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Assessment of Water Quality Index in Some Selected Local Government Area of Taraba State

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Abstract

Using the water quality index (WQI) technique, this study was conducted to evaluate the water quality for drinking purposes in a few chosen local governments in Taraba State. The goal of WQI assessment is to combine various physicochemical properties of water into a single figure that both specialists and laypeople can understand. Twelve important physico-chemical parameters used in the aggregation of the WQI were: Sulphate, Phosphate, Magnesium, Turbidity, pH, Electrical conductivity (EC), Total dissolved solids (TDS), Nitrate (NO 3), calcium, hardness, fluoride and chloride composition. The water samples analyzed were obtained from three different sources in the selected areas. The comparison of the physicochemical parameters' results with the standards suggested by WHO and NSDWQ revealed that, with the exception of fluoride in some samples, they were within the limits defined by these organisations. The results of the WQI computation revealed that the index values ranged from 50.0, which is "poor" and unfit for consumption, to 42.20, which falls within the "good" water quality category and is suitable for human consumption and other domestic uses.

Keywords: Water Quality Index (WQI), Physico-Chemical Parameters, Water Quality, NSDWQ, WHO

INTRODUCTION

Water is one of the most fundamental and vital chemicals on the earth because it is necessary for the life of all living things. Because of its remarkable ability to dissolve more chemicals than any other liquid known to exist on Earth, it is acknowledged as a universal solvent. (Jidauna *et al.,* 2013). To fully understand the complex and important nature of their ecological activities and relevance, water systems must maintain their native characteristics, both abiotic and biotic. (Komala *et al.*, 2013). Therefore, it has been proposed to conduct regular monitoring using biotic and abiotic indices. Temperature, pH, dissolved oxygen (DO), total dissolved salts (TDS), biological oxygen demand (BOD), conductivity, turbidity, and many other inorganic compounds are examples of physico-chemical parameters. Before water is used for drinking, residential, agricultural, or industrial reasons, it is crucial to know its quality. As a result, water quality evaluation is important to protect the natural ecosystem (Patil *et al.,* 2012).

The water quality index (WQI) method is the most effective way to assess water quality. Integrating diverse physicochemical characteristics of water into a single, easily comprehensible figure is the aim of WQI assessment. The WQI's water quality classification system indicates the water's suitability for human consumption (Abakpa *et al.*,2023). Throughout Nigeria, a large number of scientific studies have been carried out to examine the quality of water used for various purposes, including drinking. The results show that the water is gravely contaminated with pathogenic bacteria as well as other dangerous physical and chemical substances (Aremu *et al.*, 2011). It was against this backdrop that the need to assess the water quality index of water for drinking purposes in some part of Taraba state.

