Seasonal Assessment and Design Using Water Quality Index for Drinking: A Case Study of Bali Town and Environs, Taraba State, Nigeria

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D.O.I: 10.56201/ijgem.v10.no2.2024.pg15.21

Abstract
This study addresses the critical issue of water quality in Bali town and its surroundings, with a specific focus on the seasonal variations in the Water Quality Index (WQI) for boreholes. Groundwater, crucial for drinking purposes, lacks adequate quality testing in the region, which poses potential health risks. Water samples collected during both wet and dry seasons in 2016 and 2017 were analyzed for twenty-nine parameters. However, only nine out of the twenty-nine samples were used in calculating the Water Quality Index for the boreholes under investigation. These nine parameters include Turbidity, Total Dissolved Solids, Total Hardness, pH, Nitrate, Copper, Iron, Chloride, and Total Coliform Count. When comparing the results with the standards set by the World Health Organization (WHO) in 2010 and the Nigerian Standard for Drinking Water Quality (NSDWQ) in 2007, it was observed that most parameters increased during the wet season, indicating higher pollutant dissolution. Notably, bacteriological parameters, especially the Total Coliform Count and E. coli, exceeded permissible limits. This highlights the urgency of water treatment to achieve excellent quality and provides valuable insights for designing water infrastructure.

Keywords*: Groundwater quality, Water pollution, Physicochemical characteristics, Bacteriological parameters, Water infrastructure, Water demand, Groundwater Quality Index (GWQI.*

1.1 Background:

Groundwater is a vital resource in Nigeria, particularly in rural areas like Bali town. However, poor sanitation practices contribute to water pollution, leading to various health issues. This study addresses the lack of infrastructure in Bali, emphasizing the urgent need for assessing and monitoring groundwater quality.

1.2 Study Area

Bali local government area in Taraba State, situated between latitude 7o 46 N and 7o 54 N, and longitude 10 o 30 E and 11o 00 E, is characterized by a dry Guinea savannah. With a vast land area of 11,540 km2, it is the largest local government in Taraba State. Bali experiences a tropical climate with distinct dry and rainy seasons. The population, as per the 2006 National Population Census, was approximately 211,024 individuals. The major ethnic groups include Jibawa, Tiv, Chamba, Fulani, and Hausa, engaging in occupations such as farming, fishing, and nomadism. The inhabitants rely on rivers, ponds, wells, and a limited number of boreholes for water, facing challenges like non-functional boreholes and hygiene issues due to a high level of illiteracy. Fig 3.1 depicts Map of Bali town and surrounding communities

2.1 Study Objectives:

This research aims to evaluate the physicochemical and bacteriological characteristics of groundwater in Bali town and environs. Seasonal variations, chlorine demand for treatment, and the creation of a Water Quality Index (WQI) are considered. The study provides insights for water infrastructure design to meet the projected population's water consumption.

3.1 Research Methodology

This section delves into the study area, data sources, and water sampling procedures for the research.

3.2 Data Source

This research draws on textbooks, journals, internet resources, and academic articles to establish a comprehensive foundation.

3.3 Water Sampling

Borehole samples are the primary investigative materials. Six boreholes, randomly chosen, represent the study area. Table 3.1 details the sample locations, sources, and identification codes.

Table 3.1: Randomly selected sample location, sources, and sample identification codes.

Sample location	Source of sample	Sample Identification Code
Mission	Borehole water 1	BW1
Edi	Borehole water 2	BW 2
. Sabonlayi	Borehole water 3	BW 3
Daniya	Borehole water 4	BW 4
Nayinawa	Borehole water 5	BW 5
Federal polytechnic Bali Hostel	Borehole water 6	BW 6

