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Research Article

Total Alkalinity, Biological Oxygen Demand and Total Dissolved Solids of Feroro Stream Chikun Local Government Kaduna State, Nigeria

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ABSTRACT

Feroro stream is a perennial stream that flows into the River Kaduna, its physical and chemical qualities are fast deteriorating in quality. The stream is located in Chikun Local Government Area of Kaduna State, Nigeria. This study aimed to evaluate the total alkalinity, biological oxygen demand, and total dissolved solids of Feroro stream, Chikun Local Government Area of Kaduna State, Nigeria. The stream is threatened from anthropogenic activities. Five sampling stations were selected along the stream based on anthropogenic activities. The stream water and sediment samples were collected according to the standard methods, once monthly from the stations for twenty-four months from 2020 to 2021. Samples for Biological oxygen demand were collected in amber containers and incubated for five days. Total Dissolved Solids, Biological Oxygen Demand and Total Alkalinity were determined using a standard multi-parameter Hanna meter, Dissolved oxygen meter and titration. All the parameters tested in the stream sediment and water were within the standard limits of the World Health Organization. Total Dissolved Solids was significantly spatially different across all the stations in the stream water at $P<0.05$. Total alkalinity in the stream water and sediment were high during the dry season (38.82mg/L/$CaCO_3$ and 37.95 mg/L/$CaCO_3$ $p<0.05$ respectively. Total Dissolved Solids had a negative correlation with Biological oxygen demand and Total alkalinity in both the stream water and sediment at 19.1% and 18.2%. TDS of the stream varied across the stations. Total alkalinity, Biological oxygen demand, and Total dissolved solids in Feroro stream differ significantly across the months.

Keywords: Feroro stream; Water; Sediment; Total alkalinity; Biological Oxygen Demand; Total Dissolved Solids

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INTRODUCTION

Freshwater ecosystem constitutes 2.5% of the global water, which is now a scarce commodity due to increased pollutants from either point or non-point sources (Iyiola and Asiedu, 2020). Chikun Local Government Area (LGA) is an adjoining LGA of Kaduna metropolis found in the southern part of the state capital on a flat altitude of about 600m above sea level and has land area of about 192.3km^2. Its annual rainfall ranged from 850mm to 1200mm (Musa *et al*., 2016). The stream flows throughout the year, but its water volume decreases and increases during dry and wet seasons respectively. The stream, also known as River Quwe by the native (Gbayi) ethnic group, has its source from the Damishi hills and flows into River Kaduna (Dawuda *et al*., 2024a; Stanley *et al*., 2017). Stream water has a relationship with its sediment, because organic and inorganic materials found in the aquatic ecosystem bed are sediment, and most water pollutants end up in the sediment (Adesuyi *et al*., 2016; Enetimi *et al*., 2016).

The quality of any stream lies in its physical and chemical qualities. The assessment of freshwater ecosystems has over the years been through the measurement of physicochemical variables

(Samuel *et al*. 2021). Feroro stream is fast deteriorating due to over exploitation, pollution, and easy accessibility to waste disposal. Feroro stream serves as a source of water for different purposes such as domestic and agricultural. Stream quality gives adequate information about the extent of pollution in such a water body within a given locality (Dawuda, *et al*., 2024b), it's monitoring is important to the populace. Assessing the ecological status of rivers, creeks and streams is a fundamental (Samuel *et al*., 2021). Total dissolved solids, total alkalinity, and biological oxygen demand are some physicochemical parameters used to monitor stream quality, which can change due to various activities around the stream. Total Dissolved Solids (TDS) is the presence of both inorganic and organic materials in solution. It is a good indicator of aquatic quality and determines the ability of light penetration in the water body. Biological Oxygen Demand (BOD_5) is among the parameters used to quantify organic contamination load, directly affects the amount of dissolved oxygen in an aquatic environment (Barakat *et al*., 2016). Sources of BOD in aquatic environment include dead plant leaves and woody debris, animal manure, effluents, wastewater from industries, failing septic systems and storm water runoff (Uddin, *et al*., 2014). Total alkalinity is the buffering capacity of the aquatic environment to neutralize hydrogen ions, as a result of the presence of carbonates, bicarbonates, and hydroxides in such an aquatic environment. It is influenced by rocks and soils, salts, certain plant activities, and industrial wastewater discharges (Green and Reid, 2013). This study was to evaluate the total alkalinity, biological oxygen demand, and total dissolved solids of Feroro stream.

MATERIALS AND METHODS

Study Area and Sampling Sites

Feroro stream is located in Chikun Local Government Area of Kaduna State, Nigeria. It lies between latitude 10º 20´N and 10º 31´N, longitude 6º 40´00´´E and 7º 50´00´´E. Five sampling sites were selected along the stream (Table 1) based on anthropogenic activities such as farming, waste disposal, domestic usage, geographical pattern such as meanders and proximity of the stations to settlements. Station 1 has predominantly farming activity, no meanders and very distant from settlements. At stations 2, 3, 4 and 5, there are farming, meanders of the stream that differ, waste dumps collection points, and not distant from settlements. There was also sand excavation activity done at stations 3, 4, and 5 (Table 1).

