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Research Article
A Survey of Water Physicochemical Parameters and Heavy Metals Contaminations of ABU Reservoir and a Stretch of Samaru Stream

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Abstract
Background and Objective: Heavy metals and water physicochemical analysis is prime importance in accessing the quality and pollution load of aquatic environment. The study assessed the water physicochemical parameters and heavy metal contents in water and sediment of ABU reservoir and Samaru stream with the aimed of providing an insight into the local ecosystem and water quality. **Materials and Methods:** Physicochemical characteristics of the reservoir in five sampling stations were investigated using standard methods of American Public Health Association (APHA). Heavy metals of the water and sediment were analyzed using atomic absorption spectrophotometer and x-ray diffraction, respectively. **Results:** The peak electrical conductivity (130.00 µS cm^{-1}) obtained in August is an indication of low ionic concentration and low eutrophic status of the reservoir. However, low dissolved oxygen (DO) observed (<3.00 mg L^{-1}) in August is attributed to accumulated autochthonous, nutrient enrichment and organic matter in the reservoir. Alkalinity varied between 30-150 mg L^{-1} $CaCO_3$. The concentration of heavy metals; Fe, Mn, Zn, Cr, Ni and Pb in both water and sediment is generally low and below the least effect limit (LEL). The pollution status of sampling stations based on Pollution index is: 2>1>3>4>5. The highest mean metal concentration (0.69 ± 0.13 mg kg^{-1}) at station 2 is attributed to its close proximity to an abandoned landfill. Baseline (PLI = 1.48) level of pollutant was recorded from the result of pollution load index (PLI). **Conclusion:** The study provided data on some physicochemical conditions prevailing in the investigated rivers for future reference and also provides a valuable insight into the overall integrity of the local ecosystem and water quality.

Key words: Autochthonous, ecosystem, eutrophic, water quality and sediment

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Water bodies provide habitat for numerous aquatic lives and help in conserving the biodiversity. The use of water bodies in numerous ways such as domestic, industries and agriculture requires water quality data which integrates the chemical and biological information to evaluate the potential impacts to the aquatic ecosystem[1]. Rivers carry different kinds of waste materials, nutrients and minerals which helps in its productivity and also it is the major source of hydropower, irrigation and recharging the groundwater table[2]. The waste materials entered the river system through erosion, sewage through urban lands[3] and chemicals via industries[4]. As a result, the quality of surface water has deteriorated to a great level[5]. Several efforts are being made worldwide to identify, quantify, evaluate, monitor and control the direct inflow of pollutants into river systems[6]. Here, water-quality assessment, planning and management at different scales play an important role. This leads to the assessment of the temporal and spatial changes in water quality, identifying contaminated stretches and ascertains the causes of pollution and identifies polluters[7]. The water quality and metal pollution indices are commonly used tools to evaluate lake water[8], river water and sediment[9].

Pollution of a river first affects its chemical quality and then systematically destroys the community disrupting the delicate food web[10]. River pollution has several dimensions, effective monitoring and control of river pollution requires the expertise from various disciplines[11].

Many discharges to the aquatic environment contain substances which are sparingly water-soluble. These substances bind preferentially to suspended particle materials and bottom sediments in Lakes Rivers, Estuaries and Coastal waters. As a result, some very toxic and persistent chemicals, such as heavy metals, can be found at high concentrations in the sediment[12].

Heavy metals have long been a subject of environmental concern and research interest in the context of the aquatic environment and their impact on aquatic ecosystems[13]. Historically, water quality guidelines have been used to interpret the discharge of metals to receiving waters overlooking the fact that sediments can concentrate metal contaminants to levels that can impair their function[14]. In any aquatic ecosystem, physicochemical parameters affect macro-invertebrates either positively or negatively depending on their source. Excessive physicochemical parameters can cause long- or short-term shifts in invertebrate community richness, abundance and species composition[15].