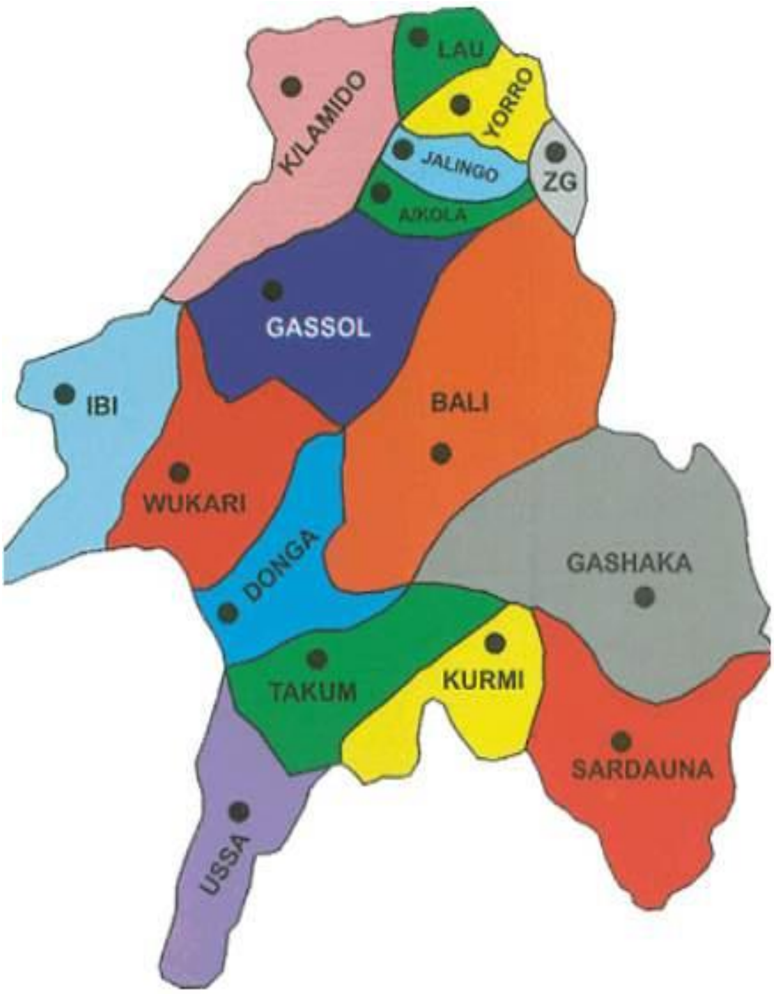
MATERIALS AND METHODS

Reagents

All materials and reagent used were of analytical standard.

Study Area

Taraba State, which is situated at 8°0'0"N 10°30'0"E, contains the study areas. Six adjacent states in Nigeria—Plateau, Benue, Bauchi, Adamawa, Gombe, and Nassarawa States—share boundaries with Taraba State. Figure 3.1. Taraba State occupies an area of 54,473 square kilometres. Taraba state is bordered to the west by the states of Plateau, Nassarawa, and Benue. Taraba State's eastern boundary is shared by Adamawa State and the Republic of Cameroon. With an undulating geography and a few isolated mountainous features, such as the stunning and well-known Mambilla Plateau, the State is primarily situated in the middle of Nigeria. The majority of the state is in the tropical zone, with grasslands making up the vegetation in both the northern and southern half.



Sample collection

In three chosen local government areas, namely Zing (Zing, Yakok, and Monkin), Jalingo (Kona, Gulum, and Maigwa), and Karim-Lamido (Karim, Mangai, and Mutumdaya), Taraba State, a total of twenty one (21) samples were randomly collected from three different sampling points (three hand-dug well samples, three borehole water samples, and three samples from the surface Stream). Before soaking in diluted HCl (0.05M) for about 24 hours, sample containers were properly cleaned with detergents, rinsed with water, and then filled with distilled water. After that, they were dried by air in a dust-free setting. Containers were washed twice with pertinent samples at the collecting station, then filled with samples and securely corked.

Determination of Water Quality Parameters

The physicochemical parameters, which include pH, temperature, TDS, dissolved oxygen (DO), turbidity, hardness, alkalinity, electrical conductivity (EC), chloride, nitrate, phosphate, magnesium, calcium, and sulphate, were measured using a multi-parameter water quality monitor. The metre was calibrated before analysis to guarantee precise quality measurement.

Calculation of Water Quality Index

The Nigerian Standard for Drinking Water Quality (NSDWQ), which has been authorised by the Standard Organisation of Nigeria (SON), and the World Health Organization's (WHO) drinking water quality standards served as the foundation for the WQI evaluation. Therefore, five successive stages were followed in order to estimate the WQI in this study, in accordance with (WHO 2008).

Stage 1: Which involved the assignment of load (w_i,) to the water quality parameters. The loads assigned ranged from 1 – 5 depending on the relative impact of the parameter in question.

Stage 2: This involved the computation of the comparative loads for each parameter.

Stage 3: Involved the estimation of the water feature score.

Stage 4: The calculation of the sub-index for each factor considered,

Stage 5: The computation of the WQI.

The relative weight (Wi) and water quality rating (qi) were estimated by eqs. 1 and 2 separately (Mahmud *et al.,* 2020).

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \qquad (1)$$

Where, W_i is the comparative load w_i is the parametric allotted load, while n represents the quntum of the sample features considered.

$$q_i = \frac{C_i}{S_i} \times 100 \qquad (2)$$

Here, qi represents the feature score; Ci represents the parametric concentrations (mg /L) in the individual water samples, while Si represents the WHO (2017) parametric limits for each variable.

The parametric sub-indexes as well as the overall WQI were estimated using equations 3 and 4 respectively.

$$SI_i = W_i \times q_i \qquad (3)$$

$$WQI = \sum_{i=1}^{n} SI_i \qquad (4)$$

Where, SIi is the parametric sub-index (wagh 2016).

The Table 1 below shows the water quality rating based on the arithmetic water quality index

Table 1: Water quality rating based on the arithmetic water quality index (Nwaogazie *et al.*., 2018)

Water Quality Index	Category	Remark
0-25	1	Excellent water
25-50	2	Good water
51-75	3	Poor water
76-100	4	Very poor
Greater than 100	5	Unsuitable for drinking

RESULTS

The test results of the analysis of the physico-chemical parameters and calculation of the water quality index (WQI) for Zing Jalingo and Karimlamido are shown in Table 2, Table 3, Table 4, Table 5 and Table 6 respectively.

