FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 9 No. 12, December (Special Issue), 2025, pp 535 – 543
DOI: https://doi.org/10.33003/fjs-2025-0912-4307

ASSESSMENT OF SOME PHYSICOCHEMICAL PROPERTIES AND HEAVY METALS IN WATER FROM FARMLANDS AROUND MAHANGA LAKE, BALI LOCAL GOVERNMENT AREA OF TARABA STATE, NIGERIA

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ABSTRACT

Water quality in agricultural landscapes is increasingly threatened by physicochemical pollutants and heavy metals arising from farming practices and anthropogenic activities. These contaminants pose serious risks to ecosystem health and human safety, particularly in rural communities that rely directly on natural water bodies for drinking, irrigation, and domestic use. This study assessed the physicochemical properties and heavy metal concentrations in water from farmlands around Mahanga Lake, Bali Local Government Area, Taraba State, Nigeria. Water samples were collected from four cardinal points (North, South, East, West) and analyzed using standard methods. Physicochemical parameters (pH, Temperature, Electrical Conductivity, Total Suspended Solids, Total Dissolved Solids, Turbidity) were measured with appropriate meters, while heavy metals (Cd, Cr, Cu, Ni, Pb) were determined using Atomic Absorption Spectroscopy. Results revealed that pH (5.7–6.8), TSS (190–210 mg/L), and turbidity (32–38 NTU) did not meet WHO drinking water standards. Heavy metal analysis showed that Cr (0.063–0.085 mg/L) and Pb (0.048–0.071 mg/L) concentrations exceeded permissible WHO limits, while Cd (0.015–0.028 mg/L), Cu (0.13–0.18 mg/L), and Ni (0.0008–0.001 mg/L) were within acceptable ranges. Pearson's correlation analysis indicated a strong positive relationship between TSS and turbidity ($r = 0.996$), and between Cr and Pb ($r = 0.955$), suggesting common pollution sources. The study concludes that the lake water is unsuitable for drinking and recommends continuous monitoring, public awareness on water safety, and implementation of remediation strategies to reduce pollutant influx from agricultural and anthropogenic activities.

Keywords: Heavy metals, Physicochemical properties, Mahanga lake, Water quality, Environmental toxicity

INTRODUCTION

Naturally, heavy metals are metals with a high atomic weight and a density greater than 5 g/cm^3 Compared with their physical properties, the chemical characteristics of heavy metals are the most practical aspects. Heavy metals like lead (Pb), cadmium (Cd), mercury (Hg), and chromium (Cr) are now recognized as priority pollutants due to their non-biodegradable nature, high persistence, and potential for bioaccumulation through trophic levels (Khan *et al.,* 2024). Environmental toxicity exceeding standard maximum residue limits (MRL) has received heightened consideration from think tanks worldwide. Cadmium (Cd), lead (Pb), copper (Cu), and zinc (Ni) cause an alarming combination of environmental and health problems (Vidican *et al*., 2020). Heavy metals arise from many sources, such as industry, mining, and agriculture. In terms of the sources in the agricultural sector, these can be categorized into fertilization, pesticides, livestock manure, and wastewater. Recently, the risk of heavy metals pollution in the environment has been increasing rapidly and creating turmoil, especially in the agricultural sector, by accumulating in the soil and in plant uptake. The heavy metals contamination problem has become urgent, and needs radical and practical solutions to reduce the hazards as much as possible (Malik *et al*., 2023).

Toxic heavy metals have certain penetrating mechanisms, including swallowing, dermal absorption, and inhalation, which cause health effects resulting from heavy metals exposure. The effects of heavy metals on children's health have become more severe than adults. More consideration should be given to heavy metals due to their high toxicity risk, extensive application, and prevalence (Abd Elnabi *et al*., 2023). The accumulation of heavy metals in internal human tissues can affect the central nervous system, and act as a pseudo-co-factor or promotor of some health problems, such as seizures (epilepsy), headache, and coma. Heavy metal contamination is considered as a health threat to both adults and children (Egbueri, 2020).

According to Chunhabundit, Cd toxicity can cause renal damage due to damaged proximal convoluted tubules, which are associated with mitochondrial dysfunction. Moreover, Cd exposure resulted in osteoporosis, pediatric cancer, and it has been related to stunted development in children. (Flannery, *et al*., 2022) stated that Cd exposure was adversely correlated with infant size at birth (height and weight). Pb exposure is one of the most common preventable poisonings of childhood. Children are particularly vulnerable to Pb toxicity and suffer irreversible neurological deficits affecting the learning ability and behavior. In Arufu and Akwana mining communities, concentrations of Pb, Fe, Cu, Cd, Ni, Zn, Sb, and Mn exceeded World Health Organization (WHO) permissible limits for drinking water, with only Cr within safe levels. This has led to contamination of water sources, posing risks such as neurotoxicity and renal dysfunction (Makhai *et al.,* 2025). Surma is a popular eye cosmetic paste used as an eyeliner for children in Afghanistan and other countries in the Middle East, Asia, and Africa. It has been confirmed to contain Pb and potentially cause Pb toxicity in infants, leading to permanent damage to multiple organ systems. (De Ronda *et al*., 2023) reported that children exposed to Pb showed inattentiveness, hyperactivity, and irritability. In addition, extremely high Pb exposure levels have been found to cause an increase in dullness, irritability, and shorter attention span in the central nervous system, subsequently resulting in seizures, epilepsy, coma, headache, and even death. Hence the need to assess the concentrations of some heavy metals as well as physicochemical properties of water around Mahanga lake of Taraba state, Nigeria.

