International Journal of Applied Chemical and Biological Sciences (2024), 5(3), 29-44
ISSN- 2582-788X

RESEARCH PAPER

Article Identifier: https://identifier.visnav.in/1.0001/ijacbs-24d-02001/

An Evaluation of Selected Physicochemical Parameters of Surface Water in River Wuye, Federal Capital Territory, Abuja, Nigeria

Idowu Rachel T., Dan-Kishiya Ahmed S., Oboh Angela and Owolabi Comfort A.*

Department of Biological Sciences, Faculty of Science, University of Abuja, P.M.B. 117, Abuja, Nigeria

* For correspondence: caowolabi@yahoo.com

Received on: 2 April 2024 *Published on: 10 October 2024*

ABSTRACT

An evaluation of selected physicochemical parameters and water quality of River Wuye, Abuja, Nigeria was undertaken from December, 2019 to November, 2020. The aim was to determine the levels of selected physicochemical parameters of surface water in River Wuye for sustainable management, conservation, utilization and early warning. Water samples were collected monthly from four sampling stations with varying human activities from upstream to downstream of the river; and analyzed using standard methods, instruments and procedures. The results obtained for fourteen physicochemical parameters examined showed that the mean values were: Water Temperature, 25.31±1.56°C, Turbidity, 40.08±58.94NTU, Dissolved Oxygen, 7.21±1.02mg/l, Biochemical Oxygen Demand, 3.54±1.20mg/l, pH, 7.27±0.29, Electrical Conductivity, 168.72±75.66µS/cm, Total Dissolved Solids, 101.80±45.73mg/l, Total Alkalinity, 117.81±151.49mg/l, Total Hardness, 155.89±233.13mg/l, Chloride, 155.89±233.13mg/l, Phosphate-Phosphorus, 8.99±4.50 mg/l, Nitrate-Nitrogen, 21.77±34.68mg/l, Salinity, 0.36±0.03mg/l and Manganese, 2.72±3.53 mg/l. Most mean and maximum values of physicochemical parameters by station exceeded the WHO permissible limits for water consumption except for Water temperature, pH, BOD, EC, TDS and Chloride which were within the limits. Analysis of variance (ANOVA) of mean physicochemical parameters showed that there were no significant difference/variation ($p>0.05$) in the values between stations. Values varied significantly between months ($p<0.05$) except for Salinity, pH and Phosphate as shown by the p-values; and between seasons, except for eight of the parameters. Pearson's Correlation Analysis revealed positive and negative relationships between the parameters. Appropriate ecosystem management strategy should be adopted and implemented to include regular and effective monitoring and control of activities in and around the river, capacity building and education of local communities on eco-friendly and sustainable waste management practices and agriculture.

Keywords: Physicochemical Parameters, Water Quality, River, Human Activities, Monitoring, Control

1. INTRODUCTION

The importance of water for the survival of life on Earth and its place in science, philosophy, religion, and other areas of human endeavor has been widely described [1-4]. It is the medium through which organic and inorganic wastes and sediments are distributed throughout the aquatic ecosystem. The unique properties of water, as the common and critical ingredient in all aquatic environments, play vital and dynamic roles in the physical, chemical, and biological characteristics of respective aquatic ecosystems and the survival, sustenance and productivity of all life (biotic community) in them [2, 5].

Freshwater is a very important resource for which adequate water quality monitoring, regulation and control are required for its effective management, conservation, and sustainable utilization [6, 7]. Freshwater ecosystems provide the main source of safe drinking water for cattle watering and industrial purposes. These water resources, particularly rivers and lakes, often perform recreational and transportation functions [8, 9].

The study of the physicochemical characteristics of the water body is important for its effective management, conservation and sustainable utilization, maintenance and control within acceptable standard limits [10]. It is also important for the understanding and interpretation of data from biological assessment of the water resource or ecosystem [7, 11]. The enhancement of the quality status of the freshwater systems will go a long way to improve productivity and livelihoods of the communities.

River Wuye is one of the freshwater bodies in Abuja, Nigeria. The water quality variables of the river are not well known. Although many researchers have worked on various water quality indices, fisheries of lakes as well as other aquatic systems, there is the need for data and information on the physicochemical characteristics and water quality of the river. It is in view of this that this study was undertaken to document data and information on the physicochemical characteristics and water quality of the river for management, conservation and sustainable utilization.

2. METHODOLOGY

2.1. Study Area

River Wuye is located in the Federal Capital Territory, Abuja, between latitude 8.931940 and 9.118771°N of the equator and longitude 7.105830 and 7.253962°E of the Meridian [13]. It is approximately 44.37km long. The total area drained by the basin is approximately 316.4km^2 (Image 1). The river takes its source from Zuba and empties downstream into River Usuma, a tributary of River Gurara that empties into River Niger [13]. River Wuye flows in a dendritic pattern and in accordance with the River Basin Model from places of high elevation (at Zuba, 320.0 meters) to places of low elevation at Gwagwalada. It has six tributaries and flows through some major settlements, namely, Angwan Dodo, Gwako, Giri, Idon Kassa, Gwari, Dakwa and Zuba. It has an all-year-round flow due to its sustenance by the seasonal rain and urban runoffs and seepages.

Human activities vary along the river from the upper stream through the mid-stream and downstream. They include washing of clothes, extraction of water for irrigation (crop farming) and domestic uses, drinking, sand mining/dredging, cattle watering, swimming and block-making.

2.2. Sampling Stations

Four sampling stations were selected based on human activities along the river; one upstream (around the

source of the river), two midstream and one downstream by the mouth of the river as follows:

Station 1 (SP1) - Located upstream at the source of River Wuye at Zuba., latitude 9.118771°N, longitude 7.25396°E and altitude of 320 meters above sea level. A major portion of the substratum was rocky and the bank had mounds of rocks and coarse sand.

Station 2 (SP2) - Located at latitude 9.01097°N, longitude 7.21393°E and altitude of 263 meters above sea level (23km downstream of Station1). It is at the point of intersection of the second tributary of River Wuye with significant anthropogenic activities including cattle rearing, agriculture (crop farming) and sand mining. The river passes through an Army Cantonment and a cattle ranch by which a small stream flowed and emptied into River Wuye.

Station 3 (SP3) - Located at latitude 8.99236°N, longitude 7.15283°E and at an altitude of 213.0 meters above sea level. It is after the point of intersection of a tributary from Wusa/Pasere Hill Ranges with River Wuye at Giri. Activities around the sampling station are sand mining, swimming, bathing, crop farming – maize, cassava, vegetables, yams, beans; animal husbandry- cattle grazing and watering, waste disposal.

