PHYSICO-CHEMICAL, HEAVY METAL AND MICROBIAL ANALYSES OF AWBA DAM WATER, UNIVERSITY OF IBADAN, IBADAN, NIGERIA

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***Received** October 16, 2023; **Revised** November 06, 2023; **Accepted** January 01, 2024*

ABSTRACT

The impacts of anthropogenic activities on surface water quality, heavy metals and microbial load of Awba Dam, University of Ibadan were studied for four months. Awba Dam was stratified into four stations (A, B, C and D) based on hydrological features. Two sampling points were randomly selected from each station. Monthly stratification covered September to December. Water samples were collected bi-weekly following standard procedures. Water samples collected were analysed for temperature (°C), dissolved oxygen (DO, mg/L); heavy metal (HM) (lead, iron, chromium and copper) in water (mg/L) and microbial loads (ML) (CFU/100 mL) according to standard methods. Data were analysed using descriptive statistics and ANOVA at $\alpha_{0.05}$. Significantly highest and least temperatures were 27.60 ± 2.23 and 27.10; DO (3.84 ± 0.35, 3.37 ± 0.11) in stations D and A, while BOD (5.81 ± 2.69, 5.30 ± 2.42) were recorded in stations A and B respectively. Significantly highest and least levels of HM were: lead (0.89 ± 0.35, 0.14 ± 0.06); iron (0.48 ± 0.08, 0.19 ± 0.05); chromium (3.51 ± 0.01, 1.50 ± 0.01) and copper (0.01 ± 0.01, 0.01 ± 0.01) were recorded in September and November, but ML (4.76 x 10^{-6} and 4.00 x 10^{-6}) were obtained as highest and lowest in December and September respectively. Results from this study showed that, Awba Dam is contaminated with lead, iron, chromium and copper and ML. It is recommended that adequate monitoring and pollution reduction strategies be implemented to improve the aquatic resources of the dam.

Keywords: Dam, Anthropogenic effluents, Heavy metals, Surface water quality, Microbial load

INTRODUCTION

Despites the usefulness of surface water, it is one of the most poorly managed natural resources in the world (Ephraim and Ajayi, 2014). Elevated discharges of effluents into the aquatic environment could cause eutrophication, fish mortality, health hazards and coral reef destruction, while the desire to protect freshwater fisheries has led to the expansion of research into water quality, heavy metal concentrations and bacteria loads of surface water (Uwah *et al.,* 2013).

Untreated effluents in the aquatic environments often alter the quality of the water, increased levels of toxic materials and bacterial load multiplication (Barakat *et al.,* 2012). Most times, abnormal changes in water quality are not identified and handled on time, except where there is an epidemic (Edward and Ugwumba, 2010). Variations in water quality are reflected in the biotic community structure in which the most vulnerable species die off, while the non-sensitive species survive to act as indicators of pollution (Mannan *et al.,* 2012). Urban run-off is a contributing factor to poor inland water quality and reduced productivity (Uwah *et al.,* 2013).

Aquatic ecosystems show daily and seasonal changes in temperature which affects the ability of the flora and fauna to reproduce and susceptibility to parasitic and disease infestation (Spellerberg *et al*., 2004). High temperature increases the toxicity of heavy metals and their potential impacts on aquatic life (Bellingham, 2012).

Dissolved oxygen (DO) is simply the amount of oxygen present in water and it is vital to all forms of aquatic life. In dams' water, it occurs through the diffusion of atmospheric oxygen, photosynthetic activities of algae and submerged aquatic macrophytes (Bellingham, 2012).

The biological oxygen demand (BOD) is the rate of uptake of oxygen by microorganisms in oxidation state. The BOD is one of the important indices for measuring organic pollution in water (Pasco and Hay, 2005).

Nitrate's major inorganic oxidation states are nitrate ion, nitrite ion, ammonia and ammonium ion. Nitrate ion is the common form of nitrogen in natural waters (Bellingham, 2012). A nitrate level of over 5 mg/L in natural waters normally indicates man made pollution. Severe changes in the pH of water bodies drastically affect its aquatic life, while changes in pH values are indications of an industrial pollutant, photosynthesis or the respiration of algae that are feeding on contaminants (Bhateria and Jain, 2016).