MATERIALS AND METHODS

Study Area

Bali is a Local Government Area (LGA) in Taraba state, Nigeria. Bali LGA was created in 1976 The Local Government Area lies between latitude 7046 N and 7054 N of the equator and longitude 10 03^0 E and 110 0^0 E of the prime meridian. This falls within the dry guinea savannah with an estimated land area of 11,540 km^2. It has some mountains like Gazabu, Dakka, Maihula, Bagoni, among others. Based on the 2006 National Population Census, Bali had a population of about 211,024 persons (NPC, 2006).

Mahanga is a historic settlement located at outskirt of Bali town with a predominant population belonging to the Jibu tribe, traces of Fulani and Tiv farmers. The lake plays a vital role in the economy of the people and their routine daily activities. It serves a source of drinking water to the populace and their livestock especially during dry season. The fishermen in the community indulge in fishing in the lake. In addition to that, it also serves as source of water for irrigation as they engage in dry season rice farming. And to the children is a place for swimming and washing of their clothes.

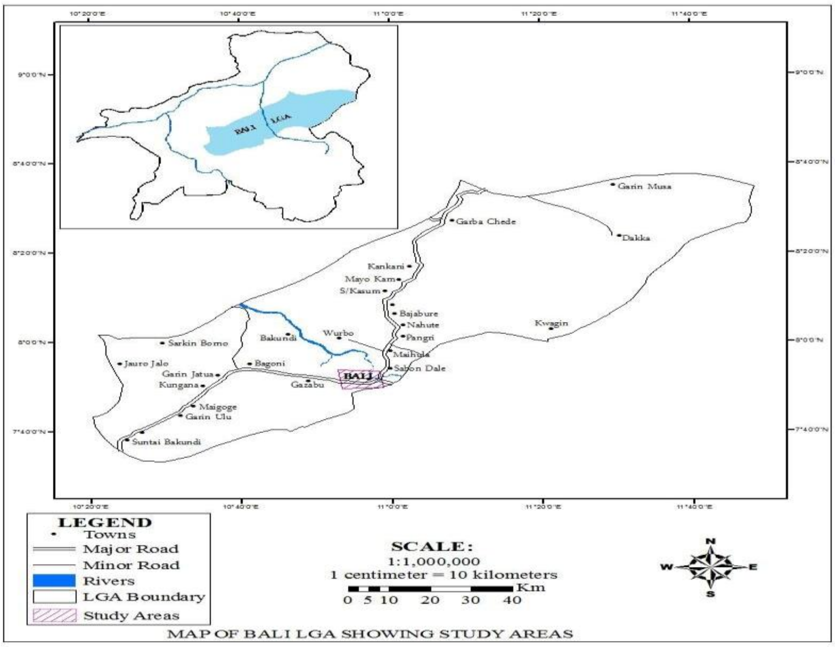

Figure 1: Map of the Study Area

Materials and Reagents

Water sample digestion vessel (Digestion tube or digestion flask), concentrated acid (HCl, HNO_3.), source of heat, gloves, goggles, fume hood, distilled water, funnel, filter papers, glass wares, vials, pH meter, separation funnel, Standard heavy metal ions for calibration of each heavy metals to be determined, Atomic Absorption Spectroscopy was used to determine the heavy metals present in the samples. All the chemicals and reagents are of analytical grade (AR). Distilled water was used throughout the research work.

Sampling and Sample Preparation

The water samples were collected by dipping plastic bottles below the water surface. Total of four samples were collected from four sampling points i.e. North, South, East and West. At each sampling locations, the sampling bottles were rinsed three times with the water before collection of the sample (Ong, 2024). Water sample was measured in to 250 ml conical flask in volume of 50ml for digestion and extraction and was taken for analysis using AAS.

Physicochemical Properties

Physical parameters of water like turbidity, EC, total dissolved solids and pH were measured using turbidity meter and HANNA HI 9810 pH meter respectively. Total suspended solids of water were measured in Modibbo Adama University Chemistry Lab. following (MASIME, 2022).

pH, TDS and EC

HANNA HI 9810 pH meter was used to measure pH, TDS, and electrical conductivity (EC) of the water samples. Buffer solutions (buffers 7 and 9) were used to reset the meter. The buffer tablet was distilled in 250 ml of beaker water (100 ml). To standardize the solution, the meter probe was inserted into it and adjusted to read 000. By first measuring the test sample's pH, TDS, and EC with distilled water and then with the samples, the electrode response was verified. Prior to making the final reading, the system was given time to stabilize.

