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Water quality evaluation of some boreholes and dug-wells in Dorayi, Kano-Nigeria

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ABSTRACT

Boreholes and dug-wells remain the main sources of potable water for drinking and domestic purposes in Kano. These water sources supplement the state's pipe-borne water facilities and a significant portion of the state's population depends largely on it. Regular monitoring of drinking water quality remains a critical routine for the healthy living of any community. To assess the water quality of the boreholes and Dug-wells in the Dorayi area of Kano-Nigeria, samples were strategically collected from carefully selected boreholes, and dug-wells and tested. Physical, chemical, and microbiological properties of the samples were evaluated and the Water Quality Index (WQI) was determined. The average WQI from the borehole samples was determined as 45 (indicating good quality) while that of the dug-wells showed an index of 115.82 suggesting poor quality (not suitable for drinking). While the borehole water is fit for drinking and other domestic uses, this work suggested that the dug-wells water should be treated prior to use. The study recommends further works to holistically investigate the sources of the dug-well's contamination in order to proffer appropriate solutions for sustainable groundwater utilization in the Dorayi area and its neighboring area.

Keywords: Boreholes; Dug-wells; Water quality index; Dorayi; Kano

1. Introduction

Quality drinking water is essential for healthy living. Oceans, springs, rivers, and groundwater are the main sources of water all over the world, with groundwater being the purest and mostly exploited by means of hand-dug-wells and boreholes. Globally, 748 million people lack access to quality drinking water [1]. Sub-Saharan Africa to which Nigeria belongs is inhabited by more than 783 million people, 40% of which have no access to quality drinking water [2,3]. According to the survey by the Nigerian Bureau of Statistics (NBS), 33% of the population lack access to portable drinking water [4]. Moreover, despite the continuous efforts of government and non-governmental organizations, the plight of water scarcity as well as its quality remains a life-threatening challenge in Nigeria. Continuous water quality evaluation is imperative in any locality in order to ensure its protection and sustainable utilization. With the increase in population and urbanization posing a great danger to groundwater contamination, any efforts to assess the water quality toward its protection, and sustainable management is of paramount importance.

Water quality can be characterized by physical indicators, such as electrical conductivity (EC), total dissolved solids (TDS), turbidity, dissolved oxygen (DO), total suspended solids (TSS), alkalinity, hardness, chemicals

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characteristics such as pH, Cu, Fe, Mn, Zn, P, Na, etc., and biological characteristics comprising of coliforms and other constituents both in ground and surface water sources [3]. The World Health Organization (WHO) reported severe health problems attached to elevated concentrations of many chemicals such as the traces of Zn, Cu, Fe, Mn, Cd, Ni, and Pb in drinking water. Heavy metals when ingested in high amounts lead to severe health risks; therefore a proper investigation is required to protect drinking water from these metals [5,6].

A number of studies indicated poor groundwater quality in Gwale Local Government area especially in Dorayi [1–3]. This can be related to increasing anthropogenic activities such as open refuse dump ditches, unregulated wells dug near septic tanks, discharge of untreated wastewater to drainages. However, these studies did not pay much attention to nitrate concentrations especially in groundwater, considering the importance of this parameter in drinking water quality assessments, this posed the need to investigate the nitrate level among other quality parameters in the study area. This work is therefore aimed to assess the quality of groundwater sources (boreholes and dug-wells) in the Dorayi ward of Kano-Nigerian in order to contribute toward its protection and good management practices.

2. Materials and methods

2.1. Study area

The study was conducted in the Dorayi-Karama, Gwale Local Government area of Kano-Nigeria; located between latitude 11°57′14″ W, longitude 8°28′6″ E, and at an altitude of 508 m, within greater Kano city. For the proper understanding and identification of the sources of portable water supply in the study area, a reconnaissance survey was conducted which shows open wells, boreholes, and tap water as the only source of portable water in the study area. The area is mainly built in residential houses, it is bordered by the old campus of Bayero University Kano to the north, Sheik Jafar road to the east, and Yamadawa to the West. Most sources of water for domestic use in the area are poorly built hand-dug-wells and boreholes located near pollution sources having no functional surface drainages. A lot of pit-latrines, soak ways, and waste disposal areas closer to the groundwater sources, a majority of the houses are compacted. Preliminary investigation revealed that this action causes some abnormalities in the water appearance such as odor, turbidity, and taste.

