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COMPARATIVE ASSESSMENT OF WATER QUALITY PARAMETERS AND MICROBIAL LOADS IN SELECTED WELL WATER AS AN INDEX OF POLLUTION. A CASE STUDY OF OGBOMOSO, OYO STATE, NIGERIA

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Abstract

Groundwater is regarded among others as the healthiest source of drinking water, but anthropogenic activities have led to its contamination in various parts of the world. This study investigated and compared water quality parameters and microbial loads in selected groundwater as an index of pollution in Ogbomoso, Oyo State. The physico-chemical parameters and the heavy metals were examined using standard laboratory procedures. Microbial loads of the water samples were quantified by membrane filteration method and media were prepared following the manufacturer's instructions. Pollution index of water samples were determined by Arithmetic Index (WQI) and Nemerow's pollution index. The result of physicochemical analysis showed temperature ranged from 25.00±0.00 – 29.00±0.00°C, Disolved Oxygen revealed higher concentration at station A (9.90±0.00 mg/L) in February while Biological Oxygen Demand showed values more than required limits across sampling stations. Electrical conductivity revealed highest value ranged from (1,166.00±7.21-5,500.00±173.21µs/cm) across the dry and wet months. highest turbidity values in December (A; 12.37±0.40, B; 10.33±0.58 and C 10.33±0.58 Ntu while range of 1.40±0.20-105.33±0.58 Ntu across stations in the wet seasons. Other Parameters were within the recommended limits of World Health Organization (WHO). However, heavy metal concentrations revealed Cu and Fe had high values in stations A to C in December, highest value was reported for Cu in A (5.47±0.29) in January. Pb revealed Below Detection Limits across the wet months except station A (0.40±0.00) in June, while its presence in some stations in the

Keywords: Contamination, WQI, Viable, Coliform Counts, EC, Pb, Dumpsite Effluents

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dry months were higher than the limits. Zn revealed highest values in December (4.57±0.25 mg/L) at station A, and January (78.40±58.20 mg/L) in station A. Microbial loads revealed highest coliform and viable counts in selected water sampled. Water quality indices indicated high pollution status of the groundwater sampled. The study concludes that majority of water samples examined were highly contaminated with large number of coliform and viable counts, high values of EC, turbidity, nutrient influx particularly phosphate concentration in some stations, heavy metal contamination in water samples collected near dumpsites and hospital were associated to influx of effluents from the sites. This study recommends serious water treatment before consumption and regular monitoring of the water sources.

Introduction

Water is an important natural resource that supports human existence, ecosystem functioning, agricultural activities, and industrial development. The quality of water is therefore a major concern in environmental management and public health, particularly in developing countries where access to safe and potable water remains a problem. Water quality refers to the physical, chemical, and biological characteristics of water that determine its suitability for different purposes such as drinking, domestic activities, irrigation, and industrial use. The assessment of these characteristics is important for determining whether water meets required standards and is safe for its intended purpose (World Health Organization [WHO], 2022). Water quality is influenced by both natural processes and anthropogenic activities. Natural factors, such as geological formations, soil composition, mineral dissolution, weathering, and hydrogeological conditions, can affect the concentration of dissolved substances in water. Similarly, human activities, including agricultural practices, improper waste disposal, industrial effluent discharge, sewage leakage, mining, and urbanisation, may introduce pollutants into water bodies. These pollutants can change the physical, chemical, and biological properties of water, potentially posing risks to human health and the environment (Afolayan *et al.,* 2012; WHO, 2022).

Water quality is commonly evaluated through the analysis of physical, chemical, and microbiological parameters. Physical parameters, such as temperature, colour, turbidity, electrical conductivity, and total dissolved solids, provide information about the general characteristics of water. Chemical parameters, including pH, dissolved oxygen, biochemical oxygen demand, nitrate, phosphate, and heavy metals, help to determine the chemical composition and degree of pollution. Microbiological parameters are used to assess the possible presence of disease-causing microorganisms and faecal contamination. The combined assessment of these parameters provides a more comprehensive understanding of water quality than the evaluation of individual parameters alone (WHO, 2022). Importance of water quality assessment is to prevent waterborne diseases caused by bacteria, heavy metals or toxic chemicals, maintenance of balanced aquatic habitats and prevent dead zone of aquatic organisms. Management of resources by ensuring water remains viable for farming, livestock, and industrial operations. However, many study have been carried out both within and outside Nigeria to assess the impact of human activities on

