Application of Statistical principles to Evaluate the Pollution Status of the Otamiri River, around FUTO axis, Owerri, Imo State

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Abstract
*This study evaluated the water quality of Otammiri River, near the Federal University of Technology, Owerri (FUTO) community. Water samples obtained from three locations were analyzed for physico-chemical parameters such as pH, temperature, total dissolved solids (TDS), dissolved oxygen (DO), biological oxygen demand (BOD), conductivity, hardness, nitrates, phosphates, sodium and potassium, microbial contaminants such as fecal coliform and Total Klebsiella, Water Quality Index (WQI), and Pollution Indices{Geo-Accumulation Index (Igeo), Contamination Index (CI), and Pollution Load Index (PLI). The pH result shows that the Otamiri River water is acidic (pH 5.6) and not drinkable. All the other parameters like TDS, DO, and conductivity were within permissible limits. Metallic elements like copper (0.034 mg/L), sodium (0.22 mg/L), calcium (4.21 mg/L), magnesium (2.6 mg/L), and potassium (4.55 mg/L) were well below FMEnv tolerable levels. Microbial contaminants like Klebsiella and faecal coliform were 0.7CFU/100 ml and 0.00000237CFU/ml respectively at the three locations while Klebsiella was present in point 1 (0.7 CFU/100 ml) and absent in points 2 and 3**)**, indicating fecal contamination and potential health hazards.*
Findings revealed WQI values of 185.01, 81.94, and 167.28 at Points 1, 2, and 3 respectively, classifying the water as poor to unsuitable for drinking. Phosphate was the greatest pollutant found, with Contamination Index value of 6.49 and Igeo value of 2.78, affirming moderate to strong pollution. On the other hand, metallic elements such as copper and sodium had Igeo values of below zero, showing no contamination by these metallic elements. Overall PLI of 0.306 confirmed that the river is unpolluted in terms of metallic elements and selected contaminants. Correlation of TDS and conductivity (r = 1.00), BOD and DO (r = 0.99), and calcium hardness with total hardness (r = 1.00) showed a good correlation with, indicating direct relationships between these parameters. Nitrate and phosphate (r = 0.98) also correlated strongly, indicating a shared source of agricultural effluent or sewage. There were extremely negative correlations for pH and nitrate (r = –0.99) and temperature and DO (r = –0.99) and signified acidification and reduced oxygen solubility with increased temperatures. There were positive correlations between conductivity and BOD (r = 0.73), phosphate and potassium (r = 0.86), copper and magnesium (r = 0.98), and magnesium and BOD (r = 0.50), and reflected interrelated effects of organic matter, nutrient content, and ionic content on water quality. The study concludes that the river is severely contaminated with microbes and nutrients, and is in dire need of remediation for the protection of both environmental and public health.

Keywords: *Otammiri River, Water Quality Index, Geo-Accumulation Index, Contamination Index, Pollution Load Index.*

1. INTRODUCTION

Rivers are a vital resource, sustaining the life of human beings, ecosystemic equilibrium, and socio-economic development. Its purity is, however, being threatened by urbanization, agriculture, and industrialization (Mishra et al., 2015). Rivers such as the Otammiri River in Imo State, Nigeria, are a potential source of freshwater for domestic use, irrigation, and fishery but are greatly polluted by sewage effluent, agrochemicals, and industrial effluents.

Otammiri River has endured poor quality water due to uncontrolled urbanization. The parameters of pollution such as increased nitrate, phosphate, and metallic elements pose dangers to aquatic life and human health (Akan et al., 2010; Ogamba & Abowei, 2013). Agricultural effluents (fertilizers, pesticides), raw domestic sewerage, sand dredging, and wastes from small-scale industries have compromised its safety (Ogamba & Abowei, 2013). The excessive nutrient loading (nitrates, phosphates) promotes eutrophication, consuming dissolved oxygen and threatening aquatic life forms (USEPA, 2019). Metallic elements and disease-causing pollutants also endanger public health, as far as waterborne diseases like cholera and dysentery are concerned (WHO, 2017).

Physicochemical parameters have significant roles to play in ascertaining the quality of water as they reflect natural and human-altered conditions. These include the pH, which is used to show the acidity or basicity of water; temperature, which affects chemical reactions and oxygen levels; and electrical conductivity, which reflects dissolved salts. The sum of dissolved solids measures the total organic and inorganic matter, while turbidity reflects suspended matter. Dissolved oxygen is required by aquatic life, whereas biological and chemical oxygen demands (BOD and COD) measure the extent of organic pollution. Alkalinity is the ability of the water to buffer, and hardness is due to calcium and magnesium. Chloride presence implies sewage or industrial pollution, whereas high nitrate and phosphate presence can lead to eutrophication. Sulfates, though naturally occurring, can also be due to industrial wastes. These parameters together determine the acceptability and safety of water for different uses (Jaffar et al., 2020; Kumar & Singh, 2021; Mishra & Patel, 2023).