Table 2

Sample location	Parameter	C_i	W_i	S_i	$q_{i=\frac{C_i}{S_i}x\,100}$	$SL_{i=}\ w_i\ x\ q_i$
Zing Borehole						
	TDS	173.52	0.09	1000	17.35	1.56
	Hardness	107.65	0.07	500	21.53	1.51
	Turbidity	1.17	0.09	5	23.40	1.64
	Chloride	0.72	0.09	200	0.36	0.03
	Nitrate	2.15	0.09	50	4.30	0.39
	Phosphate	1.52	0.07	6.50	23.38	1.64
	Magnesium	2.74	0.05	150	1.82	0.09
	Calcium	2.13	0.05	75	2.84	0.14
	Sulphate	13.59	0.07	250	5.44	0.39
	Fluoride	2.06	0.09	1.5	137.33	23.36
	EC	383.67	0.09	1500	25.58	2.30
	pH	6.95	0.09	8.5	81.76	7.36
WQI=$\sum_{i=1}^{n} \boldsymbol{SIi}$						**40.41**

Table 3

Sample location	Parameter (mg/l)	C_i	W_i	S_i	$q_{i=\frac{C_i}{S_i}x\,100}$	$SL_{i=}\ w_i\ x\ q_i$
Zing Well						
	TDS	276.67	0.09	1000	27.67	2.49
	Hardness	213.33	0.07	500	42.67	2.99
	Turbidity	6.86	0.09	5	137.20	9.60
	Chloride	1.51	0.09	200	0.76	0.07
	Nitrate	4.55	0.09	50	9.10	0.82
	Phosphate	2.13	0.07	6.50	32.77	2.29
	Magnesium	8.70	0.05	150	5.80	0.29
	Calcium	3.09	0.05	75	4.12	0.21
	Sulphate	13.50	0.07	250	5.40	0.38
	Fluoride	2.96	0.09	1.5	197.33	27.76
	EC	378.17	0.09	1500	25.21	2.269
	pH	6.74	0.09	8.5	79.29	7.14
WQI=$\sum_{i=1}^{n} \boldsymbol{SIi}$						**56.31**

Table 4

Sample location	Parameter	C_i	W_i	S_i	$q_{i=\frac{c_i}{s_i}x\,100}$	$SL_{i=}\ w_i\,x\ q_i$
Zing Stream						
	TDS	336.33	0.09	1000	33.63	3.027
	Hardness	143.33	0.07	500	28.66	2.01
	Turbidity	12.85	0.09	5	257.00	22.99
	Chloride	0.45	0.09	200	0.23	0.02
	Nitrate	2.54	0.09	50	5.08	0.46
	Phosphate	1.50	0.07	6.50	23.08	1.62
	Magnesium	9.69	0.05	150	6.46	0.32
	Calcium	2.69	0.05	75	3.59	0.18
	Sulphate	10.06	0.07	250	4.02	0.28
	Fluorides	0.40	0.09	1.5	26.66	7.4
	EC	422.00	0.09	1500	28.13	2.53
	pH	6.65	0.09	8.5	78.23	7.04
WQI=$\sum_{i=1}^{n} \boldsymbol{SIi}$						**47.89**

Table 5

Sample location	Parameter	C_i	W_i	S_i	$q_{i=\frac{c_i}{s_i}x\,100}$	$SL_{i=}\ w_i\,x\ q_i$
Jalingp Borehole						
	TDS	116.50	0.09	1000	11.65	1.05
	Hardness	109.37	0.07	500	21.87	5.53
	Turbidity	1.55	0.09	5	3.10	7.17
	Chloride	0.73	0.09	200	0.36	0.03
	Nitrate	2.16	0.09	50	4.23	0.38
	Phosphate	1.83	0.07	6.50	28.10	1.97
	Magnesium	2.79	0.05	150	1.86	0.09
	Calcium	2.16	0.05	75	2.89	0.14
	Sulphate	13.56	0.07	250	5.43	0.37
	Fluoride	1.78	0.09	1.5	118.74	20.69
	EC	322.83	0.09	1500	21.52	1.93
	pH	6.62	0.09	8.5	77.92	7.01
WQI=$\sum_{i=1}^{n} \boldsymbol{SIi}$						**46.36**