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groundwater quality. Part of this study is the one carried out in Ibeju-Lekki Lagos on quality of groundwater revealed that high values of Iron and Magnesium were observed in borehole and the well water samples. Elevated values of turbidity, TDS, EC in the well water samples were an indication of presences of pollutants in the water source (Chiemeka and Obong, 2003). Variation in well water and Borehole water quality parameter is an indication of organic pollution, suggestion was made for chemical treatment of water before drinking. Okareh *et al.* (2023) in their assessment of heavy metal contamination of Groundwater in South Western Nigeria reported lower pH values that can cause acidosis which are linked to skin and eye discomfort (Meinhardt, 2006; Longe and Balogun, 2010). They reported all other physical and chemical parameters to be within the standard limits. In all metals examined, chromium revealed lower concentration while cadmium, Lead and Arsenic showed highest values in groundwater samples which were associated with discharge from mining, paint, electroplating, fertilizers and plastic industries that are located very near to the water sources. Ali *et al.* (2012) also reported Lead and Cadmium contamination of well water samples collected from Sango abattoir in Kaduna. They also observed high values of sodium and potassium that exceeded the standard limits. Increase values of these nutrients were associated with animal dungs, animal blood, urea, and municipal wastes. High metal contamination can have a very serious health implication on those drinking such water. Findings of Owoeye and Akinneye (2018) in the assessment of well water pollution by sewage contaminants in Akure South, Ondo, also revealed groundwater contamination by observing high values of coliform bacteria and faecal coliform counts more than recommended limits. This was associated with nearness of groundwater to sewage system due to overcrowding of settlement. Other factors responsible for this also may include seasonal variation, inadequate hygiene and sanitation. Casimir *et al.* (2015) also observed heavy metal assessment of groundwater and found out that Cadmium, Iron and Manganese values were more than the standard limits of potable water indicating metal pollution of the groundwater in Gombe State. These samples of groundwater are not fit for consumption except after treatment.

Abulude *et al.* (2023) reported low values of pH and high values of EC in hand-dug well compared to other water bodies studied in Ondo, Ekiti and Osun States. They associated the low values of pH in dug wells to be too acidic for human consumption because it can harm digestive or lymphatic system, however, high value of EC can result from anthropogenic activities. According to the study carried out by Ujah *et al*. (2021) on quality of underground well water in Enugu, they observed pH ranged between 4.70-5.02 mg/L cross their sampled water, higher values of nitrate which may indicate pollution from the closeby market to the wells were also observed. However, microorganisms isolated were *E-coli, Clostridium perfringens, Streptococcus faecalis and Enterobacteria aerogenes.* Some of these organisms are of faecal origin which may pollute water source through run-off of water from open defecation site. The well water examined was considered not potable for human consumption.

Emmanuel *et al.* (2015) in their study of well water in Samaru observed high coliform count more than the limits across the well-water sampled. They also reported that all well water examined contained one or more bacterial pathogens, such as *Escherichia coli* (20%), *Klebsiella pneumoniae* (100%), and *Proteus mirabilis* (40%) while observation of *Shigella, Salmonella* and *Vibrio* species were not notified. It was revealed that majority of the well water contaminated were of faecal origin

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indicating the water sources as a sources of water-borne diseases outbreak and that the water is not fit for drinking. The study carried out in Ibadan on microbial assemblage of household water revealed that majority of households water were hand-dug wells (53.2%) and borehole (34%). They also reported non-potable water as being common during the dry season (86.8%) compared to wet season (74.1%). It was also observed that *Escherichia coli* as a result of faecal contamination was isolated, followed by *Salmonella* species, enteroaggregative *E.coli*, and enterotoxigenic *E.coli* were also isolated which revealed poor quality of the water sources (Alabi *et al.,* 2012). Mile *et al.* (2012) also reported bacterial contamination of well water examined at Makurdias being highly polluted with coliform count of ($7.0x10^5$) and ($8.2x10^5$) in wet season and ($8.5x10^5$) and ($5.5x10^5$) for dry season respectively. They associated the well water contamination to the improper construction and man activities which make those wells not safe for drinking.

In the study carried out by Atiku *et al.* (2018) in Abuja on some drinking water sources, they observed that coliform count of the water sources were above WHO standards, all physico-chemical parameters of well and bore hole water were within the limits of WHO except that of river that exceeded 0/100mL. Three bacteria isolates observed in well water were *E.coli, Pseudomona* species and *Aeromona* species, while *Pseudomona* spp and *Proteus* spp were isolated from borehole water sample. It was concluded in their study that only the sachet water sample is safe for drinking. Kangpe *et al.* (2014) also reported low coliform count below the standard limits of MPN/100ml of total coliform for portable water. All physical and chemical parameters, heavy metal concentrations were also within the standard limits of drinking water. According to the research conducted on quality of well water in Owo, it was observed that Physico-chemical parameters examined were within the recommended limits of standard organization but high microbial loads were reported for all the sample stations which were associated with runoff, open defecation, lack of proper hygiene e.t.c. The authors encouraged treatment of these well water before consumption (Oloruntade *et al.,* 2012). Ali *et al.* (2012) also revealed acidic to basic pH, high turbidity that limits the survival of microbes in well water of Zango-Abbattoir in Kaduna. High values of nitrates, neutral to basic values of pH, high values of BOD, high total coliform count and presence of *E.coli* across the water sampled indicated faecal contamination due to nearness to soak-away leading to seepage of water in residential areas of Bauchi (Garba *et al.,* 2017). The authors concluded that simple water treatment in households must be adopted before consumption and 30metres distance from nearby sewers to their well water must be complied with. However, this study was designed to assess the water quality parameters and microbial loads of selected towns in the geopolitical zone of Oyo State to suggest likely preventive measures against water contamination.