Station 4 (SP4) – Located at latitude 8.93194°N, longitude 7.10583°E and at an altitude of 177.0 meters above sea level. It is at the mouth of River Wuye (downstream) before it empties into River Usuma at Gwagwalada. Activities around the sampling station are crop farming – maize, cassava, vegetables, yams, beans, animal husbandry- cattle rearing and the use of the river as source of drinking water for the animals; block making and human settlement.

2.3. Sample Collection

Composite surface water samples were collected monthly in the morning (6.30-10.30am) from each of the four sampling stations for a twelve-month cycle, December, 2019 to November, 2020. In situ measurements were taken for physicochemical parameters of temperature, dissolved oxygen (DO), pH,

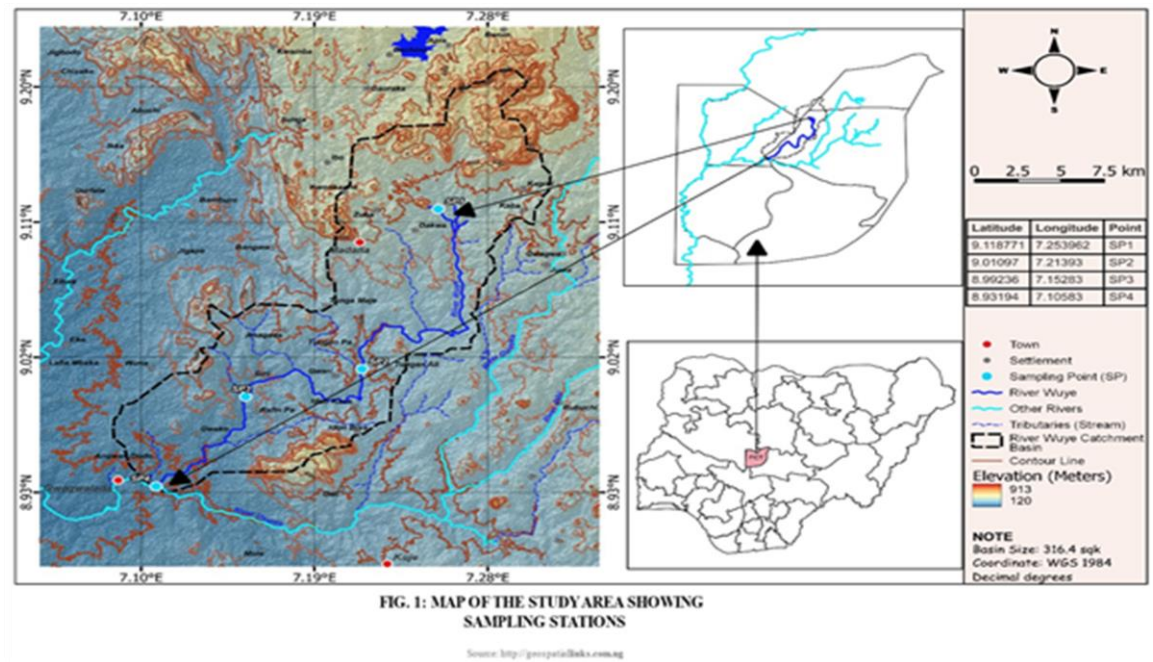

Image 1. Map of the Study Area Showing Sampling Stations
Source: http://geospatialinks.com.ng

turbidity, electrical conductivity and total dissolved solids using specific meters. Probe readings were taken monthly at 2cm below the water surface in triplicate and the average readings for each station were recorded. Specific meters used for respective parameters following standard methods APHA, 2012 (14) included: Water temperature (°C) - mercury-in-glass thermometer range 0-50°C (Model, Lasaly); Turbidity(NTU): Lovibond Turbidimeter; Hydrogen Ion Concentration (pH) - pH meter (Model St10 Pentype OHAUS); Electrical conductivity (mg/l) and Total Dissolved Solids (TDS, mg/l) portable battery-operated electronic switch gear conductivity meter/TDS (Jenway 4520); Dissolved Oxygen (DO, mg/l) - dissolved oxygen meter (Jenway Model- 970 portable DO meter). Water samples for nutrient analysis of phosphate, nitrate, biochemical oxygen demand, total hardness, total alkalinity, chloride and manganese were collected in tightly covered 1 litre plastic bottles and stored in a cooling system containing ice blocks.

All samples were duly transported and analyzed in the laboratory at the Department of Biological Sciences of the University of Abuja and the Federal Capital Territory Water Board Quality Control Laboratory located at the Lower Usuma Dam, Bwari, Abuja, following standard methods for analysis of water and wastewater [14-16]. Data quality was ensured through calibration of all equipment in line with the manufacturer's specifications, including careful standardization, blank measurements, and triplicate samples. Sampling containers and gadgets including meters were thoroughly cleaned to avoid contamination from previous samples. All samples were preserved in line with test-specific requirements [14-16] . The 5-day BOD method of laboratory analysis was applied for BOD [14, 16, 20]. The nitrate, phosphate and manganese contents of the samples were determined using the Spectrophotometer method after adding the appropriate reagents to 10ml of the replicate samples as stipulated by the American Public Health Association (APHA, 2012). Total Alkalinity was determined by the standard titrimetric method as prescribed by APHA, 2012, 22nd Edition, Sections 2320C and 2340C respectively. The Chloride - Argentometric method prescribed by APHA, 2012, 22nd Edition in 4500B were applied while Salinity was determined using standard methods in 2120D APHA, 2012 (22nd Edition).

3. RESULTS AND DISCUSSION

The results of the physicochemical analysis of the river are summarized in Tables 1-4.

3.1. Water Temperature

Water Temperature values ranged from 23.40±0.10°C-29.40±0.08°C with a mean of 25.31±1.56°C (Table 1). Within the sampling stations, the lowest mean value was recorded in Station 1 as 25.10±1.61°C whilst the highest was in Station 4, 25.58±1.56°C (Table 2). The lowest mean temperature was recorded in January, 2020, 23.40 ± 0.10°C and the highest in March, 2020, 28.90 ± 0.35°C. The values were within the permissible range of the WHO of <40°C (12). Higher seasonal mean temperatures were recorded in the dry season while lower seasonal mean temperatures were recorded during the rainy season. Low-temperature values recorded during dry season may be attributed to variation due to the effect of harmattan winds. Temperature values for River Wuye were within the WHO permissible limits for the growth of aquatic life. The values were higher than the mean temperature values recorded for Wupa River, Abuja (20.70 - 20.10°C) in the dry season [18].

