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QUANTITATIVE ASSESSMENT OF POLLUTION STATUS OF HEAVY METALS IN THE WATER FROM MAIRUA DAM, FASKARI LGA, KATSINA STATE, NORTHWESTERN NIGERIA

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ABSTRACT

Pollution of surface water by toxic metals has received considerable attention due to its risk to human health and ecology. Consequently, the present study focused on the assessment of the heavy metal concentrations in the water from Mairua dam. This research reveals the concentrations of the selected toxic metals (Pb, Cd, Co, Cr and Ni) in water samples. The following trend was observed across the sampling points; Co> Cr> Cd> Ni> Pb. The concentrations of Pb across the sampling points were within the WHO (2011) permissible limits. However the Cd concentrations across the sampling points were within the WHO limits of 0.003 mg/kg with exemption of W1, W2, W3, W4, W5, W8 and W10 respectively. Similarly the concentrations of Co in the analyzed water samples were all above WHO (2011) tolerable limits of 0.01 mg/kg. The elevated level of cobalt in the water may be attributed to leachates from farmlands and domestic waste. The concentrations of Cr across the sampling points were within the WHO (2011) permissible limits of 0.005 mg/kg with exemption of samples W2, W3, W4, W7, W8, W10 and W11 respectively. However, the concentrations of Ni across the sampling points were higher than WHO (2011) permissible limits of 0.01 mg/kg. Nickel is introduced into the environment from both natural and man-made sources. The results obtained for Contamination Factors reveals low contamination (Cf<1) with an exemption of Cd in points W1 and W2. PLI denotes no pollution and Hazard quotient values also showed that the analyzed water has no potential health effects with exemption to Cd. The results also shows that there was no significant difference in the analyzed samples at p<0.005 across the sampling sites. Pollution of the water by Cd may be as a result of anthropogenic activities that are released into the dam. It is recommended to periodically monitor the water.

Keywords: Mairua Dam, Contamination factor (CF), Pollution load indices (PLI), Hazard quotient (HQ).

INTRODUCTION

Water is the most important substance for human existence after oxygen. Water is the most abundant substance on the earth's surface that is essential for the survival of all known forms of life. Water plays an important role in the world economy, as it functions as a solvent for wide variety of chemical substances, industrial cooling, transportation and agriculture. More than 70% of fresh water is used for agriculture (Spellman 2020).

Contaminants such as bacteria, heavy metals, nitrates and salt have found their way into water supplies due to inadequate treatment and disposal of waste from human, livestock and overused of limited water resources (Kishor *et al.*, 2021). Even if no source of anthropogenic contamination exists, natural sources are also equally potential to contribute higher level of some metals and other chemicals that can harm human health (Mohammed *et al.*, 2011). Uptake of heavy metals by plant and subsequent accumulation along food chain is a potential threat to animals and human health (Singh & Kalamdhad 2011).

Human being has been exposed to heavy metals for an immeasurable time. Rapid increase in population, coupled with other factors such as urbanization, rapid industrial development, mining and agriculture. It result in huge accumulation of waste and pollutants which end up in water bodies such as dams, streams and lakes thereby polluting them (Shamsuddin *et al.*, 2018). Heavy metals also present in virtually every area of modern consumerism such as dam construction materials, cosmetics, medicines, processed food, fuel source, personal care products, etc. it is very difficult for everyone to avoid exposure to any of the heavy metals in our environment. Heavy metals toxicity represents an uncommon, yet clinical significant medical condition. If recognized or inappropriately treated, heavy metal toxicity can result in significant morbidity and mortality (Jan *et al.*, 2009).

The aim of this research is to assess the concentration of heavy metals and pollution status of water from Mairua Dam, Katsina State of Nigeria.

MATERIALS AND METHODS

Description of Study Area

Mairua Dam situated in Faskari Local Government Area of Katsina state in Nigeria at latitude 11°34'.587657" N and longitude 7°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 that discharges its waste into it (Achi *et al.*, 2021).