Heavy metals are chemical elements that have relatively high density (5.0) and are toxic at low concentrations (FEPA, 1991). They are threat to aquatic life due to their toxicity, long persistence, bio-magnification, bio-accumulation in the food chain and interfere with the cytoplasmic and nuclear functions after gaining access into the cell (Ayandiran *et al.,* 2009).

Microbial load refers to the number and types of microorganisms (bacteria, viruses and fungi) that are present in a given samples or environment and it helps in assessing the cleanliness, safety of surface water, while high microbial loads could serve as indicator of potential health risks (Santos *et al.,* 2020). *Escherichia coli* are a gram-negative and facultative anaerobic bacterium that is commonly found in the lower intestine of warm-blooded organisms but are able to survive outside the body for a limited time; this attribute makes them ideal indicator organisms for testing environmental samples for faecal contamination (Barrios-Villa *et al.,* 2018). Isolation of *E. coli* refers to the process of obtaining a pure culture of *E. coli* bacteria from a mixed sample (Boll *et al.,* 2020). This is done to separate and grow *E. coli* cells while inhibiting the growth of other bacteria by using streak plating techniques.

The Awba Dam, University of Ibadan (UI), serves as a sink for the disposal of untreated effluents from the student residential halls, UI Fish Farms, Zoological Garden, Faculty of Science Laboratories and its environment. Akin-Oriola (2003), Tyokumbur and Okorie (2013) and Ojo (2016) had earlier studied the ecology of Awba Dam, with emphasis on its physico-chemical, hydrology and plankton distribution. This study therefore, aimed at evaluating the present physico-chemical parameters, heavy metal concentrations and microbial loads of Awba Dam, UI, Nigeria.

MATERIALS AND METHODS

Study Area: Awba Dam is located in the University of Ibadan on latitude and longitude 7º 26′N and 3º 53′E respectively (Figure 1).

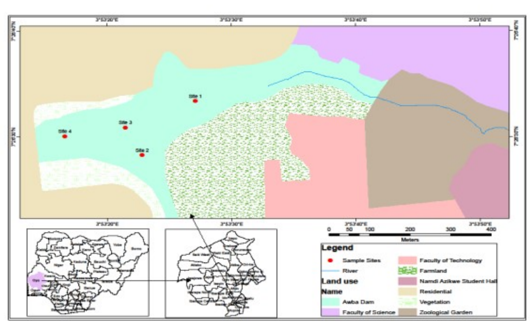

Figure 1: Map of Awba Dam. Source: Geography Department (2014)

It is about 0.69 km long and located 160 km from the Atlantic Ocean with an altitude of 185 m above sea level. It has a boundary with Ijoma Road to the North, Ekwumo Road to the east, to West is the Department of Zoology, to South is the Staff Quarters and the Faculty of technology respectively (Ojo, 2016). The study site is characterised by rainy (April to October) and dry (November to March) seasons. The amount of rainfall within the dam area ranges from 125.2 mm to 278.5 mm (Akin-Oriola, 2003). The study area has a tropical vegetation type with some floating (*Pistia stratiotes* and *Nymphae lotus*) and submerged (*Ceratophylum spicatum and Utricularia* species) aquatic flora, while some fauna species observed were *Oreochromis niloticus, Clarias gariepinus* and *Heterobranchus bidorsalis.*

Sampling Procedures: Awba Dam was stratified into four stations (A, B and C and D) based on hydrological features. Three sampling points per station were randomly selected for sample collection between September and December 2022. Water samples were collected fortnightly following standard procedures described by Baird *et al.* (2017). Water samples collected were analysed for temperature (^{o}C), dissolved oxygen (DO, mg/L), biological oxygen demand (BOD, mg/L), heavy metal (HM) – (lead, iron, chromium and copper) in water (mg/L) and microbial load (ML) (CFU/100 ml) according to standard methods.

Water samples for physicochemical and heavy metal analysis were collected in clean, 200 ml plastic and glass bottles at depth of 0 – 15 cm from the surface (Baird *et al.,* 2017). Temperature was measured in ^{0}C using mercury in glass thermometer, DO and BOD were determined *ex-situ* titrimetrically using the Winkler's method (Baird *et al.,* 2017). DO = Volume of 0.0125N Thiosulphate x 101.6 ÷ Volume titrated, BOD_5 (mg/L) = (DO_1 – DO_5) (B_1 – B_5), where DO_1 = dissolved oxygen concentration of diluted sample immediately after preparation, DO_5 = dissolved oxygen concentration of diluted sample after 5 days of incubation. B_1 = dissolved oxygen concentration in blank (distilled water only) immediately after preparation. B_5 = dissolved oxygen concentration in blank (distilled water only) after 5 days of incubation. D = decimal volumetric factor of sample used.

