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Yisa AG
Department of Zoology, Ahmadu Bello University Zaria, Kaduna, Nigeria

Gadzama IMK
Department of Biology, Ahmadu Bello University Zaria, Kaduna, Nigeria

Oniye SJ
Department of Zoology, Ahmadu Bello University Zaria, Kaduna, Nigeria

Babatunde MM
Department of Biological Sciences, Kaduna State University. Kaduna, Nigeria

Correspondence
Yisa AG
Department of Zoology, Ahmadu Bello University Zaria, Kaduna, Nigeria

Temporal and spatial variations in physico-chemical parameters of a small urban stream, Kaduna, Nigeria

Yisa AG, Gadzama IMK, Oniye SJ and Babatunde MM

Abstract
The study was conducted to investigate the effect of anthropogenic activities on Adeyemo stream. Water samples were collected from five different sampling stations along the stream from January 2016 to August 2016, for the determination of physico-chemical parameters on a monthly basis following standard methods. One-way Analysis of variance was employed to establish significant difference in the spatial and temporal variation in physicochemical parameters. Cluster analysis was used to show the similarity of the physico-chemical parameters relative to sampling stations. The physico-chemical parameters; pH, Temperature, Total Dissolved Solids, Electrical Conductivity, Nitrate-Nitrogen, Sulphate, Alkalinity, Hardness, Phosphate-Phosphorus and Dissolved Oxygen varied significantly during the months. There were no significant differences (p>0.05) within the physico-chemical parameters amongst the sampling stations except in the concentration of electrical conductivity and total dissolved solids. Station V was implicated with the lowest conductivity value (128.50 µs/cm) while the highest value (514.25 µs/cm) was at station 4. Total dissolved solid was lowest (66.50 µs/cm) at station 5 while the highest value (255.75 µs/cm) was at station 4. Stations 1, 2, 3 and 4 are more closely associated with respect to the physico-chemical parameters than station 5. DO, nitrate and phosphate were not within the stipulated WHO limits. Attention of the government and concerned agencies towards prompt conservation and restoration of the stream is solicited.

Keywords: Temporal, spatial, physico-chemical parameters, stream

Introduction

Water is an important natural resource. Its distribution and quality is influenced by climate change, topographies and human activities. Water is essential to all aspects of ecosystem biodiversity, human life, including community health, food production and economic vitality [1]. Water is the most essential element for all form of biological activities comprising over 71% of the earth's surface, of which only 3% constitute freshwater which comprises; streams, rivers, lakes, ponds, ice caps and glaciers [2]. Freshwater ecosystems play vital roles in nutrient cycling, primary production, habitat provision and biodiversity maintenance of aquatic flora and fauna [3]. Rivers are waterways of strategic importance for domestic, industrial and agricultural purposes [4].

Important physical and chemical parameters influencing the aquatic environment are temperature, rainfall, pH, dissolved oxygen and carbon dioxide. Others are total suspended and dissolved solids, total alkalinity and acidity and heavy metal contaminants [5]. Studies on the physico-chemical features of water bodies is very important so as to elucidate the extent of pollution and the ecological integrity of water ecosystems [6]. The physico-chemical parameters of a river tells much about its quality and suitability for both humans and survival of the living biota within [6]. Pollution status of water bodies are usually expressed as biological and physicochemical parameters [7].

Freshwater ecosystems have been altered by human disturbances such as agriculture, urban development, impoundment, channelization, mining, forest fire suppression and road construction [8]. All of these have led to severe degradation and loss of biodiversity [9] and as a result aquatic ecosystems have become the most endangered ecosystems on the planet. Disposal of sewage wastes into water bodies could reduce the biological oxygen demand to such a great level that the entire oxygen may be depleted [10]. This may cause the death of aerobic species including fishes. Also inputs of suspended solids to which toxic substances are absorbed; such as soil particles in surface water run-off from fields treated with pesticides affects water quality [11].

