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Spatio-seasonal physico-chemistry of Aiba stream, Iwo, Nigeria

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Seasonal variation of some physico-chemical parameters of Aiba stream at four locations was assessed in this study. Over the years, the stream has been subjected to various human interferences and water quality was getting deteriorated gradually. Major anthropogenic activities practiced in and around the river are as follows: irrigation activities, car wash, artificial pond, washing cloths and utensils, spiritual bathing, discharge of domestic waste etc. All these constitute serious threat to the aquatic biota and thereby alter the physico-chemical and biological concentration of the river. The physico-chemical parameters were determined using parameters were determined using standard literature methods. The pH, water temperature, sulphate, phosphate, total alkalinity/bicarbonate levels indicate moderate quality of water. Electrical conductivity was above the maximum allowable limit in dry season. Dissolved oxygen and nitrate levels were slightly above maximum allowable limit for aquatic biota. Biological oxygen demand (BOD) level indicates the absence of major organic pollution sources. The t-test calculated for seasonal variation shows that, of all the parameters studied, only temperature was significant at $P < 0.05$. One-way analysis of variance (ANOVA) for all the locations revealed that all the parameters studies were not significant at $P < 0.05$. The nutrient levels in the river system is a warning signal of eutrophication, hence the pollution level has to be checked. It is therefore recommended that periodical assessment of both physico-chemical and microbial analysis of the area should be carried out, as this would be helpful in early detection of any future degradation.

Key words: Water quality, nutrients, Aiba stream, physico-chemistry, pollution.

INTRODUCTION

Water is an essential natural resource for sustaining life and environment that was always thought to be available in abundance and free gift of nature (Dikio, 2010). However, chemical composition of surface or sub-surface is one of the prime factors affecting the suitability of water for domestic, industrial and agricultural purposes (Meenakshi, 2006).

Worldwide pollution of rivers and streams has been one of the most crucial environmental problems since the 20th century (Dulo, 2008). The quality of the surface water is a very sensitive issue (Simeonov et al., 2003). Dan et al. (2013) opined that the major sources of pollution in streams, rivers, and underground water arises from anthropogenic activities largely caused by the poor and uncultured living habit of people as well as the unhealthy practices of factories, industries and agricultural practices, resulting in the discharge of effluents and untreated wastes.

Anthropogenic influences (urban, industrial and agricultural activities, increasing consumption of water resources) as well as natural processes (changes in precipitation inputs, erosion, weathering of crustal materials) degrade surface waters and impair their use for drinking,

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industrial, agricultural, recreation or other purposes (Carpenter et al., 1998). Urban stream are common features of contemporary landscapes, and the effects of urban development on stream ecosystems are complex, with many physical, chemical and biological consequences (Hogg and Norris, 1991; Suren, 2000). Increased impervious surfaces due to development of roads and car parks, substantially affects urban stream flow regimes, reducing ground water recharge due to lack of precipitation infiltration, and leads to increasing runoff during rainfalls (Suren, 2000; Paul and Meyer, 2001). In addition, urban runoff can detrimentally alter stream chemistry, bringing with it suspended sediments such as nitrogen and phosphorous as well as heavy metals, polycyclic aromatic hydrocarbons (PAHs), and other pollutants that accumulate during times of low rainfall on roads and car parks (Garie and McIntosh, 1986; Beasley and Kneale, 2002). These are some of the ubiquitous consequences of urban development all of which can ultimately reduce stream "health" and biological diversity. Risks of water borne diseases are therefore a major public health concern in Iwo, a semi-urban area.

Many people in developing countries of the world such as Nigeria do not have access to safe and clean drinking water or to adequate amount of water for basic hygiene. In 2004, the World Health organization (WHO) reported that some 1.1 billion people representing 17% of the global population were without safe drinking water. Substantial numbers of these people live in China, India, Africa and Middle East. The report further revealed that 42% of sub-Sahara Africa lacks drinking water. By the end of 2008, an estimated 884 million people in the world lacked access to improved sources of drinking water and 2.6 billion people lack access to improved sanitation facilities (RADWQ, 2010). Forecast has shown that more than 47% of the global population will face severe water hardship by 2030 (Robert, 2008).