Microbiological indicators also are important in ascertaining the safety of water for domestic and recreational use. They help in the detection of disease-causing organisms that pose health risks (Kumar & Singh, 2021). Total coliforms, fecal coliforms, Escherichia coli (E. coli), and fecal streptococci are some of the key microbial indicators commonly utilized to detect fecal contamination because they originate from the intestines of warm-blooded animals (Jaffar et al., 2020). The presence of E. coli is a good measure of recent fecal contamination and high risk of waterborne disease (Mishra & Patel, 2023). Salmonella and Shigella disease-causing microorganisms may also be present together with the indicators. Microbial monitoring parameters help to determine water treatment effectiveness and health risk of water utilization (Kumar & Singh, 2021).

Metallic elements are critical water contamination indicators due to their toxicity, persistence, and bioaccumulation. Even at low concentrations, metallic elements pose major health and environmental risks (Jaffar et al., 2020). Metallic elements are often studied in water quality investigations to give estimations of contaminant levels. Their concentrations are used to measure pollution parameters such as Geo-accumulation Index (I-geo), Pollution Index (PI), and Contamination Index (CI) that help in measuring the degree of pollution. The indices use observed content of metallic elements against background concentration to classify contamination as unpolluted, moderately contaminated, or very highly contaminated (Mishra & Patel, 2023; Kumar & Singh, 2021).

Multivariate statistical techniques like Principal Component Analysis (PCA) and Correlation Analysis are useful in the interpretation of complex water quality data. PCA dimensionally compresses information by identifying significant components that explain most of the variance, making it easier to find significant pollution sources and related parameters (Kumar & Singh, 2021). Correlation analysis, on the other hand, uncovers connections between variables, such as connectivity between conductivity and total dissolved solids, as well as turbidity and metallic (Mishra & Patel, 2023). The instruments enhance environmental assessment accuracy by streamlining big data and identifying patterns guiding effective water quality management (Jaffar et al., 2020).

Without widespread monitoring, policymakers lack a means of enforcing remediation, exacerbating ecological and health risks. This study bridges this gap by examining the water quality of the River through physico-chemical, metallic elements and microbiological parameters analysis, which helped to establish its suitability for domestic, agricultural, and industrial use as well as identifying the likely and common causes of contamination.

STUDY AREA

Otammiri River located in the southeastern Nigerian falls on latitude 5023’N and 5030’N and longitude 6058’E and 7004’E. The river runs south from Egbu through Nekede, Ihiagwa, Eziobodo, Obowuumuisu, Mgbirichi and Umuagwo, all in Owerri Imo State to Ozuzu in Etche Local Government Area of River State from where it flows into the Atlantic ocean. The length of the river from it’s source to it’s confluence at Emeabian with Uramiriukwu River is 30km (Ubaka et al 2019). The watershed covers about 10,000km2 with annual rainfall of 2250-2500mm. The watershed is mostly covered by depleted rain forest vegetation, with mean temperature of 27^{0}C throughout the year (Ihenyen and Aghimien 2002).

The Otammari River lies at the sedimentary basin highly dominated by remarkable geological formations controlling hydrology, sediment transport, and water quality. The area is comprised of the Benin Formation, which is very permeable and made up of sandy materials interlaced with clay lenses. These formations contribute to highly effective groundwater recharge, while also serving as a filter for some pollutants (Amangabara, 2015).

