Monitoring and Exploring the Spatio-temporal Variation of Physico-chemical Parameters of River Hadejia, Nigeria; Using Statistical Approach

Maryam Babangida Adam¹, Jibrin Gambo²* and Edegbene A. Ovie¹

¹Department of Biological Sciences, Faculty of Natural and Applied Sciences, Sule Lamido University, Kafin Hausa, Nigeria.
²Department of Foundation Courses and Remedial Studies, School of General Studies, Binyamin Usman Polytechnic, Nigeria.

Authors’ contributions

This work was carried out in collaboration among all authors. Author MBA performed the project work and the statistical analysis. Author JG designed the first draft of the manuscript, create study area map, provided support, guidance toward the completion of the project while author EAO supervised the entire work, field data collection, laboratory and technical assistance. All authors read and approved the final manuscript.

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ABSTRACT

This study is aimed at assessing the ecological health condition of River Hadejia. The specific objectives are to; determine the monthly variation of the Physico-chemical parameters of River Hadejia. The physicochemical analysis carried out on the water samples are: pH, temperature, Electrical Conductivity, TDS, Turbidity, Nitrate, Phosphate, DO, BOD, Transparency, Depth and flow velocity which were determined by standard methods. The results of Physico-chemical parameters obtained were subjected to ANOVA using statistical package software, the mean conductivity values range between (104-127 μS/cm). Nitrate in this study ranged from 0.04–0.80 mg/l and Station 3 had the highest nitrate value. The mean turbidity values obtained from the water samples of River Hadejia ranges from 124.56±11.06-149.52±23.11. Moreover, the temperature of...
INTRODUCTION

Water Physico-chemical parameters are important factors capable of exerting influences on the species diversity and composition of freshwater ecosystems [1]. The water surface temperature is the most important parameter which controls in-born physical qualities of water. The mean air and surface water temperatures obtained are typical of African tropical rivers. Similar observation was also reported by [2,3] in some selected river in southern Nigeria. Water physico-chemistry describes the physical and chemical characteristics of the aquatic ecosystem. Human activities such as agriculture, domestic and industrial wastewater discharges, environmental engineering, and natural factors including geology and soils, hydrology, seasonal patterns, geomorphology, climate and weather can heavily influence water physico-chemistry [4]. Changes in water physico-chemicals by natural processes and human activities can adversely affect ecosystem structure and function. Water physico-chemical monitoring is the traditional approach to controlling pollution and managing water quality [4,5]. It helps water-resource managers to measure and analyse the concentrations of pollutants, determine their fate and transport, as well as their persistence in the aquatic environment [6].

Temperature is one of the most important and essential parameters of aquatic habitats because almost all the physical, chemical and biological properties are governed by it [1,7]. pH, is a measure of the concentration of hydrogen ions in the water or a measure of how acidic or basic it is on a scale of 0 to 14, with 7 being neutral [8]. Naturally occurring fresh waters have a pH range between 6.5 and 8.5. The pH of the water is important because it affects the solubility and availability of nutrients, and how they can be utilized by aquatic [9,10]. Conductivity of natural water is a measure of its ability to convey an electric current. Specific conductivity can be utilized as a rapid measurement of dissolved solids and is useful in monitoring rivers and conducting field water quality studies [11]. The level of conductivity in water gives a good indication of the amount of joinable substances dissolved in it, such as phosphate, nitrate and nitrates. Different ions vary in their ability to conduct electricity, but generally, conductivity of the natural water is directly proportional to the concentration of ions. Distilled water has a conductivity of about 1 ions/cm, while natural water normally has conductivity of 20-1500 µs/cm [11,12]. Depth is a very important factor in aquatic environment. The amount of oxygen varies with depth. Due to reduction in wind actions and amount of light as depth increases, oxygen content is low; with increase in depth goes increase in pressure, diminished light and fall in temperature, hence the oxygen content decreases with depth of water [13]. Transparency of water is an important factor determining the depth at which light, essential for photosynthesis, can penetrate. Secchi disk transparency is essentially a function of the reflection of light from its surface and is therefore influenced by the absorption characteristics both of the water and of its dissolved and particulate matter [14].

Turbidity is caused by the presence of suspended matter in water, clear water has low turbidity, and light can penetrate to a greater depth below the water surface in less turbid water. The adverse effects of turbidity on freshwaters include decreased penetration of light, hence reduced primary and secondary production [15].

