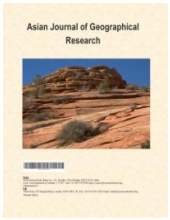

Asian Journal of Geographical Research

3(1): 49-61, 2020; Article no.AJGR.54512
ISSN: 2582-2985

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

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Authors' contributions

This work was carried out in collaboration among all authors. Authors ABM and EAO carried out the field and laboratory work and performed the statistical analyses. Authors ABM and JG designed the first draft of the manuscript. Author JG create study area map while author EAO supervised the entire work. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJGR/2020/v3i130100
Editor(s):
(1) Dr. Xu Chong, Institute of Geology, China.
Reviewers:
(1) Mbadu Zebe Victorine, Democratic Republic of the Congo.
(2) Dorota Porowska, University of Warsaw, Poland.
(3) Qiong Shi BGI Marine, China.
Complete Peer review History: http://www.sdiarticle4.com/review-history/54512

Original Research Article

Received 19 December 2019
Accepted 24 February 2020
Published 06 March 2020

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 physico-chemical analysis carried out on the water samples were: pH, temperature, electrical conductivity, TDS, turbidity, nitrate, phosphate, DO, BOD, TRANSPARENCY, Depth and flow velocity and they were determined by standard APHA methods. The results of Physico-chemical parameters obtained were subjected to ANOVA using statistical package software, the mean electrical 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 Hadejia River varied from 13ºC to 28ºC. The highest temperature

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was in November at Station 1 while the lowest was recorded in February at station 1. The study was able to elucidate the effect of anthropogenic activities of the water quality of the River Hadejia.

Keywords: Variability; assessment; water-quality; river; statistics; Nigeria.

1. INTRODUCTION

Water Physico-chemical parameters variability in water bodies had both negative and positive effect on the functional and structural composition and diversity of aquatic biota [1]. Among the various water quality variables used in assessing ecological status of rivers, surface water temperature has a direct effect on the freshwater systems as it depicts the production rate of the system as has be reported by several authors [1,2] in some selected river in the Afrotropic. Other anthropogenic factors such as urbanisation and industrialization resulting in domestic and industrial wastewater discharges and changes in the natural and geological patterns as well as soils and hydrological alteration have a debilitating effect on water physico-chemistry of riverine systems [1,3]. Changes resulting from natural processes due to human activities can adversely affect ecosystem structure and function [1]. Water physico-chemical has been used to assess the health of riverine systems for decades and has been used by aquatic resources managers in managing and sustaining the aquatic systems [3-5].

On the other hand, pH has also been used in complementation of other water physico-chemical characteristics and it measures the concentration of hydrogen ions in the water [6]. Naturally occurring fresh waters have a pH range between 6.5 and 8.5 [2].The solubility and nutrient availability in water systems is determined by pH concentration [7,8]. Aside, pH, another variable such as electrical conductivity conveys the degree of suspended solids in water systems [9,10] and it is an indication of the amount of suspended solids which entails the flow of elctricity in the water body thereby favouring biota that may need electricity for the well being in the aquatic ecosystem.

Furthermore, Depth is another important factor in aquatic environment. The amount of oxygen varies with depth [2]. Increase in depth reduces dissolved oxygen availability in water system and also light penetration reduces with depth increase, this may be consequential to the survival rate of organisms that are benthic in nature [11]. This may cause such organisms to devise a survival mechanism as depth increases.

Other physico-chemical variables such as turbidity, TDS, DO, BOD and nutrients have their deferential roles in sharpening the structural and functional diversity of aquatic biota and reduction in a particular variable may either reduce or increase the concentration of other variables and this goes along way in sharpening the ecological state of riverine systems [12-20]. For instance the higher the DO concentration the lower the concentration of BOD.

Based on the varied importance of physico-chemical variables in aquatic systems, and several studies have been conducted to determine their variation in freshwater systems [2,1,12,13,17] this study was carried out to add to the growing pool of information with regard to monitoring of freshwater systems using physico-chemical variables. Therefore, the aim of this study is to explore the spatio-temporal variation of physico-chemical variables in River Hadejia in a bid to monitor to ascertain the health staus of the river.

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 [21]. 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 [22]. Most of the flow in the Hadejia River system is controlled by Tiga Dam and Challawa Dam [23,24].

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), characterized by 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.
- Station three (3) MahucinSarki (Latitude 12.437004°N and longitude 10.041218°E), was characterized by activities such as open defacations, bathing, washing, heavy farming activity along the river bank.