Table1: Location Points of Sampling Stations

Station	Latitude	Longitude	Predominant activities	Distance from the previous (Km)
1	10^{o}26´59´´N	7^{o}30´14´´E	Farming	
2	10^{o}27´38´´N	7^{o}28´27´´E	farming, and waste dumps	2.8Km
3	10^{o}28´12´´N	7^{o}27´48´´E	Farming, waste dumps and sand excavation	2Km
4	10^{o}28´34´´N	7^{o}27´33´´E	farming, sand excavation and waste dump points	1.8Km
5	10^{o}29´15´´N	7^{o}26´34´´E	Farming, fishing, waste dumps and sand excavation	2Km

Sample Collection

Stream water and sediment samples were collected according to the standard methods APHA, (1998). The stream water was collected into 2-litres containers and the sediment into polythene bags. The samples were collected once monthly from the different stations for a period of twenty-four months. Samples for Biologicall Oxygen Demand (BOD) measurements was collected in 500ml coloured containers and taken to the laboratory for five days incubation.

Physicochemical Determination

Total Dissolved Solids was determined using standard calibrated portable multi-parameter HANNA meter (HI 9813-6N), by inserting the meter probe into the water and sediment each at every station for 2minutes before each reading was recorded respectively. The probe was rinsed in distilled water before being used for further measurement.

Biochemical Oxygen Demand (BOD_5) were determined by subtracting the final Dissolved Oxygen (DO_f) after incubation (DO_i) at 25^{o}C from the initial Dissolved Oxygen of the samples measured before incubation using Dissolved Oxygen meter (model JPB-70A). The meter probe is inserted into the sample for 2minutes, the initial Dissolved Oxygen (DO_i) of the sample collected were recorded and the samples were incubated for 5days at room temperature, then the final (DO_f) was measured. (APHA, 2010).

$$BOD5 = DOi - DOf$$

Total alkalinity was determined by titration method, where 100ml of each sample was poured into a conical flask 2 drops of bromocresol green and 2 drops of methyl red were added respectively. The mixture was swirled and titrated with solution of H_2SO_4 until colour changed. Titre value was multiplied by 10 (APHA, 1998).

Data Analysis

Multivariate statistical technique was used to determine variations in physiochemical parameters with respect to different stations, seasons and months. Canonical Corresponding analysis (CCA) was also used to indicate the relationship among water quality parameters,

RESULTS AND DISCUSSIONS

The range values of Biological Oxygen Demand (BOD), Total Dissolved Solids (TDS) and Total alkalinity of Feroro stream water and sediment are shown in Table 2. Each parameter was within the standards limit of World Health Organization.

Total dissolved solids, mean monthly total dissolved solids (TDS) variations of the stream sediment and water are presented in Figures 1 and 2. Temporal variations of TDS in the sediment and water were highest in September (133.33mg/L) and August (192.00mg/L), then lowest in February (70.40mg/L) and January (82.13mg/L) respectively. Canonical Correlation Analysis (CCA) showed that TDS is negatively correlated with BOD and Total alkalinity in both the water and sediment at 19.1% and 18.2% (Figures 3 and 4). TDS in the stream water was significantly different spatially across the sampled stations and was not different in the stream sediment presented in Table 3, $P < 0.05$. In the stream water at Stations 2, 3, 4, and 5, TDS decreased in August (99.50mg/L, 107.00mg/L, 109.17mg/L, and 92.17mg/L) respectively, followed by a rise in September. TDS across these stations also decreased from November through February and increased in March of the stream sediment and water (Figures 1 and 2). There was significant variation in TDS across the sampling months of the stream sediment and water p<0.05 (Figures 1 and 2). TDS was significantly different across the seasons of sampling presented in Table 4.

Total Dissolved Solids is the suspended and dissolved solids (salts) in solution, which depends on the degree of solubility and precipitation of minerals (Kosha and Geeta, 2017). TDS concentration range was below standard limits. This is in line with the report of Ukah *et al*. (2019) that TDS content was below the standard maximum allowable limits of 600 -1000 mg/L. Based on this, the stream water could be excellent for drinking, as also agreed with the studies of Egburi (2019), that TDS lower than the acceptable limit is good for drinking. However, high TDS observed in the wet season than in the dry season could be due to surface runoff as a result of rainfall, which brings soluble and insoluble materials from the surrounding environment into the stream, indicating that it is not suitable for human consumption. This high TDS in the stream could produce odour and colour (Ajibade and Ogungbesan, 2013). The high TDS in the stream could also be attributed to dissolution of soil/sediment minerals, water evaporation, desorption of ions attached to solids and introduction of ions present in atmospheric precipitation and groundwater discharge, which are the processes that generate TDS in streams (Mohammad *et al*., 2017; Butler and Ford (2018). The high TDS concentrations in the stream can result in dehydration of aquatic animals as indicated in the findings of Bhateria and Jain (2016) that if the TDS is due to dissolved salt, many aquatic life will be affected, the salt acts to dehydrate the skin of animals, stated also in the work of Aniyikaiye *et al*. (2019), on Physiochemical analysis of wastewater discharge from selected paint industries in Lagos. Increased TDS in the stream decreases photosynthesis capacity and temperature (Edori *et al.,* 2019).