Total dissolved solids indicate organic and inorganic matter in a sample. It is aggregated amount of the entire floating suspended solids present in water sample. The solids may be organic or inorganic in nature depending upon volatility of the substances [16]. A high of dissolved solids increases the density of water affects osmo-regulation of fresh water organisms, reduces solubility of gases and utility of water for drinking, irrigational and industrial purposes [17]. Dissolved Oxygen (DO) has primary importance in natural water as limiting factor because most organisms other than anaerobic microbes diminish rapidly when oxygen levels in water falls to zero, of all dissolved gases, oxygen plays the most important role in determining the potential
biological quality of water. It is essential for respiration, helps the breakdown of organic detritus and enables completion of biochemical pathways [18]. Phosphorus is one of the most important major nutrients that are required by living organisms [14]. Phosphorus enters rivers as inorganic phosphate ions, inorganic polymer and organic phosphorus compounds in living micro-organisms and dead detritus. Some organic forms of phosphorus are relatively unreactive and would not be detected by analyses for phosphates [19,20].

Nitrate-nitrogen is required in aquatic and terrestrial ecosystem in a moderate quantity. Nitrate ion (NO$_3^-$) is the common form of nitrogen in natural waters. Nitrite (NO$_2^-$) will oxidize into nitrate after entering an aerobic regime. The amount of nitrate in solution at a given time is determined by metabolic processes in water; that is production and decomposition of organic matter [21]. Biological oxygen demand (BOD) is a measure of the oxygen used by micro-organisms to decompose waste. There is a large quantity of organic waste in water supply, there will also be a lot of bacteria present working to decompose waste [22]. In case, when the BOD levels are high, dissolved oxygen (DO) levels decrease because the oxygen that is available in water is being consumed by bacteria, since less dissolved oxygen is available in the water, fish and other aquatic organisms may not survive [1].

2. MATERIAlS AND METHODS

2.1 Study Area

Hadejia River is located in Hadejia Local Government Area, Jigawa State, Nigeria, the River is located on Latitude (12°13’ – 13°60’ N and Longitude 9°22’ – 11°00’ E). It is a tributary of the lake chad [23]. The Hadejia River splits into three channels in the Hadejia-Nguru Wetland (HNW): the Marma Channel which flows into Nguru Lake, the Old Hadejia River which joins up with the Jama'are River to become the Yobe River and the relatively small Burum Gana River. The total annual rainfall of Hadejia area is about 600 mm [24]. Most of the flow in the Hadejia River system is controlled by Tiga Dam and Challawa Dam [25,26].

2.2 Sampling Stations

For this study, three (3) well marked stations were selected based on their distant and level of anthropogenic activities. The three stations were:

- Station one (1) Aguyaka (Latitude 12.439020° N and longitude 10.076621°E), have been characterized with human activities such as bathing, farming, fishing and transportation.
- Station two (2) BakinGada (Latitude 12.440571°N and longitude 10.031040E), also been disturbed with human activities and their resident.
- Station three (3) MahucinSarki (Latitude 12.437004°N and longitude 10.041218°E), was characterized with activities such as open defacations, bathing, washing, heavy farming activity along the river bank.

2.3 Physicochemical Analysis

The physicochemical analysis carried out on the water samples included the pH, temperature, Electrical Conductivity, Total Dissolved Solids (TDS), Turbidity, Nitrate, Phosphate, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Transparency, Depth and flow velocity which were determined by standard methods [27]. The Transparency, depth, temperature and Flow velocity were determined and recorded immediately at the site.

2.4 Determination of Physico-chemical Parameters of the River

2.4.1 Temperature

The temperature of water at each sampling station was determined using mercury in glass thermometer dipped for 2-5 minutes in the water at a depth of 5 cm on each sampling day, while for the air temperature the thermometer was hold at each station and the readings were recorded appropriately [27].

2.4.2 Flow velocity

A table tennis ball was used to measure the rate of water flow per second using the formula: Velocity =D (m)/T (sec) where D = Distance, T = Time.

Two fixed points were chosen and a table tennis ball was dropped at a point upstream at each station and the time it took the ball to reach a predetermined point was noted. The time taken was used to divide the distance covered. This exercise was repeated three times in each sampling station and the average was taken as the velocity of the water at the stations [27].
2.4.3 Depth

The depth of water at each sampling station was measured using a rod stick. The rod stick was immersed in water until it touched the substratum. The reading was taken using tape and recorded in meters [27].