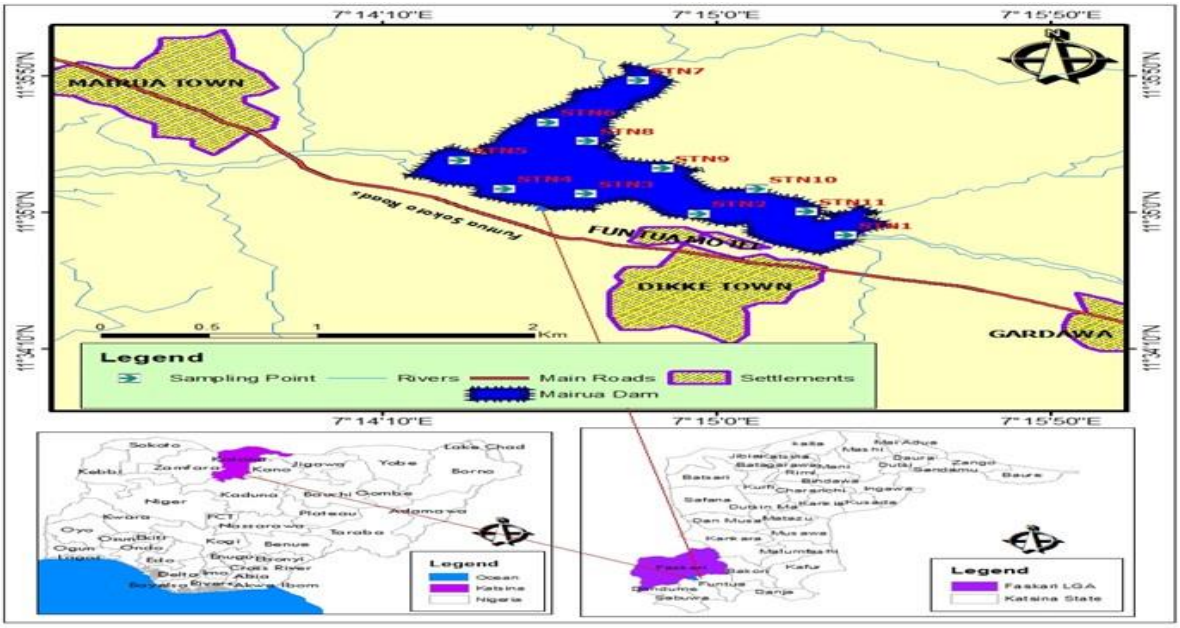

Fig. 1: Map of Mairua Dam showing the points where samples were collected.

Method

Contamination factor (Cf)

Contamination of heavy metals in sediment was determined according to contamination factor (C_f) and degree of contamination (DC). The Cf was calculated according to method described by (Saha and Hussaini, 2011) and the degree of contamination (DC) was determined as the sum of all contamination factors using the relation:

$$C_f = \frac{\text{Measured Concentration}}{\text{Background Concentration}} \text{ ------------Eqn1}$$

Pollution load indices (PLI)

Pollution load indices provide a simple way to assess the quality of sediment. This assessment is a quick tool for comparing the status of pollution at different locations. PLI represents the number of times the concentration of heavy metals in the sediment exceeds the background concentration and provides a summary indication of the overall level of heavy metal toxicity in a particular sample or location.

The PLI can be expressed in the following relation:

$$\text{Pollution load indices (PLI)} = (CF_I \times CF_2 \times CF_3 \times CFn)^{1/n} \text{ ----------------------------Eqn2}$$

Where n is the number of metals and CF is the contamination factor.

Samples collection

The plastic containers was rinsed three times and filled up at the depth of one meter below the water. The samples were collected from eleven sampling points by dipping the plastic bottles in the water before the sediment is reached and also at the surface to make a composite sample (Akan *et al.,* 2012).