Table 6

Sample location	Parameter	C_i	W_i	S_i	$q_{i=\frac{c_i}{s_i}x\,100}$	$SL_{i=}\ w_i\,x\ q_i$
Jalingo well						
	TDS	202.83	0.09	1000	20.28	1.83
	Hardness	215.83	0.07	500	43.17	6.02
	Turbidity	2.10	0.09	5	41.96	6.94
	Chloride	1.30	0.09	200	0.65	0.06
	Nitrate	4.08	0.09	50	8.17	0.73
	Phosphate	1.97	0.07	6.50	30.33	2.12
	Magnesium	8.13	0.05	150	5.42	0.27
	Calcium	2.72	0.05	75	3.63	0.18

	Sulphate	13.49	0.07	250	5.39	0.38
	Fluoride	2.23	0.09	1.5	148.77	20.39
	EC	322.33	0.09	1500	21.49	1.93
	pH	6.96	0.09	8.5	81.92	7.37
WQI=$\sum_{i=1}^{n} \boldsymbol{SIi}$						**49.22**

Table 7

Sample location Jalingo stream	Parameter (mg/l)	C_i	W_i	S_i	$q_{i=\frac{c_i}{s_i} x\, 100}$	$SL_{i=}\ w_i\, x\ q_i$
	TDS	178.17	0.09	1000	17.82	1.60
	Hardness	143.67	0.07	500	28.73	2.01
	Turbidity	12.81	0.09	5	256.17	17.93
	Chloride	0.54	0.09	200	0.27	0.02
	Nitrate	2.53	0.09	50	5.06	0.45
	Phosphate	1.45	0.07	6.50	22.36	1.56
	Magnesium	9.34	0.05	150	6.23	0.31
	Calcium	2.53	0.05	75	3.37	0.16
	Sulphate	10.07	0.07	250	4.03	0.28
	Fluoride	0.30	0.09	1.5	19.87	10.79
	EC	116.83	0.09	1500	7.79	0.70
	pH	6.61	0.09	8.5	77.78	7.01
WQI=$\sum_{i=1}^{n} \boldsymbol{SIi}$						**42.82**

Table 8

Sample location Karimlamido	parameter	C_i	W_i	S_i	$q_{i=\frac{c_i}{s_i} x\, 100}$	$SL_{i=}\ w_i\, x\ q_i$
	TDS	203.17	0.09	1000	20.32	18.28
	Hardness	113.55	0.07	500	22.71	1.59
	Turbidity	1.55	0.09	5	30.93	2.16
	Chloride	0.60	0.09	200	0.30	0.27
	Nitrate	2.02	0.09	50	4.04	0.36
	Phosphate	1.62	0.07	6.50	24.90	1.74
	Magnesium	2.93	0.05	150	1.96	0.10
	Calcium	2.25	0.05	75	3.00	0.15
	Sulphate	13.56	0.07	250	5.42	0.38
	Fluoride	0.42	0.09	1.5	28.16	2.53
	EC	264.33	0.09	1500	17.62	1.59
	pH	6.54	0.09	8.5	76.94	6.92
WQI=$\sum_{i=1}^{n} \boldsymbol{SIi}$						**56.07**

Table 9

Sample location	parameter	C_i	W_i	S_i	$q_{i=\frac{c_i}{S_i}x\,100}$	$SL_{i=}\ w_i\,x\ q_i$
Karim well						
	TDS	233.33	0.09	1000	23.33	2.10
	Hardness	218.33	0.07	500	43.66	3.06
	Turbidity	2.01	0.09	5	40.23	2.82
	Chloride	1.34	0.09	200	0.67	0.06
	Nitrate	3.46	0.09	50	6.91	0.62
	Phosphate	1.68	0.07	6.50	25.82	1.81
	Magnesium	7.54	0.05	150	5.03	0.25
	Calcium	2.48	0.05	75	3.31	0.16
	Sulphate	13.41	0.07	250	5.36	0.37
	Fluoride	0.69	0.09	1.5	46.34	4.17
	EC	226.5	0.09	1500	15.1	1.35
	pH	7.33	0.09	8.5	86.23	7.76
WQI=$\sum_{i=1}^{n} \boldsymbol{SIi}$						**52.53**

