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Assessing the water quality of a rural multipurpose stream, Southeast, Nigeria

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Abstract
The water quality need to be safeguarded in order to sustain the ecosystem services derived from the stream. A rural multipurpose stream in south-eastern Nigeria was assessed between May and October 2021 in 3 stations for suitability to support aquatic life. Eighteen parameters were evaluated using standard methods. One-way ANOVA was used to ascertain significant variation of the parameters in the stations and months. The values recorded were: water temperature (27.2–24.1ºC), pH (6.0–6.6), transparency (21.3–82.1cm), turbidity (0.2–3.2NTU), flow velocity (0.21–0.54m/s), electrical conductivity (40.1–80.1µS/cm), total dissolved solids (201.4–40.2mg/l), dissolved oxygen (3.5–7.5mg/l), biochemical oxygen demand (0.4–2.2mg/l), chemical oxygen demand (0.8–34.4mg/l), phosphate (0.02–0.60mg/l), nitrate (0.07–3.01mg/l), sulphate (0.04–0.33mg/l), chloride (30.9–88.6mg/l), sodium (0.07–0.31mg/l), potassium (0.01–0.12mg/l), calcium (0.41–1.44mg/l) and magnesium (0.24–0.88mg/l).The values were within limits except for some pH, DO and COD values. The novel water pollution indexes were in the excellent water quality category in the stations (0.33) and months (0.29–0.43); confirming the stream's suitability to support aquatic life. The water quality need to be safeguarded in order to sustain the ecosystem services derived from the stream.

1. Introduction

Water is a very precious and essential resource required for the existence of all living organisms on earth [1]. Water quality is the general condition of a water body, which include the chemical, physical and biological conditions of the water; usually in relation to its suitability for the desired use [2]. Water quality is usually determined by the local geology, ecosystem and human activities among others [3]. Human activities such as industrial activities, agriculture, large-scale urbanization, and various forms of waste discharges are some of the various sources of pollution to aquatic environment [4]. Keke *et al.* [5] observed that the reduction in the usefulness of water and its resources to both man and the aquatic biota is a major consequence of river pollution. Pollution of natural surface water bodies like rivers and streams are made up of organic and inorganic constituents [6]. Assessment of the physico-chemical parameters is very important in order to understand the quality of water by comparing with standards [7]. However, drawing the right conclusion from large volume of physicochemical parameters can be very difficult [8]. Therefore, the novel water pollution index (WPI) developed by [9] was introduced to ease the interpretation. Water pollution index (WPI) eliminated the challenges of weightage and Water sensitivity arising from indexing [10]. A water quality indexing approach can be influenced by the use of different weights and standard value of any parameter but water pollution index gives better results when compared with other existing indexing methods [11]. This is because any slight variation in the concentration of an input parameter can alter the WPI category of water quality. The index can be applied for a wide range of physicochemical and biological parameters and purposes based on the requisite water quality standard for each purpose [9]. Anya stream is a rural freshwater body used for different purposes including drinking and other domestic purposes especially during the dry season. Other uses include, washing of clothes, cars, motorcycles and tricycles as well as bathing, swimming and irrigation. The aim of this study is to assess the spatial and temporal variations of physicochemical parameters of a multipurpose rural stream, southeast, Nigeria vis-a-viz suitability to support aquatic life using novel water pollution index.

2. Methodology

2.1 Study area and sampling stations

The study was carried out in Anya Stream; lying within Latitude 05°29'20.00" - 05°3l'40.00"N and Longitude 07°27'50.40" - 07°28'548.00"E (Fig 1). The study area is within the sub-equatorial zone; having a mean annual rainfall of 4000mm. It is characterized by the wet season (May to October) and dry season (November to April); a double maxima rainfall peaks in July and September. A short period of dryness (August break) usually occurs between the peaks in August. The stream is a tributary of Anya River. It branched off in the National Root Crops Research Institute, Umudike; draining large expanse of farmland used by the Institute for wet and dry season cropping, farmlands of Olokoro community, Michael Okpara University of Agriculture, Umudike, re-joined Anya River and continued to Amoaba community.