Physicochemical analysis is of prime importance to access the quality of water for its cost usage like drinking, bathing, fishing, industrial processing etc. and to get idea about pollution load of domestic sewage and industrial wastes on receiving water bodies[16]. This study is therefore, assessed the physicochemical parameters of ABU reservoir and the adjoining Samaru River vis-à-vis the heavy metal load in both water and sediment.

MATERIALS AND METHODS

Study area: The ABU Reservoir is located in Zaria. It is also known as Ahmadu Bello University reservoir. It is constructed on river Kubanni and it supplies water to the University Community. The Lake (reservoir catchments area is 57 km^2, its width is 6 m). The lake is located within latitude 11°05'-11°31'N and longitude 07°28'-07°41'E in Samaru Zaria, Kaduna state (Fig. 1). The lake major tributaries are the Samaru and Kampagi streams. Kampagi steam, which originates from a rural settlement, has a seasonal flow. Whereas, Samaru stream that originate from a semi-urban settlement has an all-year-round flow due to its sustenance by urban runoffs and seepages[17].

Samplings were made periodically in the year 2013-2014 which covers both wet and dry seasons. Five sampling stations were selected for the purpose of this investigation. Three stations were located on Ahmadu Bello University reservoir while two were located along Samaru Stream. Each sampling stations were about 500 m apart. Sampling stations 1-5 were shown in Fig. 1.

Collection of water and sediment samples

Physicochemical parameters: Water temperatures were measured *in situ* using mercury filled centigrade thermometer of 0.1°C accuracy, pH was determined using Griffin pH meter (model 40). The following factors selected as water quality parameters were measured using the methods described for each factors as follows. Dissolved oxygen (DO) was determined by Azide modification of the Winkler method, Salinity was determined by use of salinometer TSI (model 33), turbidity was measured using formalin photometer set at a wavelength of 450 nm, total alkalinity (TA) were determine by titration method[18], total settle able solids (TSS) was measured by gravimetric method[18], biochemical oxygen demand (BOD) was measured using aluminum potassium sulphate $Alk(SO_4)_2$ method. Nitrate, phosphate and sulphate were determined separately by the use of Hach's spectrophotometer set at the wavelength of 450 nm for sulphate, 500 nm for nitrate, 700 nm for phosphate[18].

Water samples for heavy metal analysis were acidified using few drops of concentrated sulphuric acid to bring the pH between 2-3. Twenty-five milliliter of each sample was then filtered and the amount of heavy metal in each sample