Turbidity (Nephelometric method)

The water sample was gradually shaken until the air bubbles are gone. The agitated sample (about 100 ml) was poured into a cell, and the turbidity was measured immediately from the meter display. Before any sample readings are taken, the turbidity meter (HACH 2100P) was first be calibrated using a turbidity standard reagent. As stated by APHA (2022).

Laboratory Analyses

Total suspended solids (Gravimetric Method Adopted by APHA, 2022)

Filter paper that has been previously weighed was used to filter a known volume of the water sample. The drying temperature range for the filter paper is 103˚ to 105˚C. The formula below was used to calculate TSS: TSB mg/l = $(A-B) \times 10^3/C$ is the total suspended solids. Where B is the filter's weight (g); C is the sample's filtered volume (ml); and A is the filter's weight plus solids (g).

Digestion of Water Sample for Heavy Metals (Wet Acid Digestion Method Adopted by APHA, 2022)

After properly mixing 20 milliliters of concentrated HNO_3 acid with around 20 milliliters of water sample, the mixture was put into a 250-milliliter beaker. The solution was heated and concentrated HNO_3 added until it evaporates to about 20 ml and the digestion was completed, as evidenced by a clear, light-coloured solution APHA, 2022. The content was allowed to cool to room temperature. The content was transferred to a 20 ml plastic container that has already been cleaned and diluted with distilled water to the appropriate level. This solution was used in part to determine the presence of heavy metals using Atomic Absorption Spectroscopy.

RESULTS AND DISCUSSION

Physicochemical Properties

pH

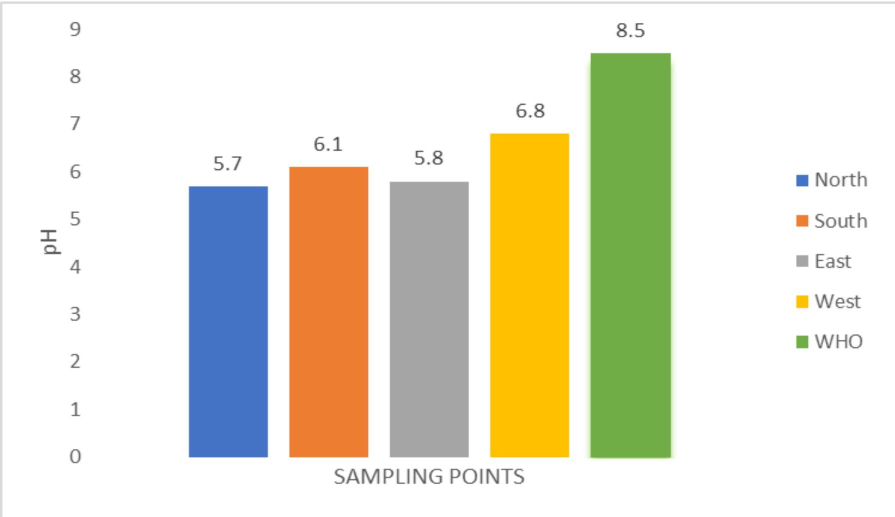

Figure 2: Mean pH Values Recorded for Water Bodies

Base on the analysed result, the water sample collected from the northern bank of the lake was the most acidic with pH of 5.7 and the maximum recorded pH of 6.8 was obtained from the western bank of the lake. The result obtained is similar to the one reported by (Mohammed *et al*., 2019). The results obtained were not within WHO standard limit for drinking water (6.5 - 8.5) except for the sample collected from the western bank.

Temperature

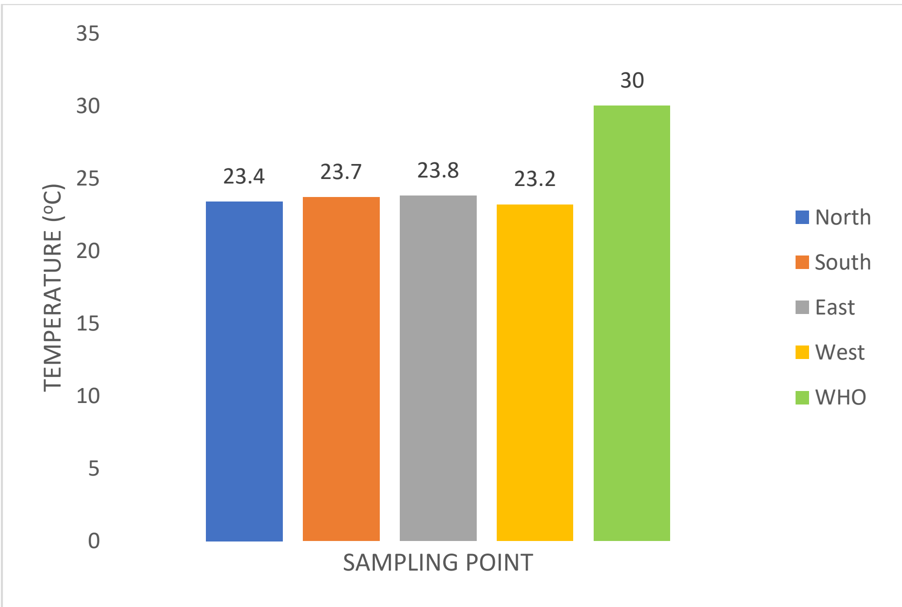

Figure 3: Mean Temperature Values Recorded for Water Bodies

The temperature value recorded in this study is presented in Figure 3 with the highest temperature 23.82 recorded at the eastern bank and the lowest 23.2 at the western bank. The result is similar to what was obtained by (Jebreen, 2019). The temperature range falls within acceptable limit of WHO standard (0-30^o).

