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Assessment of Heavy Metal Concentration around Erelu Water Dam, Oyo, South-western Nigeria

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ABSTRACT: Erelu water dam was constructed to supply quality water to Oyo town and its environs. Due to the agrarian nature of the Oyo and its environs, the dam receives inflows of anthropogenic contaminants, thereby increasing the concentration of heavy metals, which then pose threats to the water. Hence, the objective of this paper is to investigate the concentration of heavy metals around Erelu Water Dam, Oyo, Southwestern Nigeria, using appropriate standard methods, including atomic absorption spectrophotometers (AAS). The concentrations of Pb (0.008 mg/l), Cd (0.003 mg/l), As (0.006 mg/l), Ni (0.017 mg/l), Cr (0.012 mg/l), and Zn (0.035 mg/l) in treated water samples were below the permissible limit. The results of the analysis were compared with national and international standards for drinking water. The concentrations of lead, mercury, cadmium, arsenic, nickel, chromium, and zinc in all the water samples (with the exception of treated water samples) exceeded the permissible limit of the Standards Organization of Nigeria, the United States Environment Protection Agency, and the World Health Organization for drinking water. The results show a high impact of contaminants in the untreated water. Stream water and river water are not safe due to the high concentration of contaminants inflow from effluents and other industrial and anthropological activities.

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Water is a very important part of human life and is the most abundant of all chemical substances. It covers about 70 percent of the earth's surface. It can be sourced from rivers, rain, lakes, and groundwater. It plays an important part in a wide variety of natural processes and is essential for animal and plant growth, especially in the areas of agriculture, industries, and human consumption (Ademiluyi and Odugbesan 2008; Olasunkanmi *et al.,* 2021). Erelu Water Dam is one of the fourteen (14) water dams in Oyo State, southwest Nigeria. It's a major dam constructed in 1959 along the Oyo-Iseyin road. The dam was designed to supply water quality to Oyo town, Awe, Fiditi, and Ilora town (Ogunkunle *et al.,* 2019; Falaye *et al.,* 2015; Kareem *et al.,* 2018; Ufoegbune *et al.,* 2011). Because these towns are agrarian towns, the dam receives inflows of anthropogenic contaminants and other toxic metals from urbanization, thereby increasing the concentration of heavy metals and then poses threats to the water. This research gives the dam attention by determining the status of heavy metal concentration in order to give the present condition of the water and then compare the results with national and international standards values for water consumption. Heavy metals are stable metals and can be accumulated in plants and animals's tissues; they are

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metals with a specific gravity over 5 g/cm^3. The metals can be divided into essential and non-essential metals. Essential metals, which are also referred to as trace metals, include manganese, iron, copper, cobalt, and zinc, while the non-essential metals, also known as macronutrients, are cadmium, lead, and mercury. The trace elements are important and needed in small quantities for stress resistance and development; however, high concentrations are harmful for consumption and development (Amusat 2021). Although metals present in groundwater may be through disintegration of rocks from volcanic outbreaks and various human activities, a large amount of the element is present through anthropogenic activities (Amusat 2021; Martin *et al.,* 2015; Nduka and Orisakwe 2011; Chapman 2009). Furthermore, accumulation of heavy metal in groundwater (which has been highly considered globally) is a threat to humans and their environs, especially when it has exceeded the tolerance level (Adeyemi and Ojekunle 2021). Any further consumption or application in an aquatic environment can be harmful to humans or any other agricultural activities (Ahmed *et al.,* 2015a; 2015b). It is not all the metals that can pose danger to humans, but others such as iron, copper, and zinc, to mention, but few can pose danger to the growth and functionality of body systems (USEPA 2009; Firmi *et al.,* 2015; Mominul *et al.,* 2018; Wang *et al.,* 2019). Erelu water dam is located in an ancient city of Oyo town with a fast increase in anthropogenic activities such as fish farming and cassava processing, among other unplanned industrialization within the study location. These activities are daily routing that can create inflows of contaminants from solids and cassava effluent in the direction of the dam, thereby causing high concentrations of metals in the study area. Although there are numerous researchers on heavy metal concentration (Fermi *et al.,* 2015; Rahman *et al.,* 2021; Ganiyu *et al.,* 2021), only very few researches have taken place in Erelu dam; among them are: Falaye *et al.,* 2015, carried out research on the distribution, composition, and potential fish yield of Erelu dam, and it was estimated that over 136 kg/ha of potential fish yield were recorded per day. Olasunkanmi *et al.* 2021, evaluated the integrity of the Erelu water dam through the determination of geological features that influence the dam using geophysical prospecting; however, it was recommended that the seepage with the dam should be monitored every two seasons. Iroko (2003) conducted a study on the impact of the Erelu water dam on the livelihood activities of residents in Atiba Local Government Area, Oyo State. Ayoola and Ajani (2009) explored the seasonal variations in fish distribution and the physico-chemical characteristics of selected reservoirs in Oyo State. Kareem *et al.* (2018) examined the spatial and temporal limnological conditions of the Erelu reservoir. Consequently, there is dearth of information about the effect of anthropological activities on the study location. Hence, the objective of this paper is to investigate the concentration of heavy metals around Erelu Water Dam, Oyo, southwestern Nigeria.