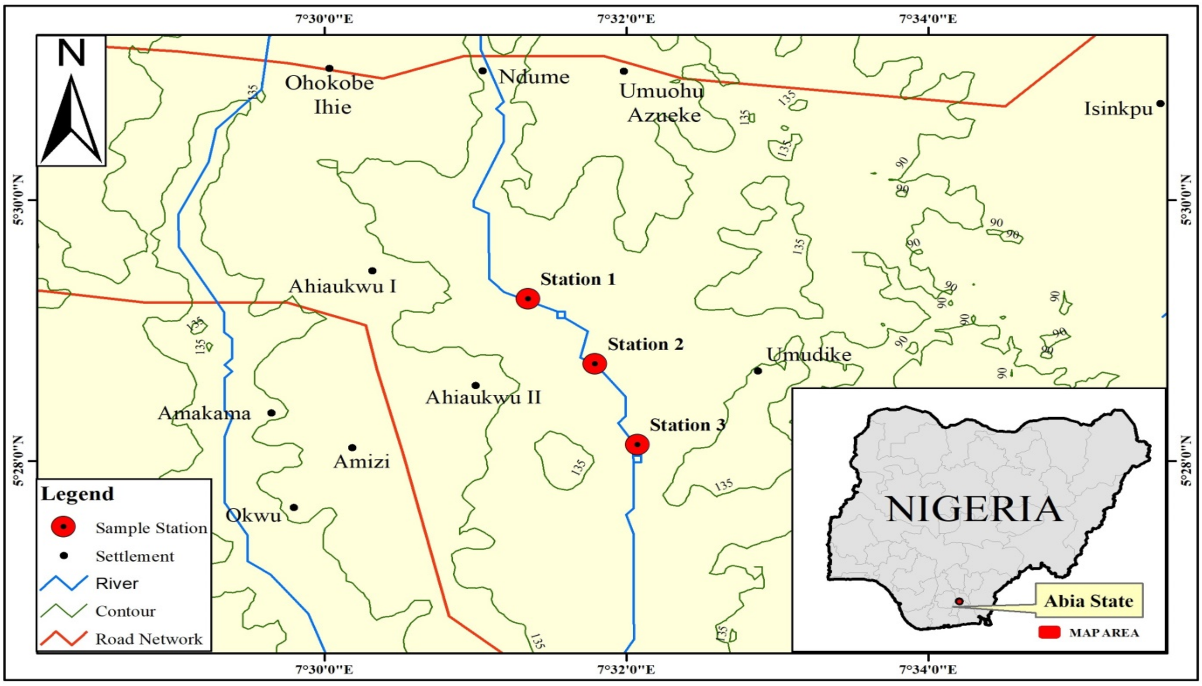

Figure 1: Map of Anya Stream, Umuahia, Nigeria showing the sampling stations

Station one

Station 1, located by the small bridge along NRCRI – Olokoro Road in Olokoro community was upstream and the reference site. The station was located downstream of NRCRI farmlands and adjacent to a large area of farmlands in Olokoro Community. Active land preparation and farming activities were observed because of the planting season. Water is extracted for drinking and other domestic purposes.

Station two

Station 2 is about 500 metres downstream of station 1, located within Michael Okpara University of Agriculture, Umudike, Nigeria. Students periodically use the station for bathing, washing and swimming because of its close proximity to students' hostels. Campus transport operators and others also periodically wash their cars, motorcycles and tricycles there.

Station three

Station 3 was about 600 metres downstream of station 2; located by the newly constructed culvert along Olokoro – Amaoba Road in Amaoba community. There were no human activities observed in the station throughout the study.

2.2 *Samples collection and analyses*

Water samples were collected from Anya stream monthly from May to October 2021. Samples were collected with 1 litre water sampler and stored in clean 1litre plastic bottles. Some physicochemical parameters were determined *in-situ* - Water Temperature (mercury-in-glass thermometer), Flow Velocity (floatation method), Transparency (Secchi Disk), pH, Electrical Conductivity and Total Dissolved Solids (pH/EC/TDS Meter- HANNA 3100 Model) while others were determined in the laboratory using standards methods described by [12]. One-way ANOVA was used to determine significant spatial and temporal variations. A total of 18 parameters were evaluated and compared with Fisheries and Recreation Quality Criteria Standard of National Environmental (Surface and Groundwater Quality Control) Regulations [13].