Electrical Conductivity

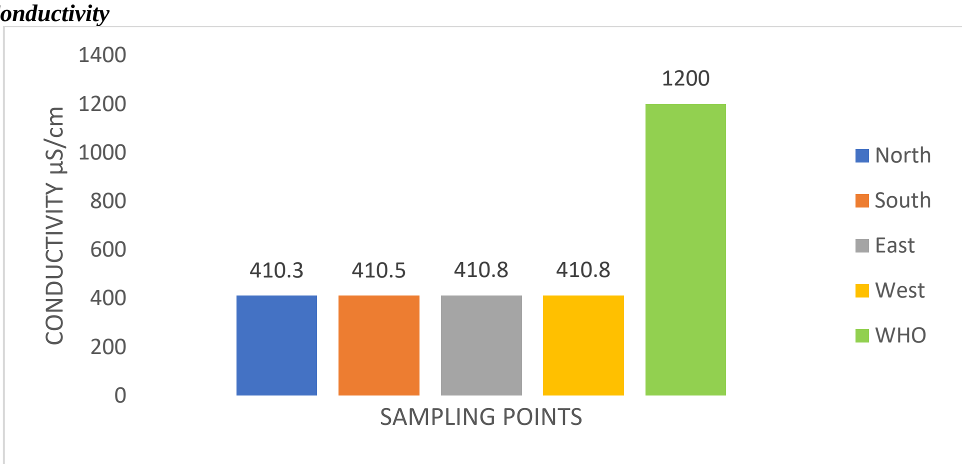

Figure 4: Mean Conductivity Values Recorded for Water Bodies

This is an indicator of the measure of dissolved inorganic salt in the water (Ogoko and Sylvester 2020). The mean conductivity value recorded were 410.8, 410.3, 410.8 and 410.5 for water sample collected from the northern sample, eastern and western banks respectively. The highest recorded were that of northern and eastern banks of the lake while the minimum conductivity was recorded for the sample collected at the Southern bank of the lake. The results obtained from the analysis are closely related to the results obtained from (Igbokwe *et al*., 2021) work and the results shows it falls within permissible limit shows if falls within permissible limit of WHO of less than 1200s/cm for drinking water.

Total Suspended Solid

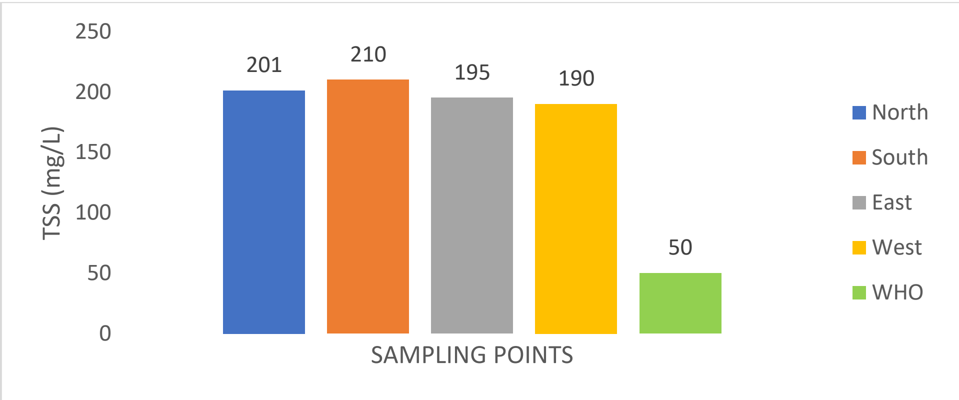

Figure 5: Mean TSS Values Recorded for Water Bodies

The Mean total suspended values obtained from analyzed sample were recorded as shown in figure 5. The value obtained were 210mg/l, 195mg/l, 190mg/l and 210mg/l for the samples collected at the northern, southern, eastern and western bank respectively. The TSS results recorded were above the WHO permissible limit (<50mg/l) at each of the sampling points.