Materials and Methods

Description of Study Area: Ogbomoso is a major historical city located in Oyo State, southwestern Nigeria. It serves as a vital gateway between the Southern Yoruba and Northern Nigeria. Ogbomoso sits on the Plateau of Yoruba land at altitude of approximately 325 to 366 metres (1,100 to 1,200 feets) above the sea level. Its specific coordinates are Latitude 8° 08' N (8.1337 ° N), Longitude 4° 14'E (4.2401°E). Ogbomoso is situated within the derived savannah. The natural landscape features a mixture of tropical tall grasses and scattered, fire-resistant trees. The native

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vegetation is highly interspersed with extensive agricultural developments. The surrounding fields are dominant producers of staple food crops such as maize, cassava, yam, cowpeas, and potatoes. Tree plantation surrounding the area are cash crops such as cashew, mangoe and others. It has two distinct seasons which include wet season (March-October/November) while the dry season span between (November -February). Temperatures in Ogbomoso remain persistently high throughout the year, with a mean annual temperature around 25 °C to 26°C. Annual minimum and maximum relative humidity typically range between 64% in the dry season and up to 89% during the peak of the rain (July to September). (Ogunbode and Ifabiyi, 2019; Ibrahim *et al.* (2019); Ewetola *et al.,* 2020; & Olafiaji, *et al.,* 2021).

Sampling Techniques and Duration: Well water samples were collected during the dry season (December - February, 2026) and wet season (April - June, 2026). Water samples were collected from three (3) locations in each geopolitical zone of Oyo State, once in a month, resulting in a total of eighteen (18) samples across sample locations. The sample locations were selected based on some ecological features such as nearness of groundwater to waste dumpsite, hospital, and natural ecosystem not fully disturbed by anthropogenic activities.

Sample Treatment: Water samples were randomly collected from different locations/sites using polypropylene bottles. Each water sample was treated with 2 mL of concentrated HNO_3 per litre sample and tightly capped to preserve the integrity of the sample until ready for use in the laboratory for analysis.

Well water Sample Collection and Determination of Water Quality Parameters: Well water samples were collected in pre-labelled 5-litres plastic kegs. Some physical parameters such as temperature and pH were measured in-situ using a pH meter and a mercury in-glass thermometer respectively. Other water quality parameters, including Electrical conductivity, Biological Oxygen Demand (BOD), Dissolved Oxygen (DO), Nitrate (NO_3^-), Phosphate (PO_4^{3-}), Total Dissolved Solids (TDS) were examined using standard laboratory procedures of Ademoroti (1996).

Determination of Heavy Metal Concentrations: The heavy metals examined for the purpose of this study were Copper (Cu), Zinc (Zn), Iron (Fe), Lead (Pb) etc. The stock solutions (1µg/ml) of each of the metal ions mentioned above were prepared using appropriate metal salt of Analytical Grade quality in dilute Hydrochloric acid (HCL). The working standard of these solutions was prepared by appropriate dilutions in distilled water. The water samples were examined for heavy metal concentrations using inductively Coupled Atomic Absorption Spectrophotometers (ICF-AAS Model Drawell M/S)

Determination of Water Quality Parameters of each Sample Stations: Water quality parameters of each station was determined using weighted Arithmetic WQI according to the Brown *et al.* (1972). The formula for calculation are as follows:

Step 1: calculation of the unit weight (Wn) factor for each parameters using formula

$$Wn = k/Sn$$

where $K = \dfrac{1}{1/S1 + 1/S2 + 1/S3 + 1/S4 ..... 1/Sn}$

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Where Sn= Standard desirable value of the nth parameters on summation of all selected parameters, unit weight factor (Wn) =**1**

Step 2: Calculation of Sub-index (Qn) value using formula

$$Qn=\frac{[Vn-Vo]}{[Sn-Vo]}x100$$

Where Vn=mean concentration of the nth parameters

Sn=Standard desirable value of nth parameters

Vo=Ideal values of the parameters in pure water, (generally, Vo=0 for most parameters except pH).

Therefore, $QpH=\frac{[VpH-7]}{[8.5-7]}x100$

Step 3: Combination of step 1&2 will give WQI value as

$$WQI=\sum WnxQn$$

The exact parameters that causes pollution of the groundwater can also be determined using Nemerow's Pollution Index (1970) as :

$$NPI=\frac{Cn}{Sn}$$ Where

Cn = concentration of the nth parameters

Sn= Prescribed Standard limits of the nth parameters

Determination of Bacteria Load /Coliform Count

Preparation of MacConkey Broth: The media were prepared according to the manufacturer's instruction. MacConkey broth was used as a differential medium for detection and enumeration of coliforms from water samples collected.