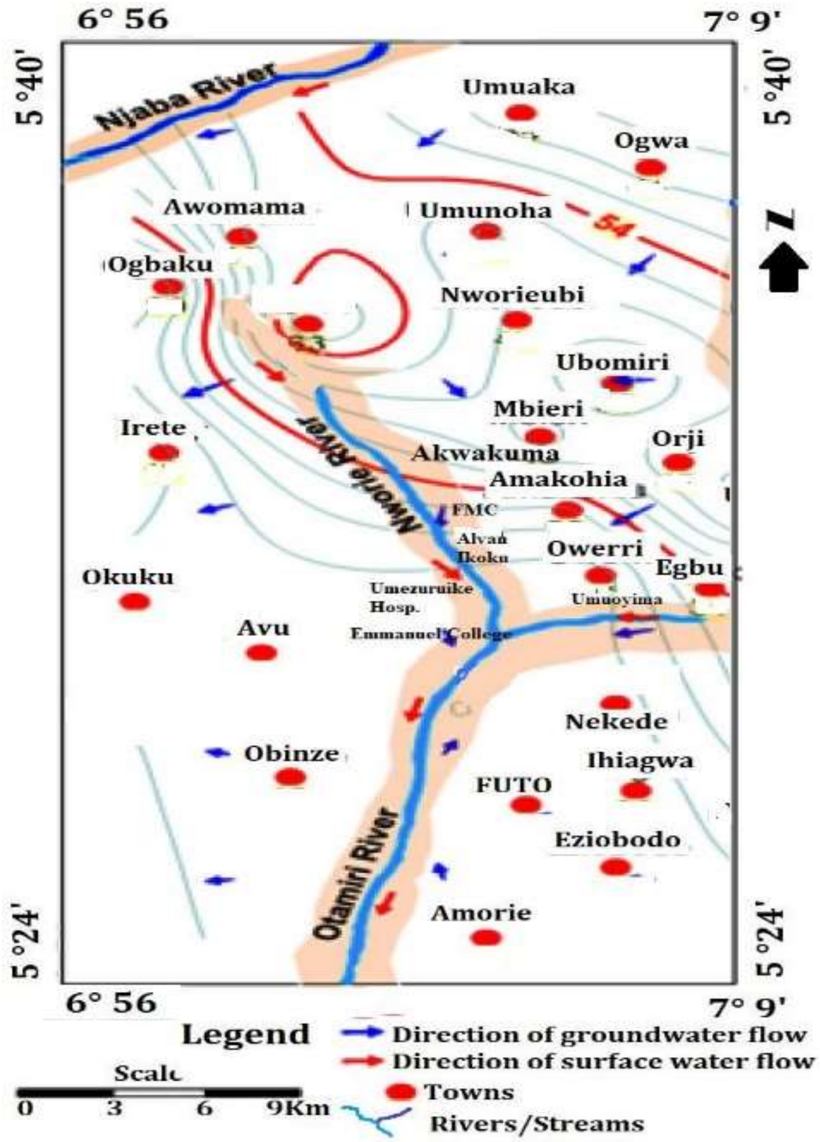


Fig 1: Location map of Otamiri River.

3. MATERIALS AND METHODS

3.1 Sample Collection

Samples were collected along the Otamiri River, which is situated near the Federal University of Technology, Owerri (FUTO), Imo State, Nigeria. Three sampling stations; Point 1 (Downstream), Point 2 (Midstream), and Point 3 (Upstream) were strategically selected in terms of varying degrees of anthropogenic influence, i.e., urban runoff, domestic discharge, and agriculture.

At each sampling location, surface water was sampled twice using pre-cleansed, sterile high-density polyethylene (HDPE) bottles. The bottles were cleaned thrice with river water at each site prior to collection to prevent contamination. Sample storage was maintained in ice boxes and transported to the lab within six hours of sampling to prevent physicochemical and biological property changes (APHA, 2017; USEPA, 2007).

Temperature, pH, EC, and DO were field-measured with portable meters-calibrated (electrode thermometer, potentiometric sensor, electro-membrane DO probes) (Jaffar et al., 2020; Mishra & Patel, 2023). Other physicochemical factors like BOD_5, TDS, nitrate (NO_3^-), phosphate (PO_4^{3-}), sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), copper (Cu^{2+}), and hardness forms were analyzed in the laboratory. Analytical techniques employed gravimetric, UV-spectrophotometric, atomic absorption spectroscopy (AAS), and titrimetric analyses as per the Federal Ministry of Environment (FMEnv, 1992) and American Public Health Association (APHA, 2017) standards.

Microbiological analysis was also conducted to determine fecal contamination presence. The number of Total Fecal Coliform and Total Klebsiella was counted by the spread plate technique under aseptic conditions to preserve microbial sample integrity (Kumar & Singh, 2021). These parameters are indicators of recent fecal contamination and microbial health hazards.

Metallic elements were determined by Atomic Absorption Spectrophotometry (AAS) after nitric acid (HNO_3) acid digestion. The digested samples were filtered and assayed for measurement of metal concentrations like Pb, Cd, Zn, and Cu (APHA, 2017; Khan et al., 2020). All parameters were measured in duplicate, and the mean value was applied to further computation, including the Water Quality Index (WQI), Pollution Load Index (PLI), and multivariate statistical analysis. The valid dataset was used as a basis for examining the pollution condition and ascertaining pollution sources in the Otamiri River.

3.2 Analytical Method

3.2.1 Water Quality Index (WQI)

The WQI was calculated using the weighted arithmetic index method, which includes selection of Parameters, assigning weight (w_i)to each parameter based on their relative importance to water quality and human health (Tyagi et al., 2013). Each parameter's concentration was compared with its standard value based on **FEMenv (1992)** guidelines. The final WQI was obtained using:

$$WQI = \sum(w_i q_i) / \sum w_i \quad (1)$$

Wi means Weight of the ith parameter
Qi means Quality rating (or sub-index) of the ith parameter
The ranges of WQI, the corresponding status of water quality and their possible use are summarized in Table 1.

Table 1: WQI and corresponding water quality status (Source: Chatterjee & Raziuddin,2002).

S/N	WQI	Status	Possible Usage
1	0 - 25	Excellent	Drinking, Irrigation and Industrial
2	25 - 50	Good	Drinking, Irrigation and Industrial
3	51 - 75	Fair	Irrigation and Industrial
4	76 - 100	Poor	Irrigation
5	101 - 150	Very poor	Restricted use for irrigation
6	Above 150	Unsuitable	Proper treatment is required before use

3.2.2 Multivariate Statistical Analysis

Multivariate analysis was utilized in order to unravel patterns, relationship, as well as origins of contamination from data collected. Two of the principal methodologies that were applied included:

- Principal Component Analysis (PCA)

PCA helped find major contributors that impact the water quality as well as flag major potential contamination sources such as runoff due to agricultural activity or industry effluent.

- Correlation Analysis (CA)

The correlation analysis provides information on which water quality parameters are related, to what degree, and in what direction (positive or negative).