2.2. Materials

The equipment used includes pH meter, turbidity meter (Hach 2100, Loveland, Colorado USA), handheld thermometer, plastic bottles were used for collecting the water samples, distilled water, refrigerator for sample storage before analysis.

2.3. Samples collection and analysis

Thirty-six (36) samples of the groundwater were collected in clean and sterilized containers from six different locations consisting of three boreholes and three hands dug-wells in 2016 (June–July). The collection bottles were treated with dilute nitric acid followed by repeated washing prior to sampling. The boreholes for sampling were randomly identified considering the wells having the highest number of water abstraction especially those where local water vendors fetch water from, the hand-dug wells were similarly identified in a random manner. Six samples from each of the boreholes and dug-wells were collected in a clean stopper bottle at a week interval in order to take the average result from each of the sampling points. The samples were then labeled BH1–BH3 for boreholes and HDW1–HDW3 for dug-wells and stored in cold boxes. The samples were analyzed in Kano State Water Board's water quality laboratory at Challawa, Kano, using standard laboratory procedures. The results were compared to the Nigerian standard for drinking water quality (NSDWQ) and WHO recommended limits.

2.4. Water quality index

A number of water quality parameters are needed to determine the drinking water quality. WQI is considered the most suitable method of measuring water quality, which includes several quality parameters in a mathematical equation in order to determine the suitability of drinking water [7]. Developed in 1965 by Horton, to measure water quality using 10 most regularly used water parameters. Many modifications have been done to this model by many experts in the field. It is assumed that the weights for various drinking water quality parameters are inversely proportional to the standards for the relevant parameters [7]. The quality status of groundwater has been evaluated by many researchers using the weighted arithmetic index method of WQI developed by brown in 1972 [8]. It is calculated using the following formulae:

$$\text{WQI} = \frac{\sum_{i=1}^{n} Q_i W_i}{\sum_{i=1}^{n} W_i} \quad (1)$$

where Q_i is the quality rating (sub-index) of ith water quality parameter; W_i is the unit weight of the ith water quality parameter; $\sum_{i=1}^{n} W_i = 1$.

Also, Q_i which relates the value of the parameter in polluted water to the standard permissible value is obtained as follows:

$$Q_i = 100\left(\frac{v_i - v_{io}}{s_i - v_{io}}\right) \quad (2)$$

where v_i is the estimated value of the ith parameter; v_{io} is the ideal value of the ith parameter; s_i is the standard permissible value of the ith parameter. In most cases, $v_{io} = 0$ except for pH and dissolved oxygen (DO). The unit weight W_i, which is inversely proportional to the values of the recommended standards is obtained as:

$$W_i = \frac{K}{s_i} \quad (3)$$

where $K = \frac{1}{\sum_{i=1}^{n} \frac{1}{s_i}}$.

The rating of the water quality using the above method is shown in Table 1.

3. Results and discussion

Summary of physico-chemical characteristics of the samples are presented in Table 2. Comparison between the borehole's and hand-dug-wells's parameters are also presented in Fig. 2. The measured values of the Water Quality parameters are presented in Table 2.

3.1. Temperature

Temperature is a measure of the degree of coldness or hotness of the water. Its measurements were taken immediately as the water sampling was made in order to investigate the presence of the thermal input of the groundwater sample. Variations in temperatures of groundwater may occur due to the differences in climatic conditions, water sources, the topology of the study area, and many more. The temperature of the water in the study area ranges from 24°C to 27°C with the temperature of water obtained from hand-dug well been slightly higher than that of the boreholes as shown in Table 1. This is due to the shallow depth the hand-dug-wells have in comparison with the boreholes. The temperature for all the sampling locations is within the acceptable range for drinking water set by the WHO.