Procedure: The sterile water samples were collected and filtered through a membrane, followed by incubation of the filtered water on a selective medium, and the resulting colonies were later counted to determine the number of viable counts and coliform bacteria per 100m/L of water sample.

Results

MONTHS/ STATIONS		DEC.			JAN			FEB				
Sample Stations	Parameters	A	B	C	A	B	C	A	B	C	WHO	NSDWQ
	Temperature (°C)	27.50±0.00	29.00±0.00	27.37±0.36	27.20±0.00	27.20±0.00	25.00±0.00	27.20±0.00	27.80±0.00	27.50±0.00	ambient	ambient
	pH (mg/L)	7.70±0.10	7.50±0.00	7.07±0.36	7.77±0.76	7.60±0.00	7.00±0.00	7.50±0.00	7.60±0.00	7.20±0.00	6.5-8.5	6.5-8.5

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MONTHS/ STATIONS		DEC.			JAN			FEB				
	DO (mg/L)	5.40± 0.00			3.60± 0.00	3.73±0 .12		9.90±0. 00	3.23±0. 06	1.73±0. 06		
			3.73±0 .12	4.60±0 .10			5.33±0 .06				4 - 6	5.0
OGBOMO SO	BOD (mg/L)	5.30± 0.00	4.52±0 .42	5.38±0 .15	8.71±0 .01	5.67±0 .21	5.73±0 .15	7.30±0. 00	4.70±0. 00	3.60±0 .00	0 - 2	< 5
	EC (µs/cm)	2563.3 3±5.77	2853.3 3±5.77	3947.3 3±12.7 0	1166.0 0±7.21	1306.6 7±11.55	1360.0 0±0.0 0	4333.33 ±152.75	5500.0 0±173.2 1	3600.0 0±0.00	100 0 - 150 0	100 0
	TDS (mg/L)	205.20 ±0.35	96.00 ±0.00	52.33± 0.58	79.73 ±0.23	105.00 ±1.73	121.33± 0.58	144.33± 1.53	65.00± 0.00	47.73± 1.42	500- 100 0	500
	Nitrate (mg/L)	24.70± 0.00	20.53± 0.06	10.97± 0.12	79.60 ±0.00	11.87± 0.06	22.00± 0.00	1.40±0. 17	16.57±0 .12	3.50±0 .35	50	50
	Phospha te(mg/L)	25.73± 0.58	24.50± 0.00	0.74±0 .12	12.50± 3.46	4.30±0 .00	5.60±0 .00	0.90±0. 00	1.73±0. 21	2.53±0. 06	5	0.3 – 5.0
	Turbidit y (NTU)	13.37± 0.40	10.33± 0.58	10.33± 0.58	4.30± 0.00	2.90±0 .00	0.13±0 .00	1.90±0. 00	27.00±1 .00	1.40±0. 10	5.0	5.0

Table 1a: Mean ± SD Values of Physico-chemical Parameters of Dry Months of Ogbomoso Water samples

Keys

A= Water samples from well water near the Dumpsite **B**= Water samples from well water near The Hospital

C= Water samples from well water in a Natural Environ. **WHO**=World Health Organisation, **NSDWQ**=Nigeria Standard for Drinking Water Quality

Table 1b: Mean ± SD Values of Physico-chemical Parameters of Rainy Months of Ogbomoso Water samples

MONTHS/ STATIONS		APRIL.			MAY			JUNE				
Sample Stations	Parameters	A	B	C	A	B	C	A	B	C	WHO	NSDWQ
	Temperature (°C)	28.00± 0.00	27.50± 0.00	28.03 ±0.33	27.90± 0.00	27.50± 0.00	27.00± 0.00	27.93± 0.60	27.50± 0.00	27.00± 0.00	ambient	ambient
	pH (mg/L)	6.80±0 .00	7.60± 0.00	7.00± 0.00	6.50±0 .00	7.60±0 .00	7.20±0. 00	8.30±0 .00	7.80±0 .00	7.70±0 .00	6.5-8.5	6.5-8.5
	DO (mg/L)	10.50± 0.10	6.80± 0.00	9.10± 0.17	10.50± 0.00	18.60± 0.00	28.60± 0.00	3.47±0 .23	2.57±0 .06	1.78±0 .03	4 - 6	5.0
OGBOMO SO	BOD (mg/L)	5.30±0 .00	4.57± 0.06	5.53± 0.06	11.07±0 .12	12.60± 0.10	4.63±0 .06	8.80± 0.10	7.10±0 .10	4.57±0 .15	0 - 2	< 5
	EC (µs/cm)	3032.6 7±0.58	497.3 3±0.5 8	375.3 3±0.5 8	2666.0 0±0.00	2390.0 0±0.00	1600.0 0±0.00	1408.0 0±1.00	1946.6 7±5.77	2034.0 0±1.73	1000 - 1500	1000