Table 2: Range Values and Standard Limits of Physico-chemical Parameters in water and sediment of Feroro stream

Parameters	Water			Sediment		
	Range		WHO	Range		WHO
	Min	Max	Standard	Min	Max	Standard
Total Dissolved Solids (mg/L)	60.67	142.93	1000	73.07	258.53	1500
Biological Oxygen Demand (mg/L)	0.99	2.44	10	0.81	1.85	10
Total Alkalinity (mg/L/CaCO3)	19.47	44.53	200	22.27	47.33	200

WHO =World Health Organization (2017)

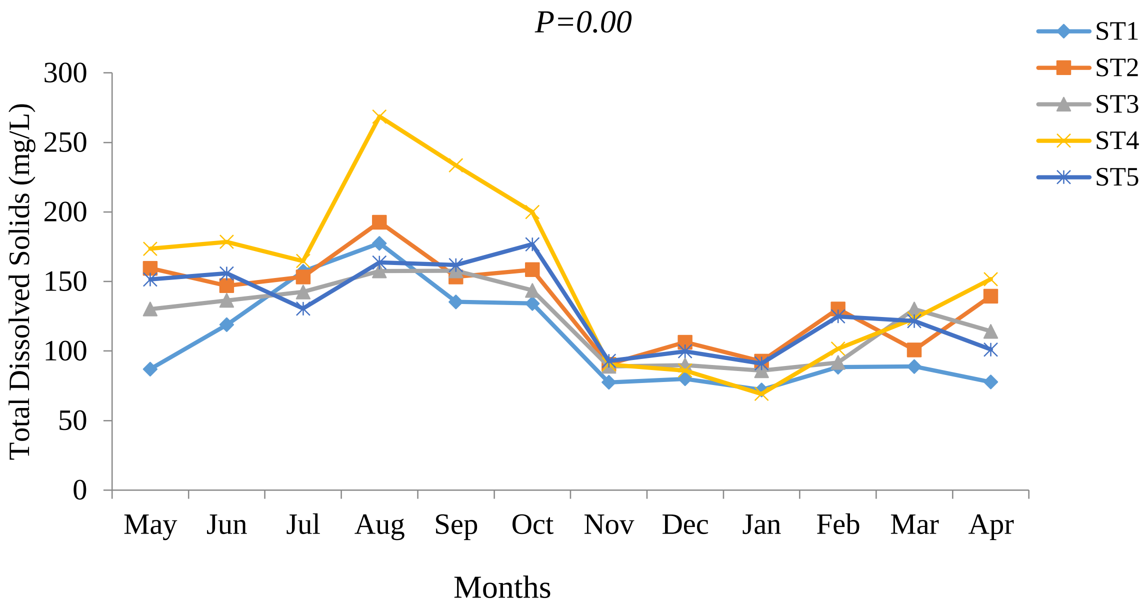