3.2. Total suspended solids

In this study, the TSS ranges from 2 to 4 mg/L as shown in Table 1. The values are low and are within the WHO (100 mg/L) and NSDWQ (500 mg/L) recommended limits.

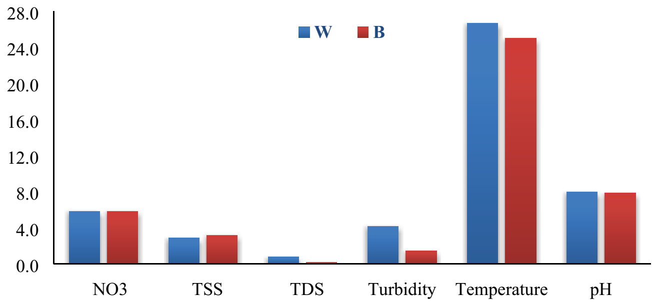

Fig. 2. Comparison of physico-chemical properties between hand-dug-wells and boreholes.

Table 1
Rating of water quality for various WQI [8]

WQI	Rating of the water quality
0–25	Excellent
26–50	Good
51–75	Poor
76–100	Very poor
Above 100	Unsuitable for drinking

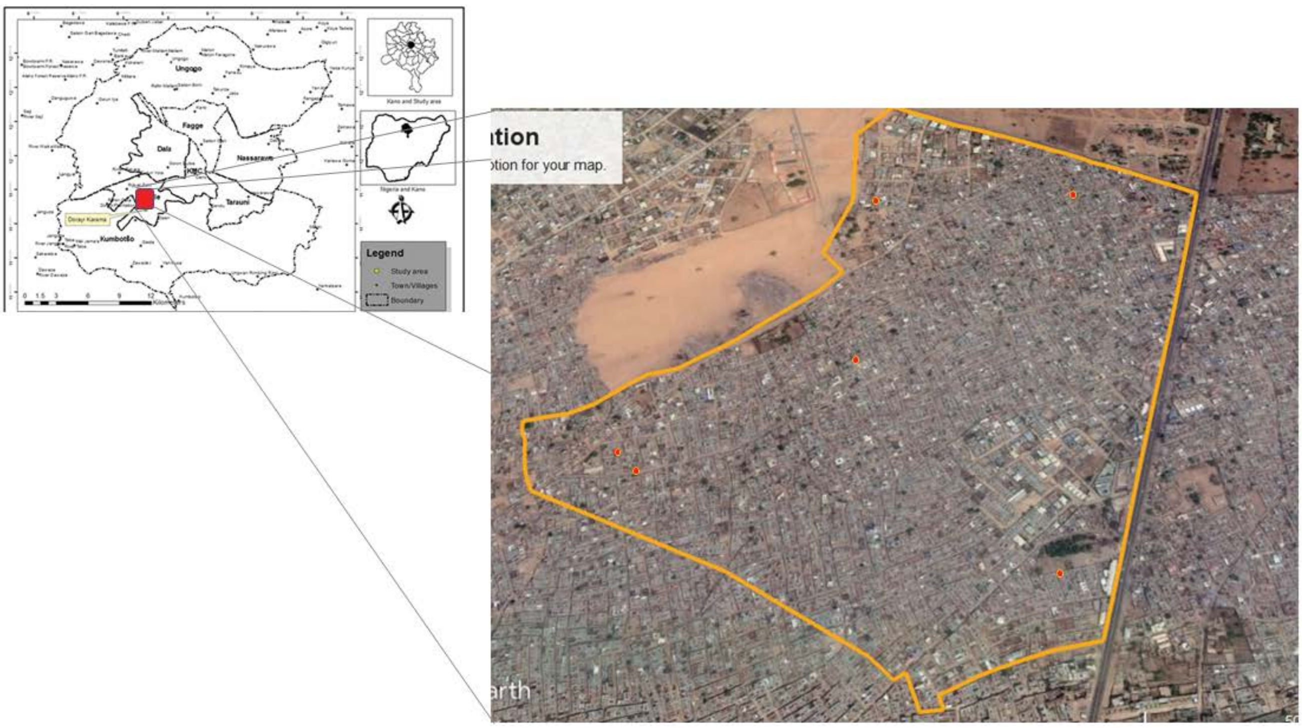

Fig. 1. Map showing the study area.

Table 2
Physico-chemical characteristics of studied water samples

Samples	TSS (mg/L)	TDS (mg/L)	Turbidity (NTU)	Temperature (°C)	NO_3 (mg/L)	pH
HDW1	2.80	0.52	7.60	26	5.05	7.60
	2.64	0.64	7.80	28	5.10	7.60
	2.70	0.66	8.20	28	5.25	7.40
	2.76	0.68	8.40	25	5.50	7.20
	2.82	0.72	7.20	27	5.00	7.20
	2.72	0.72	8.40	27	5.60	7.40
Average	2.74	0.66	8.00	27	5.25	7.40
HDW2	3.00	1.10	2.90	25	6.00	8.00
	3.30	0.96	3.10	27	6.10	8.20
	3.40	0.98	3.40	26	6.40	8.40
	3.20	1.20	3.50	25	6.20	8.60
	3.20	1.40	3.20	26	5.90	8.30