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MONTHS/ STATIONS		APRIL.			MAY			JUNE				
	TDS (mg/L)	312.67 ±1.15	106.00±0.00	73.33 ±0.58	118.33± 1.15	1.44±0.01	22.50± 0.00	306.00±0.00	18.90± 0.00	5.50±0 .00	**500-1000**	**500**
	Nitrate (mg/L)	13.33± 0.58	11.43± 0.51	10.00 ±0.00	6.20±0 .35	12.00± 0.00	5.50±0 .00	22.33± 0.58	18.20± 0.00	1.60±0 .00	**50**	**50**
	Phosphate(mg/L)	2.20±0 .00	1.23±0 .06	5.47± 0.06	0.20±0 .00	13.33±1 .15	8.00±1. 00	1.50±0 .00	1.50±0 .00	0.20±0 .00	**5**	**0.3 – 5.0**
	Turbidity (NTU)	26.00± 1.73	8.83± 0.76	2.17±0 .06	4.63±1. 69	1.40±0. 20	105.33 ±0.58	9.83±1 4.00	26.00± 0.00	14.33± 0.58	**5.0**	**5.0**

Keys

A= Well water samplenear the Dumpsite **B**= Well water sample near Hospital,

C= Well water sample in a Natural Environ. **WHO**=World Health Organisation, **NSDWQ**=Nigeria Standard for Drinking Water Quality

Table 2a: Mean ± SD Values of Heavy Metal Concentration of Dry Months of Ogbomoso Water sample

MONTHS/STATIONS		DEC.			JAN.			FEB.				
Sample Stations	**Parameters**	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**	**WHO**	**NSDWQ**
	Zinc Zn (mg/L)	4.57± 0.25	0.19±0 .01	1.30±0. 00	78.40±5 8.20	6.50± 0.00	1.07±0 .02	1.70±0 .10	0.12±0 .01	6.20± 0.17	**3 -5**	**3.0**
OGBOMOSO	**Copper Cu (mg/L)**	2.65± 0.04	2.90± 0.00	4.40±0 .10	5.47±0. 29	0.41±0 .01	0.33± 0.06	BDL	BDL	0.02± 0.01	**2.0**	**1.0**
	Iron Fe (mg/L)	6.40± 0.10	0.22±0 .02	13.43± 0.06	0.50±0. 00	0.14±0 .03	1.06±0 .05	2.33±0 .06	1.64± 0.04	2.77± 0.23	**0.2**	**0.3**
	Lead Pb (mg/L)	0.15±0 .00	BDL	0.42±0 .00	BDL	8.30± 0.00	14.17± 0.15	0.00± 0.00	BDL	BDL	**0.01**	**0.01**

Keys

A= Water samples from well water near the Dumpsite **B**= Water samples from well water near The Hospital

C= Water samples from well water in a Natural Environ. **WHO**=World Health Organisation, **NSDWQ**=Nigeria Standard for Drinking Water Quality

Table 2b: Mean ± SD Values of Heavy Metal Concentration of Rainy Months of Ogbomoso Water sample

MONTHS/STATIONS		APRIL			MAY.			JUNE				
Sample Stations	**Parameters**	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**	**WHO**	**NSDWQ**
	Zinc Zn (mg/L)	6.30±0 .10	0.30±0 .00	7.23±0 .06	1.73±0. 06	2.40± 0.10	1.02±0 .01	0.05±0 .01	0.83±0 .06	BDL	**3 -5**	**3.0**
OGBOMOSO	**Copper Cu (mg/L)**	BDL	BDL	0.40± 0.10	1.53±0. 06	1.60±0 .20	1.60±0 .26	1.63±0. 06	0.23±0. 06	BDL	**2.0**	**1.0**

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MONTHS/STATIONS		APRIL			MAY.			JUNE				
	Iron Fe (mg/L)	6.20±0.00	4.77±0.15	3.37±0.21	22.67±1.15	1.48±0.01	2.73±0.06	2.73±0.06	8.60±0.00	BDL	**0.2**	**0.3**
	Lead Pb (mg/L)	BDL	BDL	BDL	0.20±0.00	BDL	BDL	0.40±0.00	BDL	BDL	**0.01**	**0.01**

Keys

A= Water samples from well water near the Dumpsite **B**= Water samples from well water near The Hospital

C= Water samples from well water in a Natural Environ. **WHO**=World Health Organisation, **NSDWQ**=Nigeria Standard for Drinking Water Quality

Table 3: Seasonal Variations of Viable and Coliform Counts of Microbial Load Isolated from Ogbomoso water Samples

Samples/Months/ Coliform Counts	Viable Counts					
Sampling Stations	A	B	C	A	B	C
December 2025	08	---	08	TNTC	----	08
January 2026	23	24	---	18	TNTC	---
February	TNTC	08	42	10	TNTC	10
April 2026	TNTC	TNTC	TNTC	07	TNTC	---
May 2026	72	10	---	03	TNTC	---
June 2026	26	84	25	32	02	07