Changes in climatic variables relevant to streams include increased air temperature and a general drying of watersheds which may be due to increased air temperatures and higher rates of evaporation which may impair significantly on streams health and dynamics [12].
In order to mitigate the impact human societies have on natural waters, it is important to implement comprehensive monitoring agencies [13]. He posited that this will help quantify water quality, identify impairments and aid policy makers make land use decisions that will not only preserve natural areas, but improve the quality of life. Other authors have also advocated for water quality assessment since water bodies are constantly utilized directly or indirectly by aquatic organisms and by human population [14, 15]. Adeyemo Stream which is historically named River Omo by the settlers around its vicinity, is one of the most useful streams in Kaduna metropolis (Nigeria). Due to the extensive anthropogenic activities around the study area, the study was aimed at assessing the effect of such activities on the physico-chemical properties of the stream. Similar study was carried out before [6].

Materials and methods

Description of the study area

The study was undertaken at Adeyemo stream (River Omo) in Kaduna (Fig. 1). It is located between Lat. 10º 31' 13''N Long. 07º 26' 05''E and Lat.10º 29' 24''N Long. 07º 25' 33''E. The stream is commonly known as River Omo. The stream is one of the tributaries to River Kaduna [6], its source is from Kaduna North Local Government and flows southwards into River Kaduna covering a distance of about 5000 meters. The noticeable anthropogenic features around the stream banks are: Heaps of domestic waste, agricultural activities, mechanic workshops, welders and all sorts of wastes like tires, electrical appliances and litters polythene bags and other rubberized materials. The stream is often used for open defecation.

Sampling Stations

Five sampling stations (1-5) were selected along the stream course. The co-ordinates of the sampling stations were taken using Geographic Positioning System (GPS) and approximate distances of the stations were calculated. Each station is approximately 850m apart from the other and they were selected based on accessibility and the anthropogenic activities. Samples were collected for the period of eight months (January 2016 to August 2016) to cover rainy and dry seasons. Water samples were collected monthly between 7:00 am and 10:00 am.

Station 1: Channeled effluents from a budding abattoir, car wash and run-off from irrigated farms sited along this course is discharged directly into the stream. This station receives allochtonous input of organic matter from the surrounding vegetation, derived through run-offs from the surface of the soil. It is located off Nupe road, (Lat: 10º 31'N Long 07º 26'E) at an elevation of 583m with sandy substratum. At this station there was noticeable emergent vegetation especially during the rainy season. Bank side vegetation is predominantly shrubs, others are *Lufa sp., Isoberlina sp.* Maize, Banana, sugarcane. This river bed is basically coarse sand, and fast flowing, it appears disturbed with eroded macerated bones and hooves of slaughtered animals.

Station 2: There is serious impact of human activities at this station, located off Ibrahim Taiwo Road (10˚ 30'N 07˚ 26'E) at an elevation of 588m with coarse sandy substratum. It receives effluents from mechanic workshops, domestic wastes, heavy deposition of PVC materials such as abandoned tires, nylons, disposables from weddings etc. There is frequent incineration of wastes and heaps of feacal matter of human origin insensitively discharged into the stream at this site. Agricultural activities sited at this station could be an important factor for the streams ill health. The riparian vegetation are that of *Mangifera indica, Zea mays, Lycospersicum esculentus*.

Station 3: Station III appears to be undisturbed compared to stations 2 and 1 however there were noticeable partial damming of the stream with PVC materials, especially during the rainy season, it is located along Constitution road (10˚ 30'N 07 26'E) at an elevation of 590m with sandy substratum. The bankside vegetation cover are: *Luffa sp., Musa sp., Colocasia sp.* and grasses.

Station 4: Station IV receives effluents from mechanic workshops, saloons, hotels and agricultural run-offs. It is located along Kirgo Road, (10˚ 29'N 07˚ 25'E) at an elevation of 566m. The vegetation is composed mainly of trees which form a partial shade over the station, as well as shrubs and grasses (*Lycospersicum. esculentus, Zea mays, Eucalyptus sp.*). The substratum is silt.