Nitrate was determined using ultraviolet spectrophotometric screening method (Baird *et al.,* 2017), pH was measured using buffered electronic pH metre (Kent 7020 Model), heavy metals such as iron (Fe), chromium (Cr), copper (Cu) and lead (Pb) were analysed by using the Atomic Absorption Spectrophotometer (Buck Scientific Model 210, GVP); *E. coli* analysis was carried out as described by FEPA (1991). Serial dilution of the water sample was done at 10^{-6} and 10^{-8} concentrations and 10 mL was poured into the Petri dish, swirled the agar around before pouring on into the Petri dishes. The agar with the sample streaked on it was then incubated at 37°C for 24 – 36 hours. CFU = Total Coliform Counted (TCC) ÷ Volume (ml) of Sample x Dilution Factor.

Statistical Analyses: Data obtained from the study were analysed descriptively for their central tendencies. Significant differences were established using one-way analysis of variance (ANOVA) at $p<0.05$. Correlation statistics was used to establish the relationship among the physicochemical parameters. Results were presented according to their temporal and spatial mean variances. All analyses were done using the Statistical Package for the Social Sciences (SPSS Version 20.0).

RESULTS

Physico-Chemical Parameters Recorded in Awba Dam: Mean physico-chemical parameters among stations, months and correlation matrix among physico-chemical parameters are presented in Table 1, Figure 2 and Table 2 respectively. Spatially, significantly highest (5.50 ± 0.08) and least (7.35 ± 0.45) pH mean values occurred in Stations A and B, while it ranged from 6.90 ± 0.12 to 7.80 ± 0.02 in November and September respectively. The pH correlated moderately negative with BOD (r = -0.52). Spatially, BOD concentration was highest (5.81 ± 2.69 mg/L) and least (5.30 ± 2.42 mg/L) in Stations B and A, while it ranged from 4.93 ± 0.00 to 5.61 ± 0.11 mg/L in September and December respectively.

Table 1: Mean spatial physico-chemical parameters of Awba Dam water

Parameters	Stations				FEPA (1991)
	A	B	C	D	
pH	7.50 ± 0.08	7.35 ± 0.45	7.40 ± 0.26	7.38 ± 0.26	6.8 – 8.9
BOD (mg/L)	5.30 ± 2.42	5.57 ± 2.49	5.70 ± 2.45	5.81 ± 2.69	≤5.45
DO (mg/L)	3.16 ± 2.56	3.56 ± 0.47	3.67 ± 0.37	3.69 ± 0.22	≥3.50
NO_3^{2-}(mg/L-N)	1.74 ± 0.36^c	1.02 ± 0.50^b	1.10 ± 0.52^b	0.18 ± 0.55^a	1.50
Temperature (°C)	27.60 ± 2.23	27.10 ± 2.34	27.60 ± 0.42	27.45 ± 0.43	27 – 30