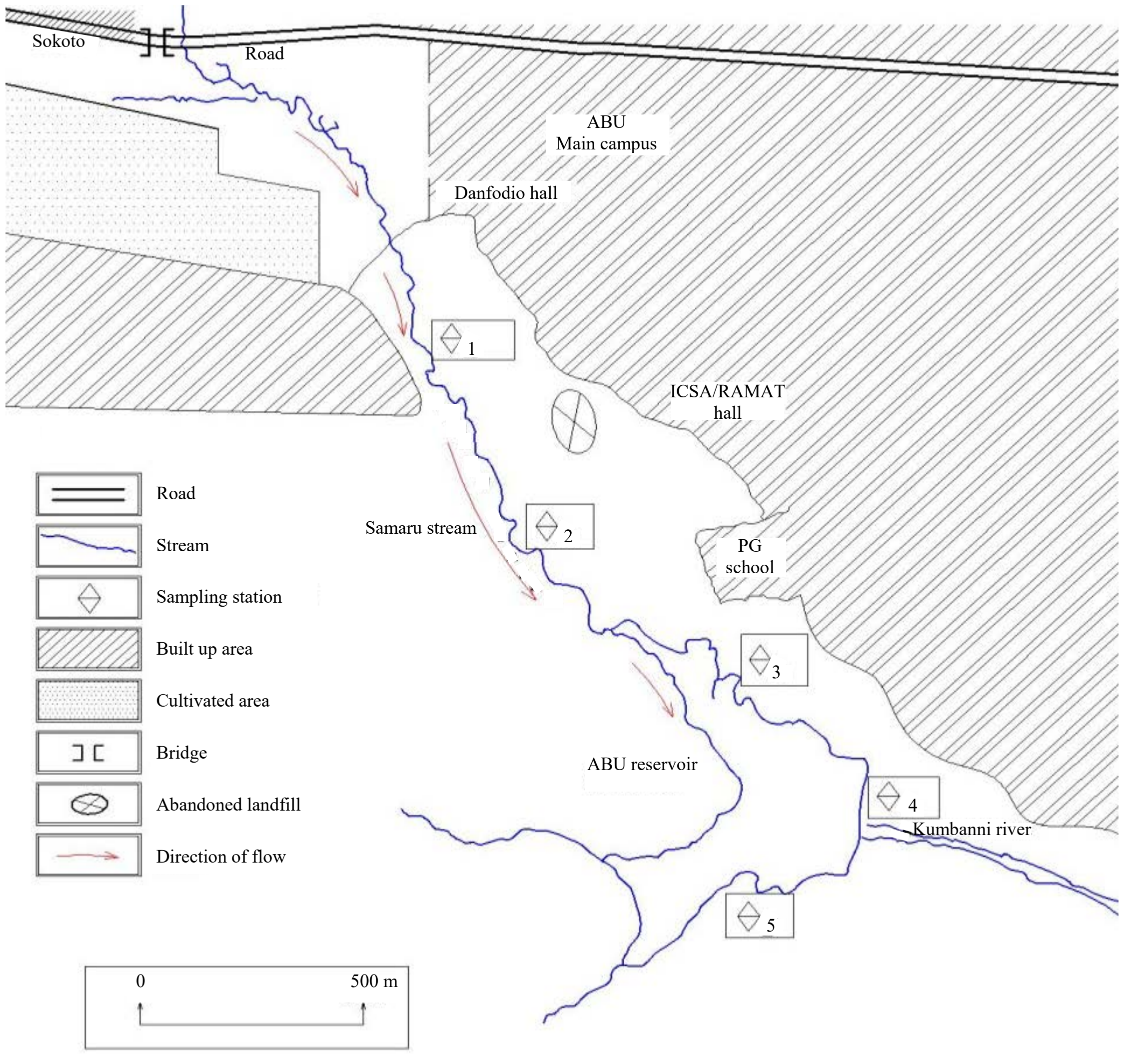

Fig. 1: Samaru stream and ABU reservoir showing the locations of the sampling stations
Source: Modified from Adakole *et al.*[17]

was determined using atomic absorption spectrophotometer (AAS). The sediment samples were collected from each of the 5 sampling stations using a labeled and pretreated PVC tube as described by Bordas and Bourg[19]. The sediments were packaged in pre-labeled new cellophane bags for analysis of heavy metals using X-ray diffraction tube (XRD).

Sediment ranking: Ranking was done base on the concentration of heavy metals in each sampling stations following the method of USEPA[20]:

$$\text{Rank} = 1+\frac{\text{Sampling station value-Minimum value}\times 99}{\text{Maximum value-Minimum value}}$$

where, sampling station value is the concentration of heavy metals in a particular sampling station, Minimum value is the sampling station with the minimum concentration of heavy metals, maximum value is the sampling station with the maximum concentration of heavy metals.

Pollution load index (PLI): The pollution load index (PLI) proposed by Tomlinson *et al.*[21] was used in this study to measure PLI in sediments of the 5 sampling stations. The PLI for a single site is the nth root of n number multiplying the contamination factors (CF values) together[21]. The CF is the quotient obtained as follows:

$$\text{CF} = \frac{C_{\text{Metal concentration}}}{C_{\text{Background concentration}}\ \text{(reference station) of the same metal}}$$

$$\text{PLI}_{\text{for a sampling station}} = \text{nth}\sqrt{\left(\text{CF}_1\times\ \text{CF}_2\ldots\times\ \text{CFn}\right)^{\text{n}}}$$

where, n equals the number of contamination factors.

Statistical analysis: The statistical relationship between sampling stations, month and seasons and mean variations in the physicochemical parameters was determined by analysis of variance (ANOVA) in a two-tailed test p<0.05. Correlation and *post hoc* test (Duncan multiple range test) were also used to test the strength of relationship between sampling station.

