Nig. J. Pure & Appl. Sci. Vol. 39 (Issue 1, 2026)
e-ISSN 2756-4045
(C) 2026 Faculty of Physical Sciences and Faculty of Life Sciences, Univ. of Ilorin, Nigeria
www.njpas.com.ng

Potability of River Waters in Ijebuode Ogun State, Nigeria: PhysİcochemicalProperties and Microbial Analysis

*Sebiomo Adewole and Ade-Ogunnowo F. Eunice

Department of Biological Sciences, Tai Solarin Federal University of Education, Ijagun, Ogun State

Date Received: 02-01-2026
Date Accepted: 05-05-2026
DOI: https://doi.org/10.48198/NJPAS/26.A03

ABSTRACT

Water occupies about 70% of the earth's surface. Although, more than three quarters of the earth's surface is made up of water, only 2.8 percent of the Earth's water is available for human consumption. Rivers therefore provide livelihood for rural populations in many developing countries. This work is therefore carried out to analyze the physicochemical content and microbial analysis of commonly used river waters in Ijebu Ode Ogun state. The grab and composite sampling method was used during sample collection, treatment and preservation. Physicochemical properties were determined using the APHA method. Concentration of metals was determined in atomic absorption spectrophotometer. The Temperature, Color, pH, Electrical conductivity (EC), Total dissolved solids (TDS), Total suspended solids (TSS), (DO), (BOD), (COD), Alkalinity, Total hardness, Nitrate, Sulphate, and Phosphate were also analyzed and compared with the World Health Organization standards. All physicochemical parameters analyzed in the river water samples were not within the recommended standards except for the pH which falls within the standard limit of 6.68-6.86. Biochemical oxygen demand (BOD) values 342.00±34.85 - 405.00±1.44 and Dissolved Oxygen (DO) 3.17±0.23 - 4.30±0.20 all generally above WHO permissible limit respectively. These results indicated that the water sources were contaminated and unfit for human consumption. This therefore, calls for appropriate treatment measures before the consumption and domestic uses of these river water by the populace to avoid long term accumulative health problems of these pollutants.

Keywords: Physicochemical, Microbial, BOD, COD, DO.

1.0 Introduction

Water is the most essential element for life, after air. This has led to a great deal of description of water quality in the scientific literature. The term "water quality" describes the properties of water that are chemical, physical, biological, and radioactive (Palansooriya *et al.*, 2020; Shah *et al.*, 2023). It is a measurement of the water's characteristics in relation to the needs of one or more biotic species and/or to any goal or demand of humans (Hassan-Omer, 2020) Life is impossible without water, which is one of the most essential elements of life. However, because of growing anti- environmental human activity as well as some natural processes, the quality of the surface water is steadily declining, endangering all life, including human life. The main factor behind the spread of numerous epidemics and certain catastrophic illnesses like cholera, typhoid, diarrhea, etc. is contaminated water (Tulchinsky, 2018). Many academics have investigated some facets of water quality and the causes of its deterioration in an effort to develop a meaningful global control strategy (Nguyen, 2023). Contaminated water can act as a vehicle for disease transmission (Balogun *et al.*, 2013; Fawell *et al.*, 2003).

Corresponding Author: **Sebiomo Adewole**
Department of Biological Sciences, Tai Solarin Federal University of Education, Ijagun, Ogun State
Email: sebiomoa@tasued.edu.ng; sebiomoadewole6@gmail.com

©2026 Creative Common License Attribution 4.0 International

Common waterborne diseases include typhoid fever, cholera, and diarrhea, among others. Population expansion, increased anthropogenic activities, as well as rapid urbanization and climate change, are the major factors in the increasing contamination of water worldwide. About 2.2 million people die from diarrheal diseases annually, many of which are linked to contaminated water (WHO, 2020). The burden of contaminated water is particularly high in third-world countries due to poor healthcare facilities (WHO, 2018). In developing countries such as Southeast Asia and Africa, diarrhea alone accounts for up to 8.5 and 7.7% of annual mortality, respectively (WHO, 2020). Drinking water is derived primarily from two sources, which are surface waters such as rivers and reservoirs, as well as groundwater such as boreholes and wells (Fawell *et al*., 2003). Water sources naturally contain contaminants, particularly inorganic substances that emanate from the geological strata through which the water flows (Fawell *et al*., 2003). Artificial contamination of water may occur through anthropogenic activities. Among the toxic chemicals in water, heavy metals are the most suspected owing to their persistence, toxicity, and wide distribution in the environment. Long-term human exposure to heavy metals such as copper (Cu), cadmium (Cd), lead (Pb), zinc (Zn), and nickel (Ni) causes health hazards.8 Some heavy metals can combine together to produce additive effects. More than 25% of the total burden of disease is linked to environmental factors to which toxic chemicals contribute significantly (WHO, 2022). Heavy metals enter the environment through both natural and anthropogenic sources, including mining, oil exploration, household and industrial waste, and urban runoff (Anyanwu *et al*., 2018). Besides heavy metals, microorganisms are another group of water contaminants that are of public health concern. There are over 500 waterborne pathogens capable of contaminating drinking water and are grouped mainly into viruses, bacteria, parasitic protozoa, and fungi (Soller *et al*., 2010). Waterborne diseases kill more than 5 million people per year (Cabral, 2010; Malik *et al*., 2012) of which over 50% are microbial intestinal infections (Cabral, 2010). In IjebuOde, Ogun State, Nigeria, groundwater, mainly boreholes and wells, is the major source of drinking water. About 81% of the residents of Ogun State depend on groundwater for drinking (Omole and Okonkwo, 2016) This is due to the cost-effectiveness of groundwater and the inadequacy of pipe-borne water in the state, which is characteristic of developing nations. Though groundwater is less vulnerable to pollution than surface waters (Fawell *et al*., 2003). It may be contaminated by anthropogenic activities and urban runoffs in metropolitan areas such as Mowe. Monitoring of water quality for its improvement can reduce the global disease burden by approximately 4% (WHO, 2015). There is a dearth of documented studies on heavy metal and microbial pollution of groundwater in the Mowe metropolis. Therefore, this study assessed the quality of borehole and well water in Mowe metropolis, Ogun State, Nigeria. A reliable supply of clean wholesome water is highly essential in a bid to promoting healthy living amongst the inhabitants of any defined geological region (Mustapha and Adam, 1991)

The rate at which rivers are polluted has necessitated the constant assessment of water quality. The quality of the river water can also be affected by the atmospheric inputs, climatic conditions and anthropogenic inputs (Liu *et al*., 2020). Rivers play important roles in the accumulation and disposal of municipal and industrial wastewater (Ukpaka and Chuku, 2025). Physiochemical properties of water usually determine the rate at which microorganisms proliferate in the ecosystem. This study determined the physicochemical and microbial load of river water samples in Ogun State Nigeria.

