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Appraisement of Some Heavy Metals in Kuru Dam, Jos South L.G.A, Plateau State, Nigeria

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ABSTRACT: The objective of this study was to assess the concentrations of selected heavy metals at Kuru Dam. The result obtained shows that Fe ranged from 0.05- 0.55ppm, As 0.13-0.18ppm, Cu 0.06-0.36ppm, Pb 0.08 -0.46, Cd 0.01-0.02ppm, while Zn 0.01-0.01ppm. The results were compared with, FAO and NESREA standards. The data revealed that Fe, Zn, Cu and Cd concentration levels were found to be less than permissible limit concentration levels of while Cd, Pb, and As in water samples were beyond acceptable limit. Excess Cd could lead to kidney damage, respiratory problems, increased risk of lung cancer, and bone diseases; high concentration of Lead could cause cognitive impairments, learning disabilities, developmental issues in children, while overexposure to Arsenic may cause skin lesions, cardiovascular diseases, lung cancer, bladder cancer, and induce developmental abnormalities in children, accordingly. More so, excess levels of cadmium, lead, and arsenic have extensive implications for human health, environmental sustainability, and socio-economic aspects in the study area.

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Agriculture uses about 70% of the world's fresh water, only about 3% is fresh, 1.1 billion people worldwide lack access to water, and a total of 2.7 billion cannot access water at least one month of the year (Sabo, 2013). Water scarcity is a significant global issue affecting various countries and regions of the world; this is caused by several factors like increase in population growth, climate change, pollution, over-extraction of groundwater, inefficient water management practices, and natural disasters such as droughts and floods. Various non-governmental organizations are actively working towards achieving sustainable development goal 6, which aims to ensure universal access to safe and affordable water for all by 2030 (WHO, 2021; Muyiwa *et al.,* 2020). The consequence of water scarcity are profound and far-reaching; lack of access to clean water not only leads to waterborne diseases, but also affect food security, sanitation and economic development in Jos. Several communities now rely on unsafe and contaminated water sources for irrigation activities. Irrigation water can be sourced from groundwater, dams, wells, surface water, rivers, lakes, and mining ponds, among other sources. Most mining ponds in Jos are used for irrigation activities; as a result, it is critical that farmers protect their agricultural water source to minimize the potential for contamination (Nguyen *et al.,* 2020). Dams are a major water source, they are barriers that are usually constructed across rivers, to hold back and contain water in a lake or reservoir (Nguyen *et al.,*

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2020). They are usually built using concrete or natural materials such as earth and rock, but in Jos south, most dams are as a result of tin mining which has been largely responsible for profound changes in the landscape over the last 70 years (Zhang *et al.,* 2021). For centuries, dams have been a vital part of the water infrastructure, and serving different purposes. Dams are used to store rainwater, before it is filtered and processed for human use, this water can also be used in hydroelectric power stations to generate electricity. Reservoirs control water flow into rivers after heavy rain, water stored in dams are used for irrigation during dry season; also, dams can be used to raise the upstream water level to improve navigation conditions (Edward and Joshua, 2021). Several dams in Jos are polluted as a result of anthropogenic activities. Contamination may originates from a single source, called point source pollution; examples include effluents discharged legally or illegally by a manufacturer, oil refinery, wastewater treatment facility, leaking septic systems, others are chemical and oil spills, and illegal dumping. The Environment Protection Agency regulates point source pollution by establishing limits on what can be discharged by a facility directly into a body of water; even though point source pollution originates from a specific place, it can affect miles of waterways and ocean (Edward and Joshua, 2021). Nonpoint source pollution is contamination derived from diverse sources; these may include agricultural, storm water runoff, debris blown into waterways from land. Nonpoint source pollution is the leading cause of water pollution in several countries, but it's difficult to regulate, since there's no single identifiable culprit (Adams and Langston, 2021). In Nigeria, water pollution occurs from both point and nonpoin**t** sources, water pollution in northern Nigeria especially in Jos South, could occur as a result of pesticide, sewage and industrial effluents. Muhammed *et al.,* (2020) reported pollution caused by heavy metals such as lead, iron, arsenic, zinc cadmium, copper in Jos. Exposure to heavy metals has been linked with developmental retardation in children, various cancers, kidney damage and even death (Abdulaziz and Mohammmed, 2020). Study by Oiganji and Dikam, (2020), assessed the concentration status of some heavy metals in Jos North, Plateau State Nigeria. It was reported that iron, lead, cadmium and manganese were present and above the recommended threshold by 277, 6,400, 1,233, and 580%. Kuru dam is presently being used for irrigation activities, with no base line data; this is worrisome because the dam is currently being used to irrigate sorghum, millet, Acha, potatoes, and other vegetables in the study area. Hence, the objective of this study was to assess the concentrations of selected heavy metals at 50 cm depth from upper, middle and lower sections of the Kuru Dam, Jos South Plateau State, Nigeria.