2.3 Water pollution index calculation

The water pollution index (WPI) proposed by [9] was used to assess the water quality. Thirteen parameters commonly determined water quality parameters (pH, turbidity, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, phosphate, nitrate, chloride, sodium, potassium, calcium and magnesium) were used in the assessment. Researchers are increasingly using the index since inception ([10-15]). The water pollution index of Anya stream was calculated using the equations described by [9] as follows:

Firstly, the pollution load (PLi) of ith parameter was calculated using formula 1:

$$\text{Pli} = 1 + \left(\frac{C_i - S_i}{S_i}\right) \quad (1)$$

where, C_i is the analyzed value of ith parameter, S_i is the highest acceptable limit for the parameter. For pH, 7 is considered as neutral and values < 7 or > 7 could be detrimental. With this consideration, [9] proposed different formula for pH, recommended for different pH ranges. When pH is < 7, formula 2 is recommended, where, S_{ia} is minimum acceptable pH value (6.5).

$$\text{Pli} = 1 + \left(\frac{C_i - 7}{S_{ia} - 7}\right) \quad (2)$$

When pH is > 7, formula 3 is recommended, where, S_{ib} is maximum acceptable pH value (8.5).

$$\text{Pli} = 1 + \left(\frac{C_i - 7}{S_{ib} - 7}\right) \quad (3)$$

Finally, the pollution status (water pollution index) of a water sample with n number of variables (parameters) can be determined by adding up all the pollution loads and dividing with n as indicated in formula 4. The total 'n' for any sample must not include the values of a parameter that is 0.

$$\text{WPI} = \frac{1}{n}\sum_{i=1}^{n} \text{PL}_i \quad (4)$$

The WPI values can be classified into four categories based on n number of parameters - WPI<0.5 (excellent quality), 0.5>WPI<0.75 (good quality), 0.75>WPI< 1 (moderately polluted water) and WPI>1 (highly polluted water).

3. Results

3.1 *Spatial and temporal variations of physicochemical parameters*

The summary of the physicochemical parameters (spatial and temporal) are presented in Tables 1 and 2. Water temperature values ranged from 22.7°C to 24.1°C. The lowest water temperature was recorded in station 3 (June 2021) while the highest was recorded in station 1 (May 2021). There was no significant difference (F = 0.01, p > 0.05) among the stations while June 2021 was significantly (F= 4.05, p<0.05) higher than May 2021.

Table 1: Summary of physico-chemical parameters recorded in the stations of Anya Stream