3.2.3 Geoaccumulation Index (Igeo)

The Geoaccumulation Index (Igeo), introduced by Müller (1969), was used to assess the degree of metal contamination in the sediments. It is computed using the formula:

$$Igeo = \log_2(Cn / 1.5Bn) \quad (2)$$

Where:
Cn = measured concentration of the element
Bn = background concentration of the element
1.5 = background matrix correction factor
The Igeo values were classified into seven pollution categories ranging from unpolluted to extremely polluted as shown in the table below.

Table 2: Igeo values and pollution level (Müller, 1969).

Igeo Value	Class	Pollution Level
≤ 0	Class 0	Unpolluted
0 – 1	Class 1	Unpolluted to moderately
1 – 2	Class 2	Moderately polluted
2 – 3	Class 3	Moderately to strongly
3 – 4	Class 4	Strongly polluted
4 – 5	Class 5	Strongly to very strongly
> 5	Class 6	Extremely polluted

3.2.4 Contamination Index (CI)

The Contamination Index (CI) evaluates the cumulative effect of multiple pollutants. It is calculated as:

$$CI = \sum Cn / \sum Sn \quad (3)$$

Where Cn is the concentration of pollutants
Sn is the standard permissible concentration according to **FMEnv Standard**
CI helps determine the overall contamination level in each sampling station (Konta et al., 2018).

Table 3: Contamination Index values and level

CI Value	Contamination Level
< 1	Low contamination
1 – 3	Moderate contamination
> 3	High contamination

3.2.5 Pollution Load Index (PLI)

The Pollution Load Index (PLI) determines the overall level of pollution in a specific location based on multiple contaminant factors. It gives a single cumulative indication of the pollution status of the water body (Tomlinson et al., 1980).

$$PLI = (CF_1 \times CF_2 \times CF_3 \times \ldots\ldots \times CF_n)^{1/n} \quad (4)$$

Where:
CFi = Contamination factor for each parameter
n = Number of parameters

4. RESULTS AND DISCUSSION

Table 4 shows all the parameters recorded, their FMEnv standard value and the mean of the observed values recorded at the three locations; Otammiri Downstream (point 1), Otammiri Midstream (point 2) and Otammiri Upstream (point 3) respectively.

Temperature: The mean temperature of 28.28^0C (Below standard 30^0C) is within a normal tropical freshwater range, supporting aquatic life. However, higher temperatures can reduce dissolved oxygen levels. This relationship between temperature and oxygen solubility is well documented in tropical water studies (Boyd & Tucker, 1998). Fig 2 was used to show this relationship.

pH: The river water is acidic, having a mean value of 5.60 (Below standard 6.50 - 8.50). This could be due to acid rain, industrial discharge, or natural soil composition
which can lead to the leaching of toxic metallic elements and negatively impact aquatic organisms. This research agrees with the findings form a research by Dewangan et al.,2023. Fig 2 was used to show this relationship.

Total Dissolved Solids (TDS): 28.50 mg/L

Much lower than FMEnv minimum of 500 mg/L, and with low Buggining impurities and very good quality potable water but maybe deficient in buffering minerals. While low TDS suggests minimal pollution from dissolved salts, it also indicates reduced buffering capacity, which may explain the low pH (FMEnv, 2001; Kumar & Singh, 2021). Fig 2 was used to show this relationship.

Dissolved Oxygen (DO): 11.05 mg/L

Much greater than FMEnv's minimum of 7.5 mg/L, and an indication of good oxygenation and supportive of good aquatic life. High DO levels suggest low organic pollution, as oxygen is not being excessively consumed by microbial decomposition (FMEnv, 2001; Jaffar et al., 2020). Fig 2 was used to show this relationship.

Biological Oxygen Demand (BOD): 3.35 mg/L

Moderate BOD level, characteristic of small rivers with low biodegradable pollution (FMEnv, 2001; Mishra & Patel, 2023).

Conductivity: 43.33 µS/cm

Far below the FMEnv limit of 1000 µS/cm, having insignificant ionic content and very insignificant anthropogenic contribution (FMEnv, 2001; Kumar & Singh, 2021).

Total Hardness: 23.57 mg/L

Soft water, below the FMEnv limit of 150 mg/L, preventing scaling but possibly causing instability of pH (FMEnv, 2001; Safe Drinking Water Foundation, 2017).

Nitrate: 17.44 mg/L
Once more than adequately within FMEnv permitted level of 50 mg/L, but ever so slightly on the higher side, perhaps by agricultural runoff (FMEnv, 2001; Jaffar et al., 2020).

Phosphate: 32.77 mg/L
Much higher than the FMEnv permissible value of 5.00 mg/L, which signifies risk of eutrophication due to fertilizer or sewage addition (FMEnv, 2001; Mishra & Patel, 2023).

Fecal Coliforms: 0.7 CFU/100 mL (Point 1); 0 CFU/100 mL (Points 2 & 3)
FMEnv requires that fecal coliforms are absent in potable water. Presence at Point 1 indicates minimal contamination by sanitation or runoff (FMEnv, 2001).