Station 5: Station V receives appears to be undisturbed compared to all the four stations (10˚ 29'N 07˚ 25'E) at an elevation of 572m. In this station, the vegetation is composed mainly of trees and shrubs and the substratum is muddy silt with rocks impediments and the only human activity at this station is irrigation farming.

Collection and analyses of water samples

In situ measurements of physicochemical parameters such as: pH, Temperature, Total Dissolved Solids and Electrical Conductivity was determined using portable handheld HANNA instrument model 98129. Other parameters such as: Nitrate - Nitrogen, Sulphate, Alkalinity, Hardness, Phosphate – Phosphorus, Dissolved Oxygen and were determined according to the method described by [16].

Statistical Analyses

Statistical analyses was carried out using SAS V.9.1 (2005) package for One-way Analysis of variance. Cluster analysis was achieved using Paleontological Statistics Software Package (PAST) V.2.17c (2013). Summary statistics (Microsoft 2013).

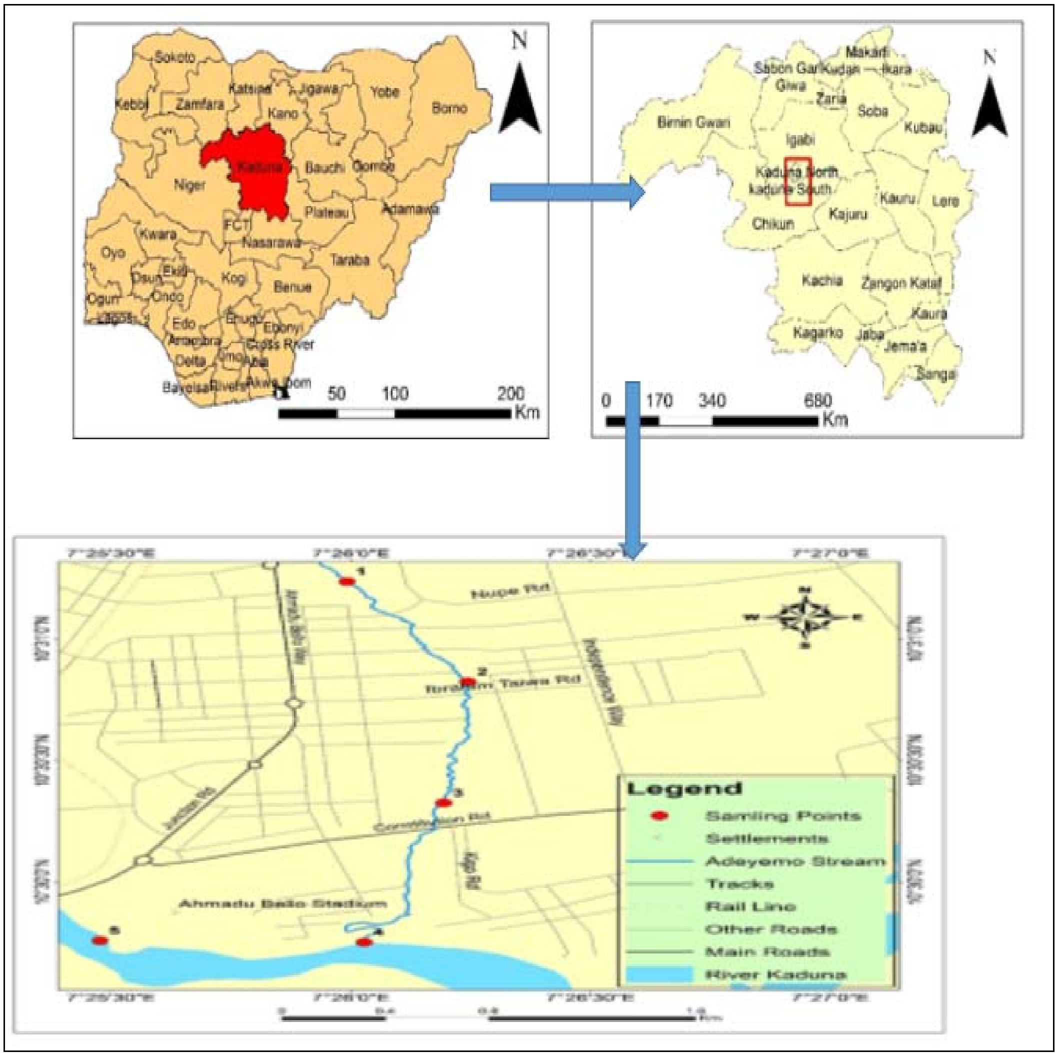

Fig 1: A map of the study area; inset is the map of Nigeria showing Kaduna state

Results

The summary of the physicochemical parameters of the study is presented in Figure 2-4. The eleven physicochemical parameters measured were highly significantly different across the month ($p<0.01$). Electrical conductivity and total dissolved solids were the only parameters to be highly significantly different ($p<0.01$) across the five sampling stations, others were not significantly different ($p>0.05$) as shown in table 1.

The range of pH was from 7.68 – 9.52, the lowest was in July while the highest was observed in August. Station 2 recorded the lowest pH, while the highest value was noted at station 5; (8.29 – 8.61). Temperature was low (18.96 ^{o}C) in January while the highest value (28.12 ^{o}C) was recorded in May. Station wise, temperature ranged from 24.26 ^{o}C (station 4) to 24.74 ^{o}C (station 3). Total dissolved solids was observed to vary from 66.50 – 255.75 mg/l at station 5 and 4 respectively. Low TDS (151.25 mg/l) was recorded in the month of August while April recorded the highest value (225.20 mg/l). Electrical conductivity ranged from 305.00 µs/cm in August to 450.40 µs/cm in May. The lowest value (128.50 µs/cm) of EC