3.2. Turbidity

Turbidity values varied from 4.07±0.08 - 313.00±0.15NTU with a mean value of 40.08±

58.94NTU (Table 1). Within the stations, the lowest mean value was recorded in Station 1 as 6.22±12.09NTU and the highest in Station 4, 54.28±63.97NTU (Table 2). P-value for turbidity, p > 0.05 (p= 0.508) indicated no significant difference between the values across stations. The lowest monthly mean value for turbidity was recorded in October, 2020 as 9.83±1.86NTU and the highest in July, 2020, 218.78±119.03NTU. Although the overall mean value for the twelve-month period exceeded the WHO limit, monthly mean turbidity values were within the WHO range for eight out of the twelve months. In this regard, the monthly mean turbidity value fluctuated steadily from the initial value of 15.68±4.98NTU in December, 2019 and slight decrease and increase for the next three months before a sharp increase in April and May, 2020 and the peak value of 218.78±119.03 NTU in July, 2020 before a sharp decrease in August, 2020 and fluctuation of the monthly mean values for the rest of the four months but within the permissible limits.

Turbidity values were higher in the wet season than dry season and exceeded the permissible limits. The higher levels of turbidity during the rainy season may be due to surface runoff and flood-carrying silt, debris, sediment and organic and inorganic matter. Associated turbidity water quality problems include higher water temperatures as a result of increased heat absorption of the water (from sunlight) resulting in reduced levels of dissolved oxygen as well as photosynthesis/primary productivity. Values observed in this study were higher than those for Ossiomo River [21] and Silver River (25) but lower than those recorded for Lower Niger River.

3.3. Dissolved Oxygen

Dissolved oxygen (DO) values for the period ranged from 5.13±0.04 to 9.05±0.04mg/l with a mean value of 7.21±1.02mg/l (Table 1). Within stations, the lowest mean value was recorded in Station 4 as 7.17±1. 13mg/l and the highest in Station 1, 7.33±0.92mg/l (Table 2). Monthly mean values fluctuated between the lowest of 5.70±0.56mg/l in March, 2020 and the highest of 8.95±0.07mg/l in September, 2020. There was no statistically significant difference between the values across stations for dissolved oxygen with p = 0.163 > 0.05.

Five of the monthly means were within the WHO limits for aquatic life of 5.0-7.0 mg/l. This included the lowest monthly mean of 5.70±0.56mg/l recorded in March, 2020. All other means at the station and monthly levels exceeded the permissible limits to varying degrees. Within the respective stations, only four monthly values were within the WHO limits in Station I, three in Station 2, and five in Stations 3 and 4 respectively.

Dissolved oxygen is vital for life in the aquatic environment, specifically for respiration and metabolism. Sources of dissolved oxygen in surface water are the ambient air and photosynthesis by aquatic plants. Pollutants in the water body, including waste and decaying or dead organic matter reduce the levels of dissolved oxygen in the water body.

The values of DO recorded in this work were comparable to those for Ossiomo River [21] and Lower Niger River [29], but lower than those recorded in River Ngadda, Northeastern Nigeria [26] and higher than in Silver River, Southern Ijaw, Bayelsa State, Nigeria [25].

Dissolved oxygen is critical for aquatic life, particularly for the bigger creatures in the aquatic food web. DO levels decreased in the rainy season whilst higher levels were observed during the dry season which represented the period of low turbidity. The cold harmattan breeze, which promotes wave action and cools the surface water, may have contributed to the higher oxygen concentration during the dry season, while heavy rains

increased turbidity and lowered oxygen concentration during the wet season.

3.4. Biochemical Oxygen Demand (BOD)

Biological oxygen demand (BOD) fluctuated from 1.50±0.00 to 5.86±0.00mg/l with a mean of 3.54±1.20mg/l (Table 1). Within stations, the lowest mean value was recorded in Station 3 as 3.14±1.35mg/l and the highest in Station 1 as 3.86±1.14mg/l (Table 2). The lowest monthly mean value was recorded in April, 2020 as 1.98±0.46mg/l and the highest in September, 2020 as 5.71±0.14g/l. There was no significant difference between BOD values across stations as p-value for BOD >0.05 (p = 0.058). Most mean values for BOD, namely, the overall mean for the entire period, the mean values per station and the monthly means were within the WHO permissible limits of 3.0-6.0mg/l. However, the monthly mean values for February, March, April and May, 2020 which varied between 1.98±0.46 and 2.47±0.70mg/l were below the lower limit of WHO standard limits.

The values of BOD recorded in this work were comparable to those for River Ngadda, Northeastern Nigeria [26], higher than in Ossiomo River [21] and the Lower Niger River [29] but lower than for Silver River [25].

Notably, biochemical oxygen demand is the amount of oxygen consumed by bacteria and other microorganisms to decompose organic matter under aerobic conditions at a specified temperature or the quantity of oxygen essential for microorganisms to break down or decompose organic substances or matter in any aquatic medium (water, wastewater and discharged effluents). It can be used as a measure of the concentration of organic matter existing in the water [28]. Increased sedimentation, organic materials, and subsequent biodegradation all contribute to high BOD levels. BOD values in River Wuye were much greater in the wet than in the dry season due to the increased volume of water flowing into the water body during the rainy season with the consequent increase in microbial population and use of oxygen in the aerobic digestion /decomposition of organic matter.

3.5. Hydrogen ion Concentration (pH)

Values for hydrogen ion concentration (pH) varied from 6.00±0.00 to 7.80±0.00 with a mean value of 7.27±0.29 (Table 1). Within stations, the lowest value was recorded in Station 1 as 6.00±0.00 and the highest in Station 4, 7.80±0.00 (Table 2). The lowest monthly mean value for the period was recorded in July, 2020, 6.70±0.75 and the highest in March, 2020, 7.55±0.10. There was no significant difference in the values across stations as p>0.05 (p = 0.716).

The surface water pH for the river varied between slight acidity and low alkalinity. Most of the values were within the WHO permissible limits of 6.5 - 8.5 for drinking water except for three instances in Station 1 with the values ranging between 6.40±0.00 and 6.40±0.02 in December 2019, May and August 2020, respectively and one instance each in Stations 2 and 3 with values of 6.10±0.00 and 6.00±0.00 in July, 2020 respectively. pH readings in this study were within the WHO permissible limits for aquatic life. pH is a critical water quality characteristic since it is involved in all metabolic activities. pH is an important parameter that regulates the suitability of water for several purposes. The observed values of pH fall within the range observed in Silver River [24] and Lower Niger River [29], but higher than for Ossiomo River, Ologbo with 5.76-6.01 [21] and lower than those observed in Okamini Stream, Rivers State, Niger Delta, Nigeria [24].

3.6. Electrical Conductivity

Monthly values for electrical conductivity (EC) ranged from 51.50±0.05 to 386.00±0.00µS/cm with the mean value of 168.72±75.66µS/cm (Table 1). Within stations, the lowest mean value for the period was recorded in Station 1, 65.06±14.2µS/cm and the highest in Station 4, 207.42±88.78µS/cm (Table 2). The lowest monthly mean value was recorded in July, 2020, 70.93±21.42µS/cm and the highest in April, 2020, 303.75±144.86µS/cm. There was no significant difference between the values of electrical conductivity across stations with p>0.05 (p = 0.062). The values were also within the WHO permissible limits. Values of Conductivity (i.e. capacity of water to conduct electricity) that are less than 50 µS/cm are considered low [10] , whilst those between 50 and 600 µS/cm are considered medium, and those more than 600 µS/cm are considered high. Natural water has also been reported to have conductivity of 20–1500 µS/cm. [10].