2.3 Physico-chemical 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 [25]. The Transparency, depth, temperature and Flow velocity were determined and recorded immediately at the site. Water temperature measured insitu using mercury-in-glass thermometer (^{o}C), pH was determine using a pH meter. Water depth was measured using a calibrated stick in meter. Turbidity meter was used in measuring turbidity (NTU) while electrical conductivity was measured using conductivity meter (µS/cm). Transparency and flow velocity were measured using seechi disc (metre) and a timed weighted cork (m/s) respectively. Dissolved oxygen, BOD, phosphate and nitrate were determined according [25] methods.

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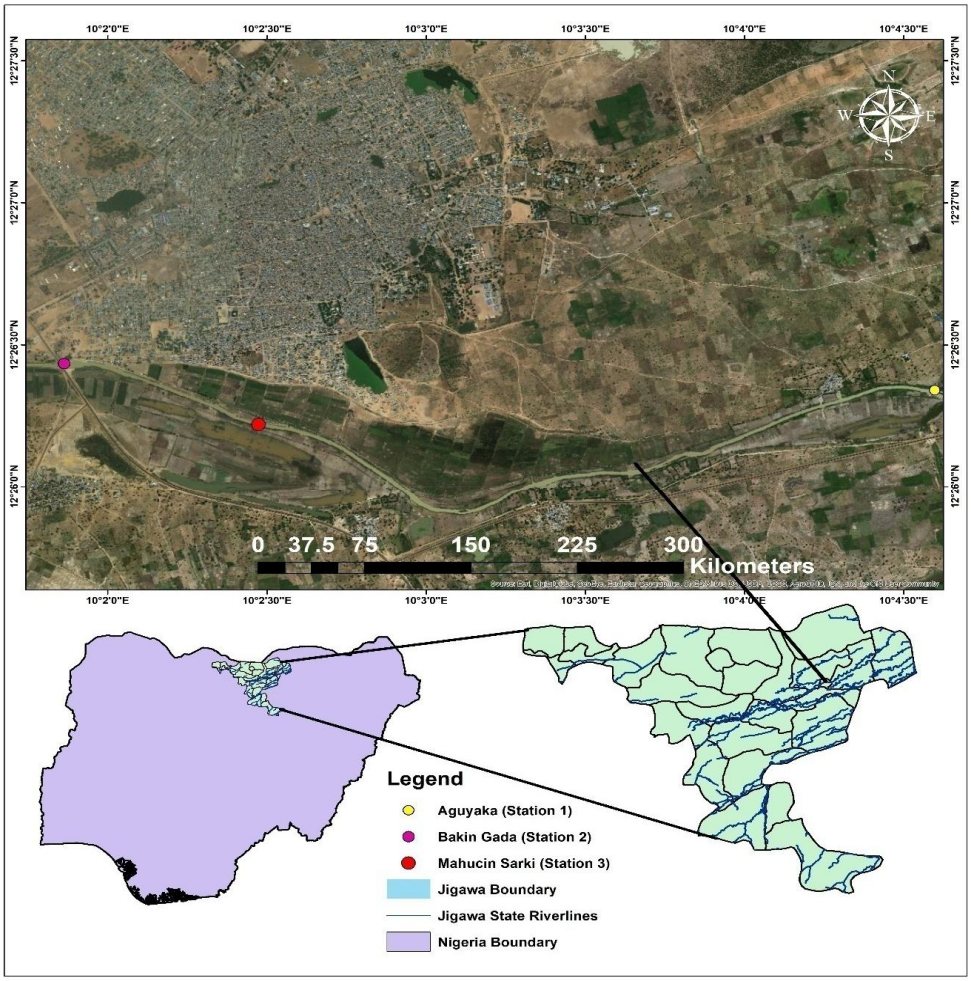

Fig. 1. Map of the study area showing the River Hadejia and sample stations

2.4 Data Analyses

The mean and standard deviation for each physico-chemical variables were calculated per station using PAST statistical package [26]. One way analysis of variance (ANOVA) was used to obtain the differences between sampling stations and months at probability level of 0.05. Microsoft Excel was used to draw all the graphs of physico-chemical variables monthly variation. performed using PAST statistical package [26].

3. RESULTS AND DISCUSSION

Dissolved Oxygen (DO) levels of 0.25 to 6.39 mg/L in this study were similar to 1.20 mg/L to 9.40 mg/L reported by Edokpayi et al. [27] in Ibiekuma River and Ibuya River in Old national park, Sepeteri. The lowest value was observed in Station 1 in November and the highest was also recorded in Station 1 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 may led to biological respiration and decomposition processes, which in turn reduced the concentration of DO in water bodies. This is in consonance with the findings of [7] 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 [28]. In this study the values of BOD range between - 7.08 mg/L-4.19 mg/L. According to several authors [13,28], 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 that organic matter increases bacteria decomposition. From this classification, it can be interpreted that the Hadejia River is moderately polluted.