In 1997, the WHO reported that 40% of deaths in developing nations occur due to infections from water related diseases. Diseases contacted through drinking water kill about five million children annually and make one-sixth of the world population (WHO, 2004); and an estimated 500 million cases of diarrhoea, occur every year in children below five years in parts of Asia, Africa and Latin America (WHO, 2011). With ever expanding population in Iwo, the water pollution has become a devastating issue as the agricul-tural, domestic and municipal sewage, containing bulk quantities of toxic heavy metals, are being continuously discharged in the stream. There is need for proper conservation and efficient utilization of fresh water bodies for sustainable development. As a result of these anthropogenic factors influences on Aiba stream, it becomes necessary that continuous monitoring of physicochemical properties and levels of inorganic pollution of Aiba stream be investigated. In the light of this, the present study evaluated some physico-chemical parameters of Aiba stream to assess the levels of anthropogenic influence and its suitability for biotic life.

MATERIALS AND METHODS

Description of the study area

This study was conducted along the Aiba stream in the city of Iwo. Aiba stream drains through Kuti road, Bowen University road and Oke-Afo before discharging into the Oba River. Location 1 (Water Works) is the exit point or the spillway of the reservoir. This area is notable for refuse dump, spiritual bath and low traffic. This location is taken as control being the closest accessible site to the source and due to relative low level of human activities in the area. Location 2 (Kuti area) runs through residential area and there is a car wash service; it was also observed that there was indiscriminate dumping of refuse into the stream; a local fish pond is also located in this area. Location 3 (Oweyo area) is along a major road leading to a private University; there is a filling station and car wash services around this area. Irrigation practices were also going on along this stream. Motor garage is also located very close to the stream. This area receives a heavy amount of domestic pollution from residential habitations and effluent from car exhaust. Location 4 (Oke-Afo) is the area about 2 km from Aiba Reservoir. It is situated at the down stream of the river. Agricultural activities and refuse dumping was observed as it runs through a residential area. The GPS (GPS Extrex Model) coordinate of the sampling locations are shown in Table 1.

Sample collection

Replicate sample for each location along the stream were collected in September, 2009 for the wet season and March, 2010 for the dry season. The sampling locations were chosen to reflect different activities in the catchment area, which may affect the water quality situation of the stream. Samples for water quality studies were collected in 2 L plastic bottles that had been previously soaked in 10% nitric acid for 48 h, and rinsed with distilled water. The water samples were collected between 8 to 10 am from each sampling locations. The container was rinsed three times on site with ambient water before collecting the water sample for water quality analysis. Samples were stored immediately in a cooler, in order to ensure that the physical properties of the water samples were maintained, and transported to the laboratory for analysis. Water temperature, pH and electrical conductivity were recorded at each sampling locations. Dissolved oxygen was fixed at each sampling locations with manganous sulphate and alkali-iodide-azide for analysis.

Determination of physico-chemical parameters

All chemicals used were AnalaR grade (BDH, England). Water temperature, and conductivity were determined using Testr II dual range meter (Eutech Instruments, Malaysia) after calibrating with standard buffer solutions while pH was measured using a pH Test meter (Eutech Instruments, Malaysia). Sulphate was determined by turbidimetric method (Ademoroti, 1996); phosphate was determined by colorimetric technique (APHA, 1998); nitrate was determined by ultraviolet screening method (APHA, 1998); total alkalinity / bicarbonate, dissolved oxygen and biological oxygen de-mand (BOD_5), were also determined by methods described by Ademoroti (1996).

Quality assurance and control

To assess the precision and accuracy of results, replicate analysis of blank, standard and samples was done. The standard errors were determined to find the accuracy of the analysis.

Table 1. The GPS (GPS Extrex Model) coordinate of the sampling locations.

Location	N Coordinate	E Coordinate	Elevation
Water works	7º 38' 10"	04º 11' 50.7"	232 m
Kuti area	7º 38' 09"	04º 11' 36.7"	230 m
Oweyo area	7º 37' 41.0"	04º 11' 0.75"	226 m
Oke-Afo area	7º 37' 19.5"	04º 10' 45.5"	224 m

Quantification process

In this study, raw data were used in calculating the mean standard error for the physicochemical parameters from duplicate replicate measurements using the Statistical Package for Social Science (SPSS) software, 15.0 for Window evaluation version. The physicochemical parameter analyses were subjected to one-way analysis of variance to determine the significant difference among locations along the stream. Duncan's multiple range test (Duncan, 1955) was used to determine which of the location(s) have significantly different values from each other. The t-test was used to determine significant difference among for season for all locations.