2.0 Materials and Method

Description of study areas

The study sites were all located within Ogun State in Nigeria. The Yemule River is located in Odogbolu Local Government Area at coordinates of 6.825535 (latitude) and 3.898783 (longitude) (Fig. 1). The Idomila River is located in Ijebu North East Local Government Area. Its coordinates are latitude 6.803565 and longitude 3.929205. The Imoru River is located in Ijebu-Ode Local Government Area at coordinates 6.809408 (latitude) and 3.936887 (longitude). The Oke-Owa River is also located in Ijebu-Ode

Local Government Area. Its coordinates are latitude 6.809553 and longitude 3.937070. The Eriwe River is a stream located in Odogbolu Local Government Area. Its coordinates are latitude 6.774893 and longitude 3.883560. All the selected rivers are located close to one another in Ogun State, Nigeria. Several activities such as washing, swimming, bathing, drinking and even defecating are carried out in all these rivers. All the rivers have fish farms and farmlands very close by. The most prominent with several fish farms is the Eriwe River.

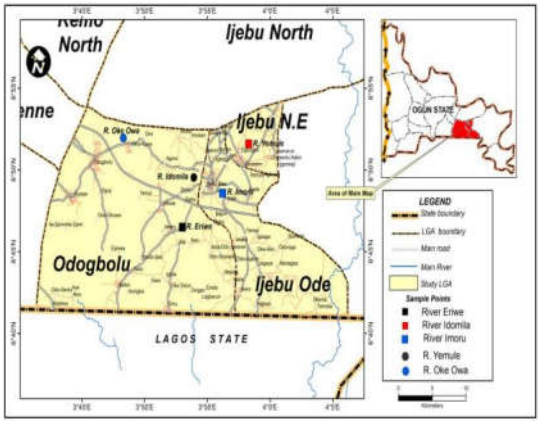

Figure 1: Map showing the location of study areas

Sample collection

The water samples were collected from the water bodies at various locations using the method described by Rao (2003) and Metcalf and Eddy (Metcalf, 2008). Water samples were obtained from five river bodies in Ogun State Nigeria.The samples were collected using clean plastic containers with screw caps. Plastic sample containers (1.5l) were washed with non-scented liquid detergent, rinsed with water and sterilized. The water samples were collected from a depth of 0.5m deep and collected up to the top with the mouth facing slightly upward in the direction of the current. The bottles were properly labeled; the samples were kept in the refrigerator at 4^0C prior to the analysis (to maintain microbial integrity i.e. prevent multiplication of microorganism) before analysis. Three samples were collected from point of pollution (this is the point at which the pollutants such as house hold waste, industrial wastes and human and animal feces enter the river before it is spread to other parts of the river) and three samples from control area 1km away (at there is reduced microbial load and the physicochemical content is also believed to thin out) from the point of pollution (CA). Thirty samples were collected in all from the five rivers. The samples were labeled appropriately.the labellings of all the collected river water samples were as follows; ROOC (River Oke-Owa Control), ROOP (River Oke-Owa Point of Pollution), RERC (River Eriwe (Control), RERP (River Eriwe Point of Pollution), RIDC (River Idomila Control), RIDP (River Idomila Point of Pollution), RIMC (River Imoru Control), RIMP (River Imoru Point of Pollution), RYEC (River Yemule Control), RYEP (River Yemule Point of Pollution).

Microbial Isolation, Enumeration and Identification

Nutrient agar (NA) was used for the enumeration of total heterotrophic bacteria by the pour plate method. Incubation was done at 30^0C for 24-48 h. Fungi were enumerated using Potato dextrose agar (PDA). Fungal isolates were incubated at 25^0C for 5-7 days. Bacterial isolates were identified based on cultural characteristics, staining reactions and biochemical reactions. Identification was thereafter made with reference to Bergey's Manual of Systemic Bacteriology.

Presumptive Test for Coliforms

The analysis of water samples for coliform bacteria was conducted using the Most Probable Number (MPN) method, which is widely recognized for assessing microbial contamination in water. This approach serves as a key indicator of water quality and potential health risks. In the initial stage, water samples were inoculated into MacConkey broth media, where the production of gas was observed using Durham tubes. The presence of gas within the first 24 hours indicated a strong likelihood of coliform bacteria, while gas observed only after 48 hours suggested the need for further investigation, as this could point to non-specific fermenters. This preliminary assessment is crucial for gaining insights into the microbial quality of the water. For samples that yielded positive or doubtful results in the presumptive test,

Confirmatory Testing

The smallest inoculum from the presumptive tubes was streaked onto Eosin Methylene Blue (EMB) agar plates. This selective medium is effective in differentiating between coliforms and other bacteria, as it inhibits the growth of gram-positive organisms while allowing gram-negative bacteria to thrive. The EMB agar supports the growth of coliforms, enabling clear.

Identification Based on their Colony Characteristics

After inoculation, the EMB agar plates were incubated at 37°C for 48 hours. This incubation period is essential for facilitating the growth of coliform bacteria, allowing them to form distinct colonies that can be visually examined. Upon completion of the incubation, colonies exhibiting typical characteristics of coliforms, such as dark purple to black coloration and a green metallic sheen indicative of *E. coli*, were observed. This visual differentiation is critical for accurately assessing the presence of potential waterborne pathogens.

Completed Test

In the complete test phase, each colony from the EMB agar plates was carefully selected using an inoculating wire loop and transferred into slant bottles filled with molten agar medium. These bottles were then incubated at 37°C for 48 hours to allow for further growth and confirmation of the bacterial isolates.

Determination of Total Coliform

Coliform counts were determined by the standard multiple tube fermentation technique. Water samples were inoculated into test tubes containing 10 ml of lactose broth and incubated at 35 ± 0.5°C. Positive presumptive test was indicated by the formation of gas (a bubble filling the concavity of Durham's tube) after 24 h of inoculation. The production of gas in the Durham tubes indicated the growth of coliform organisms. Cultures showing no production of gas in 48h were considered negative. The water samples in tubes that showed gas production were inoculated on endo or eosine-methylene-blue agar; and one or more typical colonies are picked and inoculated into Brilliant Green Bile broth and observed under the microscope to see whether the contained organisms have the morphological and staining properties of coliform bacilli.

Determination of Physico-chemical Characteristics

The water samples were processed according to the method prescribed by the American Public Health Association (1998). The pH and electrical conductivity (EC) of the water samples were tested using pre-calibrated pH and conductivity meter, while dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total solids (TS), total dissolved solids (TDS), total alkalinity (TALK), nitrate (NO_3^-), phosphate (PO_4^{3-}), sulphate (SO_4^{2-}) and chloride (Cl^-) were also determined using the methods of the APHA (1998).