Samples digestion

100 mL of each water sample was transferred into a 250 mL beaker and 5 mL conc. HNO_3 was added to it and it was then be placed on a hot plate to evaporate down to about 20 mL at 100 °C. The sample was allowed to cool and another 5ml conc. HNO_3 was added. It was then covered with a watch glass and resumed heating with addition of 2 mL of conc. HNO_3 to the mixture until the solution appear clear.

The sample was then filtered while hot to remove insoluble materials that could clog the atomizer, the filtrate was allowed to cool and then diluted to the mark in 100 cm^3 volumetric flask with distilled water (Salihu *et al*., 2019). The digested sample was subjected to AAS analysis at Bayero University, Kano.

Quality assurance

All reagents used are of analytical grade, distilled de-ionized water is been used. All the glassware and polythene 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 (Ziarati *et al*., 2012). Plastic bottles were washed with detergent, rinsed and soak in 10% HNO_3 for 24hour and finally rinsed with distilled water and then allowed to dry.

Statistical treatment of data

Microsoft spreadsheet was used to calculate the mean and the standard deviation, while SPSS version 20.0 software was used to test the significant differences in the levels of the heavy metals studied (using ANOVA) across the sampling points at 95% ($p \leq 0.05$) confidence level.

RESULTS AND DISCUSSION

Table 1 reveals the mean concentrations of heavy metal in the analyzed water samples collected from Mairua Dam. BDL means below detection limits, while W1 to W11 means water sampling point 1 to sampling point 11. The concentrations of lead (Pb), cadmium (Cd), cobalt (Co), chromium (Cr) and nickel (Ni) across the sampling points were in the ranges of BDL(W1, W2,W3,W4,W5,W7) to 0.0183 ± 0.023 (W10) for Pb, 0.00008 ± 0.002 (W9) to 0.123 ± 0.005 for Cd, 0.017 ±0.001 (W9) to 0.118± 0.022 (W2) for Co,0.0025±0.007 (W5) to 0.0185 ±0.037 (W9) for Cr and 0.0375±0.008 (W3) to 0.0633 ± 0.0059 (W10) (mg/kg) for Ni respectively. On comparing the concentrations of the metals across the sampling points, it was found that the metal concentrations were highest at W2 while the lowest concentrations were recorded at W9 respectively.

Generally, the following trend was observed with respect to the concentration of the analyzed metals across the sampling points; Co> Cr> Cd> Ni> Pb as reflected in Table 1.

The Pb concentrations across the sampling points were within the WHO (2011) permissible limits of 0.01 mg/kg. However the Cd concentrations across the sampling points were within the WHO limits of 0.003 with the exemptions of W1, W2, W3, W4, W5, W8 and W10 respectively. Similarly the concentrations of Co in the analyzed water samples were all above WHO (2011) tolerable limits of 0.01 mg/kg without an exemption. The concentrations of Cr across the sampling points were within the WHO (2011) permissible limits of 0.005 mg/kg with the exemption of samples W2, W3, W4, W7, W8, W10 and W11, respectively. However, the concentrations of Ni across the sampling points were higher than WHO (2011) permissible limits of 0.01 mg/kg without any exemption, these shows that the analyzed water samples were polluted.

On comparing the results recorded in this study with those of Awofolu *et al*., (2005) in a similar study in South Africa, the concentrations of Ni were in line with the results obtained in this study. However, concentrations of Co and Cd in Dam water were higher than the values reported in this study as shown in Table 1. High concentrations of Co in water include loss of body weight and depressed appetite. Increase in Cd concentrations in water showed that the water is unsuitable for drinking and other domestic activities.

On comparing the results obtained in this study with those of Ogbuagu *et al*., (2021) in a similar study in Ogbaru River, Anambra State, Nigeria, the concentrations of Cd, Cr, Ni and Pb reported were higher than what was reported in this study. Furthermore, on comparing the results recorded in this study with those of Uba *et al*., (2020) in Shika dam Nigeria where the concentration of Pb, Cd and Cr were higher than the concentrations obtained in this study. However, the concentrations of Co and Ni was higher than what was reported by Uba *et al*., (2020) where Co, and Ni were reported to be insignificant in the analyzed samples.