Parameter	Station 1 X±SEM	Station 2 X±SEM	Station 3 X±SEM	F-value	FMEnv (2011)
Temperature (°C)	23.4±0.19 (22.8 – 24.1)	23.5±0.13 (23.0 – 23.8)	23.4±0.20 (22.7 – 24.0)	0.01 (p>0.05)	-
pH	6.42±0.09 (6.0 – 6.6)	6.38±0.05 (6.2 – 6.5)	6.33±0.07 (6.1 – 6.5)	0.35 (p>0.05)	6.5-8.5
Transparency (cm)	42.0±7.67 (21.3 – 71.0)	57.5±6.90 (38.8 – 81.0)	55.3±8.08 (27.0 – 82.1)	1.22 (p>0.05)	-
Turbidity (NTU)	1.26±0.39 (0.6 –3.2)	1.12±0.43 (0.4–3.0)	0.83±0.28 (0.2–2.1)	0.35 (p>0.05)	5
Flow Velocity (m/s)	0.40±0.04 (0.23-0.54)	0.36±0.02 (0.28-0.46)	0.34±0.03 (0.21-0.40)	0.85 (p>0.05)	-
Electrical Conductivity (µs/cm)	69.3±5.19[a] (46.1 - 80.1)	54.0±4.27[b] (43.1 - 69.2)	45.8±2.17[b] (40.1 - 52.3)	8.51 (p<0.05)	-
Total Dissolved Solids (mg/l)	34.4±2.54[a] (221 – 40.2)	26.7±2.12[b] (21.0 – 34.3)	23.2±1.12[b] (20.4 - 26.8)	7.98 (p<0.05)	-
Dissolved Oxygen (mg/l)	4.93±0.50 (3.5 – 6.5)	5.43±0.53 (3.6 – 6.6)	6.52±0.45 (4.4 – 7.5)	2.71 (p>0.05)	6
Biochemical Oxygen Demand (mg/l)	1.08±0.12 (0.7 – 1.5)	0.92±0.21 (0.5 – 1.9)	1.03±0.33 (0.4 – 2.2)	0.36 (p>0.05)	3
Chemical Oxygen Demand (mg/l)	9.83±2.05 (4.8 – 19.2)	10.13±4.91 (3.2 – 34.4)	5.07±2.02 (0.8 – 13.6)	0.75 (p>0.05)	30
Phosphate (mg/l)	0.25±0.09 (0.06-0.60)	0.13±0.04 (0.04-0.30)	0.09±0.03 (0.02 – 0.20)	2.22 (p>0.05)	3.5
Nitrate (mg/l)	0.88±0.43 (0.27-3.01)	0.57±0.24 (0.08-1.74)	0.38±0.13 (0.07- 0.99)	0.72 (p>0.05)	9.1
Sulphate (mg/l)	0.17±0.04 (0.09-0.33)	0.16±0.03 (0.08-0.27)	0.11±0.03 (0.04-0.26)	0.81 (p>0.05)	100
Chloride (mg/l)	69.5±6.86 (51.8-88.6)	58.0±6.74 (41.0-83.4)	48.4±6.26 (30.9-70.9)	2.54 (p>0.05)	300
Sodium (mg/l)	0.19±0.03 (0.10-0.31)	0.16±0.03 (0.08-0.27)	0.13±0.02 (0.07-0.20)	1.49 (p>0.05)	120
Potassium (mg/l)	0.07±0.01 (0.03-0.12)	0.06±0.01 (0.02-0.09)	0.05±0.01 (0.01-0.08)	0.75 (p>0.05)	50
Calcium (mg/l)	1.01±0.12[a] (0.66-1.44)	0.73±0.04[a] (0.53-0.84)	0.58±0.06[b] (0.41-0.81)	7.87 (p<0.05)	180
Magnesium (mg/l)	0.61±0.09[a] (0.33-0.88)	0.44±0.06[a] (0.24-0.66)	0.33±0.02[b] (0.24-0.40)	4.74 (p<0.05)	40
WPI	0.33	0.33	0.33		

Legend: a, b, c = Means with different superscripts across the rows are significantly different at p<0.05; SEM= Standard Error of Mean; [13] = Fisheries and Recreation Quality Criteria Standard of National Environmental (Surface and Groundwater Quality Control) Regulations.

The temperature values were at ambient level. The pH values ranged between 6.0 and 6.6; most of the values were not within acceptable limit (6.5 – 8.5) set by [13]. The lowest value was recorded in station 1 (September 2021) while the highest was also recorded in station 1 (May and July 2021). There was no significant difference in pH in both stations ($F=0.35$, $p > 0.05$) and months ($F=0.68$, $p > 0.05$).

The transparency values ranged between 21.3 and 82.1 cm. The lowest value was recorded in station 1 (June 2021) while the highest was recorded in station 3 (October 2021). There was no significant difference ($F=1.22$, $p< 0.05$) among the stations while September and October 2021 were significantly ($F= 7.57$, $p<0.05$) higher than June – August 2021. Turbidity values ranged between 0.2 – 3.2 NTU. All the values were lower than the acceptable limit (5NTU) set by [13]. The lowest value was recorded in station 3 (July 2021) while the highest was recorded in station 1 (August 2021). The values generally declined from August to October 2021. There was no significant difference in the stations while August was significantly ($F=15.96$, $p< 0.05$) higher the other months. Flow velocity ranged from 0.21 to 0.54mls. The lowest was recorded in station 3(October 2021) while the highest was recorded in station 2 (August 2021) respectively. There was no significant difference in flow velocity in both stations ($F=0.85$, $P > 0.05$) and months ($F=0.63$, $P > 0.05$). Electrical conductivity (EC) ranged from 40.1 to 80.1µS/cm. The lowest value was recorded in station 3 (July 2021) while the highest was recorded in station 1 (May and August 2021). Station 1 was significantly ($F= 8.51$, $p< 0.05$) higher than stations and 2 and 3 while there was no significant difference among the months ($F=1.12$, $P > 0.05$). Total dissolved solids ranged between 20.4 and 40.2mg/l. TDS followed the same trend with EC. The lowest value was also recorded in station 3 (July 2021) while the highest was recorded in station 1 (August 2021). Station 1 was significantly ($F= 17.02$, $p< 0.05$) higher than stations 2 and 3 while May and August were significantly ($F= 4.40$, $p< 0.05$) higher than September 2021. The dissolved oxygen (DO) values ranged from 3.5 to 7.5mg/l. The lowest value was recorded in station 1 (June 2021) while the highest was recorded in station 3 (September 2021). There was no significant difference among the stations ($F=2.71$, $p > 0.05$) and months ($F=3.47$, $p > 0.05$). Most of the values were within the acceptable limit (> 6 mg/l) set by [13]. Generally, higher DO values were recorded in station 3. Biochemical oxygen demand (BOD) values ranged between 0.4 and 2.2mg/l and within acceptable limits (3 mg/l) set by [13]. The lowest and highest values were recorded in June 2021 and August 2021 respectively in station 3. There was no significant ($F= 0.13$, $p>0.05$) difference among the stations while August 2021 was significantly ($F= 6.96$, $p<0.05$) higher than May – July and October 2021 and September 2021 was also significantly higher than June 2021. Chemical oxygen demand (COD) values ranged from 0.8 to 34.4 mg/l. The lowest values were recorded in station 3 (August and October 2021) while the highest was recorded in station 2 (September 2021). The later value exceeded the acceptable limit (30 mg/l) set by [13] while others were lower. There was no significant difference among the stations while September was significantly ($F= 7.89$, $p< 0.05$) higher than the other months except June 2021.