Table 4: Showing Result of Water Quality and Pollution Indices

Months/WQI	Station A	Station B	Station C
December	216.43	196.79	93.59
January	142.80	84.49	70.40
February	58.11	173.66	62.74
April	154.23	85.07	68.68
May	81.46	121.99	503.69
June	122.32	181.44	115.74
Months/NPI	**Station A**	**Station B**	**Station C**
December	15.54	3.62	55.84
January	18.71	589.88	1007.03
February	5.59	4.10	6.63
April	14.80	11.33	8.04
May	53.94	3.66	15.12
June	28.57	20.45	2.07

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Table 5: WQI and NPI Interpretation

WQI Values	Water Quality Classification	NPI Interpretation
0-25	Excellent	**NPI <0.0:** Clean/Unpolluted
>25-50	Good	**0.0<NPI <1.0:** Low Pollution
>50-75	Poor	**1.0 < NPI<2.0:** Moderate Pollution
>75-100	Very Poor	**2.0<NPI <3.0:** High Pollution
>100	Unsuitable for Drinking	**NPI>3.0:** Very High Pollution (Poses health risk like Blue Baby Syndrome)

(Objective 1& 4: To determine the physical and chemical parameters of water samples and compare with standard values of drinking water)

Seasonal Variation of Mean Values of Physico-chemical Parameters of Ogbomoso Well Water Samples

Temperature values ranged between 27.20±0.00-29.00±0.00°C, the temperature values of rainy season months ranged between 27.00±0.00-28.00±0.00°C and were within the required limits for drinking water. Hydrogen Ion Concentration (pH) ranged between 7.07±0.36-7.77±0.76mg/L which were neutral to alkaline, while that of the rainy months were acidic to alkaline across the stations and months. Dissolved Oxygen (DO) of the dry and rainy months, station A (5.40±0.00) in December, and C (5.33±0.06) in January, and in February A (9.90±0.00) and were higher than the standard limits, while that of rainy months DO values were higher across stations except in June A (3.47±0.23), B (2.57±0.06), and C (1.78±0.03) and were within the limits set for drinking water. Biological Oxygen Demands (BOD) values were higher in many stations across the dry months than the required limits except station B (4.70±0.00) and C (3.60±0.00) in the month of February. Highest values of BOD were recorded across stations during the rainy months, which were more than the WHO set limits for drinking water. All EC values across dry season were higher than the required limits except station A (1,166.00±7.21), B (1,306.67±11.55µs/cm), C (1,360.00±0.00) in February water sampled. EC recorded hike values in April (3,032.67±0.58), May A (2,666.00±0.00), B (2,390.0±0.00), C (1600.00±0.00), June B (1,946.67±5.77), and C(2034.00±1,73µs/cm) while other station values were below the limits. TDS values were lower across dry months, even lower than the limits required for drinking water except station A (79.60±0.00) that recorded higher values in January. Rainy months TDS values were lower across stations, particularly in April C (73.33±0.58 mg/L), May B (1.44.00±0.01), C (22.50±0.00), June A (18.90±0.00), C(5.50±0.00) respectively. Nitrate values of all stations in the dry months were within the limits of standard values except station A (79.60±0.00) with high values in January. Rainy months water samples recorded lower values of nitrate below the recommended limits across station but minimum value was recorded in June at station C (1.60±0.00) respectively. Phosphate also recorded higher values in all stations C (0.74±0.12) in January, B (4.30±0.00), A (0.90±0.00), in February, B (1.73±0.21) and C (2.53±0.00mg/L), February value falls within limits of drinking water. Phosphate values were within the limits in all stations except in April, C (5.47±0.06 mg/L), May, B(13.33±1.15mg/L), C(8.00±1.00mg/L) which had higher values more than limits compare to other sample stations.

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Turbidity values of sampled water across stations were below recommended values for drinking water in dry months but highest values that greatly exceeded limits was recorded in February in station B (27.00±1.00 Ntu). The values of turbidity across stations during rainy months were higher except stations C (2.17±0.06 Ntu), A (4.63±1.69 Ntu) in May, while station B (1.40±0.20 Ntu) had lowest value respectively.

(Objective 2& 4: To determine the heavy metal concentration of the water samples and compare with the standard values)

Mean Values of Heavy Metal Concentration of Selected Groundwater Samples

Zinc concentration of dry months in Ogbomoso revealed lower values across station except December A (4.57±0.25 mg/L), January A (78.40±58.20 mg/L), B (6.50±0.00 mg/L) and February C (6.20±0.17 mg/L), while the Zinc values across rainy months showed lower values except station A (6.30±0.00 mg/L), and C (7.23±0.06 mg/L) and were more than required limits for drinking water. Copper revealed highest values in Dec, across stations and January A (5.47±0.25), other values were lower and below detective limits both in the dry and rainy months respectively. High values of Iron were revealed, some stations were below detective limits across dry and wet months. Higher mean values of Lead more than limits were revealed across dry months while it was not detected in many stations during wet months except A (0.20±0.00) in May, and A (0.40±0.00) in June respectively. If fit for drinking or not

(Objective 3: To examine the microbial load present in the water samples)

Microbial Loads of Selected Groundwater Samples

Both coliform and viable counts of Ogbomoso selected Groundwater samples were higher in numbers more than the required limits across stations, and dry months except station B in December with no viable counts, and station C in January. No coliform count recorded in station B in December 2025 and station C in January 2026 respectively.