Determination of Suspended and Dissolved Solids

Suspended solids and dissolved solids were determined gravimetrically. For TSS, each sample was filtered through a Whatman glass fiber filter disc (5.5cm in diameter), using an air pump. Each filter was then placed on a tin tray (the tin trays and glass fiber filter were previously dried at 1050C and weighed in the oven) placed in the oven and dried at 105^0C for not less than 2 hours. The trays and used filters were weighed again. The difference between the final weight and initial weight gave the amount of suspended solids in the sample. TSS mg/l was

calculated as follows:

mg/l suspended solids = (A-B) X1000/sample volume used.

Where A =Weight of glass fibre filter + dried residue in mg

B = weight of filter paper in mg

Sample volume used = 100ml.

For TDS, the filtrate obtained from TSS determination was taken and transferred to an evaporating dish (the evaporating was previously heated in the oven to 180^0C for 1 hr cooled to room temperature in desiccator and weight noted) this was evaporated to dryness on a steam bath. Evaporated sample was dried in the oven for 1hour, cooled in desiccator to balance

temperature and weighed. The drying process was repeated until a constant weight was achieved. TDS was calculated as follows:

$$\text{mg/l Dissolved Solids} = \frac{(A-B) \times 1000}{\text{sample volume used}}$$

Where, A=weight of dried residue = dish in mg

B=weight of dish in mg

Sample volume = 100ml

Electrical conductivity was determined in situ by electrochemical method using the Hach conductivity meter.

Total Alkalinity of Water Samples

Take 100ml of sample in a conical ask.Add 3-4 drops of phenolphthalein indicator. If no color is produced,the phenolphthalein alkalinity is absent.If the sample turns pink, titrate with N/50 H2SO4 till the pink colour disappears.Record the ml of acid used (P). Add 1 drop of methyl orange to same sample to the titrated mixture and retitrate with N/50 H2SO4 until first change from yellow to orange colour is noted (T).

$$\text{Alkalinity(mg/lit)} = \frac{m \times N \times 50 \times 1000}{\text{vol.of sample}}$$

Determination of Metals in Water Samples

Sample preparation including transportation of samples from the field to the laboratory at controlled temperatures of between 22 to 26 degrees Celsius and digestion of the samples using 67% nitric acid for 10 minutes, 10:50 v/v acid to sample ratio while heating on a sand bath was performed and ready samples stored in flat glass bottom flasks ready for analysis.

Thirty milliliters of IN NH_4OAC (ammonium acetate solution) was added to 2.0 ml of water sample and the flasks were shaken on a mechanical shaker for 2 h. The mixture was centrifuged at 2000 rpm for 10 min and the clear supernatant was decanted into 100 ml volumetric flasks. Thirty milliliters of ammonium acetate solution (NH_4OAC) was added two times into the flasks, and shaken on a mechanical shaker for 30 min each, and centrifuged at 2000 rpm. The clear supernatants were then transferred into the same volumetric flasks respectively. NH_4OAC solution was added to sample extract to make it up to 100 ml volume.

Metal salts standards for respective test metals were prepared by dissolving analytical standard metal salts using distilled water by serial dilution to come up with required metal standards. Experimental standards like frequency, light, cathode lamps, type of flame, detector and read out modes to be used were also set. Then actual cations analysis was carried out in the laboratory using a Shimadzu AA-6200 model Atomic Absorption Spectrophotometer (Nzeve *et al*., 2015). First, the blank solution made of distilled water treated by nitric acid was aspirated in to the AAS system to correct any background interferences followed by running of the standard solution of a specific test metal to be tested in order to obtain the calibration curve for that particular metal ion. Finally, the intended samples were introduced into the AAS system in triplicates obtaining the signal of metal absorbance vs the standard concentration curve. Using the regression equation, sample concentration was obtained from the curves by interpolating the calibration curves (Malofeeva *et al*., 1987).

Sample solutions (extract) and standard solution for each mineral were injected into the atomic absorption spectrophotometer and the mean signal response was recorded for each of the element at their respective wavelength. The concentrations of the minerals were then calculated.

Extraction of Nitrate and Ammonium Nitrogen

Four millilitre of diluents was added to 1ml of the sample and mixed. 1.5 ml of Potassium phosphate tartrate was added and mixed, 2.5 ml of alkaline phenate was also added and mixed thoroughly. To the mixture 1.5 ml of the commercial bleach was added and mixed thoroughly. The mixture was left for at least 30\text{minutes} and absorbance determined on Spectronic 20 at 630 nm}. Blank contained all the reagents. Calibration curve was then used to determine the Nitrogen content (Landon, 1984, 1991).

Determination of NO_3-N in Soil Extract using the Salicylic Acid Colorimetric Method

0.2 ml of extract was pipetted into a 50 ml Erlenmeyer flask and mixed thoroughly with 0.8 ml of salicylic acid-H_2SO_4 reagent. The reaction was allowed to take place for about 20 minutes and slowly 19 ml of 2 M NaOH was added to raise the pH to above 12. The reaction mixture was allowed to cool to room temperature and the absorbance at 410 nm was then determined. NO_3-N standards containing 0.6g of N in a 0.2 ml aliquot was analysed with each set of samples (Landon, 1984, 1991).

Determination of Chloride in Soils

Twenty millilitres of sample water was pipetted and sample pH was adjusted to 8.2 just colourless to phenolphthalein indicator, with 0.1N H_2SO_4. $AgNO_3$ solution was was then employed for the Cl titration. One millilitre of the chromate indicator was added and solution was titrated with the standard $AgNO_3$ solution until the appearance of the first permanent red colouration due to precipitation of Ag_2CrO_4. A blank was the titrated consisting ofthe same volume of chloride free water. For a 50 ml aliquot of water the net ml titre after subtraction of the blank is equal to the mg of Cl titrated with the alternative $AgNO_3$ standard solution ((Landon, 1984, 1991).

Determination of SO_4-S in Soil Extract by the Turbidimetric Method

Ten millilitres aliquot of sample solution from wet digest was pipetted into 25 ml volumetric flask. Distilled water was then added to bring the volume to approximately 20 ml. One millilitre of the gelatine - $BaCl_2$ reagent was then added and made up to volume with distilled water. The content was then mixed thoroughly. The content was then allowed to stand for 30\text{min}. Optical density was then determined at 420\text{nm} on Spectronic 20 Colorimeter (Landon, 1984, 1991).

Determination of PO_4-P İn River Water Using Vanado-Molybdate Colorimetric Method

Five millilitres of sample solution from wet digest was pipette into 50 ml volumetric flask and 25 ml distilled water was added. Within 5 mins, 10 ml of vanado molybdate reagent was added and diluted to volume, mixed and allowed to stand for 15 min. The absorbance was then determined at 470 nm. Standard curve for P was then determined by pipetting 0, 1, 2, 3, 4 and 5 ml of the 100\text{ ppm P} standard solution into series of 50 ml volumetric flasks and the colour developed according to the same procedure stated above. The absorbance was then plotted against concentration (Landon, 1984, 1991).