Table 1: Mean concentration (mg/kg) of heavy metals in water samples of Mairua dam

Sampling points	Pb	Cd	Co	Cr	Ni
W1	BDL	0.101±0.153	0.083±0.025	0.004±0.008	0.0493±0.009
W2	BDL	0.123±0.005	0.1178±0.022	0.018±0.036	0.0393±0.002
W3	BDL	0.005±0.003	0.0595±0.031	0.017±0.034	0.03775±0.008
W4	BDL	0.0063±0.001	0.0343±0.004	0.0065±0.013	0.0628±0.001
W5	BDL	0.0053±0.001	0.041±0.028	0.0025±0.007	0.053±0.007
W6	0.002±0.004	0.0023±0.001	0.0503±0.002	0.0035±0.025	0.06075±0.004
W7	BDL	0.0023±0.006	0.0238±0.004	0.0125±0.025	0.0433±0.039
W8	0.00025±0.001	0.005±0.003	0.0295±0.021	0.0045±0.009	0.0498±0.008
W9	0.00125±0.004	0.00008±0.002	0.017±0.001	0.0185±0.037	0.03875±0.023
W10	0.0183±0.023	0.005±0.00	0.03025±0.005	0.0075±0.015	0.0633±0.005
W11	0.0103±0.021	0.0033±0.004	0.023±0.001	0.012±0.024	0.0518±0.011
WHO (2011)	0.01	0.003	0.01	0.005	0.01

Table 2: Contamination factor (CF) and pollution load indices (PLI) of heavy metals in water samples

Sampling points	Pb	Cd	Co	Cr	Ni
W1	BDL	3.367	0.277	0.0048	0.224
W2	BDL	4.1	0.393	0.0214	0.179
W3	BDL	0.167	0.198	0.0202	0.171
W4	BDL	0.21	0.144	0.0077	0.285
W5	BDL	0.177	0.137	0.00298	0.241
W6	0.00465	0.077	0.168	0.0042	0.276
W7	BDL	0.077	0.079	0.015	0.197
W8	0.00058	0.167	0.098	0.0054	0.226
W9	0.00291	0.00267	0.057	0.022	0.176
W10	0.043	0.167	0.101	0.0089	0.288
W11	0.024	0.11	0.077	0.0143	0.235
PLI	2.846×10^{-6}	6.451×10^{-5}	1.566×10^{-5}	6.734×10^{-12}	2.63×10^{-4}

Table 3: Hazard quotient of water from Mairua Dam

Metals	Water samples				
	Ding-children	Ding-adults	HQ children	HQ adult	Rf (USEPA, 2011)
Pb	4.28×10^{-4}	1.834×10^{-4}	0.107	0.0459	4.00×10^{-3}
Cd	1.567×10^{-3}	6.714×10^{-4}	274.4	117.58	5.71×10^{-6}
Co	3.08×10^{-3}	1.32×10^{-3}	0.065	0.028	4.71×10^{-2}
Cr	6.455×10^{-4}	2.766×10^{-4}	0.031	0.013	2.06×10^{-2}
Ni	3.333×10^{-3}	1.428×10^{-3}	0.011	4.744×10^{-3}	3.01×10^{-1}
Σ	9.053×10^{-3}	3.879×10^{-3}	274.614	117.672	

Table 4: Analysis of variance (ANOVA) for water from Mairua Dam

		Sum of Squares	Df	Mean Square	F	Sig.
Pb	Between Groups	.003	10	.000	3.055	.040
	Within Groups	.001	11	.000		
	Total	.004	21			
Cd	Between Groups	.068	10	.007	3.168	.036
	Within Groups	.024	11	.002		
	Total	.092	21			
Co	Between Groups	491.821	10	49.182	.996	.499
	Within Groups	543.365	11	49.397		
	Total	1035.186	21			
Cr	Between Groups	.457	10	.046	90.404	.000
	Within Groups	.006	11	.001		
	Total	.462	21			
Ni	Between Groups	.007	10	.001	3.225	.034
	Within Groups	.002	11	.000		
	Total	.010	21			