The conductivity of water is useful and accessible indicator of water salinity or total salt content [28]. From this present study, the mean conductivity values range between (104-127 µS/cm) which is a reflection of the amount of dissolved ions in the river. This result is in contrast with a similar report by several authors [2,29] 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, [30] reported a conductivity value range of 105 – 1200 µS/cm which is in consonant with this present study in Hadejia River.

Nitrate and phosphate are indicators of organic pollution [30]. Their main source in a river system is through organic residue of plants and animals and sewage fertilizer. Nitrate concentration is associated with algae growth and eutrophication. Nitrate in this present study ranged from 0.04 – 0.80 mg/l and Station 3 had the highest nitrate value probably due to increased farming activities around the station. This range recorded compares favourably with similar investigation carried out by Oluyemi et al. [29] in Orogodo River, Delta State. Phosphate value recorded in this study conforms favourably with similar research by Arimoro et al. [2] in Orogodo River, Delta State.

The mean turbidity values obtained from the water samples of River Hadejia ranges from 124.56±11.06-149.52±23.11. Water turbidity is very important because high turbidity is often associated with higher level of disease-causing microorganisms such as bacteria and other parasites [31].

3.1 Physicochemical Characteristics

Sampling stations and physico-chemical variables 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 difference 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. 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. 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 ($P>0.05$).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 18.60℃, 18.00℃ and 18.00℃ in station 2, 3 and 1 respectively. Station 2 had the highest mean value of 18.60℃ followed by station 3 and station 1 which has the lowest mean value. In 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 station 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 River Hadejia 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 River Hadejia 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 stations 2 and 3 in December followed then station 1 in November, also there was fluctuations in Total Dissolved Solids values during the month of November, December, January, February and March in station 3, as shown in Fig. 5.

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 stations 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 (BOD_5)

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

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		Stations	
				F-value	P-value	F-value	P-value
Water Temperature (°C)	18.00±4.30 (13.00-23.00)	18.60±2.96 (15-22.00)	18.00±3.94 (14.00-23.00)	40.77	0.01	0.04	0.96
Air Temperature (°C)	23.80±3.63 (20.00-28.00)	21.00±2.35 (19.00-25.00)	23.60±2.88 (20.00-26.00)	4.91	0.02	1.36	0.29
pH	8.18±0.59 (7.4-9.0)	7.64±0.94 (6..2-8.7)	7.48±0.37 (7.1-8.1)	5.13	0.02	1.47	0.27
Transparency (cm)	11.45±8.26 (1.85-19.00)	12.99±11.48 (1.30-29.00)	11.74±8.44 (1.25-20.00)	37.89	0.00	0.04	0.96
Depth (m)	1.03±0.16 (0.89-1.30)	0.81±0.25 (0.59-1.23)	1.05±0.13 (0.91-1.25)	4.24	0.03	2.55	0.12
Dissolved Oxygen (DO) (mg/L)	3.00±2.41 (0.46-5.93)	1.99±2.00 (0.30-5.21)	2.12±2.63 (0.25-6.39)	3.00	0.07	0.27	0.77
Biological Oxygen Demand BOD (mg/L)	0.29±4.39 (-7.08-3.68)	-0.21±4.08 (-6.85-3.95)	-0.62±3.86 (-6.49-4.19)	60.99	0.00	0.66	0.94
Total Dissolved Solids (TDS) (mg/L)	64.46±5.36 (57.80-70.70)	67.92±5.80 (63.40-76.60)	69.02±5.04 (64.70-77.30)	4.17	0.03	0.97	0.41
Nitrate (mg/L)	0.46±0.26 (0.14-0.73)	0.55±0.25 (0.26-0.75)	0.46±0.33 (0.04-0.80)	5.59	0.01	0.18	0.84
Phosphate (mg/L)	0.77±0.29 (0.25-0.97)	0.88±0.12 (0.72-1.00)	0.77±0.38 (0.12-1.10)	3.04	0.07	0.28	0.76
Electrical Conductivity (µS/cm)	114.20±6.66 (108.40-125.40)	112.66±7.31 (105.50-124.80)	113.86±8.56 (104.00-127.00)	12.16	0.00	0.06	0.94
Flow Velocity (ms^{-1})	0.21±0.16 (0.12-0.49)	0.25±0.12 (0.13-0.46)	0.26±0.09 (0.13-0.35)	2.29	0.13	0.24	0.79
Turbidity (NTU)	149.52±23.11 (124-179.3)	124.56±11.06 (111.6-139)	124.98±18.28 (102-147)	2.09	0.16	3.09	0.08