2.4.4 Transparency

Transparency of water at each station was determined using a 20 cm diameter Secchi disc attached to a calibrated line lowered into the water and the depth at which it disappeared was noted. It was then raised gradually until it reappeared. The depth was also noted. The Secchi disc reading in centimeters was then taken as the mean depths of disappearance on lowering and reappearance on hauling the disc [27].

2.4.5 Water pH

The pH of the water was measured using battery operated pH meter (Model HANNA HI98107). pH meter was calibrated according to instructional manual provided by the manufacturer before measurement.

2.4.6 Turbidity

The turbidity of the water samples was measured using a turbidity meter. Each sample was poured in the sample holder and kept inside for few
minutes. After achieving the reading stability, the value was recorded in Nephelometric Turbidity Units (NTU) [27].

2.4.7 Electrical conductivity and total dissolved solids

These were determined using the conductivity meter of model (EC800), by connecting the adapter of the meter to the power supply, then the electrode of the conductivity meter was rinsed with distilled water and it was allowed to dry, and then it was submerged into a sample. The readings for conductivity were recorded appropriately in µS/cm and for TDS were recorded in mg/L using manual guide as a reference.

2.4.8 Phosphate-phosphorus

This was determined by using Stannous Chloride Method [27]. To 100 ml of the water samples, 2 drops of stannous Chloride was added, after that, 1 ml of Deniges reagent (i.e. 5 g of HgO in 20 ml of Conc. Sulfuric acid and 100 ml of distilled water) was added. It was mixed and allowed to stand for 10 min. The absorbance at 600 nm was measured with Spectrophotometer Model S257, using distilled water as blank. The PO₄-P Concentration of the water sample was read by using the formula

\[ X = \frac{Y}{0.076} \times \frac{V_1}{V_2} \]

Where
- \( X \) = Concentration of Phosphate-Phosphorus,
- \( Y \) = UV (observances),
- \( V_1 \) = Volume of sample used,
- \( V_2 \) = Total volume of all reagent mixed.

2.4.9 Nitrate-nitrogen

One hundred (100 ml) of water sample was poured into a crucible, evaporated to dryness, and cooled. The 2 ml of phenoldisulphoric acid was added in to the crucible, after 10 minutes, 10 ml of distilled water was added followed by 5 ml of strong ammonia solution. Absorbance of this sample was taking using a spectrophotometer Model 257 at the wave length of 430 nm, absorbance of the sample treated was obtained in triplicate and distilled water as blank [27]. The concentration of Nitrate-Nitrogen was determined using this equation below.

\[ X = \frac{Y}{0.074} \times \frac{V_1}{V_2} \]

Where
- \( X \) = Concentration of Nitrate-Nitrogen,
- \( Y \) = UV (observances),
- \( V_1 \) = Volume of sample used,
- \( V_2 \) = Makeup volume (distilled water)

2.4.10 Dissolved oxygen

The dissolved oxygen (DO) was determined using the Winkler's method [27]. A 250 ml stopper reagent bottle was placed under water. The stopper was removed from the bottle while still in water to fill the bottle and closed again immediately before bringing it out from the water. 2 ml of winkler solution was added to the water sample below the surface. The stopper was replaced and the contents of the bottle mixed rapidly by inverting the bottle several times. It was transported to the laboratory for further analysis. In the laboratory 2 ml of magnesium chloride solution was added to 100 ml of water sample, 1 ml concentrated sulphuric acid was added down the neck of the bottle and mixed well by inverting the bottle several times to dissolve the precipitate. Then 100 ml of the sample was transferred into a 250 ml conical flask and then titrated with 0.0125N of sodium thiosulphate (Na₂S₂O₃·5H₂O) solution to a pale straw yellow colour. Two millilitres of freshly prepared starch solution was added and the colour changed to blue Titration was continued by adding the thio-sulphate, drop wise, until the blue colour disappeared. The final volume of thiosulphate used was noted and used for DO calculation as volume of oxygen in mg/L [28]. The DO is calculated using following formula;

\[ DO = \frac{V \times N(D) \times 1000}{\text{Volume of sample used (ml)}} \]

Where:
- 1000= is constants,
- \( V \) =Volume of Na₂S₂O₃ used in titration and 
- \( N(D) = \) Normality of the titrant (0.025).The resultant volume was expressed in mg/L.