Table 10

Sample location	Parameter (mg/l)	C_i	W_i	S_i	$q_{i=\frac{c_i}{S_i}x\,100}$	$SL_{i=}\ w_i\,x\ q_i$
Karim stream						
	TDS	324.83	0.09	1000	32.48	2.92
	Hardness	143.83	0.07	500	28.77	2.01
	Turbidity	12.84	0.09	5	256.76	17.97
	Chloride	0.61	0.09	200	0.30	0.03
	Nitrate	2.50	0.09	50	5.01	0.45
	Phosphate	1.48	0.07	6.50	22.79	1.60
	Magnesium	10.03	0.05	150	6.68	0.33
	Calcium	2.64	0.05	75	3.52	0.18
	Sulphate	10.06	0.07	250	4.02	0.28
	Fluoride	0.20	0.09	1.5	13.25	1.19
	EC	450.83	0.09	1500	30.05	2.70
	pH	6.56	0.09	8.5	77.20	6.94
WQI=$\sum_{i=1}^{n} \boldsymbol{SIi}$						**50.60**

Table 11: Summarized results for WQI

LGA	**Water Source**		
	Borehole	**Well**	**Stream**
Zing	40.41	56.31	47.89
Jalingo	46.36	49.22	42.82
Karim lamido	56.07	52.53	50.0

Table 12: Mean Concentration Values of water quality parameter with WHO standard

Parameter	Zing			Jalingo			Karim-Lamido		
	B	W	S	B	W	S	B	W	S
PH	6.95	6.74	6.625	6.62	6.62	6.58	6.54	7.33	6.545
TDS	173.5	276.67	388	116.5	116.5	175	203.17	233.33	325
EC	384.67	378.17	452.5	322.83	322.83	119	264.5	226.5	454.5
Turbidity	1.17	6.87	13.53	1.55	1.55	12.87	1.55	2.01	13.43
Hardness	107.62	213.33	142.5	109.33	109.33	141.5	113.51	218.33	142.5
DO	3.1	3.85	3.615	3.27	3.27	2.59	3.38	4.01	3.62
Chloride	0.72	1.5	0.535	0.73	0.73	0.575	0.6	1.33	0.605
Nitrates	2.15	4.55	2.685	2.11	2.11	2.565	2.02	3.45	2.475
Phosphate	1.52	2.13	1.58	1.82	1.92	1.445	1.62	1.67	1.535
Magnesium	2.73	8.69	10.235	2.79	2.79	9.445	2.93	7.53	10.07
Calcium	2.13	3.07	2.81	2.16	2.16	2.57	3.36	2.48	2.64
Alkalinity	11.36	140.2	84.66	11.45	11.45	90.31	11.45	198.13	74.61
Sulphates	13.58	13.49	10.23	13.56	13.54	10.09	13.55	13.41	10.25
Fluoride	2.06	3.56	0.723	1.77	1.81	0.6824	1.61	1.89	0.4928

DISCUSSION

pH

The result of from the pH in ranges from 6.62-7.33 which lies within the prescribed range of 6.50 to 8.50 by WHO and NSDWQ. A water sample's pH value, which ranges from 0 to 14 and is neutral at 7, indicates how acidic or alkaline the sample is. A pH number below 7.00 indicates acidity, while a value above 7.00 suggests alkalinity. The pH level of water influences various qualities and attributes, two examples of which are the solubility and accessibility of chemical components. High pH levels are undesirable because they can give the water a harsh flavour and cause encrustation on water pipes and appliances that use water because of the high amount of mineralization that comes with alkaline water. (Etim *et al.*, 2013).

TDS

A measurement of water quality called total dissolved solids (TDS) determines how much dissolved solids are present in a sample. They originate from the weathering and dissolution of rocks and soil, which includes the dissolution of gypsum, lime, and other slowly dissolved soil minerals. (Davis 2013). The TDS of the samples from the sites under investigation in this study ranged from 116.5 mg/L to 388 mg/L, which is comparable to the results of a research study on Jalingo water supply agency sources conducted by Munta *et al.,* (2021). Nevertheless, all of these values fall within the 500 mg/l WHO and NSDWQ recommended limits.

EC

The amount of ionised salts in water is inversely correlated with its conductivity, commonly referred to as its current carrying capacity. The World Health Organisation states that the highest recommended value of conductivity in drinking water is 1500 (µS/cm). This indicates that all of the conductivity levels in Table 11—which vary from 119 in the Jalingo stream to a maximum value of 456.5 in the Karim-lamido stream—are within the recommended ranges.