Turbidity

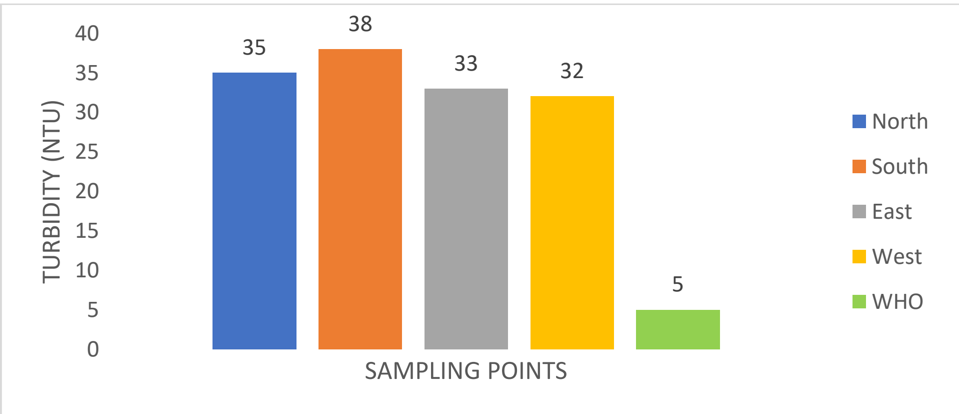

Figure 6: Mean Turbidity Values Recorded for Water Bodies

Turbidity is a measure of the degree to which water loses its transparency due to the presence of suspended and dissolve substances (Musa, 2021). The mean turbidity values recorded were 35, 38, 33 and 32 respectively for the sample collected at Northern, Southern, Eastern and Western bank of the lake. The mean turbidity value of the water sample obtained from this work were higher than the recommended limit 5 NIU for drinking water by the WHO. This could be as a result of Agricultural activities and other human activities around the lake.

Total Dissolved Solids

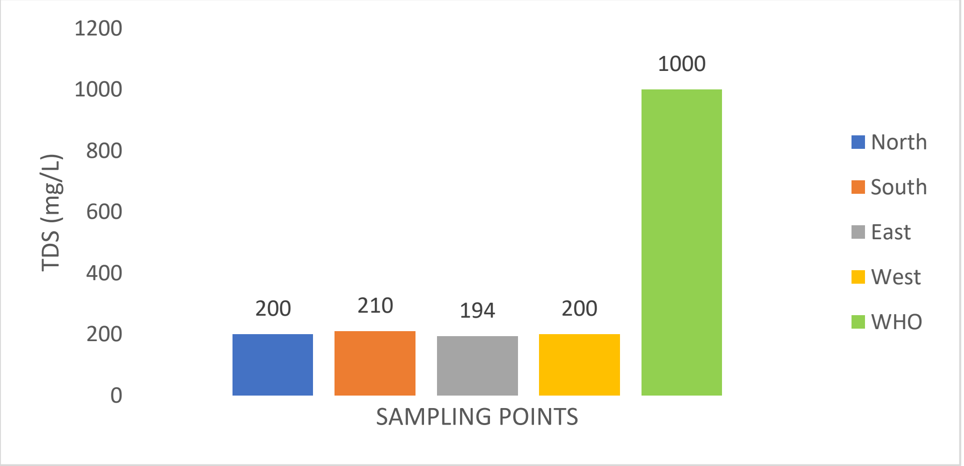

Figure 7: Mean TDS Values Recorded for Water Bodies

Inter-correlations in Physicochemical Properties

Inter correlation in the Physicochemical properties were investigated in order to reveal the relationship between each of the heavy metal. The Pearson correlation coefficient was used to measure the strength of the association between heavy metal concentrations in some physicochemical parameters such as pH, Temperature, Conductivity, TSS, Turbidity and TDS respectively. These mentioned parameters were presented in correlation matrices. The determination of strength of the association was done based on four location sites of lake Mahanga that is north, east, south and western direction.

Table 1: Pearson's Correlation Coefficient Matrix for The Means Values of Physiochemical Parameters of Mahanga Lake

		pH	Temp	Cond	TSS	Turb	TDS
pH	Pearson Correlation	1	-.634	.740	-.023	-.076	.191
	Sig. (2-tailed)		.366	.260	.977	.924	.809
	N	4	4	4	4	4	4
Temp	Pearson Correlation	-.634	1	-.494	-.732	-.709	.238
	Sig. (2-tailed)	.366		.506	.268	.291	.762
	N	4	4	4	4	4	4
Cond	Pearson Correlation	.740	-.494	1	.190	.103	.707
	Sig. (2-tailed)	.260	.506		.810	.897	.293
	N	4	4	4	4	4	4
TSS	Pearson Correlation	-.023	-.732	.190	1	.996**	-.227
	Sig. (2-tailed)	.977	.268	.810		.004	.773
	N	4	4	4	4	4	4
Turb	Pearson Correlation	-.076	-.709	.103	.996**	1	-.306
	Sig. (2-tailed)	.924	.291	.897	.004		.694
	N	4	4	4	4	4	4
TDS	Pearson Correlation	.191	.238	.707	-.227	-.306	1
	Sig. (2-tailed)	.809	.762	.293	.773	.694	
	N	4	4	4	4	4	4

**. Correlation is significant at the 0.01 level (2-tailed)

Table 1 depicts Pearson Correlation matrix which measured linear dependence between two variables. It has values between +1 and -1, where +1 indicates total positive linear correlation and -1 indicates total negative correlation, and in a correlation coefficient of 0 indicates that there is no linear relationship between the two variables. The correlation relationship offered remarkable information on the sources and pathway of the pollutant in the vicinity of the study area. The potential of hydrogen pH had a negative correlation with temperature ($r = -0.634$ and $P < 0.01$), there is a strong positive correlation between pH and Conductivity ($r = 0.740$ and $P < 0.01$), pH had weak negative correlation with TSS at ($r = -0.023$ and $P < 0.01$), respectively.