	3.40	1.60	3.10	27	6.10	8.30
Average	3.25	1.20	3.20	26	6.13	8.30
HDW3	2.80	0.48	1.40	27	6.10	7.60
	2.50	0.46	1.30	28	6.20	7.50
	2.70	0.48	1.50	26	5.90	7.80
	2.50	0.40	1.20	25	6.00	7.80
	2.40	0.46	1.10	28	6.10	7.90
	2.70	0.40	1.30	27	6.40	7.70
Average	2.61	0.44	1.30	27	6.13	7.70
BH1	4.00	0.18	1.40	26	4.18	7.70
	3.90	0.18	1.50	24	4.50	7.60
	3.78	0.16	1.30	23	4.60	7.70
	3.80	0.15	1.20	27	4.20	7.60
	3.88	0.16	1.40	26	4.40	7.50
	3.90	0.15	1.60	25	4.40	7.60
Average	3.88	0.16	1.40	25	4.38	7.60
BH2	3.00	0.20	1.10	22	5.90	7.60
	3.10	0.24	1.30	24	6.40	7.70
	2.90	0.25	1.40	26	6.20	7.50
	2.80	0.26	1.20	24	6.10	7.40
	2.80	0.28	1.00	25	6.10	7.40
	2.60	0.30	1.20	24	6.00	7.50
Average	2.89	0.26	1.20	24	6.13	7.50
BH3	2.89	0.14	1.90	27	6.90	8.20
	2.81	0.17	2.00	28	7.30	8.40
	2.76	0.16	2.00	26	7.00	8.50
	2.80	0.16	1.70	26	7.20	8.60
	2.72	0.14	1.60	25	6.80	8.80
	2.76	0.19	1.80	24	6.90	8.40
Average	2.79	0.16	1.80	26	7.01	8.50
WHO recommended range [9]	500	500	5	20–25	50	7.0–8.5

This shows that the water from all the sampling locations is clean and within the acceptable recommended limits.