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

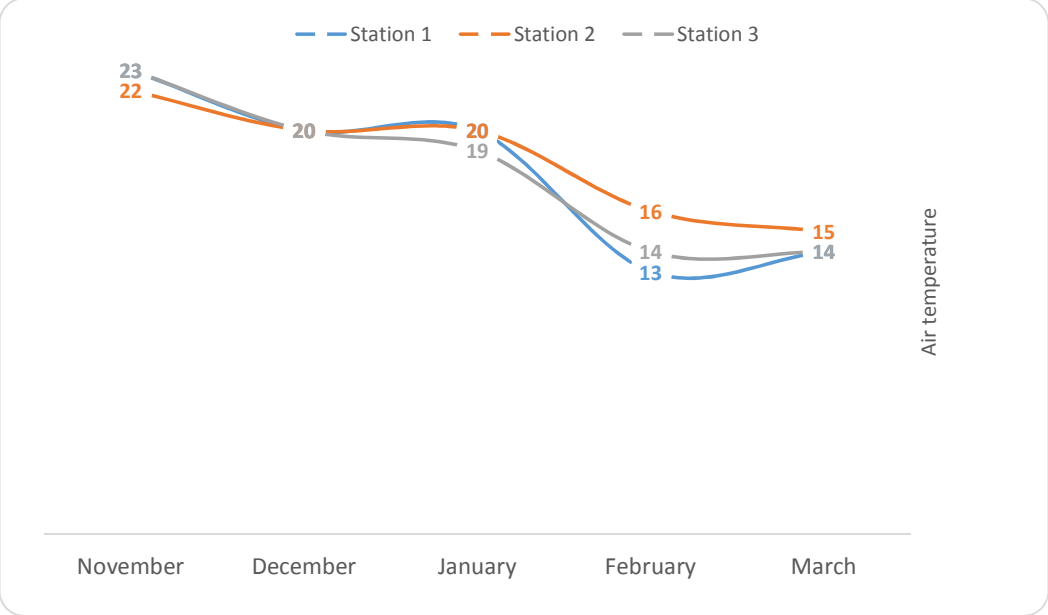

Fig. 2. Water temperature variations among three sampling stations of River Hadejia

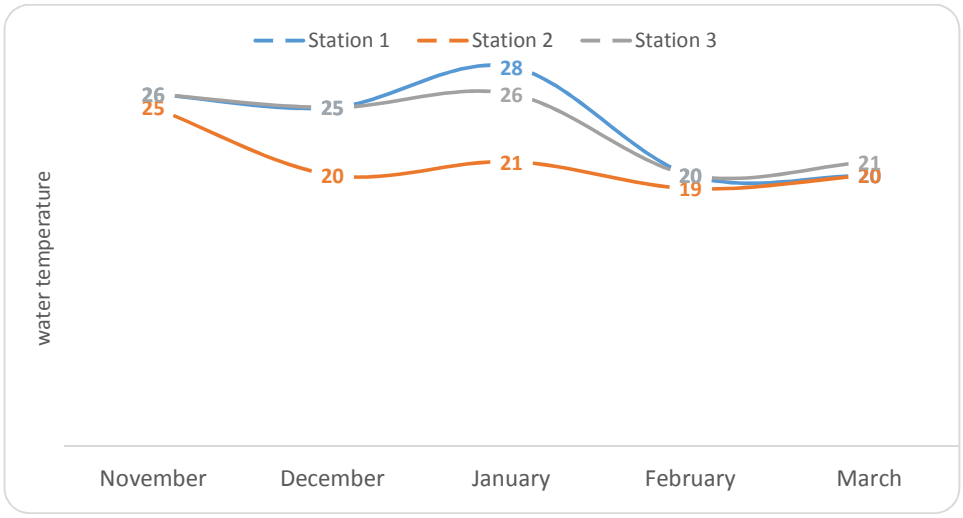

Fig. 3. Air temperature variations among three sampling stations of River Hadejia