RESULTS

The results of this study showed variations in physicochemical parameters of water, distribution of some heavy metals in the water and in sediment. The physicochemical properties of ABU Dam at the 5 sampling stations 1, 2, 3, 4 and 5 for two seasons (Wet and dry seasons) are shown in Fig. 2-4. The values of the results were compared with standard values of USEPA[20]. Figure 2 showed the seasonal variations of electrical conductivity across the stations which indicated the peak value of 130.00 µS cm^{-1} in sampling station 2. Temperature ranges 24-27°C and was significantly higher during the dry season than the wet season as shown in Fig. 3. The range of 40-130 mg L^{-1} $CaCO_3$ alkalinity (Fig. 4), with the peak of 150 mg L^{-1} in station 2 also showed significant seasonal variations. The pH ranges of 6.7-7.1 were recorded across the stations as shown in Fig. 5. Sulphate concentrations were highest (22 mg L^{-1}) during the wet season in station 1 (Fig. 6). Phosphate and nitrate varied significantly higher during the wet season than dry season as shown in Fig. 7 and 8. The DO variations ranged between 2-2.8 mg L^{-1} (Fig. 9) across the stations. The BOD (0.4-1.8 mg L^{-1}) and COD (8.0-11.0 mg L^{-1}) varied significantly between wet and dry seasons across the stations (Fig. 10, 11). The Ni, Pb, Zn and Fe were the most recorded in the water

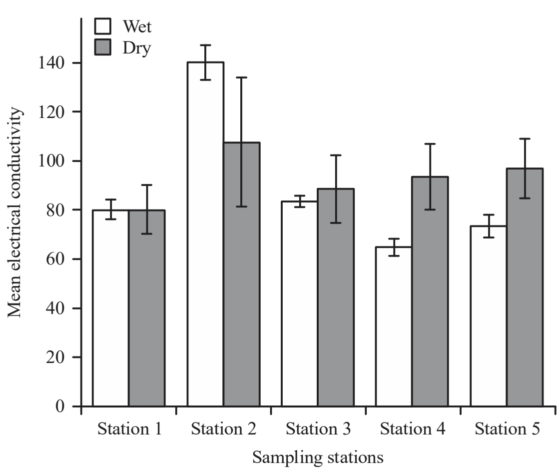

Fig. 2: Electrical conductivity (µS cm^{-1}) of ABU reservoir and a stretch of Samaru stream