2.5 Data Analysis

The mean and standard deviation for each physico-chemical parameters are calculated per station using PAST statistical package. One way analysis of variance (ANOVA) was used to obtain the differences among sampling stations and month at probability level of 0.05. To analyze the traits-based community reactions at the three sampled stations over the study period, macroinvertebrate taxa at each station were gathered together resulting in taxon-station
information for the five months. The abundance of each trait class within each station was transformed into relative abundance (Tamanova et al., 2008). Microsoft Excel was used to draw all the graphs of physico-chemical parameters monthly variation and macroinvertebrates relative abundance. The non-parametric Kruskal-Wallis multiple comparison test was used to test for significant differences between the stations for each trait class. A cluster analysis based on Bray-Curtis similarity was used to explicate the pattern of traits combination among the macroinvertebrate taxa, and box plot was then used to envisage the variation of the relative abundances of macroinvertebrates in each trait cluster across the three sampled station. Cluster analysis, Kruskal-Wallis test and box plot were performed using PAST statistical package [29].

3. RESULTS AND DISCUSSION

Dissolved Oxygen (DO) levels of 0.25 to 6.39 mg/L in this study were similar to 1.20 to 9.40 reported by [30] in Ibibikuma River and Ibuya River in Old national park, Sepeteri. The lowest value was observed station 1 of November and the highest was also recorded in station in the month March. The decrease in DO value observed at some points may be due to discharge of organic wastes at such periods, which led to biological respiration and decomposition processes, which in turn reduced the concentration of DO in water bodies. This was agreed with the findings of [9] who reported that water with high organic or inorganic pollution may contain very little oxygen in them.

Biological oxygen demand (BOD) values indicate the level of organic pollution in water quality [31]. In this study the values of BOD range between 7.08 mg/L-4.19 mg/L. According to [15,32], classified using BOD of river as follows: unpolluted (BOD<1.0 mg/l), moderately polluted (BOD between 2-9 mg/l) and heavily polluted (BOD > 10.0 mg/l i.e. it indicates organic matter is present and bacteria are decomposing this waste). From this classification, it can be interpreted that the Hadejia River is somehow unpolluted or moderately polluted.

Conductivity measures the total ionic composition of water and the overall chemical richness. The conductivity of water is a useful and accessible indicator of its salinity or total salt content [32]. From this present study, the mean conductivity values range between (104-127 μS/cm) showed a reflection of much amount of dissolved ions which showed that the river is somewhat polluted. This result is in contrast with a similar report by [2,33] in Warri River, Delta State, Nigeria. They recorded a conductivity value of 45.5 – 1735 μS/cm which showed that the river is heavily polluted. Similarly, in other part of Africa, [34] reported a conductivity value range of 105 – 1200 μS/cm which was in consonant with this present study in Hadejia River.

Nitrate and phosphate are indicators of organic pollution [35]. Their main source in a river system is through organic residue of plants and animals and sewage fertilizer. Nitrate associated with algae growth and eutrophication and concentration of inorganic nitrogen greater than 0.3 mg/l can cause algae growth in abundance and also reached high level. Nitrate in this present study ranged from 0.04 – 0.80 mg/l and Station 3 had the highest nitrate value probably due to increases of significant farming activities around the station. This range recorded compares favourably with similar investigation carried out by [33] in Orogodo River, Delta State. Phosphate value recorded in this study conforms favourably with similar research by [2] in Orogodo River, Delta State. Contrarily, an organically impacted stream. Meanwhile, phosphates concentrations low value this could be attributed to the impact of anthropogenic activities in the River.

The mean turbidity values obtained from the water samples of River Hadejia ranges from 124.56±11.06-149.52±23.11. This is exceedingly higher than the SON recommended guideline value of 5 NTU. Turbidity levels are dependent on the amount of suspended particles present in the water. Water turbidity is very important because high turbidity is often associated with higher level of disease-causing microorganisms such as bacteria and other parasites [36]. The increase in mean values of the turbidity of the River Hadejia is an indication of pollution which enhances the increase in the number of pathogens. Transparency values recorded during this research (11.45±8.26-12.99±11.48) were within the range reported by [37] who stated that the recommended range for transparency is between 11.0 cm-108.5 cm for productive waters.