was observed at station 5 while station 4 had the highest value (514.25 µs/cm). The range of other parameters are; nitrate 12.40 - 33.40 mg/l with the lowest value in August and highest in January, Station 1 recorded the lowest nitrate concentration (18.00 mg/l) while the highest nitrate concentration (22.75 mg/l) was at station 3. Sulphate ranged from 61.00 (in March) - 228.00 mg/l (July), station wise, sulphate was lowest (138.75 mg/l) at station 4 and highest value (170.00 mg/l) was recorded at station 3. Total alkalinity varied from 26.66 (in February) – 124.60 mg/l (July). Lower concentration (67.96) of total alkalinity was observed at station 5 while higher concentration (98.68 mg/l) was recorded at station 3. Hardness fluctuated from 64.40 - 200.80 mg/l with the lowest and highest observations in July and January respectively, hardness was low (80.25 mg/l) at station 5 and highest (162.89 mg/l) at station 2. Lowest phosphate value (0.66 mg/l) was recorded in January while 2.5mg/l highest value was recorded in February. Station 3 recorded low phosphate value (0.85 mg/l) while high phosphate value was observed at station V to be 1.80 mg/l. Dissolved oxygen (0.82 – 4.25 mg/l) was lowest in February and highest in January, station 5 recorded the highest Dissolved oxygen (2.64 mg/l) and the lowest Dissolved oxygen (1.24) was observed at station 2.

Cluster analysis grouped the five sampling sites into two clusters based on the similarity of their water quality characteristics as shown in figure 2. Stations 1, 2, 3 and 4 showed closed similarity in their physicochemical properties than with station 5. Physicochemical characteristics of stations 3, 4 and 1 are more closely associated than with station 2 (Figure 5).

Discussion

The high pH observed in August may be due to increased photosynthetic activities of aquatic macrophytes and microalgae, which take up carbon dioxide from the water surface during the day time thereby increasing the pH. Similar observations were made by several researchers on Nigerian water bodies in relation to high water pH [17, 18 and 19]. In contrast [6] reported lower pH (6.61) in the same Adeyemo Stream. The pH observed in August was above the maximum peak (9.0) stipulated by [20] for optimal biological activity in an aquatic environment.