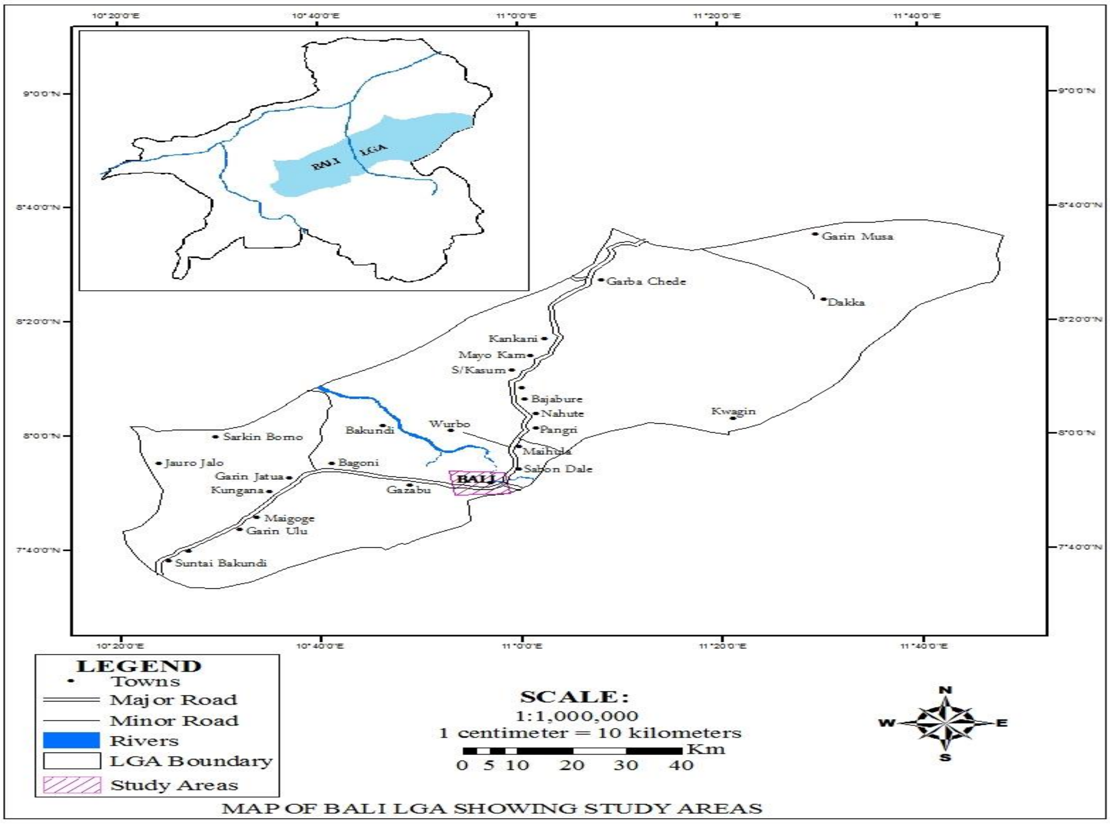

Fig 3.1: Map of Bali Local Government Area showing the study area (Bureau for Land and Survey, Jalingo, Taraba State, 2016)

3.4 Sample Collection

Samples were collected from the selected boreholes three times in both wet and dry seasons (2016-2017). Standard procedures by the American Public Health Association (APHA, 2000) were followed for collection, ensuring proper labeling and prevention of contamination. Samples were transported to the laboratory and stored at 4°C before analysis.

3.5 Laboratory Analyses

The Benue State Water Board Laboratory conducted analyses on the collected samples. Bacteriological parameters included total coliform and E. coli, while physio-chemical parameters comprised taste and odor, temperature, turbidity, color, suspended solids, total dissolved solids (TDS), electrical conductivity, pH, hardness, calcium, magnesium, iron, copper, fluoride, nitrate, sulfate, alkalinity, chloride, lead, potassium, COD, TOD, dissolved oxygen (DO), and BOD of the Boreholes.

3.6 Measurements of Physio-Chemical and Bacteriological Parameters

Standard methods recommended by organizations like the World Health Organization (WHO), United States Environmental Protection Agency (US-EPA), NSDWQ, and AHPA were employed for the preparation of reagents and determination of all water quality parameters.

Table 3.2 : Mean results of Physicochemical and Bacteriological properties of Borehole during wet season in Bali town and its environs