3.1 Physicochemical Characteristics

Sampling stations and physicochemical parameters variation are shown in Table 1. All the physicochemical parameters used in this
study shows no significance difference among sampling stations (P>0.05), while between the months pH, Biological Oxygen Demand, Nitrates, Air Temperature, Total Dissolved Solids, Depth, Electrical Conductivity, and Transparency shows significant difference among sampling month (P<0.05) and Phosphate, Turbidity, Flow velocity, Dissolved Oxygen, and Water Temperature shows no significance differences among sampling month (P>0.05). However, Water Temperature, Phosphate, Flow velocity, Dissolved Oxygen and Turbidity shows no significant different among both sampling months and stations (P>0.05). There are significance differences between the pH, Biological Oxygen Demand, Nitrates, Air Temperature, Total Dissolved Solids, Depth, Electrical Conductivity, and Transparency among sampling months (P<0.05), but shows no significance difference among sampling stations (P>0.05). The mean surface water temperature values among the sampling stations show that there are no significant differences between all the stations. But significant difference was observed among the sampling months with mean surface water Temperature values of 22.67ºC, 20.00ºC, 19.67ºC, 14.33ºC and 14.33ºC in November, December, January, February, and March respectively at 95% level of significance, p-value (P>0.05). Air temperature shows no significant difference among all the sampling stations and months at 95% level of significance (P>0.05). The mean value of water pH in station 1, station 2 and station 3, were not found to vary significantly that is there is no significant differences between them. There is no significant difference in pH among the sampling months of November, December, January, February, and March. The mean value of Total Dissolved Solids shows no significant difference at 95% level of significant in all the stations (1). There was significant difference in TDS observed among all the study months at 95%level of significance. There was no significant difference in DO between all the sampling stations and the Months at 95% level of significant. Statistically no significant difference was observed in BOD between the stations 1, 2 and 3 at 95% level of significance while between the Months significant variation was observed in BOD as presented as well as there is no significant variation in Phosphate between the all the stations and months at 95% level of significance. Also no significant difference was observed in Nitrate among all sampling stations, there was significant variation in Nitrate between the Months at 95% level of significance. There was no significant difference in the mean values of Depth observed among all the sampling stations at 95% level of significance. Between the months there was significant different observed at 95% level of significance. Statistically no significant difference was observed in transparency among all the stations at 95% level of significance. Also among the months, there was significant difference observed, at 95% level of significance. There was no significant difference in the mean values of Flow velocity observed among all the sampling stations and the Months at 95% level of significance as all indicated in Table 1.

3.2 Spatio-temporal Variation of Physicochemical Parameters in Hadejia River

3.2.1 Water temperature

The mean surface water temperature among the stations ranged from 18.60ºC, 18.00ºC and 18.00ºC in station 2, 3 and 1 respectively. Station 2 has the highest mean value of 18.60ºC followed by station 3 and station 1 which has the lowest mean value. At the month of November there is an increase in the mean values of surface water temperature but, decreases during the month of January and February as shown in Fig. 2.

3.2.2 Air temperature

The mean values of air temperature ranged from 23.80ºC, 23.60ºC and 21.00ºC in station 1, 3 and 2 respectively. The highest mean value of Air temperature was observed in station 1 followed by station 3 and then station 2. The highest air temperature mean value was observed in the month of January and the lowest mean value of air temperature was observed in the month of February as shown in Fig. 3.

3.2.3 Water pH

The measure of hydrogen ion concentration (pH) mean values of Hadejia River ranged from 8.18 in station 1, 7.64 in station 2 and 7.48 in station 3. There is an increase in pH values during the month February, but the mean values of pH decreases during the month of November as shown in Fig. 4.

3.2.4 Total Dissolved Solid (TDS)

The concentration of total dissolved solids of Hadejia River during the period of study was found to range from 69.02 mg/L, 67.92 mg/L and 64.46 mg/L in station 3, 2, and 1 respectively.
The highest mean value was observed in station 3 and 2 in December followed then station 1 in November, also there are fluctuations in Total Dissolved Solids values during the month of November, December, January, February and March in station 3, as shown in Fig. 5.