Figure 1: Monthly mean Total Dissolved Solids of Feroro stream Sediment

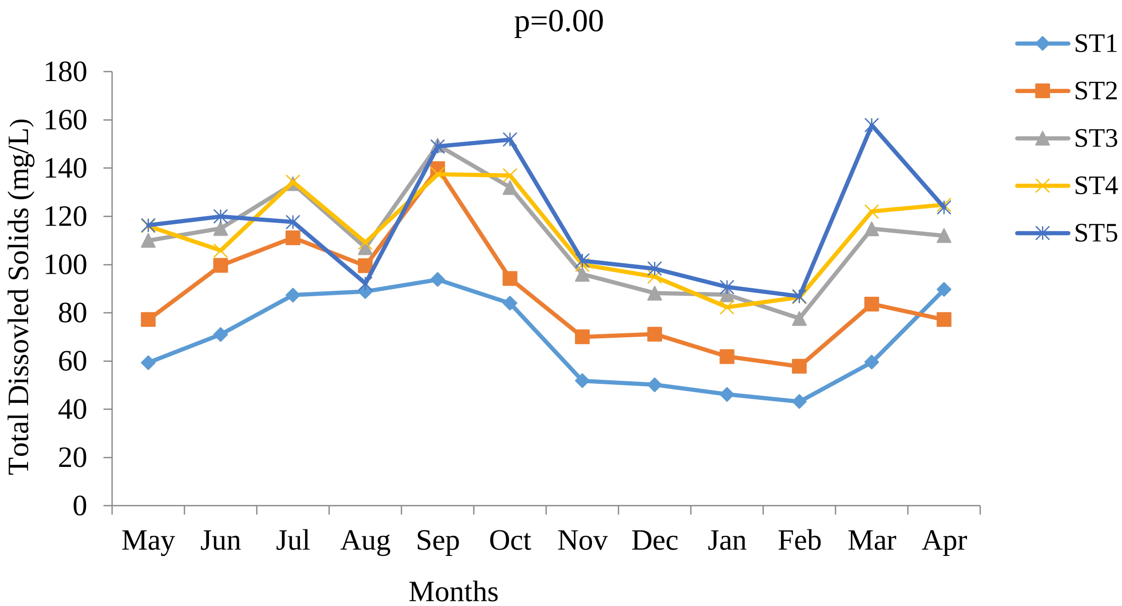

Figure 2: Monthly mean Total Dissolved Solids of Feroro stream Water

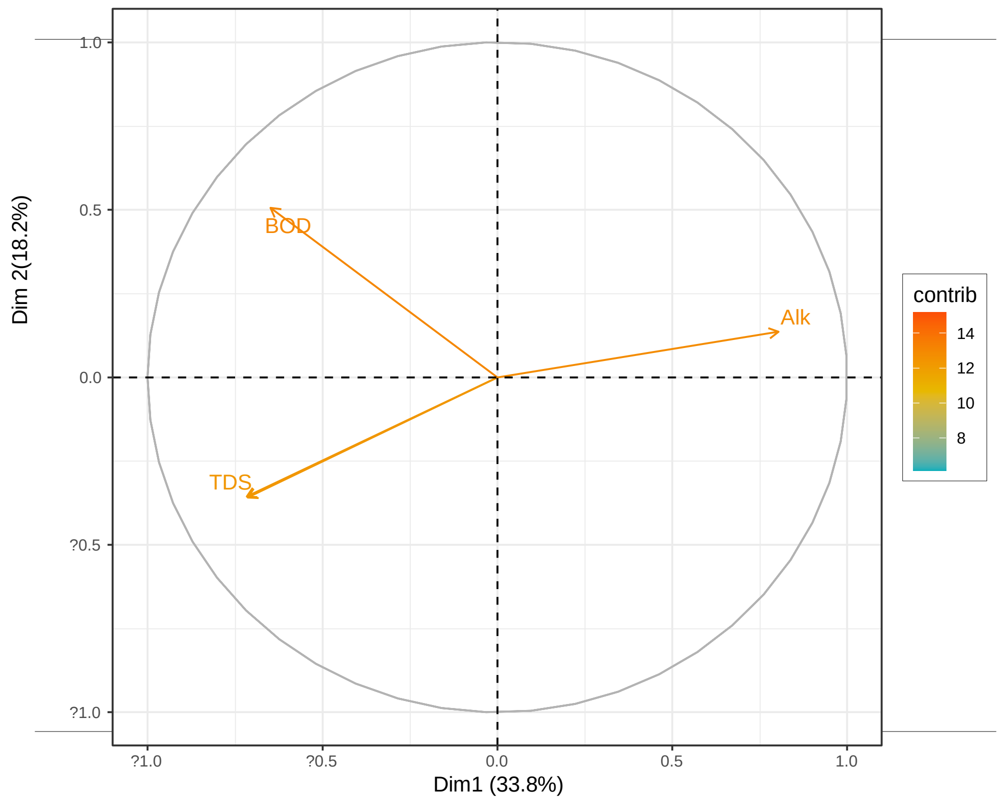

Figure 3: Canonical Corresponding Analysis of Feroro stream Sediment

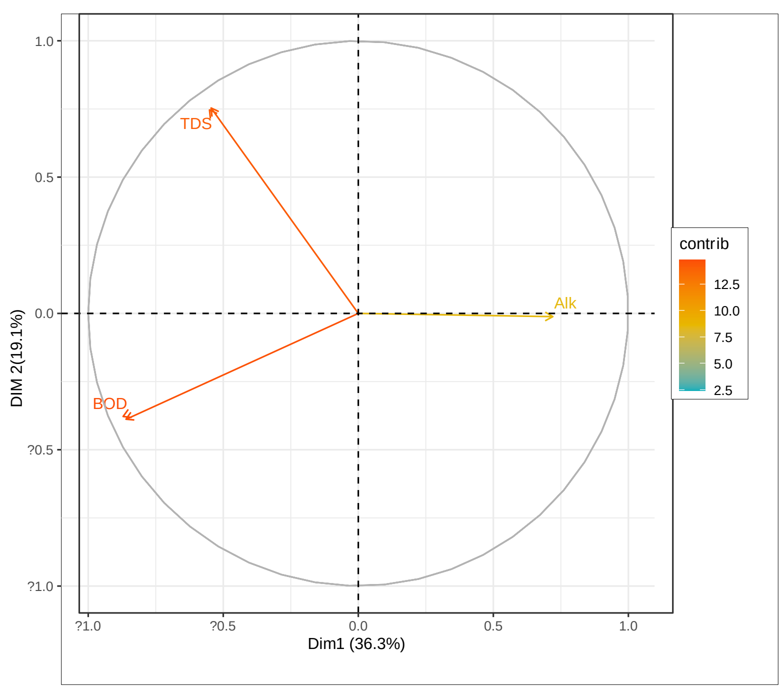

Figure 4: Canonical Corresponding Analysis of Feroro stream Water

Table 3: Mean Spatial Physico-chemical Parameters of Feroro Stream Sediment and Water