Phosphate ranged from 0.02 to 0.60 mg/l. All the values were within the acceptable limit (3.5 mg/l) set by [13]. The lowest value was recorded in station 3 (June 2021) while the highest was in station 1 (July 2021). There was no significant difference in both stations ($F=2.22$, $p> 0.05$) and months ($F=1.83$, $p> 0.05$) but station 1, July, September and October 2021 had relatively higher values. Nitrate values ranged from 0.07 to 3.01mg/l and within acceptable limit (9.1 mg/l) set by [13]. The lowest value was recorded in station 3 (August 2021) while the highest was recorded in station 1 (July 2021). There was no significant difference among the stations ($F=0.72$, $p >0.05$) while July was significantly ($F= 6.70$, $p<0.05$) higher than the other months. Station 1 also had relatively higher values.

Table 2: **Summary of physico-chemical parameters recorded monthly in Anya Stream**

Parameters	Sampling Period						F-value	FMEnv (2011)
	May-21 X±SEM	Jun-21 X±SEM	Jul-21 X±SEM	Aug-21 X±SEM	Sep-21 X±SEM	Oct-21 X±SEM		
Temperature (◦C)	23.8±0.18^{b} (23.5 - 24.1)	22.9±0.12^{a} (22.7 - 23.1)	23.5±0.09^{ab} (23.3 - 23.6)	23.6±0.31^{ab} (23.0 - 24.0)	23.6±0.06^{ab} (23.5 - 23.7)	23.2±0.15^{ab} (23.0 - 23.5)	4.05 P < 0.05	-
pH	6.4±0.12 (6.2 - 6.6)	6.3±0.12 (6.1 - 6.5)	6.5±0.06 (6.4 - 6.6)	6.3±0.09 (6.2 - 6.5)	6.3±0.15 (6.0 - 6.5)	6.4±0.03 (6.4 - 6.5)	0.68 P > 0.05	6.5-8.5
Transparency (cm)	51.2±7.36^{ab} (36.5 - 59.5)	39.6±9.20^{b} (21.3 - 50.0)	35.3±4.76^{b} (27.0 - 43.5)	37.6±4.37^{b} (29.5 - 44.5)	74.3±3.33^{a} (71.0 - 81.0)	71.5±6.99^{a} (58.3 - 82.1)	7.57 P < 0.05	-
Turbidity (NTU)	0.77±0.19^{b} (0.4 - 1.0)	0.57±0.12^{b} (0.4 - 0.8)	0.43±0.12^{b} (0.2 - 0.6)	2.77±0.34a (2.1 - 3.2)	1.2±0.25^{b} (0.9 - 1.7)	0.70±0.21^{b} (0.4 - 1.1)	15.96 P < 0.05	5
Flow Velocity (m/s)	0.36±0.02 (0.34 - 0.40)	0.37±0.01 (0.36 - 0.39)	0.36±0.04 (0.28 - 0.42)	0.41±0.07 (0.33 - 0.54)	0.40±0.03 (0.35 - 0.45)	0.30±0.08 (0.21 - 0.46)	0.63 P > 0.05	-
Electrical Conductivity (µs/cm)	64.8±8.18 (52.1 - 80.1)	55.6±5.70 (45.3 - 65.0)	52.1±10.57 (40.1 - 73.1)	67.2±8.09 (52.3 - 80.1)	45.4±2.39 (41.0 - 49.2)	53.0±9.00 (44.0 - 71.0)	1.12 P > 0.05	-