S/N	Parameter	Unit	BW1	BW2	BW3	BW4	BW5	BW6	WHO	NSDWQ
1	Taste		Unobj	Unobj	Unobj	Unobj	Unobj	Unobj		
2	Odour		Unobj	Unobj	Unobj	Unobj	Unobj	Unobj		
3	Temperature	ºC	30.5	29	31	30.5	30.5	29	29.8	Ambient
4	Turbidity	Ntu	1.99	0.80	1.96	2.26	0.26	2.23	5	5
5	Colour	Ptco	6	1	3	6	1	360	5	15
6	Suspended Solids	Mg/l	3	0.00	1	2	0	186	5	
7	Total Dissolved Solids	Mg/l	45.10	34.8	39.6	39.00	43.8	37.8	500	500
8	Total Solids	Mg/l	48.10	34.8	40.6	41.0	44.8	223	-	
9	Electrical Conductivity	µs/cm	75.4	67.2	69.8	70.8	76.4	69.7	1250	1000
10	PH		6.36	6.94	6.67	6.15	7.18	6.84	6.5-8..5	
11	Hardness	Mg/l	140	80	120	120	140	120	100	150
12	Calcium	Mg/l	80	60	80	80	80	80	50	
13	Magnesium	Mg/l	60	20	40	40	60	40	50	0.2
14	Iron	Mg/l	0.13	0.17	0.18	0.16	0.12	0.19	0.3	0.3
15	Flouride	Mg/l	0.00	0.00	0.00	0.00	0.00	0.00	1.5	1.5
16	Nitrate	Mg/l	34	30.4	36.00	38.00	32.0	36.8	10	50
17	Sulphate	Mg/l	18	14	17	19	10	20	200	100
18	Alkalinity	Mg/l	7.40	8.00	7.80	7.60	8.40	8.00	-	
19	Chloride	Mg/l	37.8	41.00	45.2	39.9	43.7	39.9	250	250
20	Copper	Mg/l	0.12	0.19	0.14	0.15	0.08	0.2	2	1
21	Lead	Mg/l	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
22	Potassium	Mg/l	1.41	1.38	1.40	1.44	1.28	1.64	2	
23	COD	Mg/l	76	52	60	44	48	64	100	
24	TOD	Mg/l	114	78	90	66	72	98	-	
25	DO_2 (1)	Mg/l	4.7	4.8	4.7	4.7	4.6	4.5	4	
26	DO2 (2)	Mg/l	4.1	4.4	4.2	4.3	4.2	4.0	-	
27	BOD	Mg/l	38	26	30	22	24	32	50	
28	Total coliform count	Cfu	8	20	17	11	14	25	5	10
29	E.Coli	Cfu	17	10	15	8	10	18	0	0

Table 3.3: **Mean results of Physicochemical and Bacteriological properties of Borehole during dry season in Bali town**

S/N	Parameter	Unit	BW1	BW2	BW3	BW4	BW5	BW6	WHO 2010	NSD WQ 2007
1	Taste		Unobj	Unobj	Unobj	Unobj	Unobj	Unobj		
2	Odour		Unobj	Unobj	Unobj	Unobj	Unobj	Unobj		
3	Temperature	°C	30	30	31	31	31	30	29.8	Ambient
4	Turbidity	Ntu	1.26	1.41	1.62	1.32	1.22	1.18	5	5
5	Colour	ptco	3	4	5	4	3	3	5	15
6	Suspended Solids	Mg/l	2	2	3	2	2	2	5	
7	TDS (mg/l)	Mg/l	44.1	41.7	40.8	47.4	48.2	46.9	500	500
8	TDS	Mg/l	46.1	43.7	43.8	49.4	50.2	48.9	-	
9	E.Condutivity	µs/cm	76.1	72.8	71.4	77.2	7.80	76.8	1250	1000
10	pH		6.70	6.80	6.40	7.40	7.80	6.80	6.5-8..5	6.5-8..5
11	Hardness	Mg/l	140	120	120	140	160	140	100	150
12	Calcium	Mg/l	80	80	80	100	100	100	50	
13	Magnesium	Mg/l	60	40	40	40	60	40	50	0.2
14	Iron	Mg/l	0.1	0.1	0.11	0.09	0.1	0.1	0.3	0.3
15	Flouride	Mg/l	0.07	0.00	0.08	0.15	0.17	0.12	1.5	1.5
16	Nitrate	Mg/l	28	24	26	28	29.2	38.2	10	50
17	Sulphate	Mg/l	25	26	26	27	28	24	200	100
18	Alkalinity	Mg/l	8.0	8.4	8.0	8.4	9.2	8.6	-	
19	Chloride	Mg/l	40.1.	39.7	37.4	41.2	42.7	39.2	250	250
20	Copper	Mg/l	0.09	0.08	0.07	0.1	0.04	0.1	2	1
21	Lead	Mg/l	0.00	0.00	0.00	0.002	0.007	0.001	0.01	0.01
22	Potassium	Mg/l	1.50	1.42	1.51	1.48	1.56	1.61	2	
23	COD	Mg/l	42	54	56	50	48	44	100	
24	TOD	Mg/l	63	81	84	75	72	66	-	
25	DO_2 (1)	Mg/l	4.9	4.8	4.8	4.7	4.7	4.9	5	
26	DO2 (2)	Mg/l	4.6	4.4	4.3	4.3	4.3	4.5	-	
27	BOD	Mg/l	21	27	28	25	24	22	-	
28	Total coliform count	cfu	4	2	7	4	2	2	5	10
29	E.Coli	cfu	2	1	5	3	1	2	0	0