Contamination factor of metals in the analyzed water samples

The contamination factor (CF) of the analyzed heavy metals in water samples were in ranges of BDL (W1, W2, W3, W4, W5, W7) to 0.043 (W10) for Pb, 0.00267 (W9) to 4.1 (W2) for Cd, 0.057 (W9) to 0.393 (W2) for Co, 0.00298 (W5) to 0.022 (W9)for Cr and 0.171 (W3) to 0.288 (W10) for Ni respectively. These ranges clearly shows that the concentration of Cd at W1 and W2 samples were considerably contaminated (3< CF <6).The high value of CF is a yardstick for assessing the levels of contamination in water samples. However, CF of Co, Cr and Ni were low (CF<1).On comparing the levels of CF in this study with those reported by Ekwuribe *et al.*, (2016) in a similar study, their results was contrary to the report in this findings where the CF reported for Pb and Ni were higher while the concentrations of Cd, Co, and Cr were BDL.

Pollution load indices

PLI < 1 denotes no pollution; whereas PLI > 1 denotes pollution. The PLI is aimed at providing a measure of the degree of overall contamination at a sampling site. The PLI of the analyzed heavy metals in water samples were all <1, with the exemption of Cd in W1 and W2 this shows that W1 and W2 sampling points are polluted with Cd. The results in this study were in line with those of Ekwuribe *et al.*, (2016) in a similar study.

Furthermore, the results of Kamari *et al.*, (2017) were higher than the results reported in this study; this might be attributed to the presence of leachates from farm land and domestic waste discharged into the water body. It can be concluded that the level of contamination of the metals studied was higher in the areas closer to the mouth (upstream) of the river compared to the (downstream) sampling sites.

Risk assessment

The hazard quotient (HQ) was calculated with assumption that, when the quotient is <1, this means no potential health effects are expected from exposure, but when it is >1, it signifies that there are potential health risks due to metal exposure (Bermudez *et al.,* 2010).

The finding shows that hazard quotient (HQ) values for all heavy metals under this study were **<**1 in all the samples with exemption of Cd in children and adults. The daily ingestion of metals by children and adults are within the Rf (USEPA, 2011) limits of 0.0000571 with exemption to the concentration of Cd in the analyzed water samples. The results in this finding were in line with the report of Liu and Ma (2020) in a similar study where HQ and carcinogenic risk concentrations of Cd, Cr, and Ni measured were all < 1.

Furthermore, the results in this study were also in line with the findings of (Ya *et al.*, 2017). In a similar study, with the exemption of Cd whose daily intake was higher than what was obtained in this study.

Statistical treatments

Table 4 reveals the analysis of variance (ANOVA) of the analyzed samples for the metal. The results obtained shows that the analyzed water samples across the sampling points were not significantly different (p<0.05) at 95% confidence limits with an exception of the concentrations of Co which shows that there is significant difference in the concentrations across the sampling points. This clearly shows that the samples do not have a common source of pollution.

The results of the correlation matrix showed significantly strong positive and negative correlations for the analyzed water samples across the sampling points. The results obtained indicate that the sources of pollution of the analyzed samples emanates from the same source.

CONCLUSION

This study reveals the concentrations of the selected toxic metals (Pb, Cd, Co, Cr and Ni) in water samples. Elevated levels of Cd, Co, Cr and Ni were detected in the analyzed water samples from the dam, which could be directly detrimental to the health of the aquatic ecosystem and indirectly to man since the water is used for drinking, other domestic use and also to irrigate nearby farmland.

RECOMMENDATIONS

It is therefore recommended that further evaluation and regulatory actions should be enforced on environmental polluters. Regular check on the levels of heavy metals in the dam should be carried out in order to safeguard health and wellbeing of the consumers.

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