Total Dissolved Solids (mg/l)	32.2±3.71 (26.4 - 39.1)	27.5±2.93 (22.2 - 36.6)	26.0±5.30 (20.4 - 36.6)	33.8±3.88 (26.8 - 40.2)	22.8±0.83 (21.2 - 24.0)	26.3±4.33 (22.0 - 35.0)	1.20 P > 0.05	-
Dissolved Oxygen (mg/l)	5.60.63 (4.4 - 6.5)	4.8±10.3 (3.5 - 6.8)	3.9±0.24 (3.6 - 4.4)	6.4±0.50 (5.4 - 7.1)	6.7±0.44 (6.0 - 7.5)	6.4±0.23 (6.0 - 6.8)	3.47 P > 0.05	6
Biochemical Oxygen Demand (mg/l)	0.8±0.15^{bc} (0.5 - 1.0)	0.5±0.09^{b} (0.4 - 0.7)	0.6±0.09^{bc} (0.5 - 0.8)	1.8±0.27^{a} (1.3 - 2.2)	1.4±0.29^{ac} (0.9 - 1.9)	0.9±0.15^{bc} (0.7 - 1.2)	6.96 P <0.05	3
Chemical Oxygen Demand (mg/l)	5.9±1.48^{b} (4.0 - 8.8)	9.3±0.90^{a} (8.0 - 11.0)	4.8±1.22^{b} (3.2 - 7.2)	2.9±1.16^{b} (0.8 - 4.8)	22.4±6.21^{a} (11.6 - 34.4)	4.8±2.11^{b} (0.8 - 8.0)	6.35 P <0.05	30
Phosphate (mg/l)	0.08±0.02 (0.04 - 0.11)	0.04±0.01 (0.02 - 0.06)	0.27±0.16 (0.10 - 0.60)	0.08±0.01 (0.07 - 0.09)	0.27±0.03 (0.20 - 0.32)	0.21±0.08 (0.11 - 0.38)	1.83 P >0.05	3.5
Nitrate (mg/l)	0.40±0.06 (0.28 - 0.47)	0.41±0.07 (0.33 - 0.55)	1.91±0.59 (0.99 3.01)	0.14±0.07 (0.07 - 0.27)	0.40±0.03 (0.37 - 0.46)	0.44±0.09 (0.28 0.60)	6.70 P<0.05	9.1
Sulphate (mg/l)	0.11±0.01^{bc} (0.09 - 0.13)	0.08±0.01^{b} (0.06 - 0.09)	0.29±0.02^{a} (0.26 - 0.33)	0.11±0.02^{bc} (0.07 - 0.14)	0.19±0.02^{bc} (0.16 - 0.21)	0.09±0.02^{b} (0.04 - 0.13)	18.0 P<0.05	100
Chloride (mg/l)	42.3±6.10^{b} (30.9 - 51.8)	58.5±1.16^{a} (56.4 - 60.4)	51.7±11.19^{a} (40.1 - 74.1)	46.2±5.42^{b} (35.5 - 53.2)	81.0±5.25^{a} (70.9 - 88.6)	71.9±9.33^{a} (56.3 - 88.6)	4.47 P<0.05	300
Sodium (mg/l)	0.09±0.01^{b} (0.07 - 0.10)	0.10±0.01^{b} (0.08 - 0.12)	0.16±0.02^{ab} (0.13 - 0.21)	0.26±0.03^{a} (0.20 - 0.31)	0.17±0.03^{ab} (0.12 - 0.21)	0.19±0.02^{ab} (0.16 - 0.23)	7.67 P<0.05	120
Potassium (mg/l)	0.02±0.004^{b} (0.01 - 0.03)	0.05±0.02^{ab} (0.03 - 0.08)	0.07±0.004^{ab} (0.06 - 0.07)	0.09±0.02^{a} (0.06 - 0.12	0.07±0.01^{a} (0.06 - 0.09)	0.06±0.01^{ab} (0.04 - 0.07)	4.82 P<0.05	50
Calcium (mg/l)	0.58±0.12 (0.41 - 0.81)	0.77±0.06 (0.66 - 0.88)	1.03±0.21 (0.81 - 1.44)	0.79±0.15 (0.54 - 1.07)	0.64±0.07 (0.52 - 0.74)	0.82±0.21 (0.51 - 1.22)	1.12 p>0.05	180
Magnesium (mg/l)	0.27±0.03 (0.24 - 0.33)	0.36±0.03 (0.31 - 0.74)	0.46±0.14 (0.32 - 0.74)	0.61±0.11 (0.39 - 0.77)	0.45±0.06 (0.33 - 0.52)	0.60±0.14 (0.40 - 0.88)	1.80 p>0.05	40
WPI	0.32	0.33	0.29	0.39	0.43	0.32		

