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Assessment of the Physicochemical Parameters, Geoaccumulation Indices and Contamination Factor of Sediments from Mairua Dam, Faskari Lga, Katsina Northwestern Nigeria

Sani . Uba, Victor O. Ajibola, Oluwaseun S. Adeosun, Divine C. Ikeh, Abdulhameed. Mikail, Abel K. John and Murtala M. Rumah

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Abstract: *Sediment constitutes a major reservoir for several aquatic pollutants including heavy metal ions. Consequently, the present study focused on the assessment of the levels of concentrations of various contaminants in sediment from Mairua dam. The study adopted different contamination indices including geo-accumulation indices (Igeo), and contamination factor (Cf). The results generated from experiments indicated the mean pH, EC, Cl- and* $NO_3^- - N$ *across in the following ranges: 7.31±0.014 (S4) to 8.54±0.085 (S8), 0.74±0.057(S8) to 1.6±0.00 µs/cm (S9), 0.6±0.00(S5,S11) to 8.95±0.071(S5) and 0.07±0.00 (S2, S6, S10) to 0.105±0.00 mg/kg (S3,S8,S11), respectively. Also, measured concentrations of* $PO_4^{3-} - P$ *,* K^+*, and CEC in the sediment samples were in the following ranges: 9.4305±0.537 (S1) to 150.85±1.06 (S11), 0.21±0.00 (S6, S11) to 0.795±0.007 mg/kg(S5) and 8.35±0.495(S11) to 19.25±0.495 mg/kg (S5). A comparison of the various analytical parameters with sampling stations (S1 to S10) indicated that the highest concentrations of environmental contaminants were concentrated at S9 while the least was recorded at S6 and S11, respectively. The mean pH for all the sampling stations (except S2 and S10) were within the WHO (2011) recommended range of 6.5 to 8.5, which validated the sediment samples to fit weak acidic to weak alkaline classification. Similar remark of meeting the WHO (2011) recommended limits were deduced from measured values of EC,* Cl^- *,* NO_3*-N and* K^+ *in the analyzed sediment samples. Evaluated values of geochemical indices and contamination factors gave evidence that the sediment samples are moderately polluted as well as the contamination factors.*

Keywords: Sediment,Mairua Dam, contamination, geo-accumulation indices, contamination factor, physicochemical parameters.

Sani Uba
Department of Chemistry, Ahmadu Bello University, Zaria-Nigeria
Email: saniuba10@yahoo.com

Victor O. Ajibola
Department of Chemistry, Ahmadu Bello University, Zaria-Nigeria
Email: tunjiajibola@gmail.com

Oluwaseun S. Adeosun*
Department of Chemistry, Ahmadu Bello University, Zaria-Nigeria
Email: simonadeosun@gmail.com
Orcid id: 0000-0002-1905-5322

Divine C. Ikeh,
Department of Chemistry, Ahmadu Bello University, Zaria-Nigeria
Email: ikehdivine081@gmail.com

AbdulHameed. Mikail
Department of Chemistry, Ahmadu Bello University, Zaria-Nigeria
Email: opeyemi072@yahoo.com

Abel K. John
Department of Chemistry, Ahmadu Bello University, Zaria-Nigeria
Email: calljohnk@gmail.com

Murtala M.Ruma

Department of Geography, Umaru Musa Yaradua University, Katsina
Email: mmruma@gmail.com

1.0 Introduction

Sediment plays a major role in the quality of the aquatic environment because of its potential to act as a sink or reservoir for various contaminants, especially heavy metal ions (Li *et al*., 2018). Studies have shown there is a constant exchange of heavy metal ions between sediment and water, such that at equilibrium partitioning, sediment tends to have higher concentrations of heavy metal ions (Eddy and Ukpong, 2005; Eddy *et* al., 2004; Mountouris *et al*., 2002). Such imbalance distribution is due to the higher sorption affinity of sediment for heavy metal ions being higher than the adsorption tendency of the metal ions for water (Rostamian *et al*., 2011). Therefore, evaluation of the quality of an aquatic environment cannot achieve remarkable standards if the environmental quality is judged based on water quality parameters without reference to their parameters in the sediment (Lepper, 2005). Sediment can be contaminated or polluted through the direct discharge of industrial wastes into a water body or the introduction of contaminants dissolved in water that is finally transferred to the water body through surface runoff (Mushtaq *et al*., 2020).