Conductivity values of River Wuye were within the medium category, 51.50±0.05 to 386.00±0.00uS/cm with the mean value of 168.72±75.66uS/cm. The reduced EC levels during the rainy season (which might be attributed to increase of organic matter pollution, other effluents and run-off with a high concentration of Nigerian waters and other tropical environments. The values of EC recorded in this work were lower than those for River Ngadda, Northeastern Nigeria [26], but higher than in Ossiomo River, Ologbo [21] and Silver River [25].

3.7. Total Dissolved Solids

Monthly values for total dissolved solids (TDS) across all stations for the first twelve months ranged from 31.00±0.00 to 234.00±0.04mg/l with the mean of 101.80±45.73mg/l (Table 1). Within stations, the lowest mean value was recorded in Station 1, 39.52±8.48mg/l and the highest in Station 4, 124.85±53.06mg/l (Table 2). The lowest monthly mean value was recorded in July, 2020, 43.55±15.02mg/l and the highest in April, 2020, 184.30±88.22mg/l.

There was no significant difference between TDS values across stations as p>0.05 = 0.158. The values were also within the WHO permissible limits of 600mg/l. The values of TDS observed in this work were higher than in Ossiomo River, Ologbo [21] and Silver River [25]. Increase in TDS may not be unconnected with contributions from surface runoffs from soil/farms and increased turbulence of the river flow that may have caused re-suspension of sediments [15-16]. In normal aquatic environment, TDS is predominantly the dissolved salts of metal ions such as carbonates, bicarbonates, chlorides, sulphates and phosphates [17].

3.8. Total Alkalinity

Monthly values for total alkalinity (TA) ranged from 20.00±0.02 to 640.00±0.11mg/l with the mean value of 117.81±151.49mg/l (Table 1). Within stations, the lowest mean value was recorded in Station 1, 78.36±128.31mg/l and the highest in Station 4, 142.92±179.26mg/l (Table 2). The lowest monthly mean value was recorded in July, 2020, 27.00±5.77mg/l and the highest in October, 2020, 540.00±83.27mg/l. There was no significant difference between the values of total alkalinity across stations, p> 0.05 = 0.879. The mean values exceeded the WHO permissible limits of 100mg/l. The values of TA recorded in this work were higher than those for Ossiomo River [21].

3.9. Total Hardness

Monthly values for total hardness (TH) ranged from 16.00±0.00 to 1200±0.15mg/l with a mean of 155.89± 233.13 (Table 1). Within stations, the lowest mean value was recorded in Station 1, 76.96±114.98mg/l and the highest in Station 4, 218.72±349.34mg/l (Table 2). The

lowest monthly mean value was recorded in July, 2020, 34.50±8.06mg/l and the highest in October, 2020, 810.00±372.92mg/l.

There was no significant difference between the values of total alkalinity across stations, p> 0.05 = 0.870. The mean values exceeded the WHO permissible limits of 100mg/l.

3.10. Chloride

Monthly values for chloride (Cl) varied from 15.60±0.00 to 423.44±0.11mg/l with a mean of 68.17±103.30mg/l for the period. Within stations, the lowest mean value was recorded in Station 1, 59.45±93.81mg/l, and the highest in Station 4, 75.69±123.99mg/l. The lowest monthly mean value was recorded in March, 2020 as 16.05±1.55mg/l and the highest in October, 2020, 357.91±44.71mg/l (Table 3). There was no significant difference between chloride values across the stations as p> 0.05 = 0.987. The mean value was within the WHO permissible limit of 300mg/l. Monthly mean values for chloride indicated that the WHO limit was only exceeded in October, 2020. Chloride levels were within the WHO permissible limits for all sites except for October values for all stations which were above the 300mg/l limit and the monthly mean value for the same month was 357.91±4 4.71mg/l. The upsurge in chloride levels might have been due to the release from precipitation and runoffs from farmlands household wastes, sewage and weathering of rocks. The values of chloride observed in this work were comparable to that in River Ngadda, Northeastern Nigeria [26], but higher than in Ossiomo River [21].

3.11. Phosphate-phosphorus

Monthly values for phosphate-phosphorus (PO_4-P) for the period varied between 0.38±0.00 and 32.40±0.12mg/l with a mean value of 8.99±4.50mg/l (Table 1). Within stations, the lowest mean value was recorded in Station 3 as 5.27±4.13mg/l and the highest in Station 1, 13.47±6.76mg/l (Table 2). The lowest monthly mean value was recorded in October, 2020, 2.99±1.45mg/l and the highest in August, 2020, 17. 17±2.48mg/l. There was no statistically significant difference between phosphate values across stations as p >0.05 = 0.334. Phosphate levels fluctuated in each of the stations. For Station 3 with the lowest mean value for the study period, respective values for two of the twelve months (August and September) exceeded the permissible limit of WHO (0.8-5.0mg/l), while the value for one of the months (May, 0.45±0.00mg/l) was below the WHO limit. For Station 4, values for five of the months (August, September, June, December and January) exceeded the limits whilst the value for one month (May) was below the limit. For Station 2, values for five of the months (December, January, August, June and September). exceeded the limits whilst the value for one month (May) was below the limit. For Station 1, values of eleven months exceeded the limits, whilst the value for one month (October) was slightly below the limit (4.95±0.00mg/l). The months with the highest values in descending order were May (26.10±0.03mg/l), July, April, August, December, January, September, November, February, March and June.

The high levels of phosphates recorded in the stations may be due to runoff from farmlands treated with fertlisers, laundry detergents/cleaning agents, animal and human waste as well as natural sources which include phosphate-containing rocks (27). The values of PO_4-P recorded in this work were lower than those for River Ngadda, Northeastern Nigeria [26], but higher than in Ossiomo River [21] and Silver River [25].

3.12. Nitrate-Nitrogen

Nitrate-Nitrogen (NO_3-N) values ranged from 1.10±0.00 - 165.40±0.05mg/l with a mean of 21.77±34.68mg/l (Table 1). Within stations, the lowest mean value was recorded in Station 1, 8.49±2.78mg/l and the highest in Station 4, 26.99±47.07mg/l (Table 2). The lowest monthly mean value was recorded in January, 2020, 4.23±2.16mg/l and the highest in August, 2020, 115.60±72.63mg/l. There is no significant difference between the values across stations, $p>0.05 = 0.296$ (Table 3). Nitrate levels fluctuated in each of the stations. Although Station 1 recorded the lowest mean value for the study period, the respective values for seven out of the twelve months exceeded the permissible limit of WHO (9.1mg/l), The values for January, June, August were below the limit, while September value was exactly at the limit. For Stations 2, 3 and 4, nitrate values were well above the permissible limits for three months of the year, namely June, August and September, respectively. The highest value of 165.40±0.05mg/l was recorded for Station 2 in August followed by 147.50±0.06mg/l in Station 4 and 141.80± 0.04mg/l in Station 3 in descending order for the same month. Monthly mean values followed the same trend, with all months below the permissible limit except the months of August, September and June.