(Objective 5: To determine the pollution status of the water samples to see whether the water)

Water Quality Indices (WQI and NPI) of Selected Water Samples

Across rainy months, all sampled water across stations recorded high viable counts except in station C in May without values, lower values of coliform counts in station A across the rainy months, though more than the required limits in drinking water, too much to count were encountered in April and May and no coliform counts found in C both in April, May but (02) in June, 2026 respectively. The WQI result revealed values ranged from 58.11 to 216.43 and 68.68 to 503.69 across stations and dry-wet months. It revealed poor to unsuitable for drinking. The NPI values ranged from 3.62 to 1007.03 and 2.07 to 53.94 across the stations and dry-wet months, which is very poor and revealed high pollution status of the groundwater examined. The study revealed that Pb, Fe, Zn, PO_4, EC and turbidity were the major culprit in the contamination of the water under study.

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Discussion

Seasonal Variation of Mean Values of Physico-chemical Parameters of Sampled Water

The temperature values that fell within the standard limits across the sampling stations may be due to ambient condition of the environment which is suitable. Similar observation was reported by Ikuesan and Balogun (2022) in their study.

The pH of water is an important parameter that reflects its acidity or alkalinity, providing essential information about the hydrogen ion concentration in the water. Range of pH of the present study that was within the standard limits, though varied from station to station, acidic values reported for the rainy months may be due to dilution of rain water in the groundwater examined. Alkaline values may be due to the burning of particles on the dumpsite, similar observation was reported by Wu *et al.* (2021). Aniyikaiye *et al*. (2019) and Patil *et al.* (2012) also identified carbonates, bicarbonates, ammonia, iron oxide, and titanium dioxide as significant contributors to groundwater alkalinity.

The pH values that were neutral to alkaline may be due to soil texture of the well water. This result is similar to that of Ondieki *et al*. (2021) who also reported acidic to alkaline pH in Eastern Africa in the drinking water examined. High values of Dissolved Oxygen in station A in dry months could be due to organic decomposition of the dumpsite and high temperature of the dry months. Other stations that fall within the range may indicate low organic pollution of the groundwater. DO values of majority of well water sampled in the dry months that were higher may be associated with high temperature that occurs at the peak of dry season. DO values within normal threshold make water taste fresh while high values more than limits can accelerate the corrosion of metal pipes that can leach out the heavy metals such as iron, lead and copper into the water. High DO in water sample collected near dumpsite can be traced to organic effluents from the dumpsite. This report is deviated from the observation of Ikuesan and Ediagbonya (2024) who observed DO values that were within the standard limits across the water samples studied in Ondo State. Gyar and Nagogo (2024) also reported highest DO values across water samples examined.

Station B with low BOD may be associated with waste properly being managed by the hospital management. The BOD values that were all higher in values can indicate organic pollution as a result of runoff during rainy seasons. Similar observation was reported by Gyar and Nagogo (2024) in Nasarawa State. Ikuesan and Ediagbonya (2024) who observed BOD values that were within the standard limits across the water samples studied in Ondo State. Ogoko (2017) also reported BOD values within the permissible limits in groundwater samples of Owerri metropolis.

Electrical conductivity (EC) determines the concentration of soluble salts which affect the taste of the drinking water. EC values that were higher in all samples may indicate high salt concentration of the groundwater which may be associated to hardness of water due to either Na, Ca or Mg dissolved in it. Alnashiri (2021) and Sahay and Kumar reported similar observation of High Values of EC in groundwater samples examined in Saudi Arabia and India. However, low values of EC were reported by Kalip *et al.* (2024), Onwualu and Uzoegbu (2022) and Nofiu (2024) all reported EC values within the permissible limits in their study areas.

TDS values of the water samples across seasons and stations that were within the limits may be due to low inorganic salt dissolved in it, no agricultural runoff into the water samples. *Ganiyu et al.*

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(2017), Ogoko (2017), Oyelakin *et al.* (2020) reported similar observation of TDS fell within the limits. Sahay and Kumar (2025) and Abdalkarem *et al.* (2026) reported high values of TDS in their samples of water examined.

All nitrate values across stations had low values except station A water samples in January, this could be attributed to dryness and groundwater samples may be in close proximity with dumpsite. The present study is in line with the observation of Syafrizah *et al.* (2024), Olanrewaju *et al.* (2025), Bakari and Muktar (2026), all reported Nitrate values within the permissible limits in their groundwater studies. However, High values more than the limits were reported by Gyar and Nagogo (2024) and Abdalkarem *et al.* (2026) in their study sites. This could be attributed to agricultural runoff, animal wastes and human sewage which dissolves easily and leach into groundwater. Chronic or long-term exposure to elevated nitrate levels has been associated with thyroid dysfunction, increase risk of certain cancers such as colorectal cancer.