MATERIALS AND METHODS

Study Area: Jos South Local Government Area lies within latitudes 90 37' and 90 54' N and between Longitudes 80 42' to 80 58' E. It is situated at the north western part of the state with its headquarters at Bukuru. It is made up of four districts: Vwang, Du, Gyel and Kuru. The Local Government Area has total land area of about 1,037km^2. The mean annual rainfall in Jos South varies from 1317.5 to 1460mm, the precipitation reaches its peak with an average of 298mm, July and August are the months with the highest number of rainy days, while the lowest number of rainy days occur in January, February, November and December (David *et. al.,* 2020).

Sampling Procedure and Water Sample Collection: The length of the dam was measured and mapped-out to be 1600 meters. Three (3) sampling stations were mapped-out at an equal interval of 533.33 meters, where samples were collected at each station. Water drawer was used to collect the samples from the upper, middle, and lower sections along the dam, as presented in Figure 3.2. Polythene bottles with screw caps were well labeled, and were filled up with the collected samples for laboratory analysis. Nine (9) water samples were collected at the depth of 50cm and at this distance, sample from the upper part was collected and labeled as 'A', another from the middle part was collected and labeled as 'B' and the last sample was collected from the lower and labeled as 'C'. The samples were collected into a well-treated container to avoid interference and impurities coming in contact with the samples. The sample was collected thrice at six weeks interval, from February-June, 2022 at about 9 am, accordingly. The water sample collected were pre-treated with few drops of concentrated nitric acid (HNO_3) to avoid metal absorption before and after digestion of the water sample for AAS analysis. The concentration levels of the heavy metals in water samples collected were digested with aqua-regia (HNO_3 67%: HCl 37% = 3:1) for an hour at the temperature of 100ºC in a fume cupboard until the solutions were transparent.

Preparation of Solutions: Different standard solutions were prepared for AAS analysis based on selected heavy metals, under Beer-Lambert method of metal analysis as reported by Dalen, (2015) and Samkwar, (2015). Atomic Absorption Spectrometer, AAS was used to analyze the selected heavy metals which were: Lead (Pb), Zinc (Zn), Copper (Cu), Arsenic (As), Cadmium (Cd), and Iron (Fe). The standard solutions of each element were run on the machine. The absorbance corresponding to the concentrations of the standard solutions and samples were recorded each time they were run. Thereafter, the concentration in ppm of the unknown samples for each element was determined graphically.

Statistical Analysis: The data collected was subjected to One-way ANOVA, and a t-test was used to compare the mean value with the permissible level with reference to acceptable standards recommended.

RESULTS AND DISCUSSION

Concentration of Heavy Metals in the Month of February: Water samples were collected to check the status of some heavy metals. Table 1 shows the concentration of the heavy metals considered in this research in the month of February at the upper, middle and lower section. Copper (Cu), Iron (Fe), Zinc (Zn) and Cadmium (Cd) were within the permissible limit for the month of February 2022. The Lead (Pb) value at the upper, middle and lower section of the Dam, ranged from 0.31 to 0.69ppm, were beyond the permissive value of 0.01. However, the As value which ranged from 0.07 to 0.35, were beyond the acceptable limit at the upper and lower section of the dam.