Water that meets all the required conditions for human consumption and other utilization is called portable water (Gleick, 1998). However, the reality of water portability rests so much on the theoretical bases, because the challenges of securing portable water from natural sources are enormous.

The toxicity of sediment has received global research concerns due to its role in the expected toxicity of the entire aquatic environment. Dam projects are semi-natural environments with some potential to support aquatic life, therefore, investigation of the toxicity of sediment from Dam settings can give a clue to the survival of aquatic life. (Ore and Adeola 2021; Xu *et al*., 2018). Although, toxic metal in dams may originate from natural sources such as mineral weathering, anthropogenic processes, agrochemicals, industrial and domestic municipal wastes, wastes from domesticated animals receiving metals in food supplements, and atmospheric deposition are of primary concern being the consequences of human population and economic activities (Sonone *et al*., 2020). The increasing load of toxic metals causes an imbalance in aquatic ecosystems and the biota growing under such habitats to accumulate high amounts of toxic metals which in turn, are being assimilated and transferred within food chains by the process of magnification (Chandra, and Kumar 2017). Although some of the metals like copper (Cu), Iron (Fe), manganese (Mn), nickel (Ni) and zinc (Zn) are essential as micronutrients for life processes in plants and microorganisms, other metals like cadmium (Cd), chromium (Cr) and lead (Pb) have no known physiological activity but are rather detrimental at a certain limit. Diseases like edema of eyelids, tumor, congestion of nasal mucous membranes and pharynx, stuffiness of the head and gastrointestinal, muscular, reproductive, neurological and genetic malfunctions caused by some of these heavy metals have been documented (Balamurugan & Balakumaran, 2015). Prolonged exposure to Pb has been linked to mental retardation, coma and eventual death (Abouchedid *et al*., 2016). Ingestion of Cd on the other hand is known to cause chronic toxicity such as impaired kidney functioning, hypertension, hepatic dysfunction, breast and ovarian cancer whereas Cu and Zn may cause kidney problems such as nephritis and anuria (Coleman *et al.,*2017). Furthermore, interactions associated with exposure to multiple heavy metals may induce more severe human health consequences that might be expected from low individual metal concentrations alone (Qu, *et al*., 2018). Exposure to heavy metals from water bodies may also occur through bioaccumulation of metals in human food sources (Khan *et al.,* 2015). Thus, even if humans do not consume heavy-metal contaminated water directly, they are often exposed to high levels of heavy metals from plant and aquatic food sources grown in polluted waters (Qu *et al* ., 2018). This is especially important in rapidly developing areas of Nigeria where Fadama and subsistent farming represents a large fraction of the food supply to both rural and urban centers.

Furthermore, the physical, chemical and biological activities occurring in the dam are also responsible for the sediment and water chemistry of dams (Lone *et al.,* 2018). This work aims to assess the physicochemical parameters, geo-accumulation indices and contamination factor of sediments from Mairua Dam, Faskari local government area in Katsina,Northwesten Nigeria.

2.0 Materials and Methods

2.1 The study area

The study area is the region selected for this study was the Mairua Dam situated in Faskari Local Government Area of Katsina state in Nigeria at latitude 11^{o}34’.587657” N and longitude 7^{0}14’.238149” E (Odipe *et al.,* 2019). The dam cut across farmlands, residential and industrial areas. Several farmlands and commercial activities are situated along its bank which discharges its waste into it (Achi *et al*., 2021).