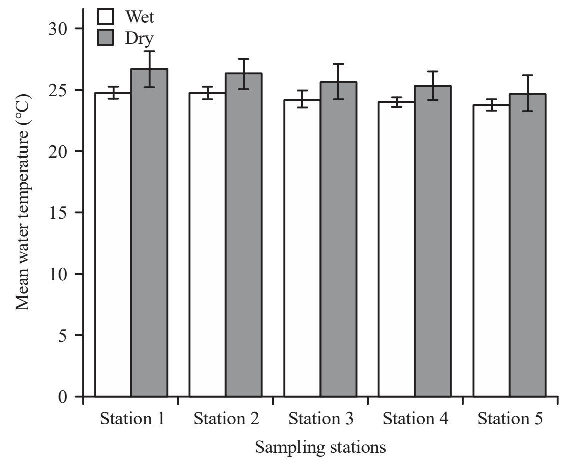

Fig. 3: Water temperature (°C) of ABU reservoir and a stretch of Samaru stream

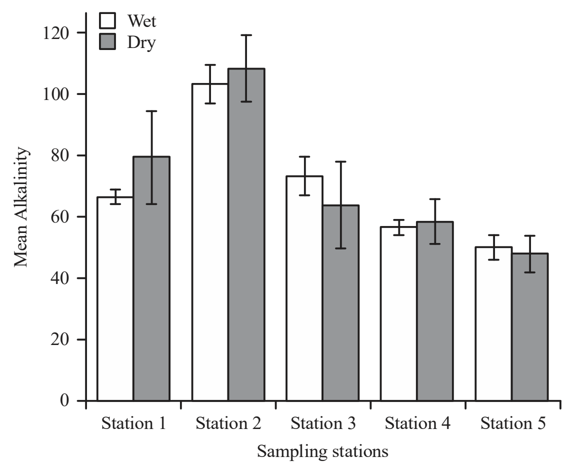

Fig. 4: Alkalinity (mg L^{-1}) of ABU reservoir and a stretch of Samaru stream

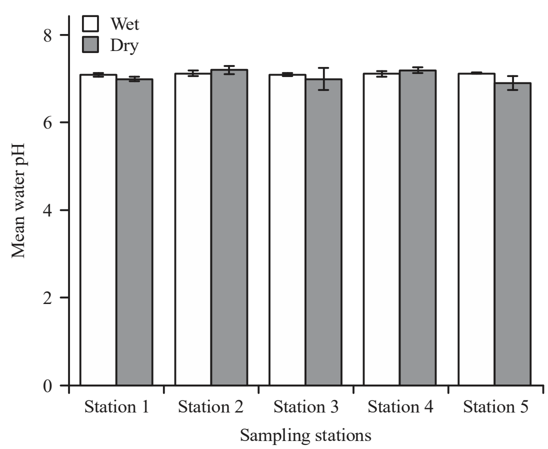

Fig. 5: Water pH of ABU reservoir and a stretch of Samaru stream

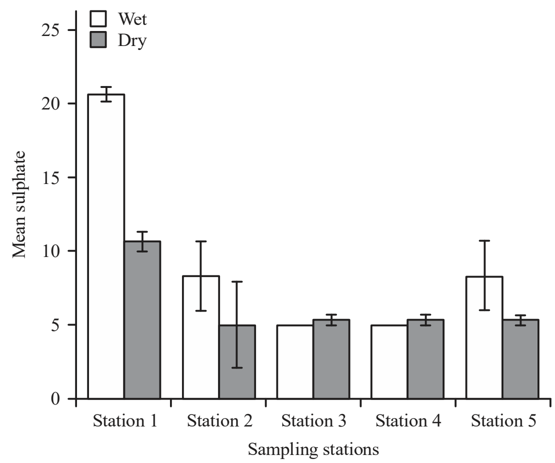

Fig. 6: Water sulphate (mg L^{-1}) of ABU reservoir and a stretch of Samaru stream

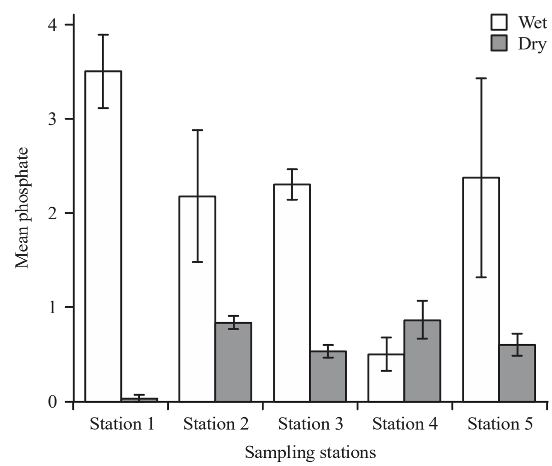

Fig. 7: Water phosphate (mg L^{-1}) of ABU reservoir and a stretch of Samaru stream

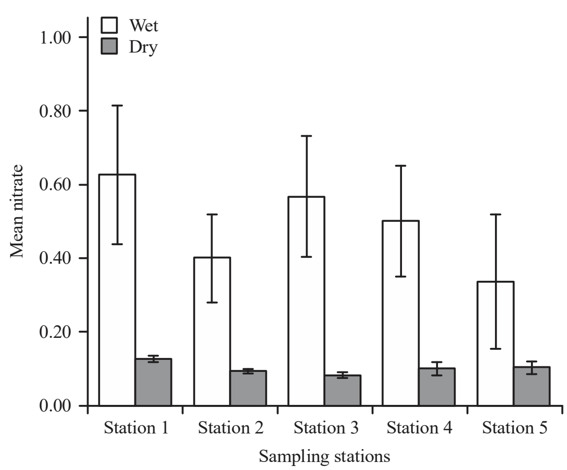

Fig. 8: Water nitrate (mg L^{-1}) of ABU reservoir and a stretch of Samaru stream