Parameters	Station 1			Station 2			Station 3			Station 4			Station 5			P-value
	Min	Max	ϰ ±SD	Min	Max	ϰ ±SD	Min	Max	ϰ ±SD	Min	max	ϰ ±SD	Min	max	ϰ ±SD	
Sediment																
TDS (mg/L)	106.25	108.83	107.87±10.27e	135.33	135.42	135.37±9.17b	122.21	122.46	122.38±7.87d	153.08	154.00	153.42±17.89a	130.42	131.38	130.93±8.80c	0.09
BOD (mg/L)	1.52	1.58	1.55±0.07a	1.36	1.37	1.36±0.07c	1.34	1.45	1.38±0.07c	1.36	1.42	1.38±0.07c	1.46	1.49	1.48±0.07b	0.25
T Alk (mg/L/ $CaCO_3$)	33.04	33.29	33.20±2.44a	32.83	33.13	32.96±1.74a	31.92	32.33	32.17±1.88b	31.29	31.83	31.53±2.06c	32.96	34.08	33.46±2.23a	0.96
Water																
TDS (mg/L)	68.46	69.25	68.74±5.52c	86.50	87.17	86.93±6.73b	109.83	110.75	110.26±6.08a	112.54	112.54	112.54±5.55a	117.04	117.25	117.17±7.16a	0.00
BOD (mg/L)	1.69	1.71	1.70±0.10a	1.48	1.50	1.49±0.08c	1.48	1.50	1.49±0.08c	1.47	1.49	1.48±0.06c	1.57	1.59	1.58±0.08b	0.16
T Alkalinity (mg/L/ $CaCO_3$)	35.29	35.92	35.57±2.17a	32.29	32.88	32.61±1.89d	32.92	33.75	33.22±2.60c	33.75	34.28	34.07±2.46b	32.33	32.83	32.58±2.40d	0.88

NOTE: Means with the same superscript across rows are not significantly different at P>0.05. ϰ = Mean, SD = Standard Deviation

Table 4: Mean physicochemical seasonal variations of Feroro stream water and sediment

	Water		Sediment			
Parameters	**Wet Season**	**Dry Season**	**Wet Season**	**Dry Season**	**P-value**	**WHO standard**
Total Dissolved Solids (mg/L)	111.32±4.41	86.93±4.83	160.04±6.12	99.94±3.77	0.000	1500
Biological Oxygen Demand (mg/L)	1.72±0.05	1.35±0.03	1.61±0.03	1.25±0.03	0.000	
Total alkalinity (mg/L/$CaCO_3$)	28.41±1.28	38.82±0.81	27.38±0.67	37.95±0.98	0.000	200

WHO standard (2017)