The high levels of nitrate detected in this work may be attributed to runoff from farmlands treated with fertlisers, organic manure from livestock, sewage, other animal waste and domestic waste from settlements. The result was higher than those recorded in Ossiomo River [21], River Ngadda, Northeastern Nigeria [26], Lower Niger River [29] and Silver River [25].

3.13. Salinity

Salinity values varied between 0.30± 0.00 and 0.40±0.00mg/l with a mean value of 0.36±0.03mg/l (Table 1). Within stations, the lowest mean value was recorded in Station 1 as 0.30±0. 00mg/l and the highest in Station 3 as 0.38±0.05mg/l (Table 2). The lowest monthly mean value was recorded respectively in August and September, 2020 as 0.30±0.00mg/l and the highest respectively in December, 2019-July and November, 2020 as 038±0.05mg/l.

There was a significant statistical difference between the stations, $p=0.038<0.05$. Both the overall mean value and most other mean values of salinity in River Wuye were higher than the permissible limit of WHO of 0.30 mg/l. The lowest records of salinity which were at the maximum permissible limit were in Station 1. The high levels were comparable to the values observed in Okamini Stream, Rivers State, Niger Delta, Nigeria [24] but lower than in Silver River [25].

3.14. Manganese

Manganese (Mn) values ranged between 0.20±0.00mg/l and 21.00±0.02mg/l with a mean value of 2.72± 3.53mg/l (Table 1). Within stations, the lowest mean value was recorded in Station 1, 1.15±0.41mg/l and the highest in Station 4, 4.23±7.30mg/l (Table 2). The lowest monthly mean value was recorded in October, 2020 as 0.30±0.14mg/l and the highest in August, 2020, 10.61±10.61mg/l.

3.15. Correlation

Results of Pearson's Correlation Analysis indicated either a positive or negative relationship with respective parameters that was either significant ($p<0.05$) or not ($p>0.05$). Water temperature and Turbidity (WT- Turbidity) exhibited a strong positive and significant relationship, with a correlation coefficient, $r=0.983$ and $p<0.05=0.02$, while Mn-TA showed a strong negative significant relationship with $r= -0.962$, $p<0.05=0.04$. Conversely, DO and pH, $r= 0.95$, $p=0.05$; implying a decrease in DO with an increase in

pH. There was no significant relationship ($p>0.05$) between the following parameters that had a strong or medium positive correlation respectively: NO_3-N and TA, r=0.91, Salinity-TH, r=0.92, TA-pH, r = 0.93; TA-TDS, r =0.94; NO3-N with TH, r=0.91, TDS, r=0.70, EC, r =0.69; Turbidity-Salinity, r=0.83; Turbidity -TA, r= 0.89.

4. CONCLUSION

The findings of this work showed that the mean and maximum values of eight of the physicochemical parameters of River Wuye, namely, Turbidity, Dissolved Oxygen, Total Alkalinity, Total Hardness, Phosphate - Phosphorus, Nitrate Nitrogen, Salinity, Manganese within the respective stations, exceeded the WHO recommended permissible limits; while values of six parameters, namely, water temperature, Hydrogen ion Concentration, pH, Biochemical Oxygen Demand, Electrical Conductivity, Total Dissolved Solids and Chloride were within the permissible limits for water consumption and aquatic life. The study provided information on the water body including the inter-relationships and dynamics between the respective parameters which should guide future work and strategy for quality enhancement and control.

5. RECOMMENDATION

A sound ecosystem management strategy should be adopted and implemented to include regular monitoring and application of proper management and corrective (control) measures to enhance the quality and productivity of the water body and effectively conserve its biota [28-35].

The Strategy should include capacity building and education/enlightenment programme on more sustainable use of the river by the communities such as sustainable waste management and eco-friendly agriculture (32-37).

6. ACKNOWLEDGEMENT

We acknowledge the support of the Technical and Laboratory Staff of the Department of Biological Sciences, University of Abuja and the Water Quality Control Laboratory, FCT, Abuja.

7. CONFLICT OF INTEREST

The authors have declared that there is no conflict of interest.

8. SOURCE/S OF FUNDING

Self-funded

9. REFERENCES

1. IPBES (2019). Global Assessment Report on Biodiversity and Ecosystem Services UN Inter Governmental Science-Policy Platform on Biodiversity and Ecosystem Services – IPBES Secretariat, **40pp**.
2. Dan-Kishiya, A. S. and Chiaha, N. Q. (2012). Physicochemical Parameters of Some Selected Stations in Lower Usuma Reservoir, Bwari, Nigeria. Report and Opinion,. **4**(2):1-6.
3. Idowu, R.T., Ali, F. A. Onyemaobi, M. and Ahmed, A. (2018). Dynamics of Phytoplankton Assemblages in Lake Chad Nigeria. *Elixir Agriculture*, **121**, 51535-51541.
4. Kareem, O.K., Falaye, A. E., Ajani, E. K. and Olanrewaju, A. N. (2015). Physico-chemical Characteristics and Fish Abundance in Erelu Reservoir, Oyo State, Nigeria. *Nigerian Journal of Ecology*, **14**, 90-101.
5. Erondu, C. J. and Solomon, R. J. (2017). Identification of Plankton (Zooplankton and Plankton) behind Girls' Hostel University of Abuja, Nigeria. *Direct Research. Journal of Public Health and Environmental Technology*, **2**(3), 21-29.