Klebsiella: Present in low concentrations in all points
Although not specified in FMEnv limits, its presence indicates industrial or biological contamination and needs to be treated before it can be consumed (Jaffar et al., 2020).

Table 4. Results from the three stream locations

Parameter	Point 1	Point 2	Point 3	Mean	FMEnv Std (Si)
Temperature (°C)	28.1	28.25	28.5	28.28	30
pH	5.65	5.55	5.6	5.6	6.5–8.5
Total Dissolved Solids (mg/L)	27.95	27.95	28.6	28.17	500
Dissolved Oxygen (mg/L)	12.35	11.4	10.4	11.38	7.5
Biological Oxygen Demand (mg/L)	4.4	3.3	2.35	3.35	N/A
Conductivity (µS/cm)	43	43	44	43.33	1000
Calcium Hardness (mg/L)	14.25	11.66	12.95	12.95	150
Total Hardness (mg/L)	27.2	22.02	22.02	23.75	150
Magnesium Hardness (mg/L)	12.65	10.36	9.07	10.69	150
Nitrate (mg/L)	17.23	19.82	11.3	16.12	50
Sodium (mg/L)	0.17	0.12	0.37	0.22	100
Phosphate (mg/L)	39.17	21.25	36.89	32.44	5
Calcium (mg/L)	4.63	3.79	4.21	4.21	200
Magnesium (mg/L)	3.08	2.52	2.21	2.6	30
Potassium (mg/L)	7.83	4	1.83	4.55	10

Copper (mg/L)	0.1	0.002	—	0.034	20
Total Faecal Coliform (CFU/mL)	0.0007	Absent	Absent	0.0007	0
Total Klebsiella (CFU/mL)	0.000004	0.000002	0.0000011	2.37E-06	0

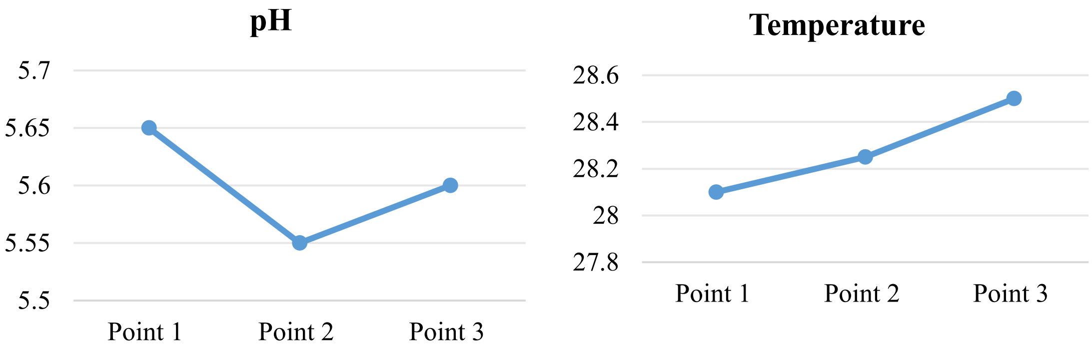
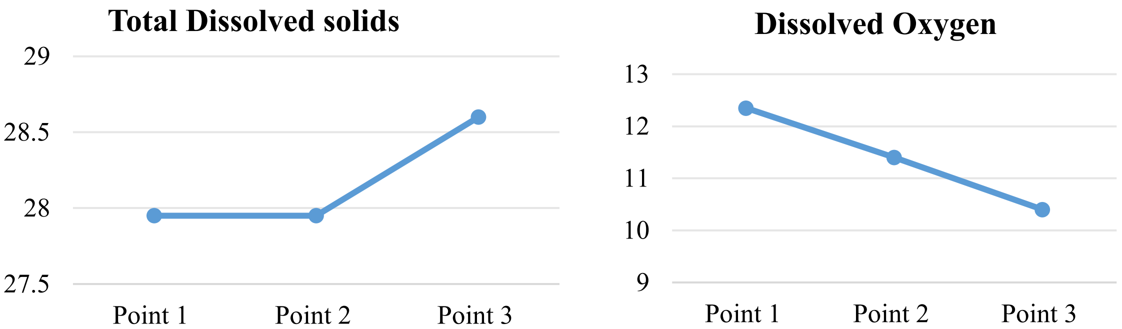


Fig 2: Line charts of values at the three locations recorded for pH, temperature, TDS and DO



4.1 Water Quality Index

The Water Quality Index calculation is summarized in Table 5. When compared to the water Quality status of Chatterjee & Raziuddin,2002), on table 1

The water quality at Point 1 is Unsuitable having a WQI value of 185.01 which is above the accepted limit (0 - 50) indicating heavy pollution. Point 2 which has WQI of 81.9427 falls in (Poor) category and is only suitable for irrigation. Point 3 has WQI of 167.28, this demonstrates an unsuitable water quality. This research agrees with the findings from research by Tyagi et al., 2013.