The low temperature recorded in January may be related to changes in the air temperature associated with the cool North – East trade winds, known as harmattan, which is associated with decreased sunshine and low incident radiation. The high temperature value in May (wet season) could be due to changes in air temperature and relative humidity [21]. Low temperature during the period of harmattan in Kaduna was attributed to the cooling effect of harmattan wind [22]. Higher (31.68 °C) temperature for dry season than wet season (29.1 °C) was reported in Abia stream, Abia State, Nigeria. This may be due to differences in the ecological zones of the stream and time of sampling [23].

The higher total dissolved solids recorded in April may be attributed to increased ion concentration due to high rate of evaporation associated with dry season months. The low total dissolved solids obtained in August could be attributed to increased dilution factor as a result of increased water volume from the heavy rainfalls in the wet season. Similar observation was reported by [5]. Higher TDS was reported in dry season than in wet season to be 902 mg/l and 1643 mg/l respectively in River Osumi in Berat, Albania which was attributed to the concentration of chemicals from tannery effluent [24]. The low conductivity recorded in August could be attributed to increase in water volume caused by rain water which elicited dilution of the dissolved solids in the stream. Low conductivity was reported in August on River Saye, in Zaria [25]. Low conductivity was also reported on Lagos Lagoon, [26]. High conductivity in dry season as reported by [27] was also attributed to high rate of evaporation as observed in April, in effect, related to increased concentration of ions as water volume decreases. The lowest TDS and EC values recorded at station 5 could be due to increased dilution of the ions after discharge and increased water volume. The highest values of TDS and EC recorded at station 4 may be due to increased ion retention due to run off from inorganic fertilizers from irrigated farms and also due to the accumulated ion load received from the stations upstream.

The high nitrate concentration observed in January may be associated with buildup of nitrate from extensive irrigation activities from farms; the low nitrate value in July is related to high dilution caused by the rains. Similar observation was made by [28] and [29] on Ibadan River in Ibadan, Oyo state, Nigeria and Mvudi River in South Africa respectively.

The high sulphate recorded in July may be due to the decomposition and drains of several plants and animal matter as well as run-off of chemical products such as ammonium sulphate fertilizers from farm lands into the stream. In contrast, [30] obtained lower Sulphate value (103 mg/l) from River Sokoto, Sokoto State, Nigeria. The alkalinity of Adeyemo stream in this study indicates that it has capacity to withstand acidification as waters with low alkalinity are very susceptible to changes in pH while those with high alkalinity have the capacity to resist major shift in pH [31]. High hardness observed in July is also associated with leeching of artificial fertilizer, increased magnesium and calcium ions into the stream which may have originated from farming activities within the immediate catchment area of the stream. Similarly, [32] attributed high hardness to level of anthropogenic activities and nature of bedrock materials. The high phosphate recorded in February could be due to various factors such as decomposition of organic matters, disposal of human and animal wastes and from fertilizers used within the immediate catchment area of the stream. Higher concentration of phosphate in Adeyemo stream was reported in Adeyemo stream [6].

The high dissolved oxygen in January may be attributed to the effect of the North east trade wind (harmattan) and low temperature. The low DO in February is thereby associated with increase in temperature and organic inputs. Factors that work against oxygen retention in tropical waters is due to the poor ability of water to hold oxygen at higher temperature and to the higher rates of microbial metabolism at higher temperature [33]. Higher DO of 7.8 mg/l, 6.47 mg/l and 5.95 mg/l in, Nguru River, Ka'radua River and Garkida River respectively which contrasts the 1.78 mg/l obtained in Adeyemo stream was reported by [34]. The DO (1.78 mg/l) obtained from the present study is below the WHO standard (>5mg/l).

Conclusions

The physico-chemical parameters of Adeyemo stream varied significantly during the study period. Dissolved Oxygen, Sulphate, Phosphate and Nitrate were not within the acceptable limits of WHO and UNEP. All other parameters were within permissible limits. It is evident that the level of human activities around the catchment has contributed to the deterioration of the stream and hence impairing on the streams aquatic productivity and domestic use.