**Table 1. Mean values of physicochemical parameter of the study stations of Hadejia River (from November 2018 to March 2019)**

| Parameters               | Station 1              | Station 2              | Station 3              | Months F-value | Stations P-value |
|--------------------------|------------------------|------------------------|------------------------|----------------|------------------|
| Water Temperature (°C)   | 18.00±4.30             | 18.60±2.96             | 18.00±3.94             | 40.77          | 0.01             |
|                          | (13.00-23.00)           | (15-22.00)             | (14.00-23.00)          |                | 0.04             |
| Air Temperature (°C)     | 23.80±3.63             | 21.00±2.35             | 23.60±2.88             | 4.91           | 1.36             |
|                          | (20.00-28.00)           | (19.00-25.00)          | (20.00-26.00)          |                | 0.29             |
| pH                       | 8.18±0.59              | 7.64±0.94              | 7.48±0.37              | 5.13           | 1.47             |
|                          | (7.4-9.0)              | (6.2-8.7)              | (7.1-8.1)              |                | 0.27             |
| Transparency (cm)        | 11.45±8.26             | 12.99±11.48            | 11.74±8.44             | 37.89          | 0.00             |
|                          | (1.85-19.00)           | (1.30-29.00)           | (1.25-20.00)           |                | 0.04             |
| Depth (m)                | 1.03±0.16              | 0.81±0.25              | 1.05±0.13              | 4.24           | 2.55             |
|                          | (0.89-1.30)            | (0.59-1.23)            | (0.91-1.25)            |                | 0.12             |
| Dissolved Oxygen (DO) (mg/L) | 3.00±2.41             | 1.99±2.00              | 2.12±2.63              | 3.00           | 0.07             |
|                          | (0.46-5.93)            | (0.30-5.21)            | (0.25-6.39)            |                | 0.27             |
| Biological Oxygen Demand BOD (mg/L) | 0.29±4.39             | -0.21±4.08             | -0.62±3.86             | 60.99          | 0.00             |
|                          | (-7.08-3.68)           | (-6.85-3.95)           | (-6.49-4.19)           |                | 0.66             |
| Total Dissolved Solids (TDS) (mg/L) | 64.46±5.36             | 67.92±5.80             | 69.02±5.04             | 4.17           | 0.03             |
|                          | (57.80-70.70)          | (63.40-76.60)          | (64.70-77.30)          |                | 0.97             |
| Nitrate (mg/L)           | 0.46±0.26              | 0.55±0.25              | 0.46±0.33              | 5.59           | 0.01             |
|                          | (0.14-0.73)            | (0.26-0.75)            | (0.04-0.80)            |                | 0.18             |
| Phosphate (mg/L)         | 0.77±0.29              | 0.88±0.12              | 0.77±0.38              | 3.04           | 0.07             |
|                          | (0.25-0.97)            | (0.72-1.00)            | (0.12-1.10)            |                | 0.28             |
| Electrical Conductivity (µS/cm) | 114.20±6.66             | 112.66±7.31             | 113.86±8.56             | 12.16          | 0.00             |
|                          | (108.40-125.40)         | (105.50-124.80)         | (104.00-127.00)         |                | 0.06             |
| Flow Velocity (m/s)      | 0.21±0.16              | 0.25±0.12              | 0.26±0.09              | 2.29           | 0.13             |
|                          | (0.12-0.49)            | (0.13-0.46)            | (0.13-0.35)            |                | 0.24             |
| Turbidity (NTU)          | 149.52±23.11           | 124.56±11.06           | 124.98±18.28           | 2.09           | 1.60             |
|                          | (124-179.3)            | (111.6-139)            | (102-147)              |                | 3.09             |
|                          |                        |                        |                        |                | 0.08             |

Note: Values are means± standard deviation, Maximum and minimum values in parenthesis

![Fig. 2. Water temperature variations among three sampling stations of Hadejia River](image)
3.2.5 Dissolved Oxygen (DO)

The mean surface values of DO ranged from 3.00 mg/L, 2.12 mg/L, and 1.99 mg/L in station 1, 2, and 3 respectively. Station 3 in March had the highest mean value, followed by station 1 in November then station 2 in March as shown in Fig. 6.
3.2.6 Biological Oxygen Demand (BOD₅)

The mean value of biological oxygen demand of Hadejia River ranged from 0.29 mg/L, 0.21 mg/L and 0.62 mg/L in station 1, 2 and 3 respectively, as shown in Fig. 6. Station 3 and 2 in March has the highest BOD value followed by station 1 also in January and March, as shown in Fig. 7.