Table 5: Summary of the Water Quality Index calculation

Parameter	W_n	Q_{n1}	Q_{n2}	Q_{n3}	$Q_{n1}W_n$	$Q_{n2}W_n$	$Q_{n3}W_n$
Temperature	0.05	92.69	93.27	94.23	4.17	4.19	4.24
pH0	0.18	-270	-290	-280	-48.56	-52.16	-50.36
Total Dissolved solids	0.0027	5.59	5.59	5.72	0.02	0.02	0.02
Dissolved Oxygen	0.1799	31.69	45.07	59.15	5.70	8.11	10.64

Bioloical oxygen demand					0	0	0
Conductivity	0.001	4.3	4.3	4.4	0.01	0.01	0.01
Calcuim Hardness	0.01	9.5	7.77	8.63	0.09	0.07	0.08
Total Hardness	0.01	18.13	14.68	14.68	0.16	0.13	0.13
Magnesuim Hardness	0.01	8.43	6.91	6.05	0.08	0.06	0.05
Nitrate	0.03	34.46	39.64	22.6	0.93	1.07	0.61
Soduim	0.01	0.17	0.12	0.37	0.0023	0.0016	0.01
Phosphate	0.27	783.4	425	737.8	211.345	114.66	199.05
Calcuim	0.001	2.32	1.90	2.11	0.02	0.01	0.01
Magnessuim	0.05	10.27	8.4	7.37	0.46	0.38	0.33
Potassuim	0.13	78.3	40	18.3	10.56	5.40	2.47
Copper	0.07	0.5	0.01	0	0.03	0.001	0
Total (∑)	**1**				**185.01**	**81.94**	**167.28**

4.2. Multivariate Statistical Analysis

4.2.1. Principal Component Analysis (PCA)

Table 6 shows the result of the PCA.

PC1 (69.5%), which is highly correlated with Dissolved Oxygen (DO) 0.287, Biochemical Oxygen Demand (BOD) 0.289, Magnesium Hardness 0.291, and Potassium 0.291, suggests that organic matter and microbial contamination play the major role in water quality.

PC2 (30.5%): Governed by pH -0.344, Calcium Hardness -0.344, Sodium -0.333, and Phosphate -0.424, suggesting mineral content and nutrient content are also part of the parameters responsible for variation in the quality of water.

PC3 (negligible contribution): much less impacting pattern data. Briefly, water quality is subject to strong influences from organic pollution, microbiological activity, and inorganic chemistry. This result is in agreement with studies done by Shrestha & Kazama, 2007

Table 6: Result of the PCA

Parameter	**PC1 (69.5%)**	**PC2 (30.5%)**	**PC3 (~0%)**
Temperature (^{0}C)	-0.279	-0.126	0.749
pH	0.181	-0.344	-0.488
TDS (mg/l)	-0.228	-0.273	0.05
DO (mg/l O2)	0.287	0.071	0.194
BOD (mg/l)	0.289	0.046	0.135
Conductivity (S/cm)	-0.228	-0.273	-0.123
Ca Hardness (mg/l)	0.181	-0.344	0.199
Total Hardness (mg/l)	0.27	-0.162	0.108
Mg Hardness (mg/l)	0.291	-0.006	-0.054

Nitrate (mg/l NO3-)	0.164	0.363	-0.011
Sodium (mg/l Na)	-0.19	-0.333	-0.069
Phosphate (mg/l PO4)	0.076	-0.424	-0.035
Calcium (mg/l)	0.181	-0.344	0.088
Magnesium (mg/l)	0.291	-0.008	0
Potassium (mg/l)	0.291	-0.005	0.135
Copper (mg/l)	0.272	-0.155	0.193
Total Klebsiella (Tcfu/ml)	0.291	-0.019	0.069

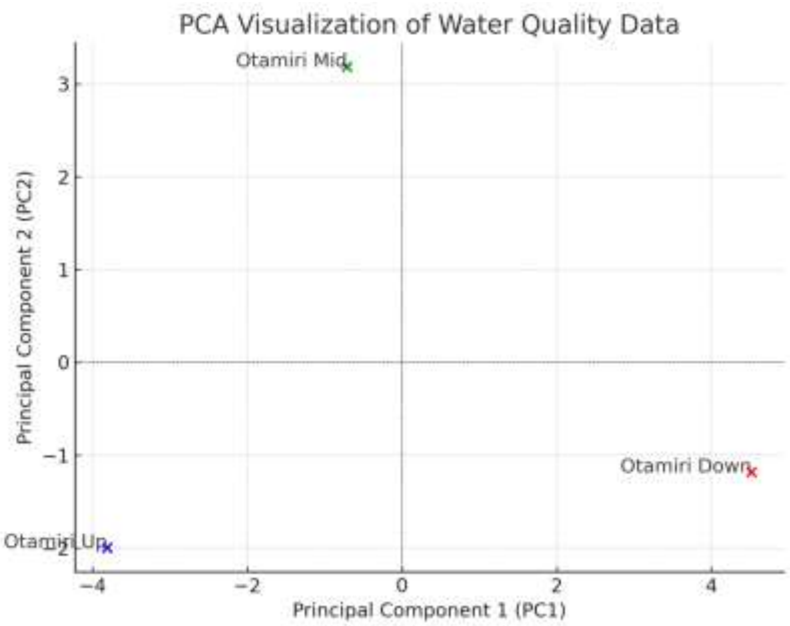


Fig 3: PCA Visualization of the water quality data

The PCA plot reveals that Otamiri Downstream is considered the most affected by anthropogenic activities, whereas Otamiri Upstream may hold a more pristine ground condition. This successfully exposes spatial variation in water quality and underlines pollution gradients along the river.