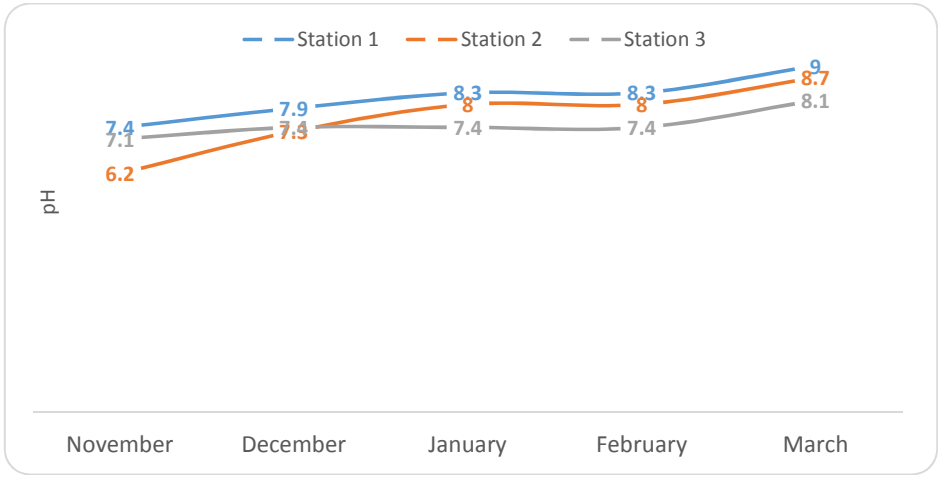

Fig. 4. pH variations among three sampling stations of River Hadejia

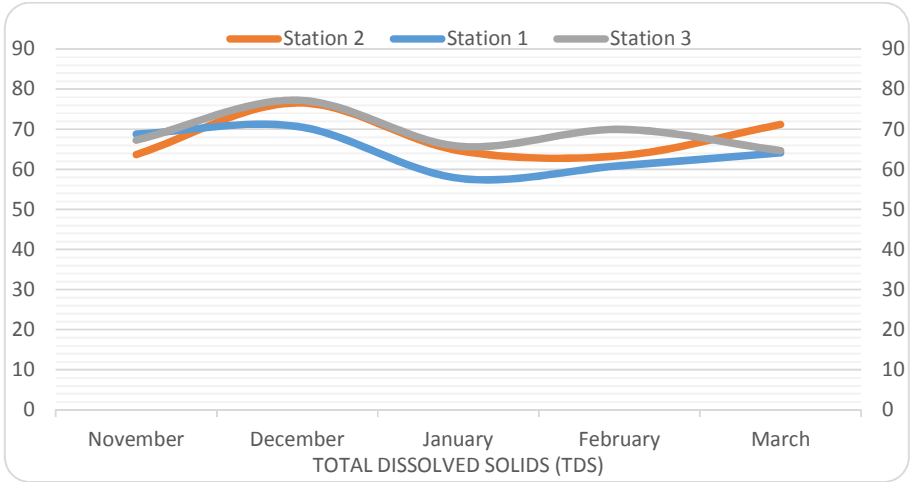

Fig. 5. Total dissolved solutes variations among three sampling stations of River Hadejia

3.2.7 Phosphate

The mean values of Phosphate in River Hadejia ranged from 0.88 mg/L, 0.77 mg/L and 0.77 mg/L in stations 1, 2 and 3 respectively. Station 3 in February had the highest Phosphate value followed by station 2 in November and then station 1 in March. There was a drop in Phosphate in stations 1 and 3 in November as shown in Fig. 8.

3.2.8 Nitrate

Nitrate concentration of River Hadejia 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, stations 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 stations 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 River Hadejia ranged from 12.99 cm, 11.74 cm and 11.45 cm in station 2, 3 and 1 respectively. Station 2 in November had the highest mean transparency value fallowed by station 2 in November then stations 1 and 2 also in November and the lowest was observed in stations 1, 2 and 3 in January. There was an increase in transparency mean value in November as shown in Fig. 11.

3.2.11 Flow velocity

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

3.2.12 Electrical conductivity

The mean values of Electrical conductivity ranged from 114.20±6.66µS/cm^{-1} in station 1, 113.86±8.56µS/cm^{-1} in station 3 and 112.66±7.31µS/cm^{-1} 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.