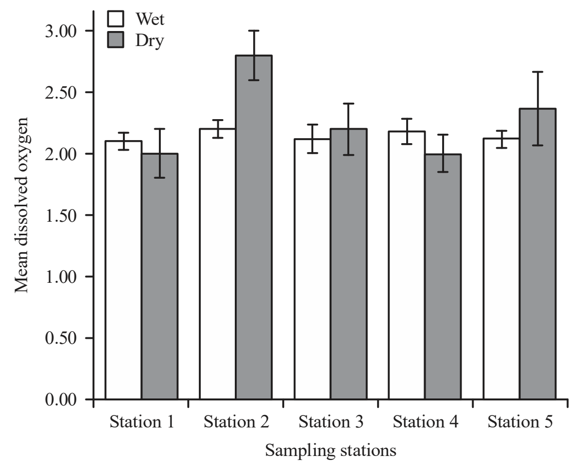

Fig. 9: Water dissolved oxygen-DO (mg L^{-1}) of ABU reservoir and a stretch of Samaru stream

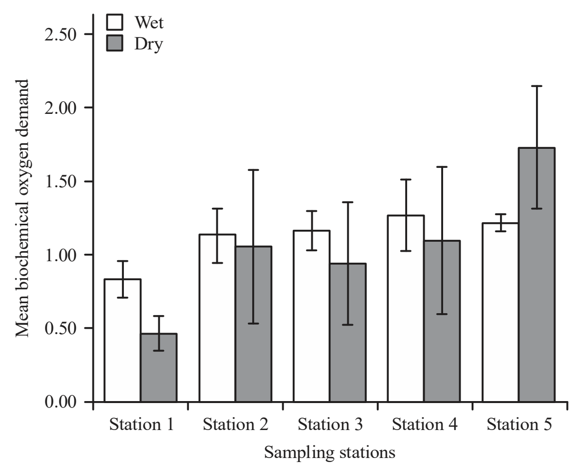

Fig. 10: Biochemical oxygen demand-BOD (mg L^{-1}) of ABU reservoir and a stretch of Samaru stream

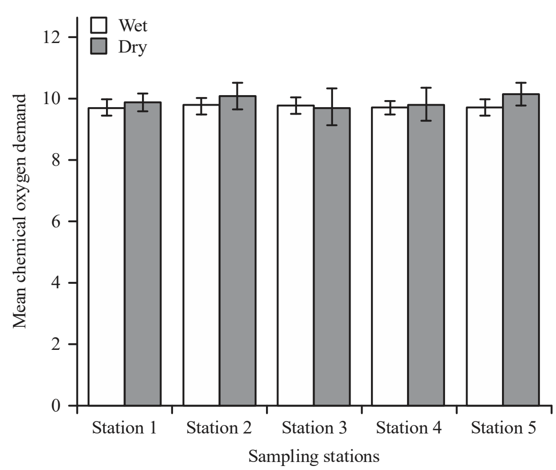

Fig. 11: Chemical oxygen demand-COD (mg L^{-1}) of ABU reservoir and a stretch of Samaru stream

Table 1: Concentration (mg kg^{-1}) of heavy metals in the sediment, sediment ranking and PLI