***Note**: a,b,c = means with different letter superscript on the same row are significantly different (p<0.05)*

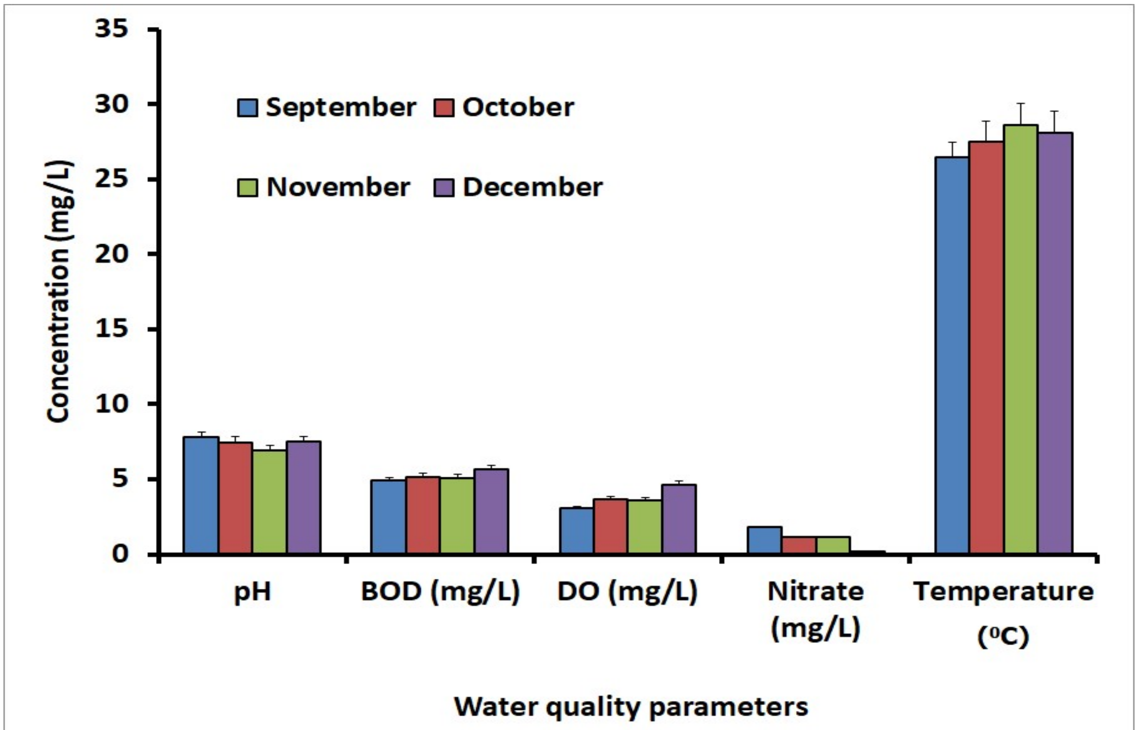

Figure 2: Mean monthly physico-chemical parameters of Awba Dam water

Table 2: Correlation matrix among physico-chemical parameters of Awba Dam

Parameters	pH	BOD	DO	Nitrate	Temperature
pH	1				
BOD	-0.52*	1			
DO	0.13	0.22	1		
Nitrate	-0.28	0.52*	-0.61*	1	
Temperature	-0.19	-0.05	-0.58*	0.39	1

***Note**: * = significant differences (p<0.05)*

BOD correlated moderately positively with Nitrate (r = 0.52). Spatially, significantly highest (3.69 ± 0.22 mg/L) and least (3.16 ± 2.56 mg/L) DO mean values where obtained in Stations D and A, and it ranged from 3.06 ± 0.03 to 4.64 ± 0.00 mg/L in September and December respectively. DO correlated negatively with Nitrate (r = -0.61) and Temperature (r = -0.58). Spatially, significantly highest (1.74 ± 0.36 mg/L) and least (0.68 ± 0.21 mg/L) Nitrate occurred in Stations A and D, and ranged from 0.20 ± 0.01 to 1.80 ± 0.01 mg/L in December and September respectively. Spatially, mean levels of Temperature ranged from 27.10 ± 2.34 to 27.65 ± 2.23 °C in Stations A and B, while monthly highest (28.60 ± 0.01 °C) and least (26.44 ± 0.00 °C) occurred in September and November respectively. Temperature correlated negatively with Nitrate (r = -0.58). The means of heavy metal concentrations in Awba Dam water among stations and months are shown in Table 3 and Figure 3 respectively.

Correlation matrix between physico-chemical parameters and heavy metal concentrations are shown in Table 4. Spatially, significantly highest (0.79 ± 0.32 mg/L) and least (0.24 ± 0.01 mg/L) mean of Pb concentrations occurred in Stations D and A, while it ranged from 0.14 ± 0.01 to 0.89 ± 0.02 mg/L in September and December respectively. Lead had strong positive correlation with BOD (r = 0.74), Temperature (r = 0.73) and moderate positive correlation with DO (r = 0.54) but moderately negatively correlated with Nitrate (r = -0.56). Spatially, highest (0.38 ± 0.01 mg/L) and least (0.10 ± 0.01 mg/L) mean of Fe were obtained in Stations A and C, it ranged from 0.19 ± 0.01 to 0.48 ± 0.03 mg/L in November and September respectively. Spatially, mean values of Cu ranged from 0.03 ± 0.02 to 0.10 ± 0.01 mg/L in Stations D and B, while a constant value of 0.01 ± 0.00 mg/L was recorded among months. Among stations, Cr levels ranged from 1.50 ± 0.02 to 3.46 ± 0.03 mg/L in C and A, while it's highest (3.51 ± 0.01 mg/L) and least (1.50 ± 0.01 mg/L) monthly means where in September and November respectively.