Legend: a, b, c = Means with different superscripts across the rows are significantly different at p<0.05; SEM= Standard Error of Mean; [13] = Fisheries and Recreation Quality Criteria Standard of National Environmental (Surface and Groundwater Quality Control) Regulations.

Sulphate value ranges from 0.04 to 0.33mg/l and within the acceptable limit (100 mg/l) set by [13]. The lowest value was recorded in station 3 (October 2021) while the highest was recorded in station1 (July 2021). There was no significant difference among the stations ($F= 0.81$, $p>0.05$) while July 2021 was significantly higher than other months and September 2021 was significantly higher than June and October 2021($F= 18.0$, $p<0.05$). Station 1 also had relatively higher values. The chloride values were within the acceptable limit (300 mg/l) set by [13]; ranging between 30.9 and 88.6mg/land. The lowest value was recorded in station 3 (May 2021) while the highest was recorded in station 1 (September and October 2021). There was significant difference among the stations ($F=2.54$, $p>0.05$) while September 2021 was significantly ($F= 4.47$, $p<0.05$) higher than May and August 2021. Sodium ranges from 0.07 to 0.31mg/l and within the acceptable limit (120 mg/l) set by [13]. The lowest value was recorded in station 3 (May 2021) while the highest was recorded in station 1 (August 2021). There was no significant difference among the stations ($F= 1.49$, $p> 0.05$) while May 2021 and June 2021 were significantly ($F=7.67$, $p< 0.05$) lower than August 2021. Potassium ranged from 0.01 to 0.12mg/l and within the acceptable limit (50 mg/l) set by [13]. The lowest value was recorded in station 3 (May 2021) while the highest was recorded in station 1 (August 2021). There was no significant ($F= 0.75$, $p>0.05$) among the stations while August 2021 and September 2021were significantly ($F= 4.82$, $p<0.05$) higher than May 2021. Calcium value ranges from 0.41 to 1.44mg/l and within the acceptable limit (180 mg/l) set [13]. The lowest value was recorded in station 3 (May 2021) while the highest was recorded in station 1 (July 2021). Station 3 was significantly ($F=7.87$, $p< 0.05$) lower than stations 2 and 3 while there was no significant difference among the stations ($F=1.12$, $p >0.05$). Magnesium ranged from 0.24 to 0.88mg/l; within the acceptable limit (40 mg/l) set by [13]. The lowest values were recorded in stations 2 and 3 (May 2021) while the highest was recorded in station 1 (October 2021). Station 3 was significantly lower than stations 2 and 3 ($F= 4.74$, $p<0.05$) while there was no significant variation among the months ($F= 1.80$, $p>0.05$).

3.2 *Water pollution index*

The water pollution index (WPI) value was 0.33 in all the stations and between 0.29 and 0.43 monthly (Tables 1 and 2). August and September 2021 values were relatively higher. The values were all within the excellent water quality category (Table 3).