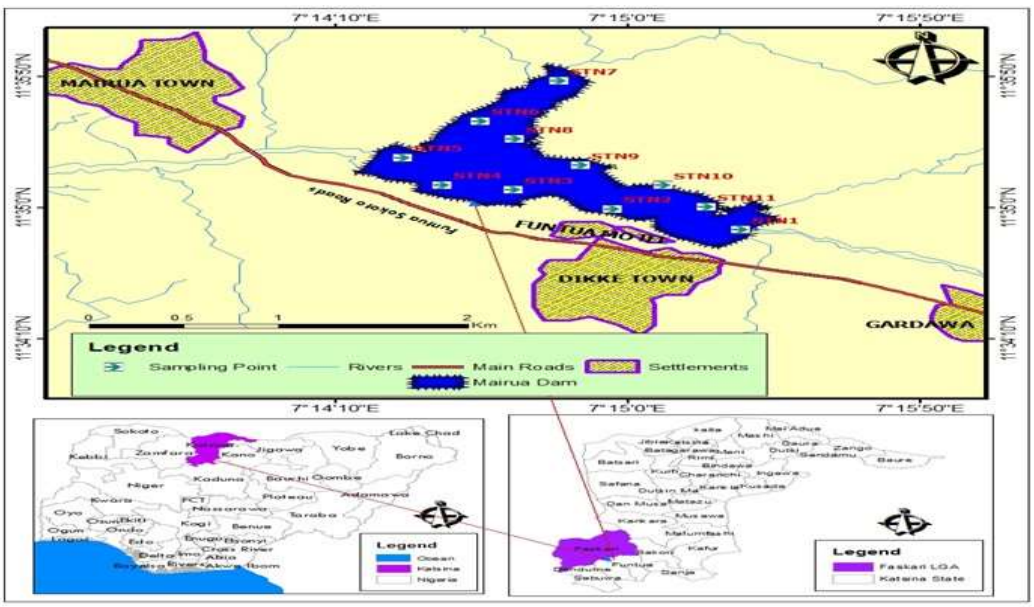

Fig. 1: Map of Mairua Dam showing the points where samples were collected.

2.2 Sampling

Sediment samples were collected at eleven selected stations (S1 to S11). The samples were kept in polythene bags, labeled and transported to the laboratory. The sediment samples collected were air-dried to constant weight in the laboratory and labeled and then kept before the determination of physicochemical parameters and digestion (Hirai *et al.*, 2011).

2.3 Quality assurance

All reagents used are of analytical grade, distilled de-ionized water is been used. All the glassware, polythene bags and sample bottles were washed with liquid soap, rinsed with distilled water, soaked in 10% HNO_3 for 24 hr and rinsed thoroughly with distilled de-ionized water and thereafter dried (Todorovi *et al*., 2001).

2.4 Determination of physico-chemical parameters

Parameters such as: pH, electrical conductivity (EC), cation exchange capacity (CEC), chloride (Cl^-), nitrate-nitrogen ($NO_3^- - N$), potassium (K^+) and phosphate – phosphorus ($PO_4^{3-} - P$) ions were determined using standard analytical methods described by APHA (2012).

3.0 Results and Discussion

3.1 *Physicochemical parameters of sediment samples*

Table 1 shows values obtained for the analyzed physicochemical parameters in the sediment samples from the Dam. The pH, electrical conductivity(EC),chloride ion (Cl^-) and $NO_3^- - N$ across the sampling points were in the ranges of 7.31±0.014 (S4) to 8.54±0.085 (S8), 0.74±0.057(S8) to 1.6±0.00 µs/cm (S9), 0.6±0.00(S5,S11) to 8.95±0.071(S5) and 0.07±0.00(S2,S6,S10) to 0.105±0.00 mg/kg (S3,S8,S11), respectively. However, concentrations of $PO_4^{3-} - P$, K^+, and CEC in the sediment samples were within the following ranges, 9.4305±0.537(S1) to 150.85±1.06(S11), 0.21±0.00 (S6, S11) to 0.795±0.007 mg/kg(S5) and 8.35±0.495(S11) to 19.25±0.495 mg/kg (S5). The highest concentrations of the analyzed parameters were from sediments in S9 while lower levels were from sediments in S6 and S11.