The pH and Turbidity had shown a strong and negative correlation at ($r = -0.076$ and $P < 0.01$), while pH and TDS showed strong and positive correlation at ($r = 0.809$ and $P < 0.01$). The temperature and conductivity indicated negative correlation ($r = -0.494$ and $P < 0.01$), Temperature and TSS had strong positive correlation (r = - 0.732 and P < 0.01), Temperature and Turbidity had a strong positive correlation at (r = - 0.0709 and P < 0.01) while in in the column Temperature and TDS had weak positive correlation at (r = 0.238 and P < 0.01) respectively. Conductivity and TSS demonstrates weak positive correlation at (r = 0.198 and P < 0.01), Conductivity and Turbidity had very strong correlation at (r = 0.103 and P < 0.01), Conductivity and TDS also had a very strong correlation at (r = 0.103 and P < 0.01), Conductivity and TDS also had very strong correlation at (r = 0.707 and P < 0.01). additionally, TSS and Turbidity had highly positive correlation with value at (r = 0.996 and P < 0.01), followed by TSS and TDS which indicated very strong negative correlation at (r = - 0.227 and P < 0.01). The turbidity and TDS made very negative correlation at (r = - 0.306 and P < 0.01).

Heavy Metals Concentration in water samples from Mahanga lake, Bali, Taraba State, Nigeria

The mean concentration of some heavy metals in water of lake Mahanga in the four directions North, South, East and West of lake Mahanga, Jalingo, Taraba State, Nigeria. Results were presented in the Figure 8 to 12 respectively. The metal concentration determined in all the sample sites of the water of lake Mahanga were also compared with international standards.

Cadmium

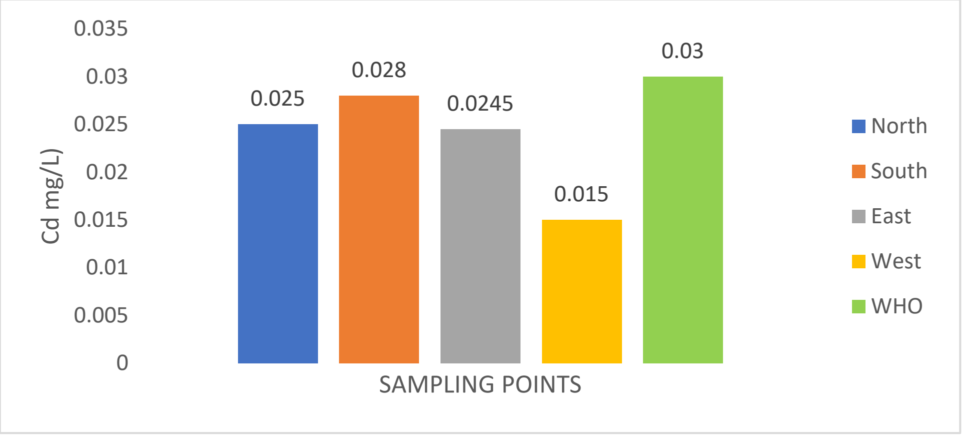

Figure 8: Mean Cadmium Values (Mg/L) Recorded in Water Bodies from Mahanga Lake

The results of Cadmium (Cd) from the four directions indicated by Figure 8 were determined at concentration of 0.025 mg/l, 0.028 mg/l, 0.0245 mg/l and 0.015 mg/l respectively. The mean level of Cadmium (Cd) concentration was in the order Cd (0.028) > Cd (0.025) >Cd (0.0245) > Cd (0.015). The results obtained showed that, the concentration of Cadmium (Cd) in the Mahanga lake water did not exceed WHO (World Health Organization); FEPA (Federal Environmental Protection Agency) standards.