Soil Electrical Conductivity Determination

Electrical conductivity was determined on 50 ml of water and the shaken at 200 rpm for 2 h, and then filtered through a filter paper (Grade 4 Whatman International Ltd, Maidstone, England). Electrical conductivity was measured on the filtered solution with an ionic probe (Orion 3 star bench-top conductivity meter Thermo Scientific) (Rhodes, 1996).

pH determination

Fifty mililitres of water sample was ddispensed into the beaker beaker, 20 ml of distilled water was then added and allowed to stand for 30 min and occasionally stirred with a glass rod. The electrode of the pH meter was inserted into the partly settled suspension and the pH was measured after the electrode and pH meter was standardized using buffers pH 4.0 and pH 7.0.

Statistical analysis

The data were statistically analysed, with SPSS version 20 software, using a one-way analysis of variance (ANOVA). Means were compared at 5% level of significance using Duncan's multiple range test.

3.0 Results

İn Table 1, *Bacillus subtilis, Bacillus cereus*, *Clostridium perfrigenes*, *E. coli*, *Enterobacter* spp *Salmonella typhi* were the most commonly occuring bacteria. In Table 2 there was no significant difference ($P \geq 0.05$) in the dissolved oxygen (DO), chemical oxygen demand (COD), biochemical oxygen demand (BOD) and total bacterial counts (TBC) of the selected river water samples. The DO, COD and BOD values ranged from 3.17±0.23 – 4.30±0.20 mg/l, 642.17±33.77 – 773.27±33.19 mg/l and 306.30±1.68 – 405.00±1.44 mg/l respectively. The DO (4.30±0.20 mg/l), COD (773.27±33.19 mg/l) and

BOD (405.00±1.44 mg/l) were highest in RYEP and RIMP respectively.

Table 1: Bacteria isolated from river water samples

River Water	Bacteria Isolated
ROOC	*Bacillus* spp, *Vibrio* spp, *Shigella* spp
ROOP	*Bacillus subtilis, Klebsiella* spp, *Salmonella* spp, *Clostridium perfrigenes, Chromobacterium violaceum, Staphylococcus aureus, E. Coli*
RERC	*Bacillus* spp, *Vibrio* spp, Shigella spp, *Bacillus cereus, Enterobacter spp , Clostridium perfrigenes, Chromobacterium violaceum, Staphylococcus aureus, E.coli*
RERP	*Bacillus cereus, Enterobacter* spp, *Clostridium perfrigenes, Chromobacterium violaceum, Staphylococcus aureus, E.coli*
RIDC	*Salmonella typhi, Chromobacterium violaceum, Enterobacter spp , Clostridium perfrigenes, Chromobacterium violaceum, Staphylococcus aureus, E.coli*
RIDP	*Vibrio spp, Enterobacter* spp, *Staphylococcus aureus, Actinomycete spp, Clostridium lockheadii, Proteus* spp, *E.coli*
RIMC	*Enterobacter* spp, *Streptococcus faecium, Klebsiella aerogens , Staphylococcus aureus, Clostridium lockheadii, Proteus spp, E.coli*
RIMP	*Bacillus subtilis, Faecal Streptococci, Klebsiella aerogens, Staphylococcus aureus, Clostridium lockheadii, Proteus* spp, *E.coli*
RYEC	*Vibrio* spp, *Enterobacter* spp, *Pseudomonas aureginosa, Staphylococcus aureus, Clostridium lockheadii, Proteus* spp, *E.coli*
RYEP	*Pseudomonas aureginosa, Bacillus subtilis, Salmonella spp, Shigella* spp, *Klebsiella aerogenes*

TBC was highest in RERC water samples ($4.23\pm0.57\times10^5$ CFU/g) and lowest in RIDC samples (3.07×10^5 ±0.52CFU/g). Meanwhile RIMP recorded the highest TFC (total fungal count) and TCC (total coliform count) values of $2.93\times10^3\pm0.19$ CFU/g and $4.47\times10^2\pm0.18$ MPN/100 ml respectively. The lowest TFC and TCC values of $2.00\times10^3\pm0.27$ CFU/g and 3.13×10^2 ±0.19 MPN/100 ml respectively were obtained in the RERP water samples.

İn Table 3 the highest Pb (15.71±1.53 mg/l), Cd (1.17±0.19 mg/l), Fe (25.30±0.60 mg/l), Zn (31.63±0.87), Cu (35.03±3.72 mg/l), Mn (10.40±0.44 mg/l) and As (1.98±0.08 mg/l) values were obtained in RIMP, ROOC, RIDP and RIMC respectively. In Table 4 there were significant differences ($P\leq0.05$) in the concentrations of Ni, Na, K, Cr, Mg and Ca assayed for in the selected river water samples. Na (180.97±1.45 mg/l), Cr (3.96±0.09 mg/l), Ca (17.53±0.57 mg/l), Ni (10.30±1.35 mg/l), Mg (29.60±2.17 mg/l) and K (326.43±18.94 mg/l) concentrations were highest in RIDP, RIMP and ROOP respectively. İn Table 5 the total solids (1530.20±20.51 mg/l), electrical conductivity (2358.10±33.42 mg/l), total hardness (509.07±11.48 mg/l) and total alkalinity (306.10±15.27 mg/l) recorded the highest values in ROOC and RIDP respectively.

There were significant differences ($P\leq0.05$) in the SO_4, Cl^- and PO_4 concentrations of the river water samples (Table 6). The NO_3 (236.00±7.59), SO_4 (139.23±1.73 mg/l), Cl^- (81.90±0.89 mg/l) and PO_4 (80.33±1.64 mg/l) concentrations were highest in RIMC and RIDP respectively.