However, no clear trend was observed for these parameters as reflected in Table 1. The pH across the sampling points was within the range (6.5 to 8.5) accepted by WHO (2011), except for samples from S2 and S10.

Therefore, the analyzed samples fall within weak acid to weak alkaline classifications. Values of EC, Cl^-, $NO_3^- - N$ and K^+ in the sediments were also within the WHO (2011) tolerable limits of 1000 µs/cm, 250, 45, and 10 mg/kg, respectively. However, the concentrations of $PO_4^{3-} - P$ across the sampling points were above the WHO (2011) standard. (i.e, 5 mg/kg) as shown in Table 1. The highest value of EC across the sampling points was recorded at S11 while the least value (0.74±0.057 µs/cm) was recorded at S8. However, the lowest concentration of CEC (8.35±0.495 Cmol/kg) was found at the S11 sample and the highest (19.25±0.495 Cmol/kg) at S5 (Table 1).

Concentration of the $PO_4^{3-} - P$ in some of the samples is an indication of ongoing or onset of eutrophication and the expected subsequent reduction in the dissolved oxygen content of the water (Gächter *et al*., 1988). This condition cannot favor aquatic life. High $PO_4^{3-} - P$ observed in some of the samples may be associated with migration of leachate from the neighboring farmlands into the Dam through surface runoff. Our results have some slight similarities with those obtained by Chakraborty *et al*.(2021) for samples from West Bengal, India who obtained the following ranges (5-7.8, 4.11-6.7,1.03 – 2.81,0.93 – 2.98, and 38.23 – 97.7 mg/kg) for pH, $NO_3^- - N, PO_4^{3-} - P$, and Cl^- respectively. Our results are also comparable to those obtained by Nnaji *et al*. (2010) for River Galma in Zaria, Nigeria, except for the higher values of Cl^- and EC. The pH reported in this study was higher than the value reported by Awofolu *et al.* (2005) for sediment samples from the Tyume River, South Africa where the pH range of 5.85 – 7.21 was recorded. Deviation in mean pH values between our work and those reported by Uba *et al*. (2020) was also observed.

3.2 Geoaccumulation index

Generally, the implications of geoaccumulation index are as follows: Igeo<0 = Practically unpolluted; 0<Igeo<1 = unpolluted to moderately polluted; 1<Igeo<2 = moderately; 2<Igeo<3 = moderately to strongly polluted; 3<Igeo<4 = strongly polluted; 4< Igeo<5= strongly to extremely polluted and Igeo >5 = extremely polluted (Mohammed *et al.,* 2014).

Table 2 presents geo-accumulation indices (Igeo) for the analyzed heavy metals in the sediment samples, The Igeo for Pb, Cd and Co ions were in the following ranges, Pb: 0.411(S7) to 1.329(S8), Cd: 1.159(S5) to 1.626(S1), Co: 0.912(S2) to 1.294(S10), Cr: 1.526(S2) to 1.969(S10), Ni: 1.294(S2) to 1.645(S9). The evaluated geoaccumulation index reveals that the sediment samples are moderately polluted since the Iigeo indices are < 2 for Cd, Cr and Ni ions. Also, the samples are moderately polluted with Co ions across the sampling points except for samples from S2 and S5. However, samples from S1, S2, S5 and S7 had Igeo values <1, which suggests that they are not polluted while the rest of the samples had igeo values > 1 as reflected in Table 2, hence they are moderately polluted (Mohammed *et al*., 2014).

A similar trend in results has been reported elsewhere. For example, in samples from Southwest Nigeria, which indicated severe pollution status of Pb (Kolawole *et al*., 2018) and for results reported by Huang *et al*. (2020) for samples from the Xiangjiang River in South China. However, slight discrepancies exist with results obtained by Yaradua *et al*. (2018) for sediment samples from three Dams in Katsina state (Ajiwa, Zobe and Dannakola), which were unpolluted. Considering the time of the analysis, such unpolluted status must have changed due to the increased intrusion of contaminants to the Dam. A contrary trend to our results was also reported for sediment from the Ogbere River in Nigeria (Achi *et* al., 2021) and sediments from Shinka Dam in Nigeria (Ekwuribe *et al*., 2016).