Concentration of Heavy Metals in the Month of April: Table 2 presents the concentration status of the heavy metals considered in this research, Cu, Cd and Zn, were within the acceptable limit of heavy metal concentration for irrigation water. The Pb value ranged from 0.04 to 0.10ppm, the Fe value ranged from 0.35 to 0.94ppm, and As value ranged from 0.10 to 0.35ppm, which were all far beyond the permissible limit status for irrigation water.

Table 1: Heavy Metals Concentrations in the Month of February

Heavy metals	Upper	Middle	Lower	Mean	SD	WHO (2011)	FAO (2011)	NESREA (2019)
Copper (Cu)	0.33	0.21	0.20	0.25	0.07	2.00	2.00	0.10
Lead (Pb)	0.69	0.31	0.38	0.46	0.20	0.01	0.05	0.10
Iron (Fe)	0.04	0.05	0.05	0.05	0.01	0.30	0.30	0.30
Zinc (Zn)	0.00	0.00	0.00	0.00	0.00	3.00	3.00	2.00
Cadmium (Cd)	0.00	0.00	0.00	0.00	0.00	0.03	0.003	0.10
Arsenic (As)	0.35	0.07	0.10	0.18	0.15	0.05	0.05	0.10

A = upper, B= Middle, and C= Lower section of the Dam, Sd = Standard deviation, FAO = Food for Agricultural Organization, NESREA = National Environmental Standards and regulations Enforcement Agency.

Table 2: Heavy Metals Concentrations in the Month of April

Heavy metals	Upper	Middle	Lower	Mean	SD	WHO (2011)	FAO (2011)	NESREA (2019)
Copper (Cu)	0.59	0.23	0.23	0.35	0.21	2.00	2.00	0.10
Lead (Pb)	0.04	0.09	0.10	0.08	0.03	0.01	0.05	0.10
Iron (Fe)	0.35	0.35	0.94	0.54	0.34	0.30	0.30	0.30
Zinc (Zn)	0.01	0.00	0.00	0.01	0.00	3.00	3.00	2.00
Cadmium (Cd)	0.01	0.01	0.01	0.01	0.00	0.03	0.003	0.10
Arsenic (As)	0.35	0.07	0.10	0.18	0.15	0.05	0.05	0.10

A = upper, B= Middle, and C= Lower section of the Dam, Sd = Standard deviation, FAO = Food for Agricultural Organization, NESREA = National Environmental Standards and regulations Enforcement Agency

Table 3: Concentration of heavy metals in the Month of June

Heavy metals	Upper	Middle	Lower	Mean	SD	WHO (2011)	FAO (2011)	NESREA (2019)
Copper (Cu)	0.00	0.08	0.08	0.05	0.05	2.00	2.00	0.10
Lead (Pb)	0.00	0.00	0.00	0.00	0.00	0.01	0.05	0.10
Iron (Fe)	0.02	0.09	0.07	0.06	0.04	0.30	0.30	0.30
Zinc (Zn)	0.00	0.00	0.00	0.00	0.00	3.00	3.00	2.00
Cadmium (Cd)	0.00	0.01	0.00	0.00	0.01	0.03	0.003	0.10
Arsenic (As)	0.06	0.13	0.19	0.13	0.06	0.05	0.05	0.10

A = upper, B= Middle, and C= Lower section of the Dam, Sd = Standard deviation, FAO = Food for Agricultural Organization, NESREA = National Environmental Standards and regulations Enforcement Agency

Concentration of heavy metals in the Month of June: Table 3 shows the concentration status of the heavy metals present in the reservoir; it appears that Copper, Lead, Iron, and Zinc were within the acceptable limit value, as recommended for irrigation water. Nevertheless, Cadmium was beyond the permissible level at the middle of the Dam, while Arsenic was slightly beyond the recommended value, as presented in Table 3.