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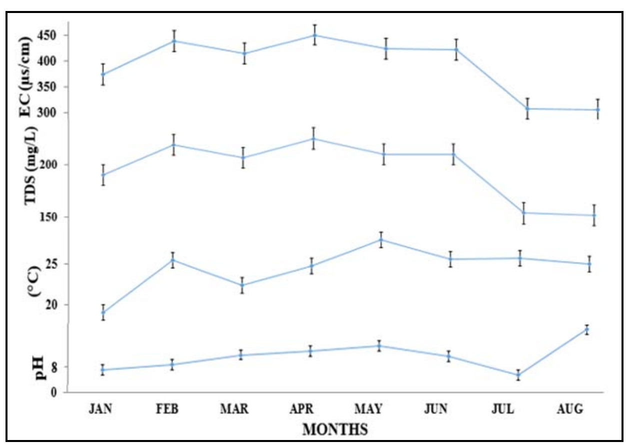
Conflicts of interest

The authors declare that there are no conflicts of interest.



Note: (°C) = Temperature, TDS = Total Dissolved Solids, EC = Electrical conductivity

Fig 2: The mean monthly variation in physical parameters of Adeyemo stream.

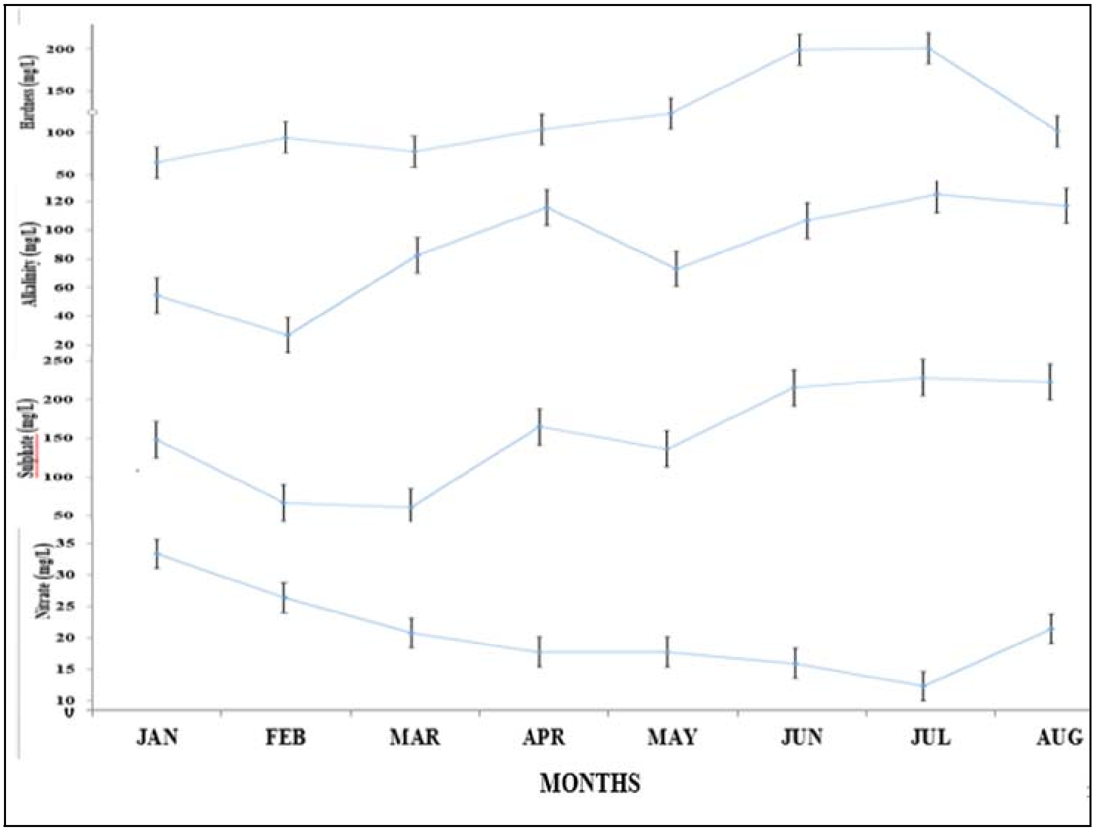


Fig 3: The mean monthly variation in Nitrate, Sulphate, Alkalinity and hardness of Adeyemo stream.