Table 2: Dissolved oxygen, chemical oxygen demand, biochemical oxygen demand, total bacterial count, total plate count and total coliform count of the selected river water samples

	DO(mg/l)	COD(mg/l)	BOD(mg/l)	TBC(CFU/ml)	TFC(CFU/ml)	TCC (MPN/100ml)
ROOC	3.83±0.19^{a}	673.10±35.41^{a}	306.30±1.68^{a}	3.27±0.35^{a}	2.57±0.18^{ab}	3.57±0.18^{ab}
ROOP	3.40±0.52^{a}	642.83±35.76^{a}	342.00±34.85^{a}	3.27±0.19^{a}	2.60±0.06^{ab}	3.87±0.22^{ab}
RERC	3.70±0.43^{a}	707.47±60.60^{a}	372.27±33.94^{a}	4.23±0.57^{a}	2.73±0.23^{ab}	3.97±0.38^{ab}
RERP	3.50±0.15^{a}	704.20±56.33^{a}	334.30±32.27^{a}	2.83±0.41^{a}	2.00±0.27^{a}	3.13±0.19^{a}
RIDC	3.17±0.23^{a}	673.67±33.50^{a}	338.80±34.37^{a}	3.07±0.52^{a}	2.47±0.23^{ab}	3.73±0.49^{ab}
RIDP	3.30±0.20^{a}	706.00±3.01^{a}	374.23±32.74^{a}	3.97±0.29^{a}	2.53±0.18^{ab}	4.07±0.18^{ab}
RIMC	3.37±0.43^{a}	706.63±56.90^{a}	340.57±33.02^{a}	3.43±0.32^{a}	2.40±0.25^{ab}	3.97±0.27^{ab}
RIMP	3.57±0.60^{a}	773.27±33.19^{a}	405.00±1.44^{a}	4.07±0.22^{a}	2.93±0.19^{b}	4.47±0.18^{b}
RYEC	3.27±0.09^{a}	704.23±57.43^{a}	340.73±66.62^{a}	3.87±0.68^{a}	2.53±0.44^{ab}	4.13±0.72^{ab}
RYEP	4.30±0.20^{a}	642.17±33.77^{a}	336.60±35.38^{a}	3.20±1.16^{a}	2.50±0.46^{ab}	3.60±0.56^{ab}

Columns with values that have the same letter show that there is no significant differences (P≥0.05) between the values, columns with values that have different letters show that there is significant difference (P≤0.05) between the values.

Table 3: Lead, cadmium, iron, zinc, copper, manganese and arsenic analyzed in selected river water samples

	Pb(mg/l)	Cd(mg/l)	Fe(mg/l)	Zn(mg/l)	Cu(mg/l)	Mn(mg/l)	As(mg/l)
ROOC	15.29±0.52^{a}	1.12±0.10^{a}	25.30±0.61^{a}	31.63±0.87^{a}	23.53±0.98^{a}	8.54±0.14^{a}	1.70±0.04^{ab}
ROOP	14.85±1.42^{a}	1.02±0.17^{a}	20.50±1.48^{a}	28.03±1.14^{a}	33.93±6.21^{a}	9.15±0.94^{a}	1.82±0.13^{abc}
RERC	13.65±0.11^{a}	0.87±0.02^{a}	22.27±2.26^{a}	27.07±1.48^{a}	29.07±5.29^{a}	9.76±1.22^{a}	1.85±0.13^{abc}
RERP	14.25±0.41^{a}	1.05±0.11^{a}	24.00±2.32^{a}	30.27±1.97^{a}	29.10±4.98^{a}	9.58±0.58^{a}	1.87±0.14^{abc}
RIDC	14.62±1.14^{a}	1.14±0.18^{a}	21.17±1.90^{a}	27.93±1.53^{a}	33.57±5.44^{a}	9.13±0.59^{a}	1.86±0.10^{abc}
RIDP	14.38±0.45^{a}	1.05±0.10^{a}	21.20±3.21^{a}	28.03±1.83^{a}	35.03±3.72^{a}	10.40±0.44^{a}	2.09±0.03^{c}
RIMC	14.80±0.96^{a}	1.17±0.20^{a}	21.60±2.63^{a}	28.07±2.52^{a}	34.43±4.97^{a}	10.18±0.89^{a}	1.98±0.08^{bc}
RIMP	15.71±1.53^{a}	1.17±0.19^{a}	24.80±2.38^{a}	31.47±1.07^{a}	31.77±5.86^{a}	9.56±0.89^{a}	1.93±0.13^{abc}
RYEC	14.85±0.17^{a}	1.14±0.06^{a}	21.77±2.79^{a}	29.27±2.29^{a}	28.33±4.93^{a}	8.74±0.23^{a}	1.80±0.15^{abc}
RYEP	13.79±0.27^{a}	0.87±0.03^{a}	24.50±0.74^{a}	29.80±0.74^{a}	21.83±0.32^{a}	8.31±0.49^{a}	1.61±0.06^{a}

Columns with values that have the same letter show that there is no significant differences (P≥0.05) between the values, columns with values that have different letters show that there is significant difference (P≤0.05) between the values.

Table 4: Nickel, sodium, potassium, chromium, magnesium and calcium determined in selected river water samples

	Ni(mg/l)	Na(mg/l)	K(mg/l)	Cr(mg/l)	Mg(mg/l)	Ca(mg/l)
ROOC	7.70±0.44^{a}	125.43±0.86^{a}	292.47±0.56^{ab}	3.13±0.12^{ab}	25.61±0.55^{a}	12.88±0.33^{a}
ROOP	8.17±0.94^{ab}	160.23±18.37^{ab}	326.43±18.94^{ab}	3.68±0.42^{ab}	28.48±2.02^{ab}	15.48±1.94^{a}
RERC	9.13±1.01^{ab}	159.37±18.40^{ab}	318.80±15.27^{ab}	3.56±0.39^{ab}	28.21±1.76^{ab}	15.43±1.77^{a}
RERP	9.00±0.10^{ab}	146.27±14.56^{ab}	308.60±13.30^{ab}	3.40±0.19^{ab}	27.67±0.75^{ab}	15.40±1.47^{a}
RIDC	8.63±0.85^{ab}	160.33±17.37^{ab}	321.27±15.38^{ab}	3.60±0.29^{ab}	27.78±1.75^{ab}	16.39±1.62^{a}
RIDP	10.60±0.70^{b}	180.97±1.45^{b}	341.43±5.72^{b}	3.96±0.09^{b}	31.41±1.02^{b}	17.53±.57^{a}
RIMC	9.43±0.64^{ab}	161.60±18.94^{ab}	322.73±15.84^{ab}	3.75±0.22^{ab}	28.40±1.33^{ab}	17.14±1.53^{a}
RIMP	10.30±1.35^{ab}	164.23±20.46^{ab}	325.87±20.43^{ab}	3.69±0.44^{ab}	29.60±2.17^{ab}	16.15±2.18^{a}
RYEC	9.43±0.84^{ab}	145.90±19.36^{ab}	312.50±20.23^{ab}	3.53±0.35^{ab}	28.75±2.66^{ab}	14.27±1.39^{a}
RYEP	7.77±0.85^{ab}	126.83±3.41^{a}	289.97±1.80^{a}	2.89±0.03^{a}	24.97±0.32^{a}	12.66±.52^{a}

Columns with values that have the same letter show that there is no significant differences (P≥0.05) between the values, columns with values that have different letters show that there is significant difference (P≤0.05) between the values.