Microbial Load Recorded in Awba Dam: Spatial and monthly distributions of *E. coli* in Awba Dam water are presented in Figures 4 and 5 respectively. Spatially, highest (4.51 ± 1.09) x 10^{-6} CFU/100 mL and least (3.76 ± 2.43) x 10^{-6} CFU/100 mL mean level of *E. coli* occurred in Stations D and A, while it ranged from 3.88 ± 0.41 x 10^{-6} CFU/100 mL to 4.16 ± 0.17 x 10^{-6} CFU/100 mL in November and October respectively. Spatial and monthly distributions of colony levels of *E. coli* in Awba Dam water are presented in Figures 6 and 7 respectively. Colonies 4 and 3 recorded the highest (45.00 ± 0.01) x 10^{-6} CFU/100 mL and least (20.00 ± 0.02) x 10^{-6} CFU/100 mL levels of colonies of *E. coli* distribution in Stations A and D, while it ranged from 30.25 ± 1.34 x 10^{-6} CFU/100 mL to 44.75 ± 3.17 x 10^{-6} CFU/100 mL in December and September respectively.

DISCUSSION

The pH ranges obtained from this study were within the acceptable limit for fish survival. This implied that the aquatic flora and fauna of Awba Dam were not under threat of pH alteration as at when this research was carried out. A similar finding had earlier been reported for Awba Dam (Edward and Ugwumba, 2010). BOD values obtained were marginally higher than the recommended concentration of ≤5.45 (FEPA, 1991). Higher value of BOD recorded in September was associated with the large volume of organic wastes brought into the Dam by storm water. BOD levels had been reported to increases with increase in temperature of water (Oguzie and Izevbigie, 2009).

The values of DO monitored during this study were within the recommended limit of ≥3.50 mg/L (FEPA, 1991). This implied that the atmospheric re-aeration and photosynthetic activities of the submerged aquatic macrophytes were able to stabilize its level within the acceptable limit and fishes its fish stock were not undergoing stress due to DO depletion (Barakat *et el*. 2012).

Nitrate level of over 5 mg/L in natural waters normally indicates man made pollution (FEPA, 1991). Values of nitrate measured were below the recommended limit of 5 mg/L (FEPA, 1991). Pollution due to nitrate causes eutrophication in dams and rivers and increases total suspended solids of the water (Bijay-Singh and Craswell, 2021). The water temperatures monitored were within the recommended range of 26.5 – 31.5°C in the tropics for optimal aquatic organism health (FEPA, 1991). This is attributable to the cooling and diluting effect of the rains which is common to the tropical waters (Oguzie and Izevbigie, 2009).

The concentrations of heavy metals detected during the study were above the recommended standard by WHO (2017) and as such pose a serious health risk to people who rely on this dam as their source of domestic water as well as those who consume the fish and other aquatic organisms harvested from the dam (Al-Haidarey *et al.,* 2010).

Table 3: Mean concentrations of heavy metals in water among stations

Stations	Pb (mg/L)	Fe (mg/L)	Cu (mg/L)	Cr (mg/L)
A	0.24 ± 0.01[a]	0.38 ± 0.01[d]	0.03 ± 0.01[c]	3.46 ± 0.03[c]
B	0.60 ± 0.14[c]	0.29 ± 0.01[c]	0.01 ± 0.01[a]	2.19 ± 0.03[b]
C	0.52 ± 0.03[b]	0.10 ± 0.01[a]	0.02 ± 0.01[b]	1.50 ± 0.02[a]
D	0.79 ± 0.32[d]	0.26 ± 0.30[b]	0.03 ± 0.02[c]	1.60 ± 0.01[a]
FEPA (1991)	0.03-0.05	0.5-1.00	1.00	0.001-0.005
WHO (2004)	0.05	1.00	1.00	0.005