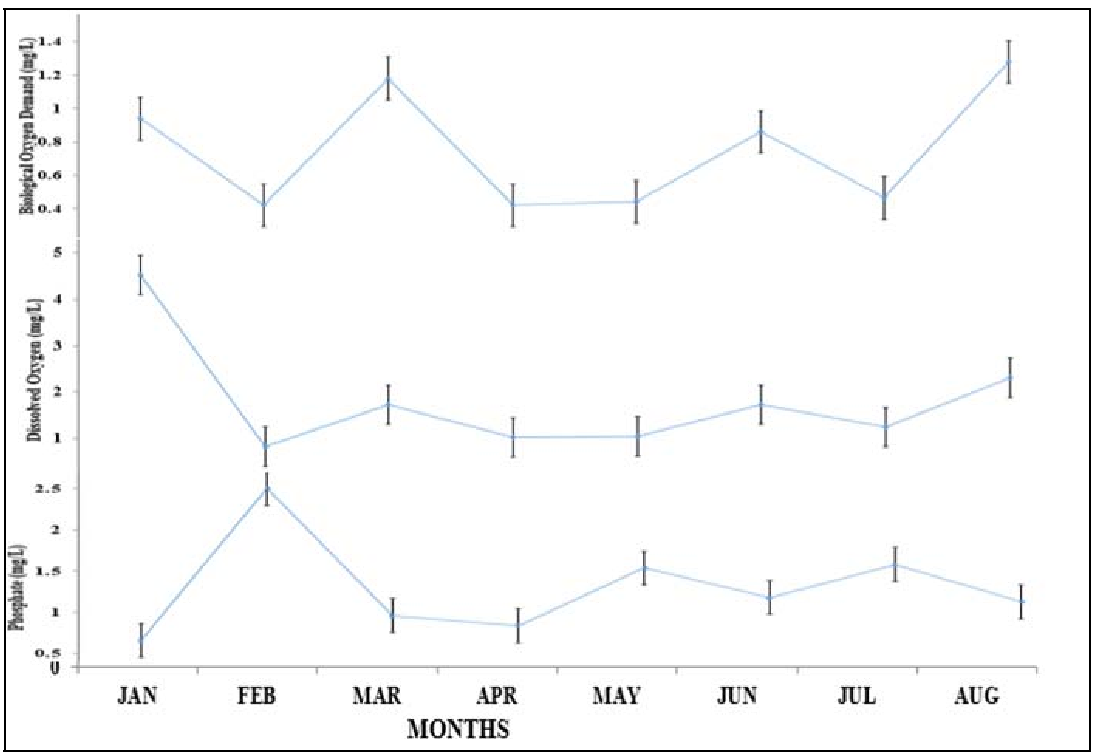


Fig 4: The mean monthly variation in Phosphate, Dissolved Oxygen and Biological oxygen Demand of Adeyemo stream.