Table 5: pH, color, total solids, total dissolved solids, electrical conductivity, total hardness and total alkalinity of selected river water samples

	Ph	COLOUR(HZ)	TS (mg/l)	TDS(mg/l)	COND((µS/cm))	TH(mg/l)	TALK(mg/l)
ROOC	6.80±0.07^{a}	9.00±0.32^{a}	1530.20±20.51^{a}	435.70±4.22^{a}	2358.10±33.42^{c}	509.07±11.48^{c}	306.10±15.27^{b}
ROOP	6.73±0.03^{a}	9.37±0.99^{a}	1423.40±42.65^{a}	578.87±78.69^{a}	2226.37±59.91^{ab}	430.53±9.63^{ab}	270.63±5.74^{ab}
RERC	6.74±0.03^{a}	9.03±0.46^{a}	1411.23±40.41^{a}	570.87±70.91^{a}	2275.00±5.40^{abc}	473.37±15.06^{bc}	266.57±8.36^{ab}
RERP	6.88±0.15^{a}	8.67±0.59^{a}	1452.47±54.11^{a}	520.43±67.23^{a}	2321.03±31.49^{bc}	501.17±16.84^{c}	270.83±20.59^{ab}
RIDC	6.68±0.11^{a}	9.10±0.47^{a}	1465.33±65.62^{a}	575.20±76.01^{a}	2263.13±66.70^{abc}	468.47±19.50^{bc}	273.33±19.09^{ab}
RIDP	6.70±0.09^{a}	9.90±0.30^{a}	1399.43±30.60^{a}	635.67±20.54^{a}	2324.93±28.53^{bc}	486.87±14.55^{c}	255.73±6.80^{ab}
RIMC	6.79±0.14^{a}	9.40±0.46^{a}	1473.53±63.24^{a}	581.37±77.51^{a}	2307.77±35.43^{abc}	496.50±7.62^{c}	277.20±27.21^{ab}
RIMP	6.68±0.04^{a}	10.23±0.64^{a}	1449.90±23.29^{a}	557.00±66.61^{a}	2307.17±21.71^{abc}	476.77±18.58^{bc}	273.87±3.34^{ab}
RYEC	6.86±0.05^{a}	9.20±0.72^{a}	1494.50±23.36^{a}	516.60±69.50^{a}	2316.53±37.63^{abc}	500.77±18.94^{c}	282.47±14.22^{ab}
RYEP	6.71±0.08^{a}	8.43±0.13^{a}	1432.27±21.10^{a}	441.33±14.43^{a}	2191.43±6.17^{a}	422.77±7.76^{a}	250.03±16.84^{a}

Columns with values that have the same letter show that there is no significant differences (P≥0.05) between the values, columns with values that have different letters show that there is significant difference (P≤0.05) between the values.

Table 6: Anions analyzed in selected river water samples

	NO_3	SO_4	Cl^-	PO_4
ROOC	229.99±6.98^{a}	125.70±0.32^{a}	66.47±1.47^{a}	61.03±2.68^{a}
ROOP	225.66±1.89^{a}	132.70±4.65^{ab}	76.47±4.42^{ab}	74.17±7.28^{ab}
RERC	225.58±2.13^{a}	131.20±4.35^{ab}	77.07±4.44^{ab}	70.70±4.61^{ab}
RERP	235.34±11.08^{a}	130.63±1.14^{ab}	75.07±2.24^{ab}	71.13±5.75^{ab}
RIDC	226.66±0.98^{a}	132.67±2.98^{ab}	75.70±4.57^{ab}	73.63±6.22^{ab}
RIDP	230.63±1.92^{a}	139.23±1.73^{b}	81.90±0.89^{b}	80.33±1.64^{b}
RIMC	236.00±7.59^{a}	132.97±2.49^{ab}	77.60±4.48^{ab}	74.27±4.83^{ab}
RIMP	229.55±2.03^{a}	133.80±4.64^{ab}	78.40±4.70^{ab}	75.77±7.04^{ab}
RYEC	235.97±9.52^{a}	129.80±4.43^{ab}	73.27±6.08^{ab}	67.93±6.64^{ab}
RYEP	221.61±1.41^{a}	130.07±3.85^{ab}	69.03±1.42^{ab}	60.93±0.88^{a}

Table 7: WHO limits of selected Physicochemical parameters

Temp	25
pH	6.5-8.2
TDC (mg/L)	≤600
BOD (mg/L)	14
Hardness (mg/L)	100
Pb (mg/L)	0/01
Zn (mg/L)	3
Cu (mg/L)	2
Nitrate (mg/L)	50
Cr (mg/L)	0.07
Fe (mg/L)	0.3
Mn (mg/L)	0.5
Ca (mg/L)	50
Mg (mg/L)	30
Cd (mg/L)	
Al (mg/L)	0.2

The samples analyzed in this study shows the presence of *E. coli* which is an indicator of faecal pollution. This could be attributed to the discharge of domestic and agricultural wastes as well as human excreta/wastes into the rivers analysed in this study. This shows that the water samples are severely contaminated. This was also reported in the work of Sivalingam *et al.* (2024). They isolated five bacterial pathogens i.e., *E. coli*, *Salmonella* species, Shigella species, *S. aureus*, and *P. aeruginosa* from river water samples collected from different sites of the Kalte River of Wolaita Sodo by using selective media. Sivalingam *et al*. (2024) also indicated that all samples they collected from the rivers were severely contaminated. with total heterotrophic, total coliform, and fecal coliform bacteria and exceeded the standard guidelines for drinking water quality set by the WHO. Sivalingam *et al*. (2024) also reported that the dominant organism

among the isolates was *E. coli,* which was found to be positive in 25 water samples with a 60% prevalence, followed by *P. aeruginosa*, which was present in 21 water samples with a 40% prevalence.

Abdulkareem *et al.* (2023) reported that the mean total bacterial count and mean total coliform counts of Omi-Oniyo stream are $3.7x10^4$ CFU/ml and 1.83x104 CFU/ml respectively while the mean total bacterial count and mean total coliform count of Omi-Igbo stream are $4.03x10^4$ CFU/ml, and $1.43x10^4$ CFU/ml respectively. The total bacterial count and total coliform count of Omi-Oniyo ranged from $2.7x10^4$ to $5.2x10^4$ CFU/ml and $1.4x10^4$ to $1.6x10^4$ CFU/ml respectively while that of Omi-Igbo ranged from $2.7x10^4$ to $5.5x10^4$ CFU/ml and $1.2x10^4$ to $1.6x10^4$ CFU/ml respectively.

Adomi *et al*. (2025) observed that sample A of their analysed samples had the highest bacterial plate count of 5×10^4 cfu/ml, followed by sample F (3.4 cfu/ml) while samples D and E had the least bacterial plate count of 1.0×10^3 cfu/ml each. They also isolated *Bacillus subtilis, Klebsiella pneumoniae, Escherichia coli*, *Proteus* spp, *Pseudomonas aeruginosa Staphylococcus aureus*, *Streptococcus* spp and

Enterobacter spp. This report (Adomi *et al*., 2025) corellated with the bacteria isolated in this study.