3.2.13 Turbidity (NTU)

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

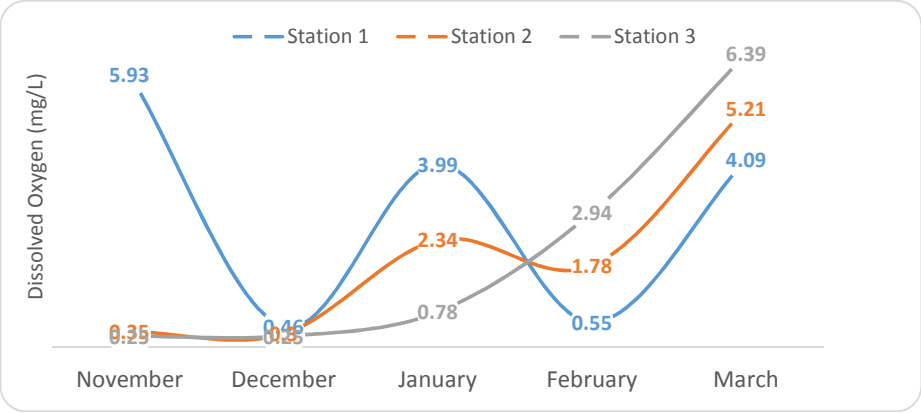

Fig. 6. Dissolved oxygen variations among three sampling stations of River Hadejia

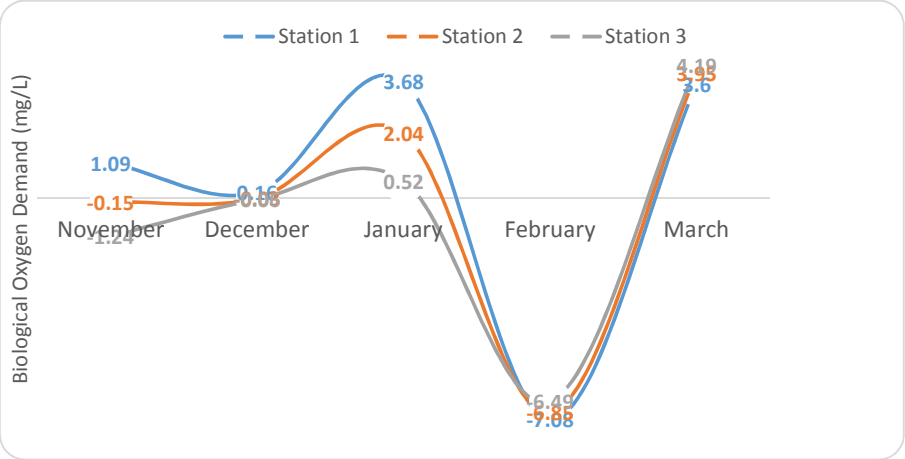

Fig. 7. Biological oxygen demand variations among three sampling stations of River Hadejia