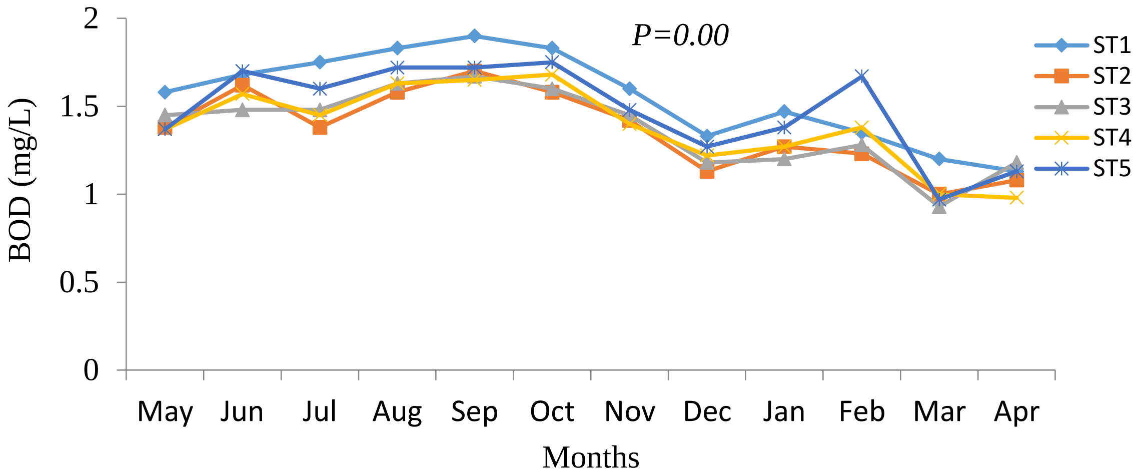

Figure 5: Monthly mean Biological Oxygen Demand (BOD) of Feroro Stream Sediment

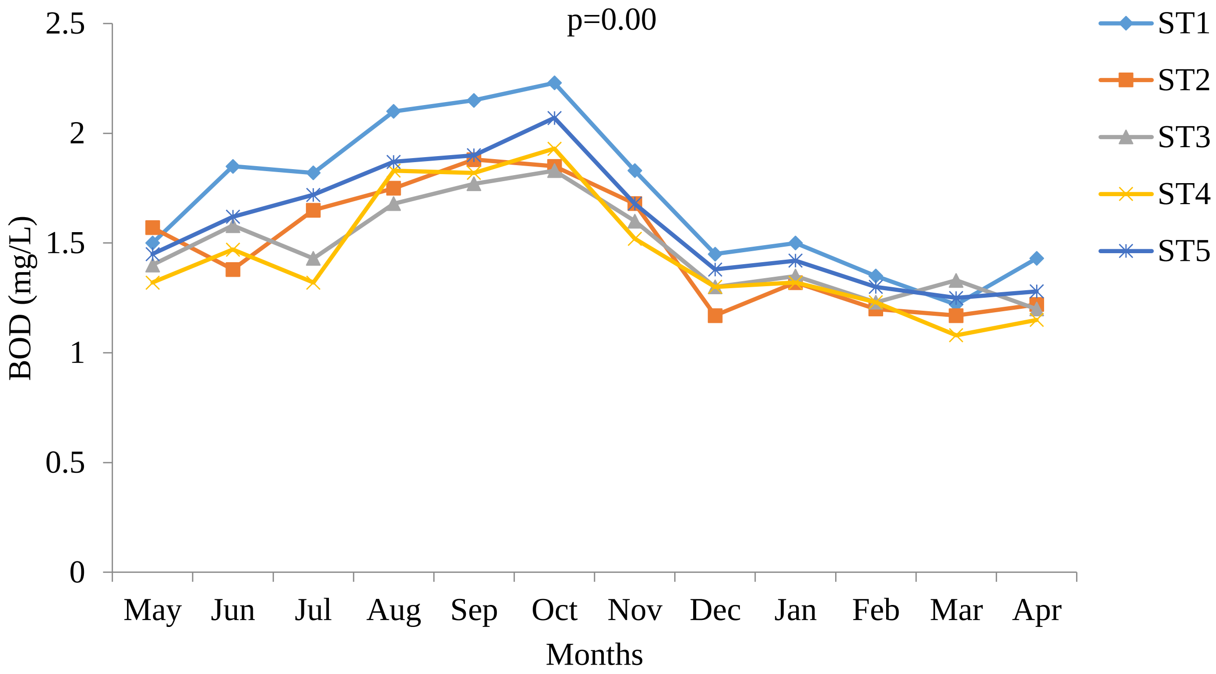

Figure 6: Monthly mean Biological Oxygen Demand (BOD) of Feroro Stream Water

Mean monthly BOD variations in the sediment and water of Feroro stream for the stations is shown in Figures 5 and 6. In the stream sediment BOD was highest in September of 1.73mg/L and lowest in March 1.02mg/L (Figure 5). Monthly variations of BOD in the stream water had highest value of 1.98mg/L in October, followed by 1.90mg/L in September and the lowest 1.21mg/L in March. Highest BOD of 1.70mg/L was recorded in station 1, followed by 1.58mg/L in station 5 and the lowest 1.48mg/L in station 4 (Table 3). Station 1 had an increase in BOD from May (1.45mg/L) to October (2.23mg/L) followed by decrease in November (1.83mg/L) to March (1.25mg/L). In Station 2, BOD decreased in June (1.38mg/L) increased from July (1.65mg/L) through to October (1.85mg/L) then decreased from November (1.68mg/L) through to March (1.17mg/L). In Stations 3 and 4, BOD also increased from May (1.40mg/L and 1.32mg/L) to June (1.58mg/L and 1.47mg/L) then decrease in July (1.43mg/L) and 1.32mg/L followed by increase in August (1.68mg/L and 1.83mg/L) through to October (1.83mg/L and 1.93mg/L) respectively. It began to decrease in November (1.60mg/L and 1.52mg/L) through to April (1.20mg/L and 1.15mg/L). At station 5 BOD increased steadily from May (1.45mg/L) through to October (2.07mg/L) followed by decrease in November (1.68mg/L) to March (1.25mg/l) (Figure 5). In the stream sediment the highest BOD 1.55mg/L was also recorded in station 1, followed by 1.48mg/L in station 5 and the lowest 1.36 mg/L in station 2. There was no significant difference $p<0.05$ respectively (Table 2). The Canonical Correlation Analysis (CCA) of the stream water revealed that BOD negatively correlated with TDS and total alkalinity but correlated positively with TDS in the stream sediment (Figure 4). BOD was significantly different across the seasons Table 3.