***Note**: a,b,c = means with different letter superscript on the same row are significantly different (p<0.05)*

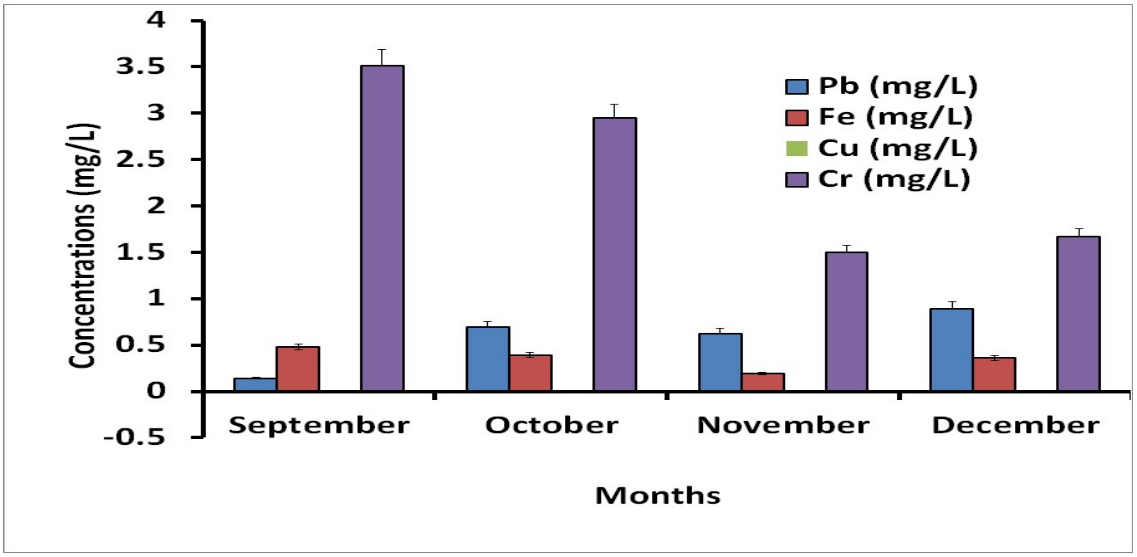

Figure 3: Mean monthly concentrations of heavy metals in Awba Dam water

Table 4: Correlation matrix among physico-chemical parameters and heavy metals levels of Awba Dam

Parameters	pH	BOD	DO	Nitrate	Temperature
Pb	-0.49	**0.74***	**0.54***	**-0.56***	**0.73***
Fe	**0.72***	-0.46	**-0.67***	**0.65***	**-0.47**
Cr	**-0.54***	**0.78***	**0.59***	**-0.61***	**0.77***

**Correlation is significant at the 0.05 level*

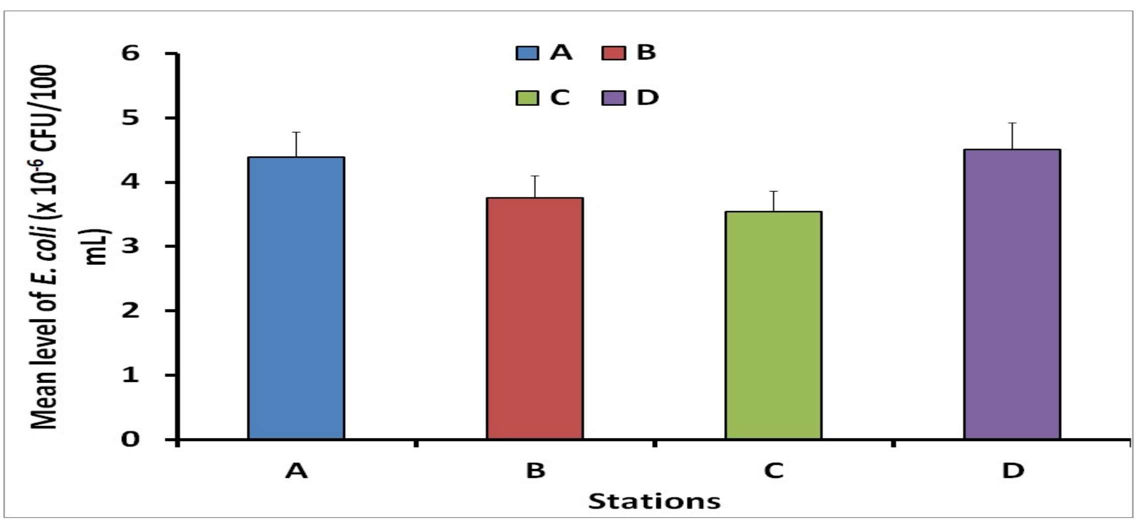

Figure 4: Spatial distribution of *Escherichia coli* levels in surface water of Awba Dam