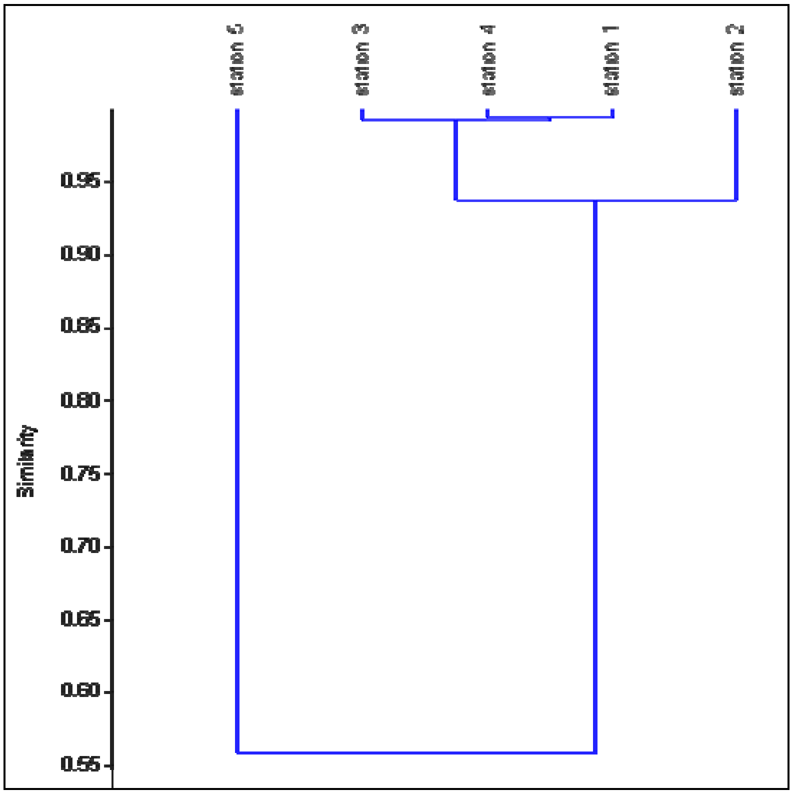


Fig 5: Dendogram of the relationship between the sampling stations relative to physicochemical parameters of Adeyemo stream.

Table 1: Mean values of physicochemical parameters of the five sampling stations of Adeyemo Stream

	STATION 1	STATION 2	STATION 3	STATION 4	STATION 5	Grand Mean	P value	WHO
pH	8.46±0.20	8.29±0.13	8.52±0.32	8.25±0.16	8.61±0.32	8.43±0.11	0.5674	6.5-8.5
TEMP	24.54±1.15	24.36±1.11	24.74±1.02	24.26±0.90	24.63±1.02	24.51±0.44	0.8882	<40
TDS (mg/l)	205.25 ± 9.04^{c}	216.43 ± 19.25^{bc}	242.88 ± 6.71^{ab}	255.75 ± 12.03^{a}	66.50 ± 15.15^{d}	196.87±12.39	0.0001 **	500
Ec (µs/cm)	411.25 ± 18.83^{b}	433.14 ± 38.82^{b}	488.25 ± 13.72^{c}	514.25 ± 23.77^{a}	128.50 ± 29.99^{d}	394.10±25.18	0.0001 **	750
NO_3 -N (mg/l)	18.00±1.91	19.57±2.77	22.75±3.83	21.38±2.35	21.88±2.99	20.74±1.24	0.3376	1
SLPH (mg/l)	152.50±26.00	145.71±25.27	170.00±28.97	138.75±34.29	160.00±39.70	153.59±13.5	0.9145	150
ALK (mg/l)	89.76±14.24	80.94±12.19	98.68±13.12	97.55±15.46	67.96±21.22	87.14±6.92	0.2973	120
HARD	137.50±28.67	162.89±33.97	136.75±41.36	94.25±12.38	80.25±10.96	121.18±12.75	0.1175	300
PO_4 -P (mg/l)	1.30±0.27	1.63±0.28	0.85±0.18	0.98±0.23	1.80±0.57	1.30±0.15	0.1458	0.1
DO (mg/l)	1.50±0.26	1.24±0.50	1.71±0.26	1.76±0.27	2.64±1.04	1.78±0.25	0.1811	5.0-7.0

Note: Means with the same superscript across rows are not significantly different at $p>0.05$, $p<0.01$= highly significant (**)
Key: pH= Hydrogen ion, TEMP =Temperature, TDS = Total Dissolved Solids, EC = Electrical conductivity, NO_3^-N= Nitrate-Nitrogen, SLPH = Sulphate, ALK = Alkalinity, HARD = Hardness, PO_4^-P = Phosphate Phosphorus, DO= Dissolved oxygen.

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