6. Akaahan T. J. A., Araoye P. A. and Azua E.T. (2015). Physicochemical Characteristics and MacroInvertebrates of River Benue at Makurdi.
7. Yakubu, O. A., Idowu, R. T., Ali, F. A. (2018). Diversity and Abundance of the Macroinvertebrate Community of River Ngadda, North-Eastern, Nigeria. *International Journal of Research*, **5**(21).
8. Olanrewaju A. N., Ajani E. K., Kareem O. K. (2017). Physicochemical Status of Eleiyele Reservoir, Ibadan, *Nigeria. Journal of Aquatic Resources Development*, **8**, 512. doi: 10.4172/2155-9546. 1000512.
9. Mohammad, M., Krishna, J., Lamma, P. V. and Shabbar, K. (2015). Analysis of Water Quality using Limnological Studies of Wyra Reservoir, Khammam District, Telangana, India. *International Journal of Current Microbiology and Applied Sciences*, **4**(2), 880-895.
10. Idowu, R. T., Inyang, N. M. and Eyo, J. E. (2004). The Physicochemical Parameters of an African Arid Zone Man-made Lake. *Animal Research International*, **1**(2), 113-119.
11. Akhmad M., Mudian P., Admi A., Erna R., Ruzkiah A. and Hidayat S. S. (2022). Temporal and Spatial Analysis of Coastal Water Quality to Support Application of Whiteleg Shrimp *Litopenaeus vannamei* Intensive Technology, *Sustainability*, **4**(5), 2659.
12. WHO (2011). Guidelines for Drinking Water Quality (4th Edition). World Health Organization, Geneva. In Mahi S. A. and Isah S. (2016). *International Journal of Scientific and Publications*. **6**(1), 125-138.
13. FCDA (1996). Map of Abuja Showing the Area Councils.
14. American Public Health Association -APHA (2012). Standard Methods for the Examination of Water and Waste Water, 22nd edition. American Public Health Association/ American Water Works Association / Water Environment Federation, Washington D. C Section, 1000-3000.
15. Ali, F.A., Ofori-Danson, P.K., Nunoo, F. K. E., Idowu, R. T., Tayib, Y. (2017). Community Dynamics of the Fishes and some Aspects of the Limnology of Two West African Reservoirs. *Journal of Fisheries and Life Sciences*, **2**(2), 40- 49.
16. Echoke J. C., Ndana R. W. and Idowu, R. T. (2018) Water Quality Index as a Tool for the Assessment of the Health of Usuma Reservoir, in FCT Abuja Nigeria. *Direct Research. Journal of Public Health and Environ. Technology*, **3**(6), 73-80.
17. Boyd, C. E. (1990). Water Quality Management for Pond Fish Culture. Agriculture Experimental Station, Auburn University, Alabama. 215pp.
18. Adanominu Ja'afar, Marcus (2022). Assessment of the Physicochemical Characteristics of Water in an Urban River in Abuja, Nigeria. *Science World Journal*, **17**(4).
19. Edori, O.S. (2020). Physical and Chemical Characteristics of Water from Ede Onyima Creek, Okarki-Engenni, Rivers State, Nigeria. *Chemistry Research Journal*, **5**(3), 144-154.
20. Ibhadon, S., Idowu, R.T., and Dan-Kishiya, A.S. (2022). Assessment of Some Aspects of the Physicochemical Parameters of Surface Water at Karshi Reservoir (Dam Site), Federal Capital Territory, Abuja, Nigeria. *International Journal of Applied Chemical and Biological Sciences*, **3**(1), 21-30.
21. Ikhuoriah, S. O and Oronsaye, C. G (2016). Assessment of Physicochemical Characteristics and Some Heavy Metals of Ossiomo River, Ologbo. A Tributary of Benin River, Southern Nigeria. *Journal of Applied Science and Environmental Management*, **20**(2), 472-481.

22. Ezeamaka, C. K., Queen, S., Mwanret, D., Moses, O. and Wado, A. T. (2019). Assessing the Pollution Status of Jabi Lake, In FCT, Abuja Nigeria. *Indonesia Journal of Geography*, **51**(3):324-331.
23. Keke, U.N., Arimoro, A.V., Aliyu, S.M. (2015). Physicochemical Parameters and Heavy Metals Content of Surface Water in Downstream Kauna River, Zungeru, Niger State, Nigeria. *Applied Science Research Journal*, **3**(2), 46-57.
24. Edori, O.S. and Aniekan M. U. (2021). Physical and Chemical Characteristics of Water from Okamini Stream, Obio/Akpor, Rivers State, Niger Delta, Nigeria. *GSC Advanced Research and Reviews*, **08**(1): 175-182.
25. Edori, O.S., Kleri, B.S.I. and Festus, C. (2019). Physicochemical Characteristics of Surface Water and Sediment of Silver River, Southern Ijaw, Bayelsa State, Niger Delta, Nigeria. *American Journal of Environmental Science and Engineering*, **3** (2): 39-46.
26. Ali, A., Idowu R.T., Addo S. and Addi, E. (2014). Water Quality Assessment of River Ngadda, Nigeria. Elixir Aquaculture, **76;** 28716-28719.
27. Roy, M., Shamim F. and Chatterjee, S. (2021). Evaluation of Physicochemical and Biological Parameters on the Water Quality of Shilabati River, West Bengal, India. *Water Science*, **35**(1):71-81.
28. FRN (2004). National Water Policy (NWP, 2004).
29. FRN (2011). S. 1. No.22. National Environmental (Surface and Groundwater Quality Control) Regulations, 2011. Federal Republic of Nigeria Official Gazette, **24** May, 2011.
30. Oboh, A. (2022). Diversification of Farmed Fish Species: A Means to Increase Aquaculture Production in Nigeria. *Reviews in Aquaculture* **14**(4).
31. FMEnv. (2021). National Waste Management Policy. Federal Ministry of Environment, Abuja.
32. FMEnv. (2016). National Policy on the Environment. Federal Ministry of Environment, Abuja.
33. FMEnv. (2004). Nigeria National Biodiversity Strategy and Action Plan. Federal Ministry of Environment, Abuja. **82pp**.
34. FMEHUD (2008). Report of the First National Environment Summit on Greening the Environment for Sustainable Economic Development, Abuja. **20-21** October, FMEHUD. 198pp.
35. FMEnv. (2021). National Policy on Climate Change. Department of Climate Change. Federal Ministry of Environment, Abuja. **80pp**.

Annexure

Table 1. Ranges, Mean Variations and P-values (ANOVA) of Physicochemical parameters in River Wuye (Dec. 2019 - Nov. 2020)