3.3. Total dissolved solids

Total dissolved solids (TDSs) values of the samples indicate the quality of non-filterable particles and serves as an indicator of water aesthetic characteristics. TDSs are one of the key aspects and one of the physical standards of measuring the portability of drinking water. It consists of some amount of organic matter, dissolved gases, and many inorganic salts such as NO_3^-, SO_4^{2-}, Cl^-, Mg, Ca, and many more. A water test can also be attributed to the presence of dissolved solids. Moreover, the palatability of drinking water could also be categorized as pleasant (<300 mg/L), good (300–600 mg/L), fair (600–900 mg/L), poor (900–1,200 mg/L), and unsuitable (>1,200 mg/L). For this study, the TDSs range from 0 to 1 mg/L which is a meager amount as shown in Table 1 above. The values are low and are within acceptable limits set by the WHO (100 mg/L) and NSDWQ (500 mg/L) and fall within the freshwater group.

3.4. Turbidity

The turbidity of the water samples is within the recommended (5 NTU) value with the exception of HDW1 where the turbidity is 8.0 NTU. This is due to the water drawing activity by people in the study area from the well and the area is densely populated. As the water levels go down, the remaining water gets mixed with the soil and other organic matters at the bottom of the well, also the debris from the walls of the well also increases the turbidity of the water. Other factors that increase turbidity in open wells include shallow depth of the open wells and lack of well cover. Higher turbidity was also observed in open wells than closed wells like boreholes in a similar study conducted by Kilungo et al. [2] in Tanzania.

3.5. pH

The pH of water is an extremely important parameter in assessing the quality of drinking water as it serves as a measure of the strength of water to react with the acidic or alkaline material present. The pH of the water samples is alkaline ranging between 7.4 and 8.5. This is within the range of the acceptable level set by WHO for drinking water. The fluctuation of pH may be due to an increase in toxicity of poisons or acidic constituents in water bodies that must have seeped into the groundwater over the years [10].

Table 3
Result of the coliform count

Samples	50 mL	10 mL	Probable number of coliform organisms
	1	5	per 100 mL of water
*W*1	+	– – + + +	8
*W*2	+	– – + + +	17
*W*3	+	– + + + +	16
*B*1	+	– – – – +	5
*B*2	+	– – – + +	6
*B*3	–	– – – – –	–

3.6. Nitrate

The range 0.23–13.5 mg/L NO_3 was chosen according to WHO standard which states that any water with less than 50 mg/L NO_3 is to be considered safe for drinking, and anything above is considered unsafe and unhygienic. For this study, the nitrate content is between (4.38 and 7.01) mg/L as the minimum and maximum concentrations of nitrate in all the samples. These values are lower than the maximum permissible concentration of 50 mg/L. These results are in line with the study conducted by Amoo et al. [11] regarding the nitrate (NO_3) concentration obtainable in Kano and its environment. However, the result of the nitrate shows that the background concentrations of nitrogen in the groundwater are close to zero. Hence, the origin of the nitrate can be attributed to anthropogenic sources.

3.7. Total coliform count

The presence of total coliforms in water samples indicates the entry of pathogens into the water source and also provides a warning that some microorganisms may have found their way into the wells [12]. The total coliform count in the study area ranges from 0 to 17 per 100 mL of water as shown in Table 3. The bacteriological quality of the water in Dorayi Karama was found to be above the recommended WHO value for drinking water except for borehole B3. The reason for the contamination of the groundwater is the presence of a large number of pits latrines and other dumpsites around the area which infiltrates and contaminate the groundwater and this corroborates with a study conducted in Kano-Nigeria [13] and Pakistan [14] where total coliforms were observed in open wells and water canals. The coliform count for the hand-dug-wells was found to be almost three times that of the boreholes which were due to the inadequate sanitary arrangement around the dug-wells. Coliform bacteria were also found in open well and canal water in Iran [15].

3.8. Water quality index

WQI for the hand dug-wells and that of the boreholes were computed and labeled as HDW1, HDW2, HDW3, BH1, BH2, and BH3. Computed result from Table 4 shows the WQI of all HDWs is grouped into the category of being very poor quality water, which is not recommended for drinking as suggested by Brown et al. [8]. The high WQI values in HDWs from this study have been caused by a high content of bacteria in the water which is the result of the overflow of domestic sewage or non-point sources of human and animal wastes. Sometimes contamination of water in dug-wells is caused by the contamination of the rusty metallic containers used in drawing the water, seeping action of water from pit-latrines as well as dumpsites.