Differentiation in Concentrations of Metals across the Sampling Periods: Heavy metals were compared across periods (February, April, and June) as presented in Fig 1; Copper and Arsenic concentrations throughout the sampling period were not statistically significant. Nonetheless, lead, iron, zinc, and cadmium exhibited statistically significant (p<5%) variation between sampling periods. The maximum Pb concentration was recorded in February and the lowest in June. The month of April had the greatest concentrations of cadmium and zinc.

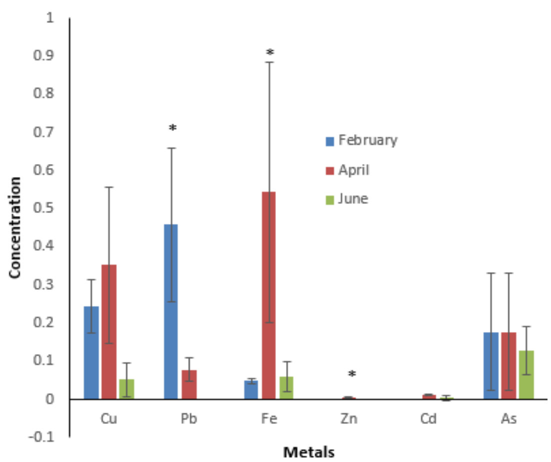

Fig 1 Concentrations of the Metals across Sampling Periods

Iron: Iron (Fe) mean values obtained ranged from 0.05–0.54 (ppm), the highest mean value of 0.54ppm was recorded in June, 2022, while the lowest mean value of 0.05ppm was recorded in February. However, the mean values for the months of June and February obtained fell within the permissible limit of 0.30ppm, while the concentration for the month of April appears higher than this limit stipulated by WHO/FAO (2011) as presented in Fig 1 and Table 2. It was observed that the mean concentration values of Fe differ significantly at (P<0.05) within the months of February, April and June, 2022. Variation of concentration level of Fe may be due to fluctuation rate of surface run-off and effluents discharge from factories residents and water treatment plant as reported by Aliyu *et al.,* (2019). Similarly, Henry *et al.,* (2018), worked on assessment of heavy metal concentration in water, soil and vegetables in Ex-mining Pond, in Jos South L.G.A. He reported an unacceptable concentration value of 0.42ppm. Waida *et al.,* (2022) conducted a similar study, on toxicity and health effects of heavy metals in soil, water and edible vegetables in Jos South, Plateau State, where unacceptable concentration value of 0.32ppm was reported. Furthermore, Olatoyinbo, (2018) worked on heavy metal uptake by maize in Zawan and Mista Ali, reported a concentration value of 0.56ppm which was far above the acceptable limit. Nimyel and Elizabeth (2021), assessed heavy metals in soil, water and vegetables in Langtang north, reported Fe value within the recommended value by NESREA (2019). The outcome of this research, seems not to be in accordance with the work of Ezekiel *et al.,* (2020); they assessed the concentration status of some heavy metals in water along River Dilimi, Jos North, Plateau State-Nigeria and reported Fe mean value of 0.63-1.13 (ppm) in the months of July-December in 2019, which was above the values obtained during this study. The following metals: Cd, Fe, Cu, and Zn concentrations were within the acceptable range, whereas Pb concentrations were surprisingly beyond the permissible limit, the recorded value of Lead (Pb) exceeded the permissible concentration by 18 times as presented in Fig 2.