Table 1:Physicochemical parameters of sediment samples collected from Mairua dam

Station	pH	EC(µs/cm)	Cl-(mg/kg)	NO_3^{3-} - N(mg/kg)	PO_4^{3-}- P(mg/kg)	K(mg/kg)	CEC Cmol/kg
S1	8.47± 0.276	0.795±0.007	0.625±0.035	0.0875±0.025	9.4305±0.537	0.42±0.000	15.8±0.424
S2	8.52±0.085	0.95±0.071	1.665±0.049	0.07±0.000	18.291±0.267	0.305±0.007	11.55±0.212
S3	7.42±0.156	0.965±0.021	5.15±0.071	0.105±0.000	14.52±0.806	0.37±0.000	16.85±0.778
S4	7.31±0.014	0.875±0.035	1.95±0.071	0.088±0.025	18.11±0.530	0.45±0.014	15±0.283
S5	7.86±0.156	0.975± 0.035	0.6±0.000	0.0875±0.025	25.46±0.269	0.795±0.007	19.25±0.495
S6	7.575±0.106	0.875±0.035	0.95±0.071	0.07±0.000	33.75±0.269	0.21±0.000	11.15±0.354
S7	7.37±0.071	0.8±0.000	0.725±0.035	0.0875±0.025	27.155±0.530	0.34±0.000	10.3±0.141
S8	8.13±0.085	0.74±0.057	8.95±0.071	0.105±0.00	16.79±0.80	0.465±0.007	14.9±0.566
S9	8.025±0.078	1.6±0.000	2.7±0.000	0.123±0.025	21.9±0.537	0.56±0.000	16.65±0.212
S10	8.54±0.085	0.975±0.035	3.875±0.035	0.07±0.000	11.5±0.269	0.34±0.000	13.05±0.212
S11	7.9±0.099	1.15±0.07	0.6±0.000	0.105±0.000	150.85±1.06	0.21±0.000	8.35±0.495
**	**6.5-8.5**	**1000**	**250**	**45**	**5**	**10**	**NG**

**** WHO(2011) standard**

Table 2: Heavy metals geo-accumulation index for sediment samples from Mairua Dams in Katsina State

Sampling points	Pb	Cd	Co	Cr	Ni
S1	0.571	1.626	1.056	1.612	1.395
S2	0.816	1.184	0.912	1.526	1.294
S3	1.150	1.301	1.150	1.717	1.498
S4	1.179	1.257	1.147	1.789	1.542
S5	0.973	1.159	0.985	1.625	1.459
S6	1.199	1.457	1.278	1.963	1.569
S7	0.411	1.330	1.039	1.868	1.465
S8	1.329	1.477	1.199	1.858	1.573
S9	1.294	1.301	1.186	1.868	1.645
S10	1.457	1.444	1.294	1.969	1.636
S11	1.279	1.319	1.195	1.680	1.515

Table 3: Contamination factor of heavy metals in sediment samples from Mairua Dam

Sampling points	Pb	Cd	Co	Cr	Ni
S1	5.581	63.33	17.08	61.43	37.27
S2	9.823	22.93	12.25	50.42	29.55
S3	21.22	30.00	21.21	78.21	12.39
S4	22.65	27.08	21.04	92.29	52.27
S5	14.09	21.67	14.5	63.19	43.18
S6	23.75	42.93	28.46	137.9	55.59
S7	27.12	32.10	16.43	110.7	43.77
S8	32.01	45.00	23.77	108.0	56.14
S9	29.53	30.00	23.00	110.6	66.19
S10	42.94	41.67	29.50	139.8	64.82
S11	28.49	31.27	23.50	71.79	49.05