BOD is the amount of oxygen utilized by aerobic bacteria in the decomposition of waste (Oniye *et al*., 2014). According to Abolude *et al*. (2012), classification of water bodies based on BOD from moderately polluted to clean; is >1.0mg/L<2.0mg/L and heavily polluted is >10mg/L. Therefore, the low BOD values obtained indicates Feroro stream to be classified as moderately polluted to clean, since its BOD value is >1.0mg/L<2.0mg/L. Increasing BOD concentrations across the sampling months and stations showed that the stream was moderately polluted by influx of organic matter from the numerous anthropogenic activities including washing detergents from laundry, processing of agricultural products and dumping of refuse into the stream. The higher the amount of BOD values in the Station 1, months of September and October in the stream water can be attributed to the discharge and decomposition of pollutants especially organic waste and untreated sewage into the stream as also reported in the studies of the Amel *et al*. (2021). The low BOD in the rainy season was contrary to the Abubakar *et al*. (2015) that reported high BOD in the rainy season. From the BOD concentration range of the stream, the stream can easily undergo self -purification. Gupta *et al*. (2017) reported BOD range of 0.35mg/L and 2.18mg/L in river Narmada, Madhya Pradesh, India and most rivers possess the ability to undergo self-purification at BOD value of less than 4mg/L, however this ability is compromised when it exceeds this value. Although in the study of Salman *et al*. (2013), which had BOD_5 values ranging between >1.0 to <10.0mg/L was considered unpolluted to moderately polluted and the findings of Kalal *et al.* (2021) revealed that BOD of surface water above the standard limit range of 2mg/L to 3mg/L indicates high pollution and not suitable for aquatic organisms. The consequences of high BOD on aquatic organisms is that they become stressed, suffocate, and even die (Uddin, *et al*., 2014).

Mean monthly total alkalinity variations of Feroro stream sediment and water is shown in Figures 7 and 8. Monthly variations of total alkalinity in the stream water had highest value of 42.50mg/L/$CaCO_3$ in March, followed by 42.47mg/L/$CaCO_3$ in January and the lowest value of 21.03mg/L/$CaCO_3$ in September of the stream water (Figure 8). Station 1 had the highest total alkalinity of 35.57mg/L/$CaCO_3$, followed by 34.07mg/L/$CaCO_3$ in station 4 and the lowest 32.58mg/L/$CaCO_3$ in station 5 of the stream water (Table 2). At stations 1, 2 and 3 total alkalinity decreased from May (44.83mg/L/$CaCO_3$, 37.00 mg/L/$CaCO_3$ and 40.17mg/L/$CaCO_3$) through to September (24.33mg/L/$CaCO_3$, 19.50 mg/L/$CaCO_3$ and 27.67mg/L/$CaCO_3$) respectively, followed by increase in October (30.50 mg/L/$CaCO_3$) through to April (43.17 mg/L/$CaCO_3$) at station 1. At Stations 4 and 5, it also decreased in May to September and increased in October to January, then decreased in March and April. There was no significant variation in total alkalinity of the stream water across the stations but was significant in all the sampling months. In the stream sediment the highest total alkalinity of 33.46mg/L/$CaCO_3$ was recorded in station 5, followed by 33.20mg/L/$CaCO_3$ in station 1 and the lowest 31.53mg/L/$CaCO_3$ in station 4. Total alkalinity in all the Stations also decreased in the month of May to September then increased from October through to January and decreased in March to April (Figures 7 and 8). Total alkalinity in the sediment was also significantly different in the months $p<0.05$ (Figure 7). Across the sampling stations, total alkalinity was not significantly different $p<0.05$ Table 3. Total alkalinity in the water and sediment were high during the dry season as compared to the wet season $p<0.05$ Table 3. The Canonical Correlation Analysis (CCA) revealed that total alkalinity correlated positively with BOD in sediment and TDS in water of the stream Figures 3 and 4. The total alkalinity of the stream was high during the dry season and low in the wet season, which can be attributed to increased evaporation and concentration of ions in the stream during the dry season. This agrees with the findings of Agbugui and Deekae (2014) where higher total alkalinity was recorded in the dry season than the wet season of a water body in new Calabar-Bonny River. Total alkalinity is a measure of the acid neutralizing and buffering ability (Halim *et al*., 2018). Total alkalinity values of Feroro stream is contrary to the findings obtained by Mustapha and Abodunrin (2021), where total alkalinity was more pronounced during the rains in a reservoir, however, there was no significant difference ($p>0.05$) across the stations. The occurrence of total alkalinity in Feroro stream could also be attributed to geologic formations of the stream which consist of carbonate, bicarbonate and hydroxide compounds, as suggested in the studies of Seiyabah and Izah (2017). Water body containing more than 200mg/L of Total alkalinity is not desirable for drinking purpose (Halim *et al*., 2018).