RESULTS AND DISCUSSION

The pH of the stream water ranged from 6.90 to 8.80 with mean value of 7.45 ± 0.19 for dry season while in wet season, the pH ranged from 7.50 to 8.80 with mean value of 8.08 ± 0.34 (Table 2). It is evident that the pH was higher in wet season than dry season. In general, the Aiba stream water is said to be slightly alkaline. Most biochemical and chemical reactions are influenced by pH (Simpi et al., 2011). The reduced rate of photosynthetic activities reduces the assimilation of carbon dioxide and bicarbonate which are consequently responsible for increase in pH. The higher pH observed in wet season suggests that carbon dioxide, carbonate-bicarbonate equilibrium is affected more due to change in physico-chemical condition (Tiwari et al., 2009). Atobatele and Ugwumba (2008) earlier reported range value of 5.53 to 9.48 with mean value of 7.98 ± 0.11. The pH range was in conformity with pH range of 6.5 to 8.5, the stipulated value for drinking and domestic purposes by World Health Organization (WHO, 2006). The pH obtained was also within the range 6 to 9 set by European Union (EU) for fisheries and aquatic life (Chapman, 1996). Therefore, the pH of the stream would not adversely affect its use for domestic and recreational purposes.

Temperature is one of the most important ecological features. It controls behavioural characteristics of organisms, solubility of gases and salt in water (Dixit and Tawari, 2007). Temperature ranged from 29.1 to 35.1°C with mean value of 31.68 ± 1.25°C for dry season while in wet season, temperature ranged from 26.30 to 29.30°C with mean value of 27.20 ± 0.70°C. The mean value of temperature in dry season was higher than wet season. The study area with surface temperatures of mean value of 30.40 ±1.10°C is typical of African rivers. The temperature of water from Aiba stream for both seasons were within the range of < 40°C recommended by Federal Environmental Protection Agency (FEPA, 1991). Trend in surface water temperature revealed no significant difference within the locations; the water samples were collected at a very close time interval.

Electrical conductivity (EC) values for dry season ranged from 210 to 620 µScm^{-1} with mean value of 412.51 ± 228.24 µScm^{-1} while wet season ranged from 110 to 180 µScm^{-1} with mean value of 147.50 ± 29.86 µScm^{-1} (Table 2). This result indicates that the mean values for dry season was higher than the wet season. The high value of electrical conductivity for the dry season may be attributed to evaporation resulting in the concentration of the constituents in the water (Chikere and Okpokwasili, 2002). The results of EC for all the locations revealed that the EC increases from the source down stream (Table 3). This finding is in agreement with that reported (Ferrar, 1989); the EC of a river is generally lowest at the source of its catchments and leaches ions from the soils and also picks organic material from biota and its detritus as it flows. The mean EC value of typically unpolluted river is approximately 350 µScm^{-1}(Koning and Ross, 1999). This suggests that the EC of the stream fall below the acceptable limit in the wet season while in the dry season, the EC was above the acceptable limit but the total mean value was below the acceptable limit. The effects of high electrical conductivity may include disturbances of salt and water balance and high salt concentrations in waste effluents; however it can increase the salinity of the receiving water, which may result in adverse ecological effects on aquatic biota (Fried, 1991).

Dissolved oxygen (DO) is one of the most important factors in stream health (Vankatesharaju et al., 2010). The deficiency of DO directly affects the ecosystem of a river due to bioaccumulation and biomagnification (Venkatesharaju et al., 2010). The seasonal variation shows that dry season (9.32±0.94 mg/L) with range value of 8.06 to 12.09 is higher than wet season (5.60 ± 1.59 mg/L) with range value of 2.02 to 12.09 mg/L (Table 2). Total average varied between 2.02 to 12.09 with mean value of 7.46 ± 1.11 mg/L and showed decreasing trend along the stream (Table 3). The DO levels decreased along the stream. A lot of factors could be responsible for this finding; the perpetual dumping of waste especially domestic wastes have been implicated to increase the levels of nitrate and phosphate in the stream water leading to increase in plant and algae growth in the water which subsequently deplete the oxygen levels and

Table 2. Mean (± standard error) and range of measured physico-chemical parameters for Aiba stream for wet and dry seasons.