Table 3: Water Pollution Indices and Water Quality Classification

WQI Value	Water Quality Classification*
WPI<0.5	excellent quality
0.5>WPI<0.75	good quality
0.75>WPI< 1	moderately polluted water
WPI>1	highly polluted water

*[9]

4. Discussion

The normal and optimal functioning of aquatic ecosystem and suitability to support aquatic life depend solely on the physicochemical parameters [16,17]. Aquatic organisms survive and flourish within certain range of each physicochemical parameter. Natural and anthropogenic processes can alter these optimal ranges to the detriment of the aquatic biota [18]. When streams flow through areas of different land-use, they are subjected to varying type of pollutions [19,20] and the pollutant types that produce the most adverse effects may also differ with land-use types [21]. All the parameters evaluated were within their respective acceptable limits except some values of pH, dissolved oxygen, COD. Spatially, most of the parameters evaluated had their highest values in station 1 except COD (station 2) and BOD (station 3) as well as the lowest values for transparency and DO. This could be attributed to anthropogenic impact arising from agricultural activities around station 1; influenced by season [22,23]. Agriculture related pollution has exceeded that from other sources in most developed and many developing countries; runoffs from farms consisting of large quantities of agrochemicals, organic matter, drug residues discharge into waterbodies in the watersheds [24]. Relatively higher values were recorded for most parameters in station 2 compared to station 3. This could be attributed to other anthropogenic activities other than agriculture. Washing of cars, motorbikes and tricycle was very common around station 2. Studies have shown that vehicle washing effluent is capable of increasing COD in surface water [25-27]. Swimming has also been reported to affect the water quality especially during the dry season [28]. Students often wash clothes and swim in station 2 due to its closeness to students' hostels. The highest BOD value was recorded in station 3 in August 2021 and could be attributed to season since no human activities was observed in the station throughout the study. Most of the other parameters in station 3 were either low or within the acceptable limits. Temporally, the results showed interplay between anthropogenic activities and precipitation. Precipitation strongly influences physicochemical parameters of surface water in the tropics [29]. Some parameters were recorded either in high or low concentrations before the onset of rains and changed later towards the peaks of rains as a result of allochthonous input from the environment and dilution [30,31]. Most of the lowest values were recorded between May and July 2021 in station 3 while most of the highest values were recorded between July and October 2021 in station 1. For example, electrical conductivity, TDS, turbidity, chloride and the cations had their lowest values between May and July 2021 in station 3 and their highest values between July and October 2021 in station 1. Transparency was lowest in June 2021 (station 1) and highest in October 2021 in station 3 while dissolved oxygen was lowest in June 2021 (station 1) and highest in September 2021 (station 3). The highest BOD value was recorded in station 3 in August 2021. This could be attributed to season rather than human activities. BOD tends to increase when rainfall is low and reduce when rainfall increases [32, 33]. This is due to increased temperature, biological activity, respiration of organisms and decomposition rate of organic matters [33] associated with "August break". The BOD mean values decreased as the rains increased from August to October 2021.

The WPI values recorded in the stations were the same and within the excellent category [9] because most of the parameters evaluated were within acceptable limits. Secondly, the observed human activities in the stream did not result in significant differences in most parameters in the stations. According to [11], slightest change in the values of the input parameters can alter the WPI category of water quality. The lowest WPI value (0.29) recorded in July 2021 could be attributed to dilution after the onset of the rains. On the hand, the highest value (0.43) recorded in September 2021 could be due to allochthonous input from increased rainfall [31]. The relatively high value (0.39) recorded in August 2021 could be attributed to the effect of "August break". The short period (2 – 3 weeks) of break in rains (August break) is also known as short dry season [34]. During the break, values of water parameters tend to increase due to concentration caused by little or no rainfall, reduced flow velocity, high temperatures and evaporation [35]. The water pollution index showed that the waters of Anya stream were suitable to support aquatic life. The quality could improve or deteriorate depending on increase or decrease in the human activities in the stream. Chakraborty *et al.* [10] reported that WPI for 90.90% and 9.10% of water samples from River Damodar, India improved to 'good quality' and 'moderately polluted' respectively during the COVID lockdown compared to the pre-lockdown WPI of 100% 'highly polluted' water samples.

Conclusion

Anya stream, a rural multipurpose freshwater body is being subjected to a number of anthropogenic activities in the watershed. The physicochemical parameters were within acceptable limits to support aquatic biodiversity except for some pH, DO and COD values. However, WPI results confirmed that the water was of excellent quality category to support aquatic life. The spatial variation was not significantly influenced by human activities while the temporal variation was due to interplay between anthropogenic activities and precipitation. The water quality need to be safeguarded in order to sustain the ecosystem services derived from the stream.

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