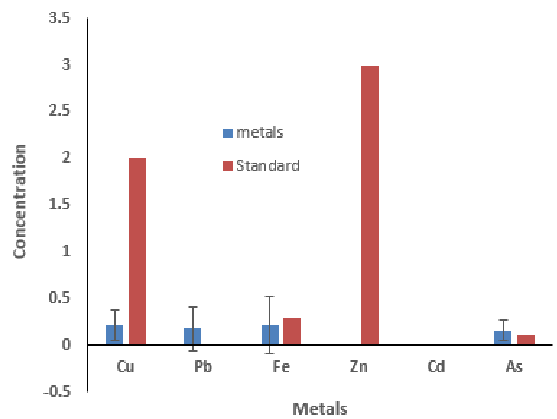

Fig 2: Concentrations of metals with respect to Permissible limit

Arsenic: The mean values of Arsenic obtained ranged from 0.13-0.18 (ppm), the highest mean value of 0.18 ppm was recorded in February and April 2020, while the lowest mean value of 0.13ppm was obtained June 2020. However, the mean values obtained were higher than the permissible limit of 0.1 ppm according to all standards reported. The concentration value of arsenic in April (2020) appears to be decreasing from upper, middle and lower section of the dam, while an opposite trend is observed in the month of June where the concentration of arsenic appears to increase from upper section of the dam, this is as a result of the effluent discharge from factories residents and water treatment plant as reported by Aliyu *et al.,* (2019). Malakar *et al.,*(2019), also reported that high arsenic content in irrigation water, accumulates in the top soil (10-15cm) which can change soil quality, consequently altering food quality and human health in the long run. Additionally, increased As level has been found to decrease edible biomass production in beans and the deposition of arsenic in the beans; Mafuyai *et al.,* (2020) worked on health risk assessment of heavy metals in consumption of vegetables irrigated with tin mine pond water in Jos South, Plateau State, reported As concentration of 0.94ppm. Olatoyinbo in 2018 and Ogenyi (2018) reported As value to be above the recommended permissible limits. Therefore, the water from Kuru dam is not safe for irrigation purpose within the period of this study.

Copper: The mean concentration values of copper (Cu) obtained ranged from 0.05-0.35 (ppm), the highest mean value of 0.35 ppm was recorded in the month of April, 2022, while the lowest mean value of 0.05 ppm was also recorded during June, 2022. The mean values for the months of February and April appear higher than the permissible limit of 2.00 ppm set by WHO/FAO (2011) as shown in Fig.2. Like other metals, the mean value of Cu appears to decrease from the upper, to the middle and to the lower section of the dam in the month of June. Therefore, the water from Kuru dam in June can be said to be safe for irrigation. However, the same is said to be unsafe for irrigation in the months of February and April. This seems to be dissimilar with the work of Ezekiel *et al.,* (2020) who assessed the concentration status of some heavy metals in water along River Dilimi, Jos North, Plateau State-Nigeria and reported Cu mean value of 0.00-0.04 ppm between the months of July-December in 2019, which is below the permissible limit. However, the study by Henry, (2018) agrees with the findings from this study, they found Cu to be above the permissible limit stated by the WHO/FAO (2011). The variation in the mean concentration values of Cu between the upper section and the lower section does differ significantly at ($P<0.05$). The study by Mafuyai *et al.,* (2020) on health risk assessment of heavy metals in consumption of vegetables reported Cu concentration in mining pond water to be 0.43+/-0.01. This value exceeds the permissible limits of 0.1mg/l set by NESREA (2011). Furthermore, Dogun (2018) reported copper concentration of 0.02ppm, lesser than the permissible limit by WHO/FAO (2011). Another study similar to this study is that by Malakar *et al.,* (2019), they found copper concentration lesser that the permissible limits by WHO/FAO (2011), during their study on heavy metals and their presence in vegetables, they found copper to have a concentration of 0.01ppm. The water from Kuru dam can be said to be free from Cu toxicity.