Turbidity

The word "turbidity" refers to the degree of haziness in water samples. The mean turbidity and suspended solids levels were low in borehole and well sources from all locations, with values ranging from 1.17 to 2.01, which was similar to the results obtained by Munta et al., 2021, to 12.87–13.53 for stream sources, which was similar to the results obtained by David *et al.,* 2020. All of these results were higher than the WHO recommended limits of 5 mg/L.

Hardness

The total calcium and magnesium contents, both expressed as calcium carbonates in mg/L, determine the hardness of a given body of water. It also gauges how simple it is to get lather when using soap and water. Kannel *et al.,* (2007) mention the four categories for hardness: soft (between 0 and 60 mg/l), moderately hard (between 61 and 120 mg/l), hard (between 121 and 180 mg/l), and extremely hard (being over 180 mg/l). from the outcome, which has a range of 107.62 to 218.33 The study area's high carbonate content could have an impact on human skin, fabric colour, water heating appliances, pipelines, and soap and detergent efficiency.

Chlorides

Although chloride is found naturally in lakes, streams, and groundwater, a concentration of chloride over 250 mg/l in freshwater may indicate the presence of contaminated wastewater (Chatterjee 2001). The chloride content in the current investigation ranges from 0.53 mg/l to 1.50 mg/l, which is within the WHO's recommended range of 200 mg/l. High chloride concentrations are the reason why drinking water has an unpleasant, salty flavour.

Nitrates

The study area's borehole, well, and stream sources had nitrate amounts ranging from 2.02 to 4.55 mg/L in their water samples. Despite the fact that farmers in the study area use a lot of fertilisers and agrochemicals, no violations were found. The permissible limits of 50 mg/L specified in standards were met by all samples (WHO, 2020; NSDWQ, 2007).

Calcium and Magnesium

One of the main indicators of water hardness is the concentration of calcium and magnesium ions. Both for domestic usage and industrial purposes, high calcium and magnesium levels in water can have a number of effects. The three main issues are plumbing, health, and equipment upkeep (Oko *et al.*, 2014). In the study, the results ranges from (2.16-3.36mg/L) and (2.73-10.23mg/L) for calcium and magnesium respectively.

Alkalinity

Alkalinity is the quantity of ions in water that will react to neutralise hydrogen ions. An excessive amount gives water an unpleasant flavour. Every result is within the WHO's recommended drinking limit of 250 mg/L. Studies have shown that excessive alkalinity can lead to chlorosis in plants and ocular discomfort in humans (Sisodia and Moundiotiya, 2006).

Fluoride

Water naturally contains the mineral fluoride in varying levels. According to the current study's findings, the fluoride concentrations in the Zing water sample from the well and borehole were 2.06 and 3.56 mg/l, respectively. The range for Jalingo and Karim-Lamido is 1.61-1.89 mg/L. With the exception of the stream water sample, these results are higher above the 1.500 mg/l NSDWQ suggested threshold. A 1.0 mg/l fluoride concentration in drinking water is beneficial for promoting good oral health and reducing tooth decay, particularly in youngsters (APHA 2005). On the other hand, dental fluorosis, or discoloured teeth, is brought on by an excessive amount of fluoride (Oladoja et al., 2016).

Water Quality Index (WQI)

The WQI calculation for each of the study area was summarized in Table 11. From the Table 11, Zing Well, with an index value of 56.31, has the highest WQI value. The samples from the Karim-lamido well, stream, and borehole, with index values of 56.07, 52.53, and 50.00, respectively, come next. The water sample from the Zing borehole had the lowest index value, measuring 40.41. These outcomes were discovered to be comparable to those attained by Munta et al., 2021 Taraba State, for the water supply agency in Jalingo. When the WQI value of each study location is compared to Table 1, it can be seen that all of the water sources in Jalingo, Zing borehole, and Stream have water quality ratings that are "good." Water from these investigated sources is therefore suitable for human consumption and other household use. Conversely, every water source in Karim-lamido and Zing well has a water quality rating of "poor" for drinking purposes.

CONCLUSION

When determining the water quality index, a number of water quality metrics are combined to represent the sample's water quality. This study evaluated the water quality using the WQI for various drinking water sources and other domestic uses in a few chosen local governments in Taraba state. it is concluded that there exists no significant difference in the physicochemical parameters of the samples from all the study areas except for alkalinity and hardness, also all the water samples examined were within the WHO recommended limits with fluoride as an exception. In this research water samples from Jalingo, Zing boeehole and stream are safe and potable for human consumption and other domestic uses. However, water sources from Karim-Lamido and Zing well were poor for drinking purposes therefore is the need for appropriate treatment of the water before consumption.

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