Phosphate values of groundwater samples near waste dumpsite and hospital that were high could be attributed to the influx of waste effluents from the site, particularly in the dry season months. Elevated values of phosphate can affect the taste of water, odour and algal bloom on the surface water due to nutrients influx into the water bodies. High level of phosphate can cause stomach or digestive discomfort in sensitive individuals. The present study is in line with the observation of Yohanna and Abdul (2022), Gyar and Nagogo (2024) who reported high values of phosphate more than required in drinking water for some of their study stations. Gopi *et al.* (2023), Bakari and Muktar (2026) reported low values in their study as related to this study for many stations.

High values of Turbidity during wet seasons could be associated with flood, runoff from the surrounding covets of the groundwater, in fact, the turbidity values of groundwater near hospital and dumpsite revealed peak values that may be due to effluents percolated into the water tables. The assumed clean groundwater that revealed low turbidity indicated low suspended particles except during rainfall months that can result from runoff as a result of erosion during wet seasons. This observation is in line with Yohanna and Abdul (2022) who reported high values of turbidity more than permissible limits, contrary observation of low Turbidity was also reported by Idowu *et al.* (2026) who reported low values of turbidity below the required limits for drinking water.

Zinc concentration that revealed high values in groundwater near dumpsites in January, April may be due to effluents influx, Copper also revealed high values in all stations in December while Iron concentration revealed high values which could be found in the water due to burning on the dumping site. Ganiyu *et al.* (2017), Oyelakin *et al.* (2020) reported low zinc concentration in their study. Iron concentration that was high in most stations may be attributed to the groundwater rock dissolving these metals in the water. Lead concentration were below detection limits in many stations while other stations with high values may be due to burning in the surroundings of the groundwater. The present study aligned with the observation of Egbeyale *et al.* (2024) who opined that high values of Pb in well water examined can be traced to the anthropogenic origin, road construction, and lead-based painting in Malete area, Kwara State. Similar observation was reported by Aduku and Yahaya (2026), Ozoffor (2025) also revealed below detective limits of Pb. Highest values of heavy metals such as Zn, Cu, Pb, As were also observed by Alnashiri (2021) and Zirra *et al.* (2026) in their study areas. However, low values of Cu, Fe and Pb that are within

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permissible limits were also reported by Ogoko (2017) in Groundwater samples of Owerri communities.

All microbial Load encountered in this study indicated contamination of water bodies that may be attributed to surrounding particles, environmental factors that favoured the coliform growth, seepage of effluents from hospital and dumpsite near the groundwater samples. This study corroborates the observation of Chapelle *et al.* (2009) who opined that runoff from feedlots, pastures and other areas containing other animal wastes are potential source of coliform bacterial contamination of groundwater. Joseph (2021) also reported Total coliform ranged from 0.00-4.00 cfu/100ml in Yobe State. Syafrizah *et al.* (2024) and Ozoffor (2025) also observed highest coliform count in their study areas. Exceeded number of coliform and viable counts were also reported by Idowu *et al.* (2026) and Akber *et al.* (2026) in their study areas. The water quality index examined that showed high pollution status could be traced to human activities surrounding the source of water samples examined. This result is similar to that of Satish Chandra *et al.* (2017) who also reported poor to very poor WQI in in both seasons in their study areas. This result is also in line with the report of Verma *et al*. (2020), Al-humairi *et al.* (2020) and Abayneh (2025). However, this observation is deviated from the report of Ameen (2019) in Iraq and Wekesa (2022) in Kenya who reported low values of WQI which indicated good to excellent water quality.

Conclusion

Groundwater samples were collected for six months considering the wet and dry seasons, physical and chemical parameters examined revealed values that were within standard limits of drinking water, except turbidity, conductivity, Biological Oxygen Demands with high values. However, Copper, Iron and lead also had high levels across stations and months, particularly water samples collected near dumpsite and hospital. Microbial counts were highest in number more than the required limits in all stations, except some areas free of waste dumping that revealed no coliforms. Water quality index showed that majority of the water samples collected were highly polluted, while some are unsuitable for drinking at all. The contamination of the groundwater examined according to NPI result is linked to high values of phosphate, Pb, Cu, Iron, BOD and EC, in some of the sample stations and months. The study concludes that the groundwaters are highly polluted due to high suspended particles as a result of human activities surrounding the groundwater. Hence, there is need for water monitoring and intervention from the Government by providing potable water to the affected town. There should be public awareness on the distance needed to cover before digging their well water near the dumpsites and hospitals and proper ways of waste management.

Declaration of Conflict of Interest

The authors declared no conflict of interest as far as this study is concerned

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