Stations	Seasons	Fe	Mn	Cr	Zn	Pb	Ni	Rank	Position	PLI**	Status**
1	Wet	9.993	0.045	0.044	ND	ND	0.432				
	Dry	13	0.135	0.39	0.231	0.655	ND	153.9	2nd	1.00	Baseline
2	Wet	7.198	0.039	0.045	ND	ND	0.311				
	Dry	28.73	0.198	0.24	0.286	1.64	1.126	198.0	1st	1.47	Baseline
3	Wet	8.595	0.118	0.038	ND	ND	0.921				
	Dry	10.15	0.662	ND	0.216	0.601	1.016	146.3	3rd	0.98	Baseline
4	Wet	1.419	0.023	0.032	ND	ND	0.356				
	Dry	3.53	0.023	ND	0.202	0.659	1.002	101.7	4th	0.46	Baseline
5	Wet	1.691	ND	0.05	ND	ND	0.412				
	Dry	3.44	0.015	ND	0.203	0.006	0.51	99.00	5th	0.18	Baseline
	*LEL	NS	NS	26	120	31	16				
	*SEL	NS	NS	110	820	250	75				

ND: Not detected, NS: No sediment criterion, PLI: Pollution load index, *Ontario[30], Status: Pollution status, **Tomlinson[21]

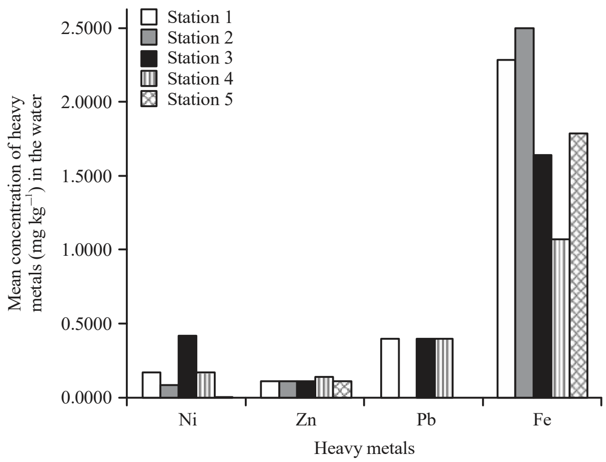

Fig. 12: Concentration (mg L^{-1}) of heavy metals in the water of ABU reservoir and a stretch of Samaru stream

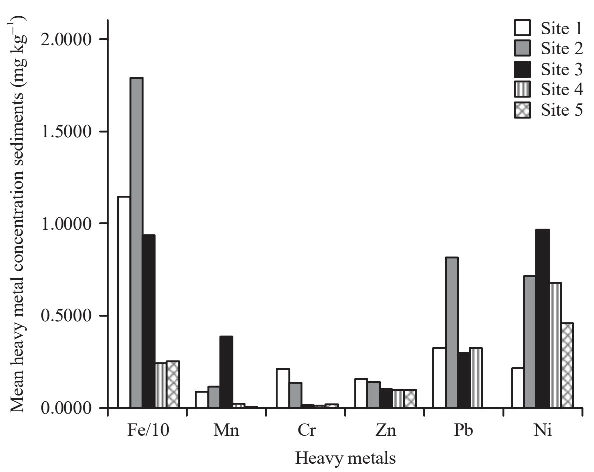

Fig. 13: Heavy metals concentration (mg kg^{-1}) in the sediment of ABU reservoir and a stretch of Samaru stream

while Fe, Mn, Cr, Pb, Zn and Ni were recorded in the sediment (Fig. 12, 13). Heavy metal concentrations in sediments in both seasons and pollution load index were presented in Table 1.

DISCUSSION

The physicochemical parameters measured served as an indication of the pollution status of the water. Variations in temperature during the study period may be attributed to the characteristic cool dry North-East trade wind which is typical of the seasons. This finding agreed with that of Tukura *et al.*[22], who reported low water temperatures during the period of harmattan, in his research on trace metals in Ahmadu Bello University Reservoir. Electrical conductivity was found to be lower in the rainy months than as obtained in the dry months in most of the sampling stations. The difference could be due to dilutions of the reservoir during the rainy months and possibly the precipitation of the metallic ions during this period coupled with the low water level in the dry month's period. The higher conductivity observed in sampling station 2 may be as a result of the higher metallic ions contained in landfill seepage and effluents discharged from student hostels. The level of electrical conductivity is a pointer to the ionic concentration and the eutrophic status of the reservoir.