	PARAMETERS (UNITS)	RANGE (MIN-MAX) + SD	MEAN	p-value (stations)	p-value (months)	p-value (seasons)	WHO LIMITS (12)
1	Water Temperature (^{0}C)	23.40±0.10-29.40±0.08	25.31±1.56	0.123	0.000^b	0.000^b	<40
2.	Turbidity (NTU)	4.07±0.08-313.00±0.15*	40.08±58.94*	0.508	0.000^b	0.047^b	<25
3.	Dissolved Oxygen (mg/l)	5.13±0.04-9.05±0.04	7.21±1.02	0.163	0.000^b	0.026*	5.0-7.0
4.	Biochemical Oxygen Demand (BOD)mg/l	1.50±0.00-5.86±0.00	3.54±1.20	0.058	0.000*	0.647	3.0-6.0
5.	pH	6.00±0.00-7.80±0.00	7.27±0.29	0.716	0.084	0.032^b	6.0-9.0
6.	Electrical Conductivity (µS/cm)	51.50±0.05-386.00±0.00*	168.72±75.66	0.062	0.001^b	0.029^b	750
7.	Total Dissolved Solids (mg/l)	31.60±0.00-234.00±0.04	101.80±45.73	0.158	0.001^b	0.028^b	600
8.	Total Alkalinity (mg/l)	20.00±0.02-640.00±0.11*	117.81±151.49*	0.879	0.000^b	0.188	100
9.	Total Hardness (mg/l)	16.00±0.00--1200.00±0.15*	155.89±233.13*	0.870	0.000^b	0.091	100
10.	Chloride (mg/l)	13.80±0.00-423.44±0.11*	68.17±103.30	0.987	0.000^b	0.023^b	300
11	Phosphate-Phosphorus (mg/l)	0.38±0.00-32.40±0.12*	8.99±4.50*	0.334	0.206	0.741	0.8-5.0
12.	Nitrate Nitrogen (mg/l)	1.10±0.00-165.40±0.05*	21.77±34.68*	0.296	0.000^b	0.055	9.1
13.	Salinity (mg/l)	0.30±0.00-0.40±0.00*	0.36±0.03*	0.38	0.130	0.539	0.3
14.	Manganese (mg/l)	0.20±0.00-21.00±0.02*	2.72±3.53*	0.094	0.004^b	0.127	0.5

* WHO limit exceeded ^{b}P-value significant

Table 2. Mean Variations in Stations Sampled in River Wuye (Dec. 2019 – Nov. 2020)

	STATION 1		STATION 2		STATION 3		STATION 4			
	RANGE(Min-Max)	MEAN	RANGE (Min-Max)	MEAN	RANGE(Min-Max)	MEAN	RANGE(Min-Max)	MEAN	GRAND (MEAN)	WHO LIMITS (12)
Water Temp. ^{0}C	23.4-28.8	25.1±1.61	23.6-28.8	25.36±1.56	23.5-28.6	25.2±1.54	24.2-29.4	25.58±1.56	25.31±1.56	**<40**
Turbidity (NTU)	4.07-51.1*	16.22±12.09	7.3-293*	43.46±80.19*	7.99-313*	46.35±85.75*	7.8-218*	54.28±63.97*	40.08±58.94*	**<25**
DO (mg/l)	5.49-8.88*	7.33±0.92*	5.66-8.92*	7.17±0.96*	5.13-9.05*	7.18±1.3*	5.3-8.93*	7.17±1.13*	7.21±1.02*	**5.0-7.0**
BOD (mg/l)	2.38-5.86	3.86±1.14	2-5.6	3.49±1.14	1.5-5.57	3.14±1.35	1.5-5.8	3.67±1.38*	3.54±1.20	**3.0-6.0**
pH	6.4-7.4	6.91±0.38	6.1-7.7	7.33±0.49	6-7.7	7.37±0.49	6.8-7.8	7.47±0.29	7.27±0.29	**6.0-9.0**
EC (µS/cm)	51.5-94.9	65.08±14.24	56-386	204.29±107.29	54.8-380	198.09±103.4	71.9-362	207.42±88.78	168.72±103.71	**750**
TDS (mg/l)	31-57.7	39.52±8.48	33.4-234	121.91±64.39	32.5-232.5	120.93±63.43	42.2-218.3	124.85±53.06	101.8±62.53	**600**
Total Alkalinity (mg/l)	20-440*	78.36±128.31*	22-560*	127.4±156.05*	28-520*	122.55±144.2*	22-640*	142.92±179.26*	117.81±150.09*	**100**
Total Hardness (mg/l)	16-400*	76.96±114.98*	30-1040*	192.28±302.59*	34-600	135.62±166.72*	46-1200*	218.72±349.34*	155.89±250.26*	**100**
Cl- (mg/l)	15.6-322.62*	59.45±93.81	17-342.79*	70.43±98.42	13.8-342.79*	64.1±99.53	14.4-423.44*	75.69±123.99	67.42±101.4	**300**
PO_4-P (mg/l)	4.95-26.1*	13.47±6.76*	0.38-32.4*	11.04±11.2*	0.45-14.94*	5.27±4.13*	0.52-19.53*	6.18±5.37*	8.99±7.91*	**0.8-5.0**
NO_3-N (mg/l)	1.1-11.1*	8.49±2.78	4-165.4*	25.77±48.2*	3-141.8*	25.85±44.43*	1.2-147.5*	26.99±47.07*	21.77±39.83*	**9.1**
Salinity (mg/l)	0.3-0.3	0.3±0	0.3-0.4*	0.37±0.05*	0.3-0.4*	0.38±0.05*	0.3-0.4	0.38±0.04*	0.36±0.05*	**0.3**
Mn (mg/l)	0.2-1.6*	1.15±0.41*	0.3-5.6*	1.72±1.68*	0.5-18.5*	3.79±6.05*	0.2-21*	4.23±7.3*	2.72±4.85*	**0.5**

* WHO limit exceeded

Table 3. Monthly and Seasonal Mean Values of Physicochemical Parameters, Dec., 2019 - Nov., 2020