For the Boreholes (BWs) side, the computed WQI presented in Table 5 indicates that the water is good with an average value of 45.3 and is grouped into the category of a

Table 4
Calculated values of WQI for hand dug-wells (HDWs)

S/N	Parameter	s_i	$1/s_i$	Unit weight (W_i)	HDW1 (Q_i)	HDW2 (Q_i)	HDW3 (Q_i)	HDW1 (W_iQ_i)	HDW2 (W_iQ_i)	HDW3 (W_iQ_i)
1	pH	8.5	0.18	0.216	26.67	86.67	46.67	5.76	18.72	10.08
2	Total suspended solids (TSS) mg/L	500	0.002	0.004	0.548	0.65	0.522	0.0022	0.0026	0.002
3	Total dissolved solids (TDS) mg/L	500	0.002	0.004	0.132	0.24	0.088	0.00053	0.00096	0.00035
4	Nitrate (mg/L)	50	0.02	0.04	10.5	12.26	12.26	0.42	0.49	0.4904
5	Temperature (°C)	25	0.04	0.07	140	64.0	26	9.8	4.48	1.82
6	Turbidity (NTU)	5	0.2	0.4	160	120	140	64.000	48	56
7	Total coliform (count/100 ml)	10	0.1	0.1838	80	170	160	14.704	31.246	29.41
			$K = 1.838$	$\sum_{i=1}^{7} W_i = 0.8478$			$\sum_{i=1}^{7} W_iQ_i$	94.67	102.94	97.8
							WQI	110.67	121.42	115.36
							Average WQI	115.82		

Table 5
Calculated values of WQI for boreholes (BWs)

S/N	Parameter	s_i	$1/s_i$	Unit weight (W_i)	BW1 (Q_i)	BW2 (Q_i)	BW3 (Q_i)	BW1 (W_iQ_i)	BW2 (W_iQ_i)	BW3 (W_iQ_i)
1	pH	8.5	0.18	0.216	40	33.33	100	8.64	7.199	21.6
2	Total suspended solids (TSS) mg/L	500	0.002	0.004	0.776	0.578	0.558	0.003	0.0023	0.00223
3	Total dissolved solids (TDS) mg/L	500	0.002	0.004	0.032	0.052	0.032	0.00013	0.0002	0.00013
4	Nitrate (mg/L)	50	0.02	0.04	8.76	12.26	14.02	0.3504	0.49	0.561
5	Temperature (°C)	25	0.04	0.07	100	80	120	7	5.6	8.4
6	Turbidity (NTU)	5	0.2	0.4	28	24	36	11.2	9.6	14.4
7	Total coliform (count/100 mL)	10	0.1	0.1838	50	60	–	9.19	11.03	–
			$K = 1.838$	$\sum_{i=1}^{7} W_i = 0.8478$			$\sum_{i=1}^{7} W_iQ_i$	36.38	33.92	44.96
							WQI	42.9	40	53
							Average WQI	45.3		

good water quality, which is drinkable and safe for domestic as well as irrigation and industrial activities.

4. Summary and conclusion

Water quality of some hand-dug and boreholes in Dorayi of Kano-Nigeria were evaluated to assess its quality for drinking. The result of the study indicated that the groundwater in the study area was contaminated by the presence of pit-latrines and refuse dumpsites around the area, as 83% of the wells tested have total coliforms over the recommended WHO limit, hence the water is not safe for drinking without adequate treatment. However, the WQI from boreholes samples suggests good quality water that is safe for domestic as well as irrigation and industrial activities. Comparison between the hand dug-wells and boreholes parameters show higher turbidity in hand-dug wells than the boreholes, this is a result of the water being disturbed by the frequent drawing which affected its clarity.

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