3.7 Calculation of Ground Water Quality Index (GWQI)

Water Quality Index(WQI) is calculated using Weighted Arithmetic Index method as employed by Shinde et al (2013), Brown et al (1972; Badmus et al, 2015).The quality rating / sub index (Q_i)corresponding to the i^{th} parameter is calculated by using following expression

$$Qi = \sum_{i=1}^{n} \left[\left\{ Mi(-)Ii / \left(Pi - Ii \right) \right\} \right] x100 \qquad \text{Equation-1}$$

Where Mi = estimated values / of the i[th] parameter in the laboratory, Ii = ideal values of the i[th] parameter, Pi =standard values of the i[th] parameter and $\sum$ = *Summation.* The sign $(-)$ indicates the numerical difference of the two values, ignoring the algebraic sign. All the ideal values (Ii) are taken as zero except for pH=7, DO=14.6 and fluorides=1. In the present study unit weight (Wi) was calculated by a value inversely proportional to the recommended standard (Pi) of the corresponding parameter.

$Wi = 1/Pi$

The overall Ground water quality index (GWQI) is calculated by aggregating the quality rating (Qi) with unit weight (Wi) linearly.

$$WQI = \left\{ \left(\sum_{i=1}^{n} Qi\,Wi \right) / \left(\sum_{i=1}^{n} Wi \right) \right\} \qquad \text{Equation-2}$$

4.1 Results, Analysis, and Discussion:

The study analyzes water quality results, comparing them with standards, assessing water demand, and proposing water infrastructure design. Borehole water generally showed good quality, except for BW6. Treatment significantly improved borehole water values. Statistical analysis revealed a significant relationship between standards and borehole water quality in Bali town.

4.2Water Demand Analysis:

The study examines water demand for domestic, industrial, and public uses, considering wastage and theft. Design techniques based on population growth projections from 2006 to 2031 are employed, leading to a projected population of 122,198 persons in 2031. Water demand calculations result in the design of four tanks with a total capacity of 6,600 m3.

S/N	Uses	Consumption (l/p/day)
1	Domestic	70
2	Industrial	20
3	Commercial	10
4	Public	10
5	Water uncounted for	10
	Total	120l/c/day

4.3 Disinfection and Treatment Process:

Chlorine dosage calculations suggest the need for water treatment to achieve excellent quality. The article details the design of chlorine contact tanks and the treatment process, emphasizing the importance of disinfection for safe drinking water.

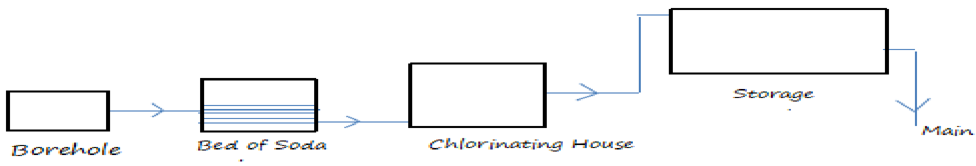

Figure 4.1: Treatment process

5.1 Conclusion

The section summarizes findings, concluding that water pollution is more pronounced in the wet season. Bacteriological parameters exceeded acceptable levels, but treatment achieved excellent water quality. Recommendations include water purification before consumption and continuous water quality monitoring. Public awareness campaigns, waste disposal regulation, and sanitation improvement are recommended. The study contributes valuable data on water quality in Bali town, offering insights for policymakers and stakeholders. The study used simplifies complex water quality parameters for public understanding. Treatment procedures are identified for safe drinking water, and the research highlights potential causes of waterborne diseases.

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