Table 4: Anova of physicochemical parameter of sediment samples ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
pH	Between Groups	4.288	10	.429	26.449	.000
	Within Groups	.178	11	.016		
	Total	4.467	21			
EC	Between Groups	1.120	10	.112	65.902	.000
	Within Groups	.019	11	.002		
	Total	1.139	21			
Cl	Between Groups	135.673	10	13.567	5696.191	.000
	Within Groups	.026	11	.002		
	Total	135.699	21			
NO3	Between Groups	.006	10	.001	2.120	.117
	Within Groups	.003	11	.000		
	Total	.009	21			
P	Between Groups	32286.532	10	3228.653	9247.223	.000
	Within Groups	3.841	11	.349		
	Total	32290.373	21			
K	Between Groups	.555	10	.056	1745.486	.000
	Within Groups	.000	11	.000		
	Total	.556	21			
CEC	Between Groups	216.555	10	21.655	121.847	.000
	Within Groups	1.955	11	.178		
	Total	218.510	21			

3.3 Contamination factor of the analyzed metals in the sediment samples

The contamination factor (Cf) of the analyzed heavy metals in the sediment samples were in the ranges of Pb: 5.581 (S1) to 42.94 (S10), Cd: 21.67 (S5) to 63.33(S1), Co: 12.25 (S2) to 29.50 (S10), Cr: 50.42 (S2) to 139.8 (S10) and Ni: 12.39 (S3) to 66.19 (S9), respectively. These ranges clearly show that Cd, Co, Pb, Cr and Ni ions have high Cf (Cf>6). A similar trend has been reported by Ozkan (2012) for samples from Izmir Bay in Turkey and those reported for the Ahmadu Bello University Dam (Ekwuribe, *et al*., 2016). Studies conducted by Kolawole *et al*. (2018) revealed that most of the metals such as Ni, Co, Fe, Cr, Pb and Mn were having Cf<1, this clearly shows low contamination while Cu, Cd and Pb were having Cf > 6, very high contamination.

3.4 Statistical treatment of the data (ANOVA)

Table 4 shows results obtained for the analysis of variance (ANOVA) regarding the physicochemical parameters of the samples. The results obtained reveal that the magnitude of analyzed physicochemical parameters across the sampling points was not significantly different ($p<0.05$) at 95% confidence limits except $NO_3^- - N$. The result of ANOVA in this study was in line with those reported by Ilechukwu *et al*., (2020) in sediments of Usuma dam Abuja, Nigeria.

Statistical analysis indicated significant strong positive and negative correlations for the analyzed parameters across the sampling points. A strongly positive correlation was observed between pH1 vs pH2, pH5 vs pH7, EC vs EC5, etc. However, strong negative correlations were observed between CEC1 and EC5, CEC and EC2 and others, reflected in Appendix 1. A significant positive correlation indicates a direct relationship and a common pollution source, while a significant negative correlation shows that the pollution might emanate from a different source and an inverse relationship.

4.0 Conclusion

This research reveals the levels of the selected physicochemical parameters (pH, EC, Cl^-,$NO_3^- - N, PO_4^{3-} - P$, K^+ and CEC),Igeo and CF in sediment samples. The analyzed samples fall within weak acidic to weak alkaline classifications. The highest concentration of $PO_4^{3-} - P$ was found in sample S11. The concentrations of EC, Cl^-, $NO_3^- - N$, K^+, and CEC were all found to be within the WHO (2011) tolerable limits. In addition, the pH of samples from S2 and S10 were above the WHO (2011) tolerance limit due to leachate migration from the neigbouring farmlands and fish feeds being used by the fishermen in the dam. The evaluated geoaccumulation indices (Igeo) indicated that the sediment samples are moderately polluted while the calculated Cf values show that the samples are contaminated with Cd, Co, Cr and Ni. Therefore, it is recommended that the sediments of Mairua Dam should be continuously monitored to assess the level of pollution and the farming activities be constantly monitored to ensure that toxicant entrance into the dam are significantly minimized.

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Conflict of Interest

The authors declared no conflict of interest