Alkalinity in natural water is caused by carbonates, hydrogen carbonates and hydroxyl ions[23]. Higher dry month's values may be linked to high concentration of these salts during this period. Thus explaining the highest mean value observed in November. The observed range of alkalinity (40-130 mg L^{-1}) is within the range of 35-200 mg L^{-1} for streams as stipulated by WHO[24]. Dissolved oxygen concentrations in all the sampling stations and months were generally low below 3 mg L^{-1}. The low dissolved oxygen recorded could be attributed to the decomposition of accumulated sewage and domestic effluents introduced from Samaru community which resulted in the depletion of the dissolved oxygen content. The result of the DO in this work agrees with the result of Tukura *et al.*[22] (<4.00 mg L^{-1}), who worked on the same reservoir. Tukura *et al.*[22] reported that the increase in aerobic respiration, stimulated by the rise in bacterial activities might have been responsible for the low level of DO observed. Also Chukwu and Nwankwo[25] reported low DO of <2.8 mg L^{-1} and attributed it to stress imposed by effluents from land base sources as well as substrate instability.

The low level of biochemical oxygen demand could be as a result of low level of biogenous materials and also due to the bacterial degradation of the organic load mainly from domestic wastes which drain into the reservoir. Chemical oxygen demand (COD) was considerably moderate during the study period. A higher COD observed during the dry season could be as a result of less dilution of water from rain. Generally, the moderate level of COD in the reservoir could be as a result of high organic matters discharge into the reservoir from Samaru town and ABU premises. Macronutrients (PO_4-P, NO_3-N and SO_4) were generally low throughout the study period. This could be attributed to low level of farming activities along Samaru stream and within the university premises. Improper disposal of human excreta and domestic sewage increase nitrate-nitrogen in water bodies[26]. The higher levels of PO_4-P and NO_3-N in the wet season may be due to the effect of direct discharge from the university premises and Samaru town into the reservoir.

The sediment concentrations of all the metals were higher than their respective surface water concentrations. According to Mansour *et al.*[27], sediment are the ultimate sink for most heavy metals released into the aquatic environment and can record information on long and medium- term metal flukes. Level of heavy metals concentrations observed in this work may be attributed to the leachate from the abandoned landfill, nature of domestic effluents and urban storm-water runoff discharged into the reservoir. Okoye[28] reported anthropogenic heavy metal enrichment of the Lagos Lagoon with Cd, Co, Cu, Fe, Mn, Ni, Pb and Zn and implicated land-based urban and industrial waste sources. The concentration of Co, Cu and Cd were below detection limit as compared to other metals.

The toxicity ranking order generated in this study revealed that sampling station 2 is the most hazardous of heavy metals contamination within the sampling stations (ABU reservoir and Samaru stream). This order 2>1>3>4>5, suggest the introduction of heavy metals into the environment via leachate from the abandoned landfill nearby sampling station 2. The concentration of heavy metals recorded in all the sampling stations are still below the least effect limit and severe effect limit of heavy metals in natural sediment. The pollution load index of each sampling station which indicated the level and extent of heavy metal contamination revealed a range between 0.18-1.47. This is an indication of baseline level of contamination. The contamination levels is classified based on their intensities on a scale ranging from 1-6 (0 = None, 1 = Baseline/medium, 2 = Moderate, 3 = Moderately to strong, 4 = Strongly polluted, 5 = Strong to very strong, 6 = Very strong)[29,30]. The study therefore, provides data on some physicochemical conditions prevailing in the investigated rivers for future reference and also provides a valuable insight into the overall integrity of the local ecosystem and water quality.

SIGNIFICANT STATEMENT

This study discovers the possible leachate of heavy metals from the landfill site along Samaru River into the reservoir that can be deleterious to the biota. This study will help the researcher to uncover the critical area of heavy metal leachate from abandon landfill where previous researchers were not able to explore. Thus environmental planers are therefore, advised not to sight any landfill nearby a flowing river in other to avoid possible leachate of heavy metals.

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