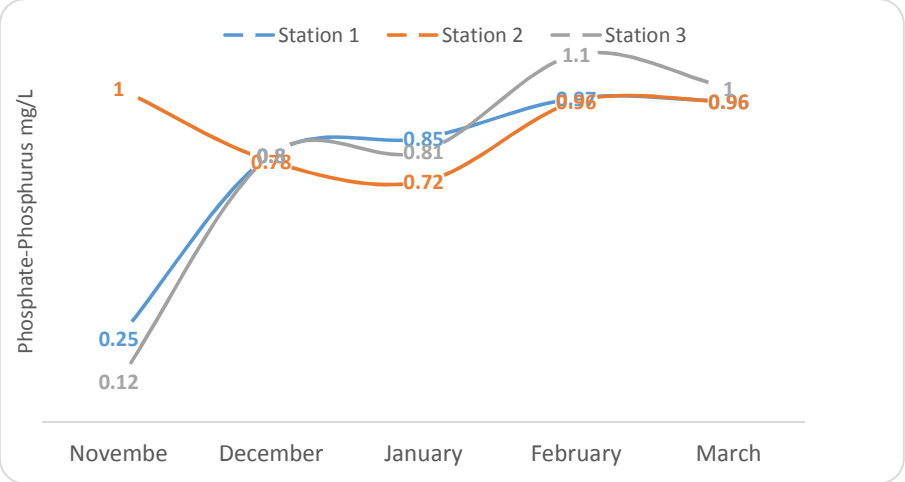

Fig. 8. Phosphate variations among three sampling stations of River Hadejia

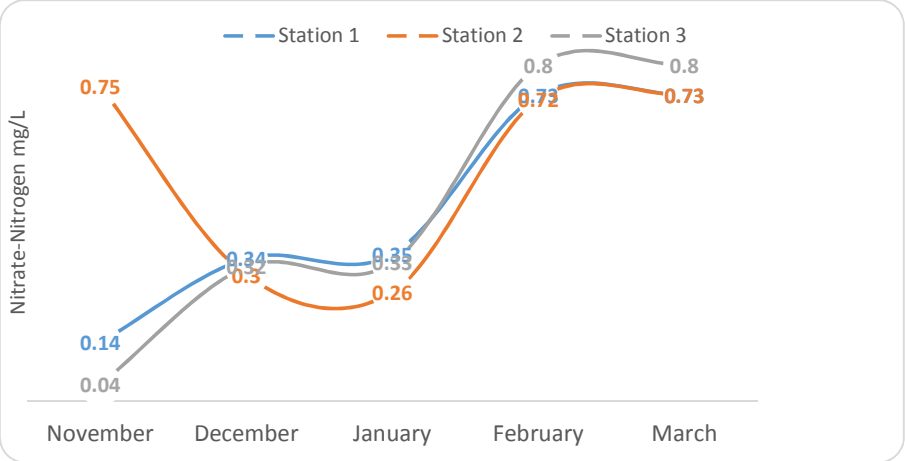

Fig. 9. Nitrate variations among three sampling stations of River Hadejia

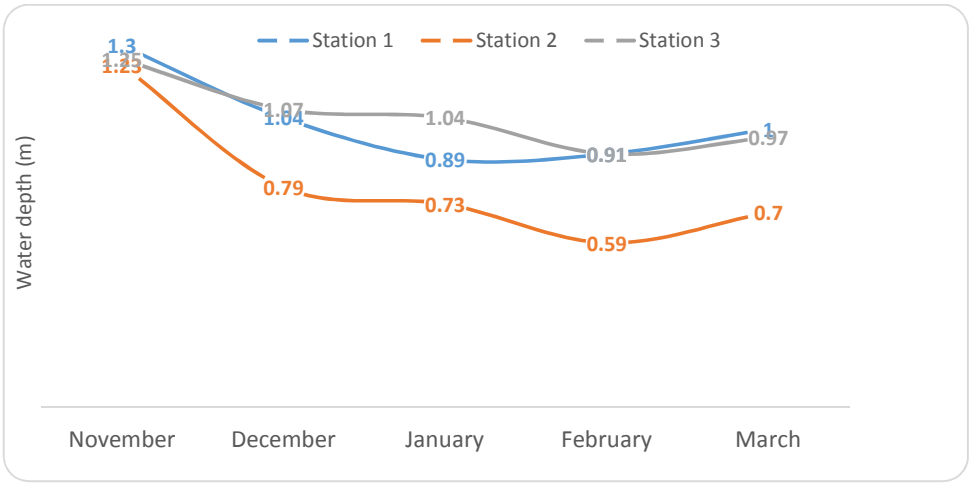

Fig. 10. Water depth variations among three sampling stations of River Hadejia

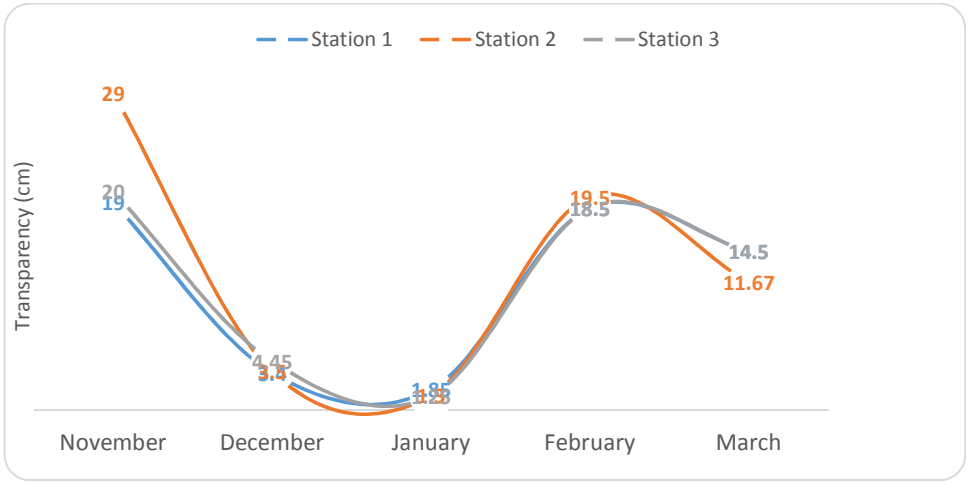

Fig. 11. Transparency variations among three sampling stations of River Hadejia

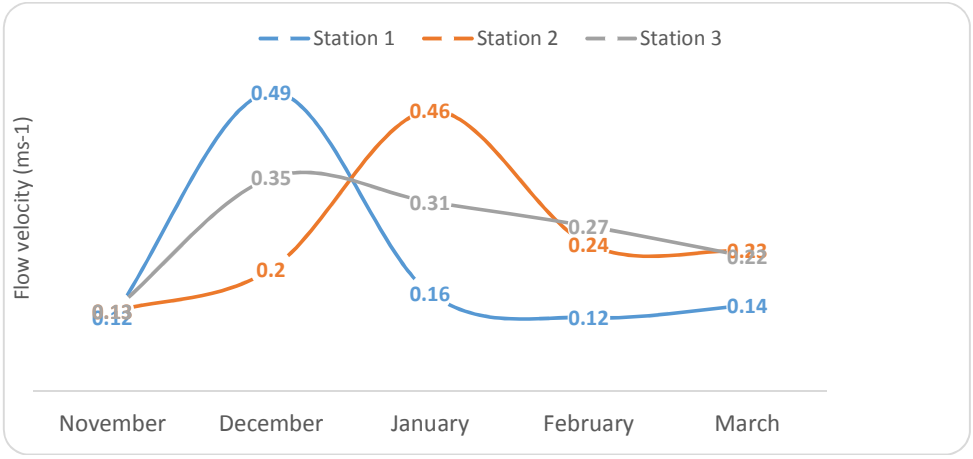

Fig. 12. Flow velocity variations among three sampling stations of River Hadejia

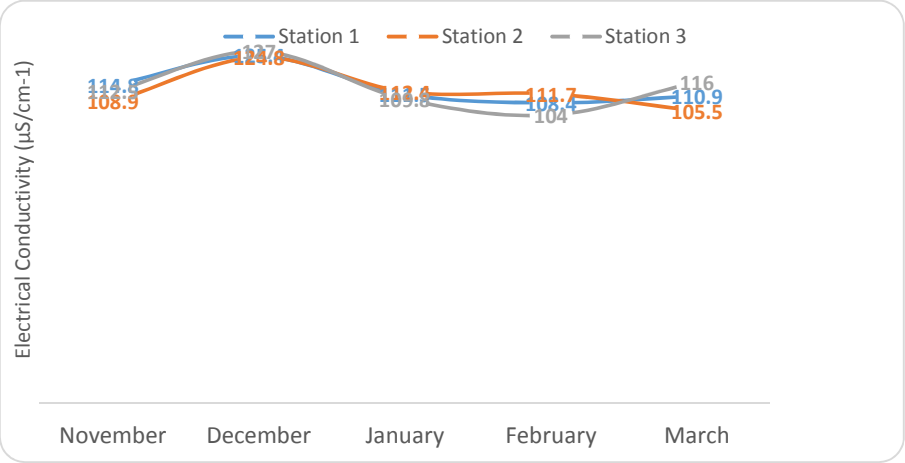

Fig. 13. Electrical conductivity variations among three sampling stations of River Hadejia

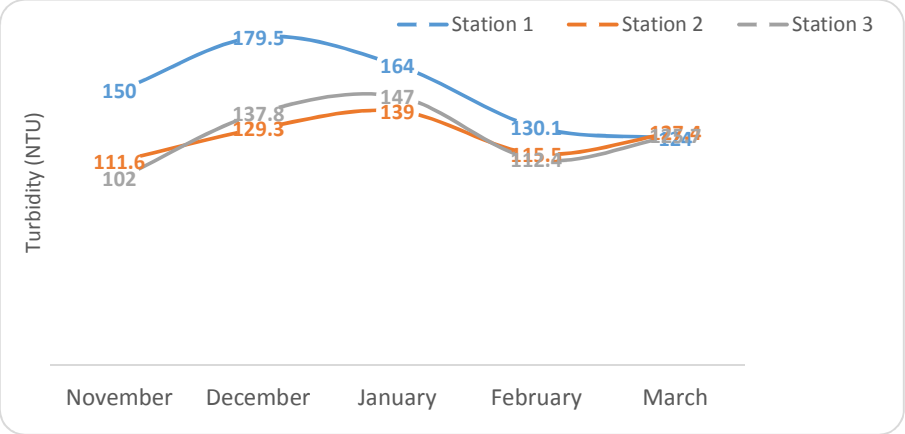

Fig. 14. Turbidity variations among three sampling stations of River Hadejia

4. CONCLUSION

The physico-chemical variables of River Hadejia varied significantly in time and space. The River Hadejia can be inferred to be polluted as indicated by high values of electrical conductivity, Turbidity and low values of and dissolved oxygen recorded in some of the stations sampled. With this, it is obvious that the level of anthropogenic activities around the River Hadejia and its tributaries has contributed to the change of physico-chemical variables and thus could led to disabling the efficiency and utilization of river water for domestic purpose.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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