Lead: The mean values of Lead (Pb) obtained ranged from 0.08-0.46 ppm, the highest mean value of 0.46ppm was recorded in the month of February, while the lowest mean value of 0.08 was obtained in April 2022, respectively. However, the mean values obtained were higher than the permissible limit of 0.01 ppm according to WHO/FAO (2011) as presented in Table 1. Therefore, Kuru dam during the considered periods can be said to be highly concentrated with Pb. which is quite alarming owing to its persistence, accumulation properties and adverse effects on human health, plant physiology and aquatic life, the concentrations for the month of February 2022 appear to be decreasing from upper, middle and lower section of the dam, while that for the month of April appears to increase from upper to middle to lower sections of the dam, this may be as a result of anthropogenic activities such as mining, pesticides application and effluents discharged within the location as reported by Edwin, (2018), this may be true because of the presence of farmlands around the dam. However, there was no trace of Pb recorded for the month of June 2022. This study seems to be in concordance with the work by Ezekiel *et al.,* (2020); they assessed the concentration status of some heavy metals in water along River Dilimi, Jos North, Plateau State-Nigeria and reported Pb mean value of 0.31-0.65 ppm in the months of July-December in 2019, which is above the values obtained during this study and above the permissible limits. This study also reaffirmed the work of Ahmed *et al.,* (2011), who assessed Trace Metals' Contamination of Stream Water and Irrigated Crops at Naraguta, Jos, during November 2008 and reported the mean concentration value of 1.57ppm at the center section of the river, which is higher than the obtained values during this research, which is indicative of the fact that Pb concentration level increases as the rains depletes as reported by Aliyu *et al.,* (2019).

Cadmium: The mean values of Cadmium (Cd) obtained ranged from 0.004-0.013 ppm, the highest mean value of 0.013 ppm was recorded in April 2022, while the lowest mean value of 0.004 ppm was obtained June, 2022. However, the mean values obtained were higher than the permissible limit of 0.003 ppm according to WHO/FAO, (2011) as presented in Table 1. This makes it quite alarming owing to its devastating effects on human health and aquatic life. There is no significant difference in mean values of Cadmium obtained throughout the period of this study. Therefore, Kuru dam during the study period can be said to be highly concentrated with Cd, this is not good because the dam is unfit for both agricultural and domestic purposes. This study seems to be similar with the study by Aliyu *et al.,* (2019), who assessed heavy metals in water and plants along Rivers Dilimi and Jenta, Jos, even though they did not specify the period. They reported Cd mean concentration value of 0.127 ppm at Katako, which is higher than the obtained values during this research but, still above permissible limit by WHO/FAO (2011). This study also reaffirms the work of Ahmed *et al.,* (2011), who assessed trace metals' contamination of stream water and irrigated crops at Naraguta, Jos, during November 2008 and reported Cd mean concentration value of 0.138 ppm at the lower section of the stream which is lower than the obtained values during this study, but still against the threshold limit as presented in Table 1. Waida *et al.,* (2022) worked on pollution load index of heavy metals resulting from mining activities in Plateau state, they reported Cd concentrations that cut across five local governments in the state, including Jos South. Bassa, Barkin Ladi and Jos South appear to have the same concentration of Cd (0.003ppm) which is at the same value as the permissible limits by WHO/FAO (2011). Henry (2018) however, had a contrary report after assessing heavy metal concentration in water, soil and vegetable in ex-mining pond in Jos south. They reported that cadmium is absent in the pond used for studies, and went further to recommend the water for irrigation since it is free of Cd.

Zinc: A null value of Zinc was throughout the sections of the dam. This study seems not to be at par with that by Sabo *et al.,* (2013) who reported mean concentration values of Zn to be 1.64 ppm which is above the values obtained during this study, as a result, the water may not be suitable for irrigation. However, Kuru dam during the considered periods can be said to be free of Zn toxicity, this seems not to be in concordance with the work of Aliyu *et al.,* (2019), who assessed heavy metals in water and plants along Rivers Dilimi and Jenta, Jos, they reported Zn mean values of 0.26 ppm at Angwan Soya along river Jenta, which is above the obtained values during this study.

Conclusion: The concentration levels of Cadmium, Lead and Arsenic were beyond acceptable limit, which have significant implications for human health, environment and economic impact in the study area, this will adversely affect plants, animal and aquatic ecosystems, which could disrupt the food chain and subsequently pose a threat to biodiversity. Regulatory actions are required to minimize exposure, and protect public health. Stricter regulations on anthropogenic activities, to limit these elements into the environment be employed in the study area.

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