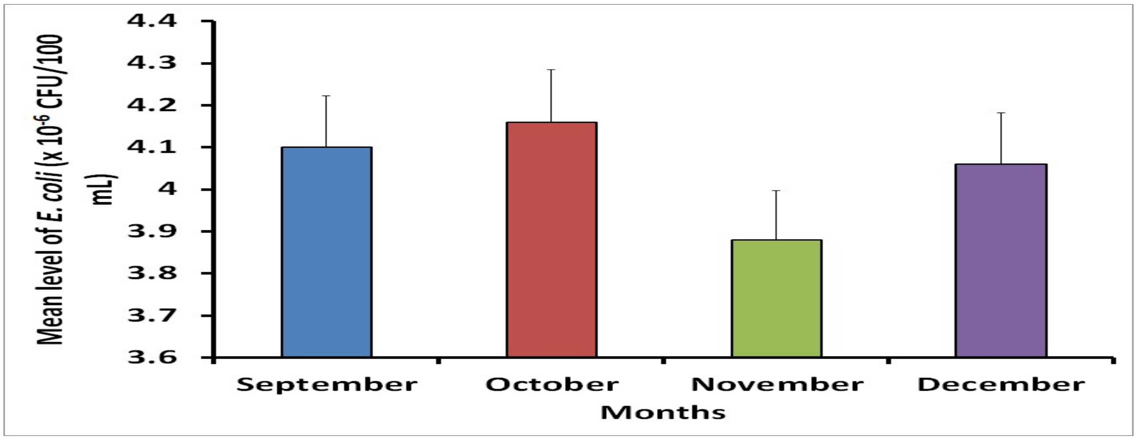

Figure 5: Mean monthly distribution of *Escherichia coli* levels in surface water of Awba Dam

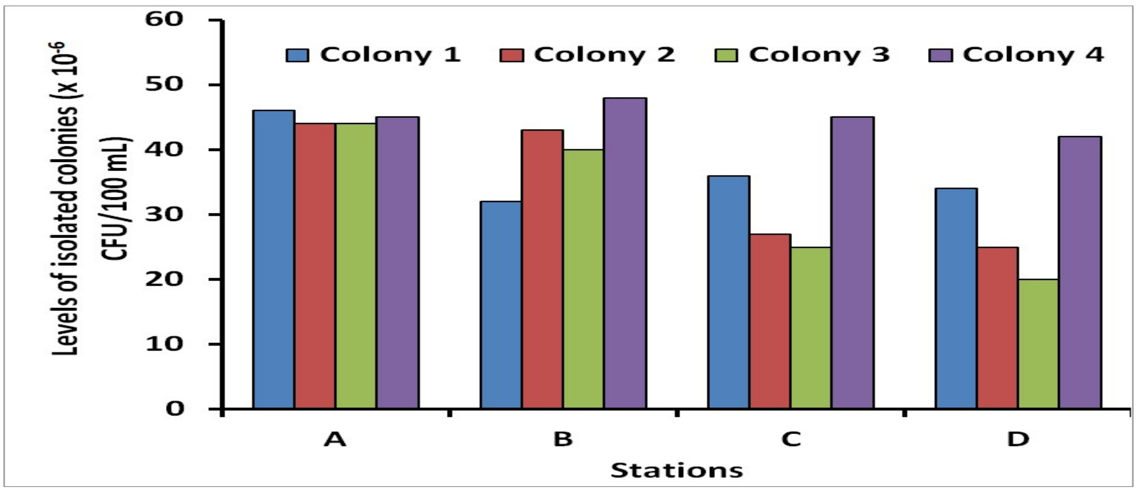

Figure 6: Spatial distribution of colonies of *Escherichia coli* in surface water of Awba Dam