Season	pH	Temperature (°C)	Conductivity (µS/cm)	Dissolved oxygen (mg/L)	PO_4^{3-} (mg/L)	SO_4^{2-} (mg/L)	NO_3^- (mg/L)	Total alkalinity (mg/L)	BOD (mg/L)
Dry									
Mean ± SE	7.45±0.19	31.68±1.25*	412.50 ± 114.10	9.32±0.94	0.55±0.07	6.85 ± 3.20	2.28 ± 1.54	75.00±14.29	3.56±1.33
Range	6.90 -7.70	29.10-35.10	210.00 - 620.00	8.06 - 12.09	0.37 -0.70	1.21- 14.24	0.00-6.76	40.00 - 110.00	1.75-7.50
Wet									
Mean ± SE	8.08± 0.34	27.20 ± 0.70	147.50 ± 14.93	5.60 ±1.59	10.46±10.45	Nd	Nd	91.25±10.08	3.0±0.51
Range	7.50-8.80	26.30-29.30	110.00-180.00	2.02-8.67	0.00-41.85			75.00 - 120.00	2.25-4.50
Total									
Mean ± SE	7.80±0.21	29.44±1.08	280.00±73.10	7.46±1.11	5.50±5.19	3.43±1.97	1.14±0.83	83.12±8.66	3.28±0.67
Range	6.90 -8.80	26.30-35.1	110.00-620.00	2.02-12.09	0.00-41.85	0.00-14.24	0.00-6.76	40.00-120.00	1.75-7.50

*Significantly different at P<0.05.

Table 3. Mean ±SE value of measured physico-chemical parameters of Aiba stream for each locations.

Location	pH	Temperature (°C)	Conductivity (µS/cm)	Dissolved oxygen (mg/L)	PO_4^{3-} (mg/L)	SO_4^{2-} (mg/L)	NO_3^- (mg/L)	Total alkalinity (mg/L)	BOD (mg/L)
Water works									
Mean±SE	8.20±0.60^{a}	27.70±1.40^{a}	165.00±55.00^{a}	10.38±1.71^{a}	0.18±0.18^{a}	7.12±7.12^{a}	3.38±3.38^{a}	75.00±0.00^{a}	2.50±0.25^{a}
Range	7.60 -8.80	26.30-29.10	110.00-220.00	8.67-12.09	0.00 -0.37	0.00-14.24	0.00-6.76	-	2.25-2.75
Kuti									
Mean±SE	8.05±0.45^{a}	30.80±4.30^{a}	175.00±35.00^{a}	8.37±0.51^{a}	0.35±0.35^{a}	5.08±5.08^{a}	0.94±0.94^{a}	77.50±2.50a	5.12±2.38^{a}
Range	7.60-8.50	26.50-35.10	140.00-210.00	7.86-8.87	0.00-0.70	0.00-10.17	0..00-1.87	75.00-80.00	2.75-7.50
Oweyo									
Mean±SE	7.20±0.30^{a}	28.85±2.15^{a}	390.00±230.00^{a}	6.04±2.21^{a}	21.22±20.63^{a}	0.60±0.60^{a}	Nd	65.00±25.00^{a}	2.38±0.13^{a}
Range	6.90-7.500	26.70-31.00	160.00-620.00	3.83-8.25	0.59-41.85	0.00-1.21	0	40.00-90.00	2.25-2.50
Oke-Afo									
Mean±SE	7.60±0.10^{a}	30.40±1.10^{a}	390.00±210.00^{a}	5.04±3.02^{a}	0.26±0.26^{a}	0.9±0.90^{a}	0.24±0.24^{a}	115.00±5.00^{a}	3.12±1.38^{a}
Range	7.50-7.70	29.30-31.50	180.00-600.00	2.02-8.06	0.00-0.52	0.00-1.79	0.00-0.49	110.00-120.00	1.75-4.50

*Mean±SE with the same superscript are not significantly different at P < 0.05.

irrigation practices along the bed of the stream especially locations 2 and 3 could also support depletion of oxygen levels. Moreover, the use of nitrate and phosphate fertilizer used during irrigation purposes could be leached into the stream water and hence eutrophication of the water body. The responsible factor for high level of DO during the dry season might be due to long days of intensive heat as a result of sunlight which seem to have increase photosynthesis by phytoplankton, utilizing carbon dioxide and giving off oxygen. Atobatele and Ugwumba (2008) earlier reported range value of 1.75 to 11.20 mg/L with mean value of 7.23 ± 0.20 mg/L. The standard for sustaining aquatic biological life is stipulated at 5 mg/L; a concentration below this value adversely affect biological life, while concentration below 2 mg/L may lead to death for most fishes (Chapman, 1997).