Chromium

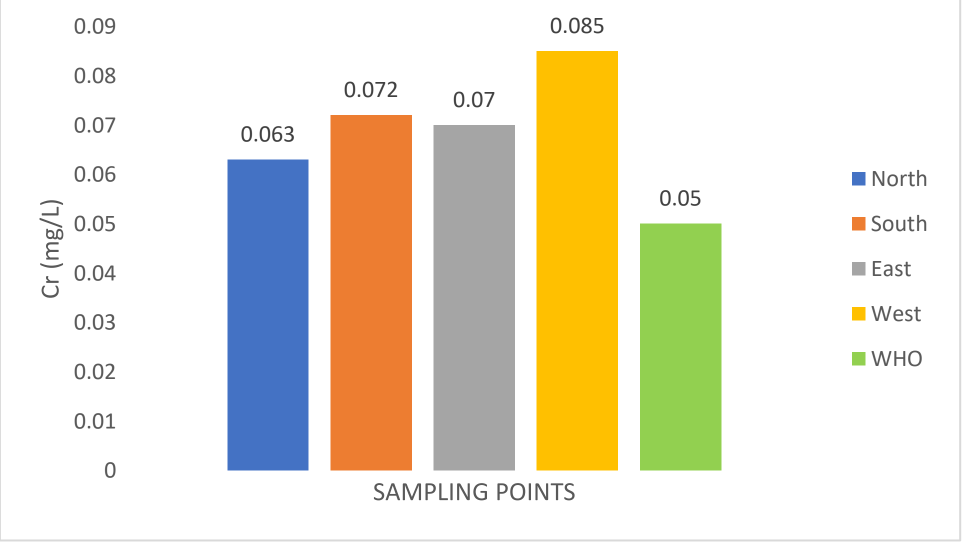

Figure 9: Mean Chromium Values (Mg/L) Recorded in Water Bodies from Mahanga Lake

The concentration of Chromium (Cr) in the four directions of lake, according to analysis results the following findings were obtained for the concentration and were in the order North (0.063), South (0.072), East (0.070) and West (0.085). The results obtained showed that, the concentration of Chromium (Cr) in the Mahanga lake water all exceed WHO (World Health Organization); FEPA (Federal Environmental Protection Agency)

Copper

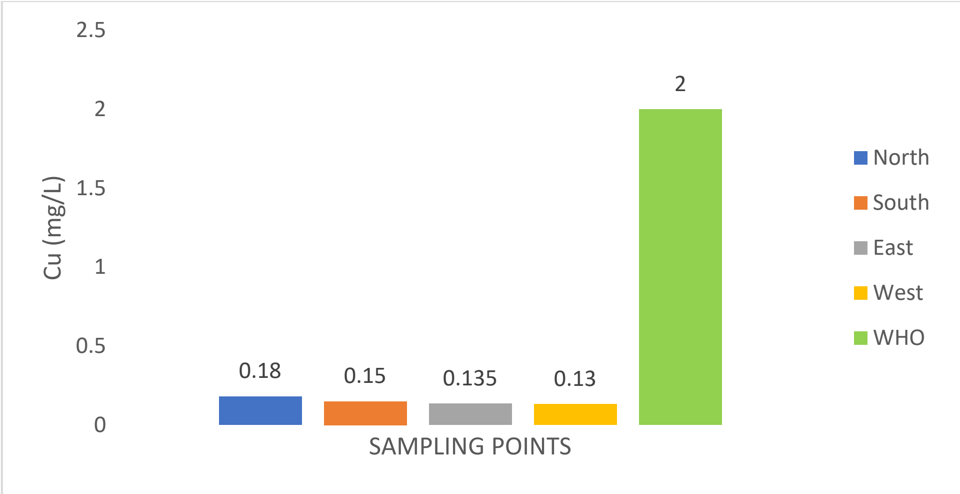

Figure 10: Mean Copper Values (Mg/L) Recorded in Water Bodies from Mahanga Lake

The concentration of Copper (Cu) from the four directions of the lake were determined and followed accordingly, North (0.18), South (0.15), East (0.135) and West (0.13) respectively. The order of copper concentration in abundance in the four-cardinal direction of the lake was in the order Cu (0.18) > Cu (0.15) > Cu (0.135) > Cu (0.13). The results obtained showed that, the concentration of Copper (Cu) in the Mahanga lake water did not exceed WHO (World Health Organization); FEPA (Federal Environmental Protection Agency)

Nickel

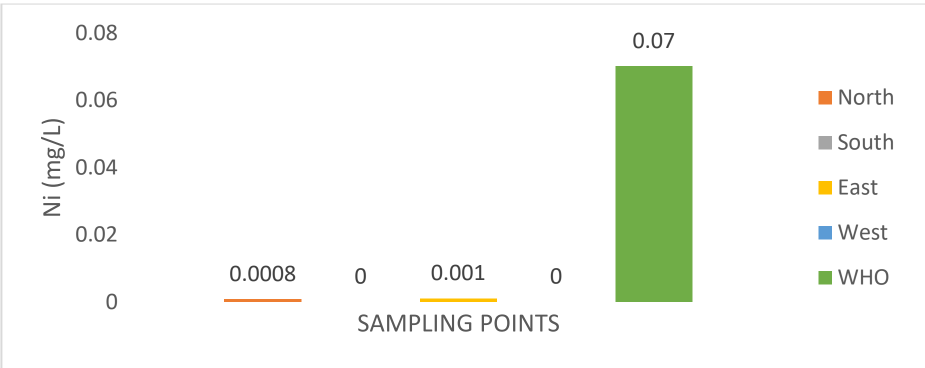

Figure 11: Mean Nickel Values (Mg/L) Recorded in Water Bodies from Mahanga Lake

The concentration of Nickel (Ni) from Mahanga lake at each of the cardinal points, North, South, East, and West were presented according to the determined concentrations. Nickel (Ni) and 0.0008 metal concentration in North, and 0.001 concentration of nickel (Ni) in the east direction of the lakes, while South and West sides of the lake were not detected. The results obtained showed that, the concentration of Nickel (Ni) in the Mahanga lake water did not exceed WHO (World Health Organization); FEPA (Federal Environmental Protection Agency)