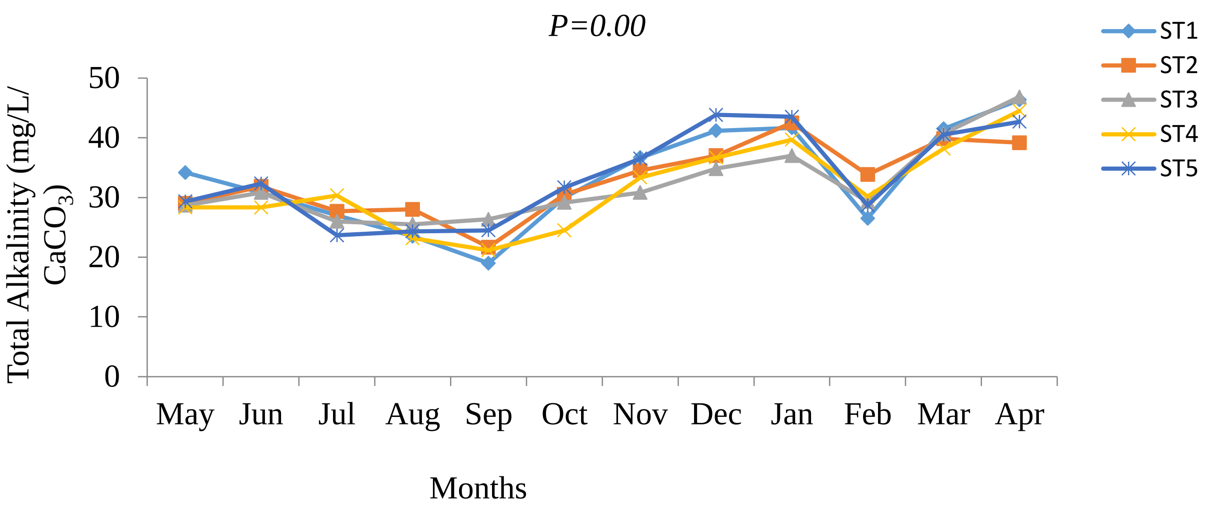

Figure 7: Monthly mean Total Alkalinity of Feroro stream Sediment

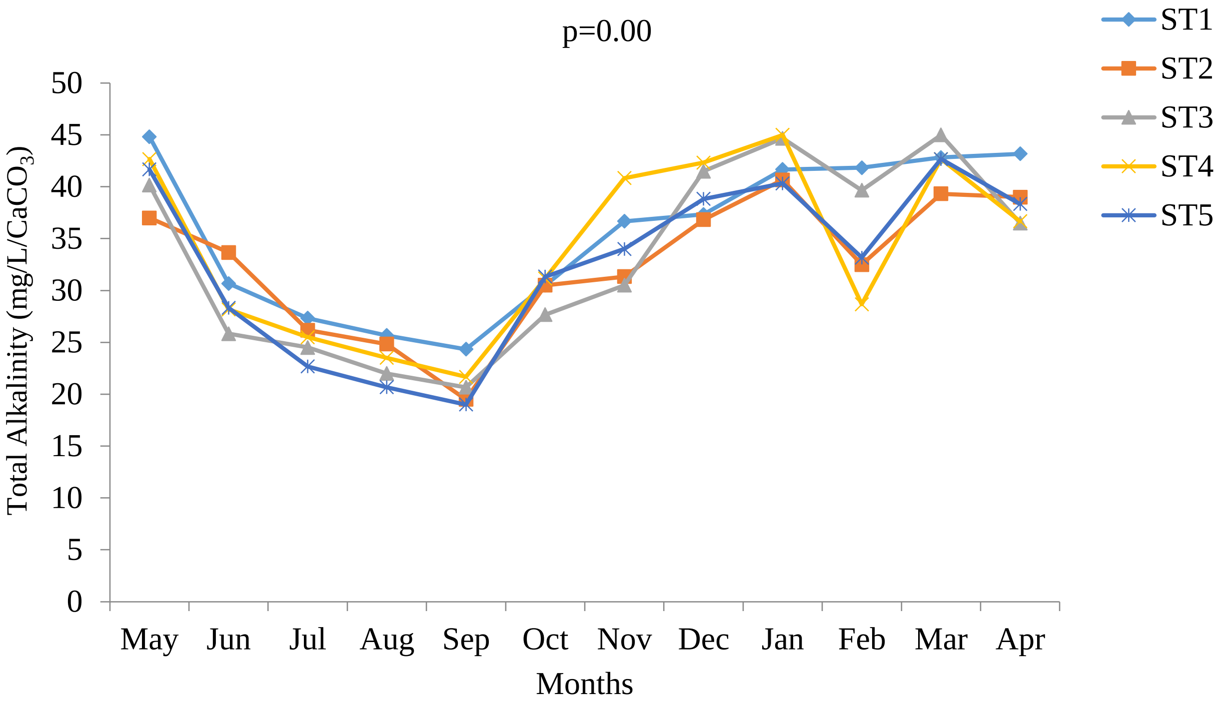

Figure 8: Monthly mean Total Alkalinity of Feroro stream Water

CONCLUSION

Temporal variations of TDS in the sediment and water was highest in August and September, then lowest in January and February respectively. TDS was significant difference spatially across the Stations in the stream water but not different in the sediment. TDS had negative correlation with BOD and Total alkalinity in both the water and sediment. BOD negatively correlated with TDS and total alkalinity but correlated positively with TDS in the stream sediment. Total alkalinity in the sediment was also significantly different in the months. Across the sampling stations, BOD and total alkalinity are not significantly different. All the parameters were significantly different across the seasons. Total alkalinity in the water and sediment were high during the dry season as compared to the wet season.

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