The DO range in this study were found to be lower than the stipulated 5 mg/l (the standard for sustaining life in water bodies) showed that the dissolved oxygen in the rivers analyzed is inadequate to support aquatic life. BOD which increases as a result of accumulating fecal contaminant and organic matter, results in increased microbial activity. This consequently increases demand on the DO of the rivers, by the increased level of microbial activity, which will result in further reduction of the DO levels in future. In general, DO levels less than 3 mg/l are stressful to most aquatic organisms. Most fish die at 1 - 2 mg/l. DO concentration is vital for the survival of fishes. Kannel *et al.* (2007) reported that DO measures the ecological health of a stream and its increasing availability protects fishes from dying.

The BOD levels reported in this study is dangerously higher than stipulated in the EU guidelines of 3.0 to 6.0 mg/l. Increased BOD levels results in decreased DO because the bacteria make use of the available oxygen in the water. The high BOD levels reported in this study is as a result of the several activities such as, defecating, washing, swimming etc. These indices shows increased microbial population and microbial activities.

The total alkalinity in this study were within the WHO permissible limits of 200-600 mg/l. The re port of Okokon *et al.* (2021) conerning total alkalinity correlated with what was obtained in this study. According to Okokon *et al.* (2021), the titratable alkalinity ranged between 20.00 - 23.44 mg/l and 16.20-17.65 mg/l while titratable acidity ranged between14.86-14.25 mg/l and 18.27-18.33 mg/l for both Enang stream and Mbiaso river respectively. The values were within the WHO permissible limits of 200-600 mg/l and were in consonance with similar report in a study done in India. The results oif the total hardness observed in this study were found to be higher than what was obtained in the work of Okokon *et al.* (2021). Okokon *et al.* (2021) reported that the total hardness (TH) in their study varied between 11.00-11.73 mg/l and 14.56-18.22 mg/l in Enang stream and Mbiaso river respectively and indicated that the water was soft. The standard in TH is 0.5 -50.0mg/L is considered soft while 100-150mg/L is moderately soft water. The results were within WHO permissible limits and agree with other with the results. For aesthetic reasons, a limit of 500mg/L is typically recommended for potable water supplies.

The TSS and TDS obtained in this study were wthin what WHO recommended except for the TDS value of 635.67±20.54 mg/l obtained in RIDP. Okokon *et al.* (2021) also reported that the Total suspended solid (TSS) as well as Total dissolved solids (TDS) in their study were within permissible limits set by WHO for drinking water. The values were; 34.31 mg/l, 29.26 mg/l, 11.84 mg/l and 12.32 mg/l for TSS and 56.00 mg/l, 41.45 mg/l, 18.93 and 20.66 mg/l for TDS respectively. The BOD recorded were higher than the WHO permissible standard limits of less than 4.0 mg/l which imply that the water samples were not clean. On the other hand, the COD

values ranged between 3.31 mg/l to 6.60 mg/l for all water samples and were within WHO standard for good water quality which is set at less than 10 mg/l. The values recorded for the BOD and COD makes the water suitable for domestic purposes other than potable use. The Chloride, Nitrate and Sulphate concentrations were all within WHO permissible standards. The results recorded is similar to those obtained by Shally *et al*. (2016) and Okereke *et al*. (2014) and poses no risk to consumers either for drinking or domestic usage.

The Electrical Conductivity (EC) reported in this study is higher than what was reported by Zazouli *et al.* (2013); they stated that the average EC ranged from 464 ± 148 µs/cm to 1193 ± 536 µs/cm. High electrical conductivity indicates the accumulation of salts in the water samples as a result of pollution by human and industrial activities.

Concentration of Zn in river waters recorded in this study seriously exceed the recommended limit of 3 mg l^{-1} for Zn levels in drinking water reported by WHO (2008). Drinking water containing high levels of zinc can cause stomach cramps, nausea and vomiting. Cr content of river water samples obtained in this study exceeded the recommended limit of 0.05 mg L^{-1} (WHO, 2008) for Cr in drinking water. In all the rivers analyzed in this study, the average Mn concentration levels were found to be higher than the recommended limit of 0.40 mg l^{-1} for Mn in drinking water reported by WHO (2008). This study recorded higher As values compared to the WHO permissible level of 0.01 mg/l, therefore adverse effects on drinking are expected. Hence the waters of the rivers in this study are not suitable for drinking. The Fe and nitrate concentrations reported in this study were higher than the WHO standard value of 0.3 ppm.

The PO_4 levels obtained in this study were higher than what was obtained in the findings of Olajire and Imeokparia (2001) who reported that PO_4 levels fluctuate between 0.46 and 0.59 mg/l in Osun River, Nigeria. The levels of sulphate in the water samples in all the sampling locations were below the 200 mg/L WHO maximum permissible levels.

The Total Coliform values in this study were found to be higher than the prescribed values. Enterotoxigenic *E. coli* (ETEC) is a common cause of "traveler's diarrhea" in developing countries infecting only humans and transmission occurs through water and food contaminated with human waste. The TCC observed for the water samples in this study revealed that the samples crossed the permissible limit of WHO (WHO, 2003). Several pathogenic bacteria isolated from the river waters analyzed in this study indicates high level of pollution of the river water samples hence their unsuitability for drinking.

Conclusion

The rivers analyzed in this study recorded high BOD and COD which is detrimental to all aquatic organisms in the river. The high concentration of heavy metals are poisonous to man and animals when ingested. The nitrate and phosphate content of the river waters encourage algal bloom in streams reduces dissolved oxygen in rivers. the rivers in this study show high level of faecal contamination

Conflict of interest

The author in this state that there is no conflict of interests.

References

Abdulkareem, M.A., Omotunde, O.T., Momoh-Salami, T.M., Bamikole, O.J., & Olajide, T.H. (2023) Bacteriological and Physicochemical Analysis of Surface Water; Implications on Public Health. *Biomed J Sci & Tech Res*, 51(4)-2023. BJSTR. MS.ID.008130.

Adomi, P.O., Anozie, A.J., Morka, E., & Odum, E.I. (2025). Microbial and Physicochemical Quality of River Water in Delta State, Nigeria. *World Journal of Environmental Biosciences*, 14, (1): 21-28

American Public Health Association. Standard methods for the Examination of Water and Wastewater (1998) (20th ed). New York: American Public Health, Association (APHA), American Water Works

Association (AWWA), and Water Pollution Control Federation (WPCF), (1998).

Anyanwu, B.O., Ezejiofor, A.N,, Igweze, Z.N., & Orisakwe, O.E. (2018) Heavy Metal Mixture Exposure and Effects in Developing Nations: An Update. *Toxics*, 6(4):65.