Lead

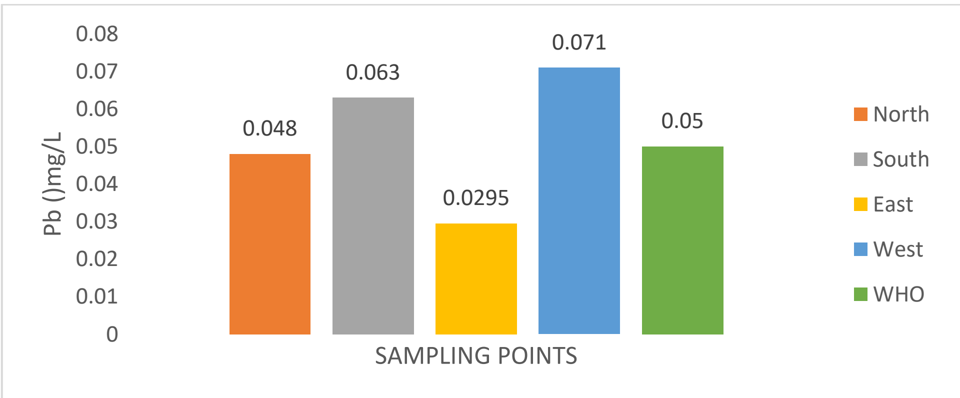

Figure 12: Mean Lead Values (Mg/L) Recorded in Water Bodies from Mahanga Lake

The concentration of Lead (Pb) from the four cardinal directions were determined and presented accordingly. North site of the lake had concentration of Pb recorded at 0.048 mg/l, while South, East and West sides of the lake had concentrations of 0.063 mg/l, 0.0295 mg/l and 0.071 mg/l respectively. The results obtained showed that, the concentration of Lead (Pb) in North, South and West sampling point of Mahanga lake water all exceeded WHO (World Health Organization); FEPA (Federal Environmental Protection Agency) while sampling point from the East was below the WHO standard. Similarly, high level of Pb was obtained in a comparative study in Arufu and Akwana, Wukari local Government Area, Taraba State (Makhai *et al.*, 2025). The differential concentration of the metals observed in each zone of the lake that is North, South, East and West is a reflection of the municipal and agricultural activities in the different area that supply their runs off to the different sections of the lake Mahanga.

Table 2: Pearson's Correlation Coefficient Matrix for The Means Values of Heavy Metals in Mahanga Lake

		Cd	**Cr**	**Cu**	**Ni**	**Pb**
Cd	Pearson Correlation	1	-.365	.521	.323	-.451
	Sig. (2-tailed)		.635	.479	.677	.549
	N	4	4	4	4	4
Cr	Pearson Correlation	-.365	1	.159	-.825	.955*
	Sig. (2-tailed)	.635		.841	.175	.045
	N	4	4	4	4	4
Cu	Pearson Correlation	.521	.159	1	.317	-.128
	Sig. (2-tailed)	.479	.841		.683	.872
	N	4	4	4	4	4
Ni	Pearson Correlation	.323	-.825	.317	1	-.946
	Sig. (2-tailed)	.677	.175	.683		.054
	N	4	4	4	4	4
Pb	Pearson Correlation	-.451	.955*	-.128	-.946	1
	Sig. (2-tailed)	.549	.045	.872	.054	
	N	4	4	4	4	4

*. Correlation is significant at the 0.05 level (2-tailed)

Interaction between heavy metals Cd and Cr indicates a negative correlation at ($r = -0.365$ and $P < 0.01$), Cd and Cu also had a fair positive correlation at ($r = 0.521$ and $P < 0.01$), similarly, Cd and Ni had a weak positive correlation at ($r = 0.323$ and $P < 0.01$), Cr and Cu had a very strong Positive correlation ($r = 0.159$ and $P < 0.01$), Cr and Ni in the group showed a strong negative correlation at ($r = -0.825$ and $P < 0.01$), Cu and Ni indicates weak positive correlation at ($r = 0.317$ and $P < 0.01$), Pb and Ni had a very strong negative correlation at ($r = -0.946$).

CONCLUSION

The assessment of physicochemical properties and heavy metals in Mahanga lake water revealed that temperature, electrical conductivity and dissolved solids were within WHO limits, parameters such as turbidity and total suspended solids exceeded permissible standards. Heavy metal analysis showed elevated levels of chromium and lead, indicating significant contamination risks, whereas cadmium, copper and nickel remained within safe limits. Correlation analysis suggested common sources of pollution, particularly for turbidity and suspended solids, as well as chromium and lead. Overall, the lake water is unsuitable for drinking, and urgent measures such as continuous monitoring, public sensitization and remediation strategies are recommended to protect community health and environment.

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