, 2015) recommended limits of 100–150 mg/L for drinking water, while all borehole water samples remained within acceptable limits. Similar results were reported by Adesakin et al. (2020),

whereas lower values were documented by Adekola et al. (2015) and Rey-Romero et al. (2020). In contrast, higher concentrations were found in the study by Adebola et al. (2023). Although hard water does not pose direct health risks, it can create challenges in domestic tasks such as washing and cleaning. Agricultural activities significantly influence water hardness, with contributing factors including the use of calcium- and magnesium-based fertilizers, soil erosion from poor tilling practices, livestock farming, and pesticide application, all of which can increase hardness levels in water sources.

ELECTRICAL CONDUCTIVITY

Electrical conductivity is a key indicator of ion concentration in water, affecting both its taste and overall acceptability to consumers. The analyzed water samples exhibited varying conductivity levels. Well water samples had electrical conductivity values ranging from 31 µS/cm to 56 µS/cm, with an average of 40.2 µS/cm. In contrast, borehole water samples showed higher conductivity levels, ranging from 112 µS/cm to 220 µS/cm, with an average of 220.5 µS/cm. All recorded values fell within the permissible limits set by the World Health Organization (WHO, 2017) and the Nigerian Standards for Drinking Water Quality (NSDWQ, 2015). Higher conductivity values were reported in previous studies by Adebola et al. (2023), Adesakin et al. (2020), Oni et al. (2020), and Adekola et al. (2015), while Rey-Romero et al. (2020) documented lower levels.

TOTAL POTASSIUM

The study revealed varying potassium concentrations across the water samples. Potassium levels in well water ranged from 6 mg/L to 18 mg/L, with an average of 9.4 mg/L. Borehole water samples exhibited lower concentrations, ranging from 5.2 mg/L to 18 mg/L, with an average of 6.7 mg/L. All borehole water samples complied with the World Health Organization (WHO, 2017) maximum permissible limit of 10 mg/L for drinking water. Similarly, all surface water samples were within the recommended limits. Overall, the potassium concentrations observed in this study were higher than those reported by Adebola et al. (2023) and Rey-Romero et al. (2020).

DISSOLVED OXYGEN

Dissolved oxygen (DO) levels in the water samples varied depending on the source. Well water samples showed concentrations ranging from 5.2 mg/L to 10.3 mg/L, with an average of 7.17 mg/L, while borehole water samples exhibited a slightly higher range of 6.1 mg/L to 10.6 mg/L, averaging 8.2 mg/L, as presented in Table 2. All well water samples met the minimum acceptable limit for dissolved oxygen in drinking water (7.5 mg/L), as recommended by the WHO (2017) and NSDWQ (2015), except for four samples from Daniya (5.4 mg/L), Anguwan Idi (6.4 mg/L), Anguwan Musa (5.6 mg/L), and Anguwan Jibawa (6.6 mg/L). Similarly, all borehole water samples met the recommended limit, except for three samples from Anguwan Adamu (6.1 mg/L), Anguwan Sa'adu (6.3 mg/L), and Daniya (7.2 mg/L). These results align with the findings of Adebola et al. (2023) and Rey-Romero et al. (2020), but differ from those of Adesakin et al. (2020), who reported lower DO levels. Dissolved oxygen is a critical parameter for assessing water quality, as it influences nutrient availability, microbial activity, pollution levels, photosynthesis, and the regulation of plant growth and oxygen toxicity.

FAECAL COLIFORM

Bacteriological analysis of borehole water samples revealed no presence of faecal coliforms. In contrast, all well water samples tested positive for faecal coliforms, with concentrations

ranging from 3 to 13 cfu/100 mL and an average of 9.3 cfu/100 mL. These levels exceeded the maximum permissible limit of 0 cfu/100 mL set by the World Health Organization (WHO, 2017) and the Nigerian Standards for Drinking Water Quality (NSDWQ, 2015), as shown in Table 3. The use of organic fertilizerssuch as cow dung, compost, poultry waste, and refuse from dump sitescontributes significantly to the susceptibility of well water sources in the study area to coliform contamination. Surface runoff plays a major role in transporting these contaminants into nearby water sources, further degrading water quality. These findings are consistent with the studies of Oni et al. (2020) and Rey-Romero et al. (2020), who also reported elevated levels of contamination in similar environments.

TOTAL COLIFORM

Total coliform bacteria were detected in all well water samples, with the highest concentration recorded in the sample from Daniya at 116 cfu/100 mL. All measured values exceeded the maximum permissible limit of 10 cfu/100 mL established by the World Health Organization (WHO, 2017) and the Nigerian Standards for Drinking Water Quality (NSDWQ, 2015), as shown in Table 3. Total coliforms are important indicators of contamination by both pathogenic and non-pathogenic microorganisms. Similar studies by Oni et al. (2020) and Rey-Romero et al. (2020) reported even higher concentrations.

CONCLUSION

The study revealed notable variations in water quality, with samples from Anguwan Mission, Kwararrafa, Anguwan Jibawa, Daniya, and Sabon Layi identified as major contributors to water pollution and degradation within the study area. For well water samples, parameters such as electrical conductivity, ammoniacal nitrogen, nitrate, total suspended solids, total dissolved solids, and total solids complied with the standards set by WHO (2017) and NSDWQ (2015). Similarly, borehole water samples met the permissible limits for nitrate, ammoniacal nitrogen, total hardness, electrical conductivity, total potassium, total suspended solids, total dissolved solids, and total solids. However, elevated levels of turbidity and total hardness were recorded in some well water samples, exceeding maximum allowable limits. Additionally, two samples from Anguwan Adamu and Sabon Layi exceeded the recommended pH levels; two from Anguwan Adamu and Anguwan Idi had total potassium concentrations above permissible thresholds; and four samples from Daniya, Anguwan Idi, Anguwan Musa, and Anguwan Jibawa had dissolved oxygen levels that exceeded standards. In borehole water samples, turbidity levels in three locations; Anguwan Sa'adu, Anguwan Idi, and Anguwan Jibawa exceeded standard limits. Furthermore, two samples from Anguwan Adamu and Daniya recorded elevated total potassium, and three from Anguwan Adamu, Anguwan Sa’adu, and Daniya exceeded acceptable dissolved oxygen levels. Bacteriological analysis of well water detected the presence of faecal and total coliform bacteria, indicating potential contamination due to inadequate sanitation, poor hygiene practices, and agricultural runoff. In contrast, borehole water samples showed no presence of faecal or total coliforms, suggesting an absence of microbial contamination. These findings underscore the significant impact of poor sanitation, hygiene, and agricultural activities on water quality. Addressing these challenges requires urgent interventions, including improved waste management, consistent water quality monitoring, appropriate treatment measures, and enhanced public awareness. Such actions are essential to protect public health and ensure the sustainability of local water resources.

RECOMMENDATIONS

Based on the findings of the study, the following recommendations are proposed:

a. The government should establish modern water treatment facilities in Bali town to ensure the community has reliable access to safe and potable water.

b. Comprehensive public awareness campaigns should be implemented to educate residents about the health risks associated with poor sanitation and hygiene practices.

c. Sustainable agricultural practices should be promoted, including afforestation, integrated farming systems, organic agriculture, and the use of integrated nutrient and pest management techniques, to minimize environmental impacts on water quality.

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