3.2.7 Phosphate

The mean values of Phosphate in Hadejia River ranged from 0.88 mg/L, 0.77 mg/L and 0.77 mg/L in station 2, 1 and 3 respectively. Station 3 in February has the highest Phosphate value followed by station 2 in November and then station 1 in March and also there is drop in Phosphate observed in station 1 and 3 in November as shown in Fig. 8.

3.2.8 Nitrate

Nitrate concentration of Hadejia River ranged from 0.55 mg/L in station 2, 0.46 mg/L in station 1 and 0.46 mg/L in station 3, as shown in Fig. 8, station 1 and 3 has the same mean values of 0.46 mg/L. The highest mean value was observed in station 3 in February and March followed by station 2 in November and 3 March as shown in Fig. 9.

3.2.9 Depth

The mean value of Depth in Hadejia River during the period of study was found to range from 1.05 m, 1.03 m, and 0.81 m in station 3, 1 and 2 respectively. The highest value observed in station 1 in November, followed by station 2 and 3 in November while station 2 in February had the lowest value of depth value as shown in Fig. 10.

3.2.10 Transparency

The mean values of transparency in Hadejia River ranged from 12.99 cm, 11.74 cm and 11.45 cm in station 2, 3 and 1 respectively. Station 2 in November has the highest mean transparency value followed by station 2 in November then station 1 and 2 also in November and the lowest was observed in all three stations in January. There is an increase in transparency mean value in November and fall in January, as shown in Fig. 11.

3.2.11 Flow velocity

The mean values of Flow velocity air temperature ranged from 0.26ms⁻¹, 0.25 ms⁻¹ and 0.21 ms⁻¹ in station 3, 2 and station 1 respectively. The highest mean value of Flow Velocity was observed in station 3, followed by station 2 and then station 1. The highest Flow Velocity value was observed in the month of December in station 1, then followed by in January in station 2 and then December in Station 3 as shown in Fig. 12.

3.2.12 Electrical conductivity

The mean values of Electrical conductivity ranged from 114.20±6.66 in station 1, 113.86±8.56 in station 3 and 112.66±7.31 in station 2. The highest Electrical conductivity value was recorded in December (127µS/cm⁻¹) in station 3, followed by station 1 also in December and then lowest value was recorded in February (104µS/cm⁻¹) in station 3 as shown in Fig. 13.

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Fig. 6. Dissolved oxygen variations among three sampling stations of Hadejia River
Fig. 7. Biological oxygen demand variations among three sampling stations of Hadejia River

Fig. 8. Phosphate variations among three sampling stations of Hadejia River

Fig. 9. Nitrate variations among three sampling stations of Hadejia River
3.2.13 Turbidity (NTU)

The mean values of Turbidity ranged from 149.52±23.11 in station 1, 124.98±18.28 in station 3 and 124.56±11.06 in station 2. The highest Turbidity was recorded in December (179.3NTU) in station 1 then followed by 147NTU in station 3 of January and the lowest was recorded in November (102NTU) in station 3 as shown in Fig. 14.

Fig. 10. Water depth variations among three sampling stations of Hadejia River

Fig. 11. Transparency variations among three sampling stations of Hadejia River

Fig. 12. Flow velocity variations among three sampling stations of Hadejia River
4. CONCLUSION

The physicochemical parameters of River Hadejia varied significantly over temporal time and reveals that the water were polluted as was indicated with having high values of electrical conductivity, Turbidity and low values of Nitrates and dissolved oxygen. It is obvious that the level of anthropogenic activities around the river Hadejia and its tributaries has contributed to the change of physicochemical parameters and thus disabling the efficiency and utilization of river water for domestic purpose. Nevertheless, others parameters were within tolerable limits of WHO standard.

5. RECOMMENDATIONS

Based on the investigation undertaken in this study, the following are recommended for managing freshwater resources of River Hadejia.

1. It is recommended that the usefulness of the TBA should be further investigated under different water bodies to assess the health condition of the water and to predict expected communities.
2. Human activities like washing, bathing, defecation and sewage disposal around the Hadejia River should be prohibited.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.
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