4.2.2. Correlation Analysis

Correlation analysis identifies substantial correlations between water quality parameters that facilitate comprehension of the sources of pollutants and environmental processes.

Some significant positive correlations ($r \approx +1.00$) indicate that some variables go hand in hand with one another. Conductivity and TDS ($r \approx 1.00$) strongly correlate because conductivity reflects ion concentration.BOD and DO ($r \approx 0.99$) illustrate that rising organic content is associated with greater oxygen demand. Calcium Hardness and Total Hardness ($r \approx 1.00$) reflect calcium as the main source of water hardness. Similarly, Nitrate and Phosphate ($r \approx 0.98$)

both rise together, maybe through runoff or sewerage, with effects of eutrophication. Very strong negative correlations (r ≈ –0.80 to –1.00) are also present. pH and Nitrate (r ≈ –0.99) show that nitrate pollution comes with acidification. Temperature and DO (r ≈ –0.99) reveal the decreased oxygen-carrying capacity of warm water. Sodium and Nitrate (r ≈ –1.00) signify a dilution effect or separate source of pollution.

Partial associations are shown by high to very high correlations (r ≈ 0.50–0.98). Conductivity and BOD (r ≈ 0.73) reflect ionic release due to decomposing organics. Phosphate and Potassium (r ≈ 0.86) may share a common source like fertilizers. Copper and Magnesium (r ≈ 0.98) reflect industrial or mineral sources. This result is in agreement with the studies done by Singh et al., 2004.

Table 8: Correlation result

Parameter	Temp	pH	TDS	DO	BOD	Cond	Ca Hard	TH	Mg Hard	NO3	Na	PO4	Ca	Mg	K	Cu	Kleb
Temperature (^{0}C)	1	-0.84	-0.5	-0.99	-0.98	-0.5	-0.94	-0.96	-0.99	-0.44	0.47	-0.85	-0.94	-0.99	-0.99	-0.96	-0.99
pH	-0.84	1	0.96	0.87	0.94	0.96	0.99	0.99	0.87	0.99	-0.99	1	0.99	0.87	0.85	0.97	0.87
TDS (mg/l)	-0.5	0.96	1	0.59	0.73	1	0.92	0.94	0.6	1	-0.99	0.99	0.93	0.61	0.56	0.99	0.59
DO (mg/l O2)	-0.99	0.87	0.59	1	0.99	0.6	0.97	0.98	1	0.52	-0.56	0.88	0.97	1	1	0.98	1
BOD (mg/l)	-0.98	0.94	0.73	0.99	1	0.73	0.99	0.99	0.99	0.69	-0.73	0.95	0.99	0.99	0.99	0.99	0.99
Conductivity (S/cm)	-0.5	0.96	1	0.6	0.73	1	0.92	0.94	0.6	1	-0.99	0.99	0.93	0.61	0.56	0.99	0.59
Ca Hardness (mg/l)	-0.94	0.99	0.92	0.97	0.99	0.92	1	1	0.97	0.89	-0.92	0.99	1	0.97	0.95	0.99	0.97
Total Hardness	-0.96	0.99	0.94	0.98	0.99	0.94	1	1	0.98	0.91	-0.94	0.99	1	0.98	0.96	0.99	0.98

(mg/l)																	
Mg Hardness (mg/l)	-0.99	0.87	0.6	1	0.99	0.6	0.97	0.98	1	0.52	-0.57	0.88	0.97	1	1	0.98	1
Nitrate (mg/l NO3-)	-0.44	0.99	1	0.52	0.69	1	0.89	0.91	0.52	1	-1	0.98	0.89	0.53	0.47	0.99	0.52
Sodium (mg/l Na)	0.47	-0.99	-0.99	-0.56	-0.73	-0.99	-0.92	-0.94	-0.57	-1	1	-0.98	-0.92	-0.57	-0.5	-0.99	-0.56
Phosphate (mg/l PO4)	-0.85	1	0.99	0.88	0.95	0.99	0.99	0.99	0.88	0.98	-0.98	1	0.99	0.88	0.86	0.99	0.88
Calcium (mg/l)	-0.94	0.99	0.93	0.97	0.99	0.93	1	1	0.97	0.89	-0.92	0.99	1	0.97	0.95	0.99	0.97
Magnesium (mg/l)	-0.99	0.87	0.61	1	0.99	0.61	0.97	0.98	1	0.53	-0.57	0.88	0.97	1	1	0.98	1
Potassium (mg/l)	-0.99	0.85	0.56	1	0.99	0.56	0.95	0.96	1	0.47	-0.5	0.86	0.95	1	1	0.97	1
Copper (mg/l)	-0.96	0.97	0.99	0.98	0.99	0.99	0.99	0.99	0.98	0.99	-0.99	0.99	0.99	0.98	0.97	1	0.98
Total Klebsiella	-0.99	0.87	0.59	1	0.99	0.59	0.97	0.98	1	0.52	-0.56	0.88	0.97	1	1	0.98	1