	Water Temp °C	Turbidity (NTU)	DO (mg/l)	BOD (mg/l)	pH	EC (µS/cm)	TDS (mg/l)	Total Alkalinity (mg/l)	Total Hardness (mg/l)	Cl (mg/l)	PO_4-P (mg/l)	NO_3-N (mg/l)	Salinity (mg/l)	Mn (mg/l)
Dec-19	24.48±0.25	15.68±4.98	7.75±0.13*	4.44±0.22	7.38±0.65	151.28±65.91	90.73±39.31	58.50±24.46	46.50±20.49	18.82±1.36	14.92±12.23*	7.70±2.28	0.38±0.05*	1.23±0.26*
Jan-20	23.68±0.36	12.21±5.36	7.81±0.21*	4.57±0.27	7.45±0.24	199.90±92.27	120.03±55.48	71.00±30.04	68.00±27.47	17.75±1.83	13.82±12.52*	4.23±2.16	0.38±0.05*	1.20±0.18*
Feb-20	24.85±0.25	12.56±5.92	5.71±0.54	2.47±0.70	7.50±0.20	189.13±88.55	115.78±53.62	67.75±28.39	62.55±26.00	24.25±19.31	4.75±2.47	6.35±2.63	0.38±0.05*	1.18±0.15*
Mar-20	28.90±0.35	12.75±5.90	5.70±0.56	2.21±0.37	7.55±0.10	191.05±89.68	117.20±54.30	69.40±28.97	65.68±26.36	16.05±1.55	4.62±2.48	6.50±2.53	0.38±0.05*	1.23±0.18*
Apr-20	27.40±0.14	54.10±40.06*	6.48±0.46	1.98±0.46	7.40±0.34	303.75±144.86	184.30±88.22	86.03±38.01	92.00±41.69	35.78±13.11	5.86±7.85*	5.55±3.06	0.38±0.05*	1.29±0.17*
May-20	26.68±0.15	59.65±42.29*	7.26±0.38*	2.13±0.54	7.25±0.57	295.23±135.60	176.80±80.65	71.00±27.54	92.50±44.40	50.60±25.88	6.86±12.83*	4.58±3.69	0.38±0.05*	1.33±0.34*
Jun-20	25.53±0.25	38.78±22.86	6.29±0.85	3.05±0.82	7.35±0.38	169.63±78.96	101.43±47.10	58.50±33.64	69.00±18.87	30.63±1.61	9.34±2.65*	28.68±16.98*	0.38±0.05*	2.55±2.36*
Jul-20	24.73±0.22	218.78±119.03*	7.97±0.19*	4.54±0.65	6.70±0.75	70.93±21.42	43.55±15.02	27.00±5.77	34.50±8.06	21.66±4.40	9.25±10.65*	4.50±3.66	0.33±0.05*	1.18±0.21*
Aug-20	24.15±0.34	11.62±5.04	8.18±0.47	3.49±0.38	6.70±0.26	78.65±10.70	46.95±6.71	28.50±2.52	53.00±6.22	28.75±0.70	17.17±2.48*	115.60±72.63*	0.30±0.00	10.61±10.61*
Sep-20	24.15±0.19	23.79±12.67	8.95±0.07*	5.71±0.14	7.15±0.19	80.98±6.26	48.58±3.65	34.50±7.90	40.00±6.53	23.79±2.13	11.34±0.77*	66.63±39.76*	0.30±0.00	9.78±8.20*
Oct-20	24.55±0.17	9.83±1.86	7.62±0.09*	4.39±0.14	7.40±0.43	136.58±65.83	82.03±39.82	540.00±83.27*	810.00±372.92*	357.91±44.71*	2.99±1.45	4.68±2.55	0.35±0.06*	0.30±0.14
Nov-20	24.63±0.13	11.20±4.13	6.86±0.44	3.53±0.86	7.40±0.40	157.58±72.64	94.28±42.12	301.50±53.24*	437.00±195.73*	192.09±23.16	6.96±2.98*	6.29±2.01	0.38±0.05*	0.81±0.22*
DRY /S	25.48±2.04	13.30±5.01	6.74±1.10	3.42±1.15	7.47±0.32	182.84±75.75	110.93±45.80	66.66±24.77	60.68±23.41	19.22±8.99	9.53±9.13*	6.19±2.43	0.38±0.04*	1.21±0.17*
WET/S	25.23±1.15	53.47±77.15*	7.45±0.93*	3.60±1.27	7.17±0.48	161.66±113.05	97.24±68.06	143.38±175.55*	203.50±291.41*	92.65±114.85	8.72±7.07*	29.56±46.31*	0.35±0.05*	3.48±5.73*
WHO Limits (12)	**<40**	**<25**	**5.0-7.0**	**3.0-6.0**	**6.0-9.0**	**750**	**600**	**100**	**100**	**300**	**0.8-5.0**	**9.1**	**0.3**	**0.5**

Table 4. Correlations between Physico-chemical Parameters for River Wuye (Dec 2019 - Nov 2020)

		Water Temp °C	Turbidity (NTU)	DO (mg/l)	BOD (mg/l)	pH	EC (µS/cm)	TDS (mg/l)	Total Alkalinity (mg/l)	Total Hardness (mg/l)	Cl (mg/l)	PO_4P (mg/l)	NO_3 -N (mg/l)	Salinity (mg/l)	Mn (mg/l)
Water Temp. °C	Pearson Correlation	1													
	Sig. (2 tailed)														
Turbidity (NTU)	Pearson Correlation	.983*	1												
	Sig. (2 tailed)	0.02													
DO (mg/l)	Pearson Correlation	-0.75	-0.79	1											
	Sig. (2 tailed)	0.25	0.21												
BOD (mg/l)	Pearson Correlation	0.85	0.89	-.982*	1										
	Sig. (2 tailed)	0.15	0.11	0.02											
pH	Pearson Correlation	0.56	0.66	0.95	0.90	1									
	Sig. (2 tailed)	0.44	0.34	0.05	0.10										
EC (uS/cm)	Pearson Correlation	0.72	0.75	-.996**	.969*	0.93	1								
	Sig. (2 tailed)	0.28	0.25	0.00	0.03	0.07									
TDS (mg/l)	Pearson Correlation	0.73	0.77	-.999**	.976*	0.94	.999**	1							
	Sig. (2 tailed)	0.27	0.23	0.00	0.02	0.06	0.00								
Total Alkalinity (mg/l)	Pearson Correlation	0.82	0.89	.952*	.977*	0.93	0.92	0.94	1						
	Sig. (2 tailed)	0.18	0.11	0.05	0.02	0.07	0.08	0.06							
Total Hardness (mg/l)	Pearson Correlation	.955*	.987*	-0.87	0.95	0.77	0.84	0.86	.950*	1					
	Sig. (2 tailed)	0.05	0.01	0.13	0.05	0.23	0.16	0.14	0.05						
Cl (mg/l)	Pearson Correlation	.952*	.987*	-0.87	0.95	0.77	0.84	0.85	.952*	1.000**	1				
	Sig. (2 tailed)	0.05	0.01	0.13	0.05	0.23	0.16	0.15	0.05	0.00					
$PO^{4-}P$ (mg/l)	Pearson Correlation	-0.03	0.03	0.64	0.48	0.74	0.67	0.66	0.45	0.19	0.1 8	1			
	Sig. (2 tailed)	0.97	0.97	0.36	0.52	0.26	0.33	0.34	0.55	0.81	0.8 2				
NO_3 -N (mg/l)	Pearson Correlation	0.81	0.90	0.74	0.82	0.75	0.68	0.70	0.91	0.92	0.9 2	0.10	1		
	Sig. (2 tailed)	0.19	0.10	0.26	0.18	0.25	0.32	0.30	0.09	0.08	0.0 8	0.90			
Salinity (mg/l)	Pearson Correlation	0.76	0.83	-.980*	.979*	.965*	.959*	.969*	.990**	0.91	0.9 1	0.57	0. 85	1	
	Sig. (2 tailed)	0.24	0.17	0.02	0.02	0.03	0.04	0.03	0.01	0.09	0.0 9	0.43	0. 15		
Mn (mg/l)	Pearson Correlation	0.91	.96*	0.85	0.93	0.80	0.81	0.83	.962*	.988*	.990**	0.19	.967*	0.92	1
	Sig. (2 tailed)	0.09	0.03	0.15	0.07	0.20	0.19	0.17	0.04	0.01	0.0 1	0.81	0. 03	0.08	