Phosphate and nitrate estimation are important in evaluating the potential biological productivity of surface water (Vankatesharaju et al., 2010). Phosphate comes from fertilizers, pesticides, industry and cleaning compounds. Natural sources include phosphate containing rocks and solid or liquid wastes. These are classified as orthophosphate, condensed phosphates and originally bound phosphates (Jayalakshmi et al., 2011). Any increase in the levels of any of these two nutrients will increase the risk of experiencing eutrophication. Seasonal variation shows that the value of phosphate was very high in wet season (10.46 ± 10.45 mg/L) than dry season (0.55 ± 0.07 mg/L) while the total mean value was 5.50 ± 5.19 mg/L (Table 2). Phosphate levels in location 3 (Oweyo) was unusually high (21.22 ± 20.63 mg/L) compared with other locations (Table 3). This might be due to car wash and irrigation practices going on along this area. The value of phosphate obtained in this study is well above 5 µg/L which would reduce the likelihood of alga and other plant growth (DWAF, 1999). Simpi et al. (2011) reported high phosphate content of 5.75 mg/L in the month of August in their study of physico-chemical analysis of tank irrigation water in India. The high value of phosphate in wet season are mainly due to rain, surface water runoff, agriculture runoff, laundry, and car wash activities could have also contribute to the inorganic phosphate content (Simpi et al., 2011)

Nitrate is a form of nitrogen and a vital nutrient for growth, reproduction, and the survival of organisms (Adeyemo et al., 2008). Nitrate was not detected in wet season while the dry season had a mean value of 2.28 ± 1.54 mg/L ranging from 0 to 6.76 mg/L (Table 2). The total means value for nitrate was 1.14 ± 0.83 mg/L with range of 0 to 6.76 mg/L (Table 2). High nitrate levels (> 1 mg/L) are not good for aquatic life (Johnson et al., 2000).

The high levels of nitrate observed in this study are in agreement with those reported by Wolfhard and Reinhard (1998); and Adeyemo et al. (2008). Wolfhard and Reinhard (1998) reported that nitrate is usually built up during the dry season and that high levels of nitrate are only observed during early rainy season. This is because initial rain flush out deposited nitrate from near-surface soil and nitrate levels reduces drastically as rainy season progresses. Similarly, nitrate value during dry season may possibly be due to increase in the degradation of organic matter by microbial activities.

The sulphate content of natural waters is an important consideration in determining their suitability for public and industrial supplies (Venkatesharaju et al., 2010). Sulphate was not detected in the wet season while the mean value for dry season was 6.85 ± 3.20 mg/L. The total mean value was 3.43 ± 1.97 ranging from 1.21 to 14.24 mg/L. The mean value obtained for this study was below the WHO (2004) limit of 250 mg/L for drinking water. Based on the results, the sulphate are not likely to cause health hazard and can be said to be potable. The presence of sulphate in drinking water can cause noticeable taste, and very high levels might cause a laxative effecting unaccustomed consumers (WHO, 2011).

The result of the seasonal variation of total alkalinity (TA) is presented in Table 2. The determined phenolphthalein alkalinity for this study was zero; as a result, the values for total alkalinity and bicarbonate were the same. The mean value for wet season was higher than that for dry season while the total mean value was 83.12 ± 8.66 mg/L. WHO (2004) guideline recommended TA mg $CaCO_3$/L of 200 mg/L. The total alkalinity obtained in this study was below the recommended limit; hence this may not pose any threat in terms of the safety of the water for drinking purpose

The levels of BOD_5 in Aiba stream revealed that the level for dry season (with mean 3.56 ± 1.33 mg/L) was slightly higher than for wet season with mean value of 3.0 ± 0.51 mg/L. The total mean value was 3.28 ± 0.67 mg/L ranging from 1.75 to 7.50 mg/L. The variation was as a result of increased dilution and influx of fresh water during the raining season and sedimentation process during the dry season. Higher content of organic load as well as the high proliferation of micro-organism are the causative factors for maximum BOD levels (Shukla et al. 1989).

The t-test calculated for seasonal variation shows that of all the parameters studied, only temperature was significant at $P < 0.05$. One-way ANOVA for all the locations revealed that all the parameters studies were not significant at $P < 0.05$.

Conclusion

This study summarizes the seasonal variation in physico-chemical parameters of the Aiba stream. The result shows that the physico-chemical properties indicate moderate quality of water. Electrical conductivity was above the maximum allowable limit in dry season. Dissolved oxygen and nitrate levels were slightly above maximum allowable limit for aquatic biota. BOD level indicates the absence of major organic pollution sources. The t-test calculated for seasonal variation shows that of all the parameters studied only temperature was significant at $P < 0.05$. One-way ANOVA for all the locations revealed that all the parameters studies were not significant at $P < 0.05$. The nutrient levels in the river system is a warning signal of eutrophication, hence the pollution level has to be checked.

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