4.3. Geo-accumulaton Index

The Geo-Accumulation Index values of the six trace elements as seen from Table 9 show that Copper, Calcium, Magnesium, and Sodium are well within the unpolluted category, wherein Igeo values are significantly lower than zero, indicating no pollution or anthropogenic enrichment. Potassium is somewhat enriched (Igeo = -0.72) but falls into the "not polluted to moderately polluted" category. Thus, it may imply minimal external controlled activities such as organic decay or low fertilizer runoff. The highest Igeo value of 2.78 is for phosphate, placing it in the "moderately to strongly polluted" category. Thus, pollution from agricultural runoff, detergent use, or even effluent discharge is most probably the reason for this. This is corroborated by studies held on such similar tropical water bodies (Edokpayi et al., 2015).

Table 9: Geo-Accumulation Index (Igeo) Table

Element	**Mean Conc. (Ci)**	**FMEnv Standard (Bi)**	**Igeo**	**Pollution Class**
Copper	0.034	20	-8.43	Class 0 – Unpolluted
Calcium	4.21	200	-5.17	Class 0 – Unpolluted
Magnesium	2.6	30	-3.53	Class 0 – Unpolluted
Sodium	0.22	100	-8.09	Class 0 – Unpolluted
Potassium	4.55	10	-0.72	Class 1 – Unpolluted to moderately polluted
Phosphate	32.44	5	2.78	Class 3 – Moderately to strongly polluted

4.4. Contamination Index (CI)

Phosphate is the only highly contaminated parameter with CI = 6.49, which indicates heavy anthropogenic influence perhaps because of detergent effluent, fertilizer run off, or sewage inflow.

Dissolved Oxygen is fairly contaminated, perhaps due to high organic content or microbial action, which will also affect BOD levels.

CI values of all the other physicochemical parameters are < 1, indicating a low level of contamination and good water quality for these elements.

This tendency is in agreement with the finding from Geo-accumulattion Index, where phosphate was also identified as the principal pollutant of concern (Ojekunle et al., 2020).

Table 10: The contamination level of each parameter

Parameter	**Mean (Ci)**	**FMEnv Standard (Si)**	**CI**	**Contamination Level**
pH	5.6	6.5	0.86	Low contamination
Total Dissolved Solids	28.17	500	0.06	Low contamination

Dissolved Oxygen	11.38	7.5	1.52	Moderate contamination
Conductivity	43.33	1000	0.043	Low contamination
Calcium Hardness	12.95	150	0.09	Low contamination
Total Hardness	23.75	150	0.16	Low contamination
Magnesium Hardness	10.69	150	0.07	Low contamination
Nitrate	16.12	50	0.32	Low contamination
Sodium	0.22	100	0.0022	Low contamination
Phosphate	32.44	5	6.49	**High contamination**
Calcium	4.21	200	0.021	Low contamination
Magnesium	2.6	30	0.087	Low contamination
Potassium	4.55	10	0.455	Low contamination
Copper	0.034	20	0.0017	Low contamination

4.5. Pollution Load Index (PLI)

The following parameters were used in calculating the PLI; Copper, Calcium, Magnesium, Sodium, Potassium and Phosphate.
The resulting calculated value of PLI is 0.306 indicating that the Otammiri River (FUTO area) is overall unpolluted in terms of metallic elements and selected contaminants.
Despite the relatively high level of phosphate (CF = 6.49), the very low levels of other parameters' contaminations overwhelmingly outweigh the total load.
This corresponds to previous research that phosphate is the most significant contaminant to worry about, with metal impurities as minute or negligible (Simeonov et al., 2003).

5. CONCLUSION

Water quality assessment of Otammiri River (FUTO axis) showed that the river is not suitable for domestic and industrial use, as indicated by high Water Quality Index (WQI) values—especially at Points 1 and 3.
Phosphate was the prevailing pollutant, with maximum geo-accumulation and contamination values, which could be because of fertilizers, detergents, or sewage. The metallic elements copper, sodium, calcium, and magnesium, however, were low in contamination, with indications of low Pollution Load Index (PLI = 0.306).
Multivariate statistics (PCA and correlation) also confirmed that organic matter, nutrients, and microbial activity are the primary drivers of water quality. High correlations (e.g., between DO and BOD, nitrate and phosphate) also indicate related pollution sources.
Microbial parameters such as faecal coliforms and Klebsiella indicate potential health risks, justifying the need for treatment before use. The pollution is diffuse rather than point source, suggesting non-point source contamination from urban and agricultural activities.
The Otammiri River (FUTO axis) is significantly polluted, primarily by phosphate from agricultural runoff and domestic waste. While metal contamination is low, nutrient and

microbial pollution render the water unsuitable for domestic use without treatment. Immediate intervention and monitoring are recommended to protect public health and the environment.

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