Balogun, S.A., Akingbade, O.A., Oyekunle, M.A., & Okerentugba, P.O. (2014). Physicochemical and Microbiological Profile of Drinking Water Sold in Abeokuta, Ogun State, Nigeria. *Nat Sci*., 12(3):103-105.

Cabral, J.P. (2010). Water microbiology. Bacterial pathogens and water. *Int J Environ Res Pub Health*, 7(10):3657-3703.

Fawell J and Nieuwenhuijsen MJ. Contaminants in drinking water: Environmental pollution and health.

Hassan Omer, N. (2020). Water Quality Parameters. In: Summers, K., Ed., *Water Quality — Science*, *Assessments and Policy*, IntechOpen, 8. https://doi.org/10.5772/intechopen.89657

Kannel, P.R., Lee, S., Lee, Y.S., Kanel, S.R. & Pelletier, G.J. (2020) Application of automated QUAL2Kw for water quality modeling and management in the Bagmati River, Nepal. *Ecol. Model.*, 202(3-4) (2007) 503-17.

Landon, J.R. (ed.) (1984, 1991). Booker Tropical Soil Manual. Booker Tate, Thame, U.K. (In U.S.A: Longman, New York).

Liu, Y., Li, H., Cui, G., & Cao Y. (2020). Water quality attribution and simulation of non-point source pollution load flux in the Hulan River basin. *Sci Rep.,*10, 3012.

Malik, A., Yasar, A., Tabinda, A., & Abubakar, M. (2012). Water-borne diseases, cost of illness and willingness to pay for diseases interventions in rural communities of developing countries. *Iran J Pub Health*, 41(6):39-49.

Metcalf, C., & Eddy, R. (2003). *Waste Water Engineering Treatment and Re-Use*. Tata McGraw-Hill Publishing Company Limited, New Delhi. (2003) 91-211.

Mustapha, S. & Adam, E. A. (1991). Discussion on Water Problems in Nigeria: Focus on Bauchi State. National Water Research Institute.

Nguyen, T.T., Grote, U., Neubacher, F., Rahut, D.B. Do, M. & Paudel, G. P. (2023). Security risks from climate change and environmental degradation: implications for sustainable land use transformation in the Global South. *Current Opinion in Environmental Sustainability*, 63,101322, doi: 10.1016/j.cosust.2023.101322

Okereke, V.E., Ogwo, P.A., Okoronkwo, C.U., & Udensi EA.(2014). Evaluation of the physicochemical and heavy metal properties of igwi-stream in Abia State University, Uturu, Abia State, Nigeria. IOSR *Journal of Environmental Science, Toxicology and Food Technology*, 8(7):54-57.

Okokon, J.E., Davies, K., John, L., Iwara, K., Li, W., & Thomas, P.S. (2021). Phytochemical characterization, antihyperglycaemic and antihyperlipidemic activities of *Setaria megaphylla* in alloxan-induced diabetic rats. *Phytomedicine Plus*, 2(1), 100182

Omole, D.O., & Okunowo. O.S. (2016). People Perception of Domestic Water Supply Situation in Ogun State, Nigeria. *Res J Appl Sci Eng Technol*., 12(1):94-99.

Palansooriyaa, K.N., Shaheenb, S.M., Chene, S.S., Tsange, D.C.W., Hashimoto, Y., Hou, D., Bolan, N.S., Rinklebe, J., & OK, Y.S. (2020). Soil amendments for immobilization of potentially toxic elements in contaminated soils: A critical review. *Environment International*, 134, 105046

Rao, P.V. (2004)Text Book of Environmental Engineering, Princetice-Hall of India, (2004) 206-218.

Rhodes, J.D. (1996). Salinity, electrical conductivity, and total dissolved solids. In: D.L. Sparks (ED). Methods of soil analysis. Part 3. Chemical methods. Madison, WI, USA: *Soil Science Society of America*, 417-435.

Shah, S.A.R., Zhang, Q., Abbas, J., Tang, H., Al-Sulaiti, K.I. (2023). Waste management, quality of life and natural resources utilization matter for renewable electricity generation: The main and moderate role of environmental policy. *Utilities Policy*, 82, 101584

Shally, S.C., Ajay, K,, Hiramoni, D., Mukutamoni, D., Chinmoy, B., Aniruddha S, Parag D. (2016). Preliminary physicochemical and microbiological analysis of Bahini River Water of Guwahati, Assam, India. Int. *J.Curr. Microbiol. App. Sc*i., 5(2), 684-692.

Sivalingam, K.M., Choramo, I.S., & Chutulo, E.C. (2024). Bacteriological quality and physicochemical analysis of the Kalte River at Wolaita Sodo Town, southern Ethiopia. *BMC Research Notes*, 17, 192 https://doi.org/10.1186/s13104-024-06854-0

Soller, J.A., Bartrand, T., Ashbolt, N.J, Ravenscroft, J., Wade, T.J. (2010). Estimating the primary etiologic agents in recreational freshwaters impacted by human sources of faecal contamination. *Water Res*., 44 (16), 4736–4747.

Tulchinsky, T.H. (2018) John Snow, Cholera, the Broad Street Pump; Waterborne Diseases Then and Now. In: Tulchinsky, T.H., Ed., *Case Studies in Public Health*, Elsevier, 77-99. https://doi.org/10.1016/b978-0-12-804571-8.00017-2

Ukpaka, C. P. & Chuku, J.(2025). Assessing Water Quality and Portability of Rivers in Rivers State, Nigeria: A Physicochemical Analysis *African Journal of Environmental and Waste Management*, 12 (2), 001-018.

World Health Organisation (2008). Guidelines for drinking water quality, World Health Organization, Geneva, (2008).

World Health Organization. Fact Sheet: Drinking-Water. [2018]. Available at http://www.who.int/countryfocus/cooperation_strategy/ccs_npl_en.pdf. (Accessed February 15, 2022).

World Health Organization. Health Risk Assessment Toolkit. Chemical hazards. International Program on Chemical Safety Harmonization Project Document. No. 8, WHO, 2010. Trop J Nat Prod Res, May 2022; 6(5):811-817 ISSN 2616-0684 (Print) ISSN 2616-0692 (Electronic) 816

World Health Organization. Water Sanitation and Health (2015). Available online at http://www.who.int/water_sanitation_health/diseases.

World Health Organization. Water-related diseasesDiarrhoea. (2020). Available at https://www.who.int/water_sanitation_health/diseasesrisks/diseases/diarrhoea/en/(Accessed February 15, 2022).

Zazouli, M.A., Bandpei, A.M., Mirbagheri, S.A. & Esfandyari, Y. (2013). Survey on monthly variations of water quality in the Tajan River (Sari, Iran). *African Journal of Biotechnology*, 12(25), 3984-3991.