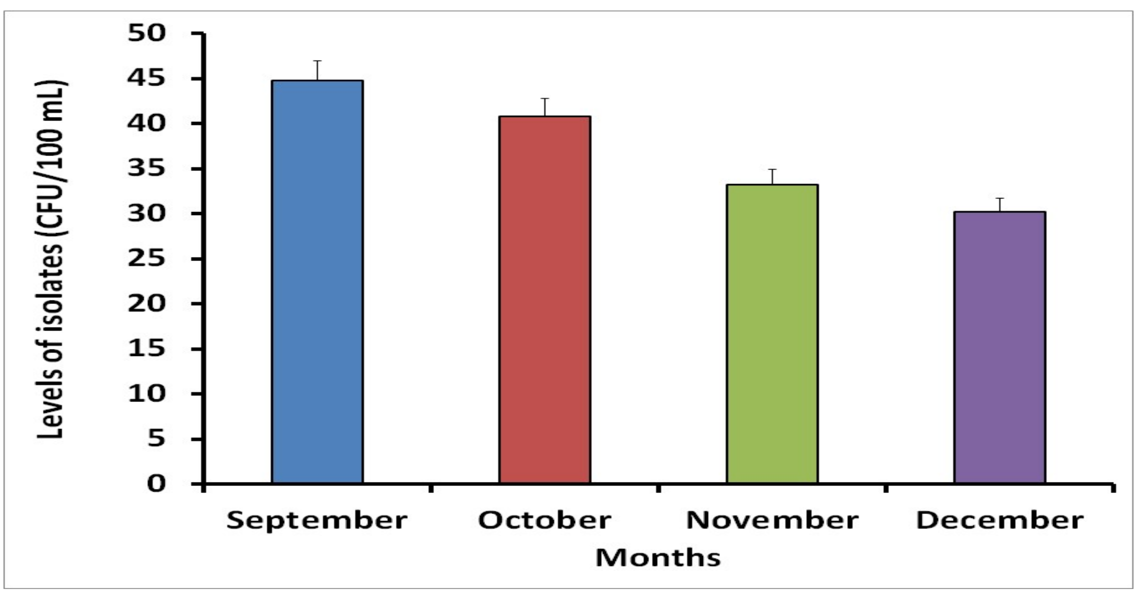

Figure 7: Mean monthly distribution of isolated colonies in surface water of Awba Dam

Heavy metals bio-accumulate in fish tissues thereby causing different physiological and behavioural changes (Ephraim and Ajayi, 2014; Ibemenuga *et al.*, 2019). Lead impairs the nervous system of fish, affecting their ability to swim, feed, grow, immune function and reproduce (Uwah *et al.,* 2013). As the concentration of these metals builds up along the food chain, they become bio-magnified, leading to higher exposure levels in predatory fish (Majolagbe *et al.,* 2012). Higher concentration of heavy metal in water can lead to the loss of biodiversity and the degradation of habitats (Uwah *et al.,* 2013).

Levels of *E. coli* obtained among stations exceeded recommended values established (FEPA, 1991) and served as indicator of faecal contamination, suggesting the potential presence of other harmful pathogens (Johnson and Russo, 2018) which will not be unconnected with the direct flow of sewage from and within the University of Ibadan Community into Awba Dam. The rise in the total coliform counted from December to September may be due to the increased storm water (Gomes *et al.,* 2016). Significant *E. coli* contamination in water could pose major risks to public health and possible outbreak of waterborne diseases. Outbreaks of *E. coli* could results in increased healthcare costs and increase water treatment and remediation costs (Barrios-Villa *et al.,* 2018).

The presence of *E. coli* in a fish culture medium can cause infections and fish diseases, leading to a decrease in fish stock abundance and compromised fish health (Santos *et al.,* 2020). Water contaminated with *E. coli* can have significant economic consequences on recreational activities resulting in lost revenue for local businesses and tourism industries (Boll *et al.,* 2020).

Conclusion: Heavy metal contents in water increased remarkably from November to December. This showed that Awba Dam contained higher level of Pb, Fe and Cr that may be detrimental to the health of aquatic organisms. Furthermore, *E. coli* presence is an indication of faecal pollution. This result also show that the Dam is loaded with large volume of faecal deposit both from within and outside the University of Ibadan Community. It is therefore recommended that the water from the dam should be properly treated before consumption and adequate monitoring be carried out to ensure its improved quality.

ACKNOWLEDGMENTS

The authors are grateful to the Management of the Department of Fisheries and Aquaculture, Faculty of Renewable Natural Resources, University of Ibadan, Ibadan, Nigeria for granting us access to the Laboratory for the analyses of all the collected samples used for this research.

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