MATERIALS AND METHODS

Description of the study area: The research location is Erelu Water Dam; it is a gravity dam located in Oyo town (capital of Oyo State). The dam was constructed on the Awon river along the Oyo-Iseyin Road as commissioned in 1961 to supply quality water in Oyo, Awe, Fiditi, and Ilora towns for domestic, agricultural, and irrigation purposes.

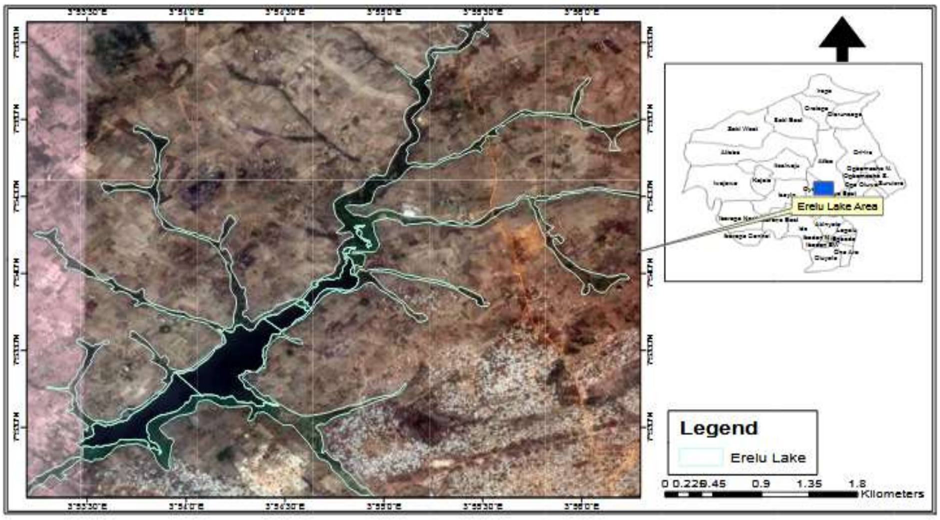

Fig. 1: Map of Erelu water dam (Kareem et al., 2015)

The reservoir, which is less than 7 km from Owode (the epicentre of Oyo town), has the geographic coordinates of longitude and latitude from 3°53’ to 3°55’ E and from 7°53’ and 7°54' N, respectively. The dam has a mean temperature and relative humidity of about 27 ºC and 77.16 % respectively; it’s also occupied a surface area of over 160 ha with a height of approximately 13 m (Popoola *et al.,* 2019). Erelu water dam is geologically situated on the Precambrian complex basement of southwestern Nigeria, consisting of quartzite, green schist faces, and Pan African granitoids and has further been discussed by Olasunkanmmi *et al.,* 2021; Egbeyale *et al.,* 2022; Adegbola and Adewoye, 2016; and Ufoegbune *et al.,* 2011.

Methodology: A total of eight (8) water samples were collected in 100-ml plastic bottles and labelled before the hours of 9 a.m. These water samples were made of sludge water, river water, stream water, and treated water of two (2) samples each. The collected samples were transported to the laboratory and stored at 4 °C in a refrigerator for preservation to avoid any biological or chemical reaction before the analyses begin (Ukah *et al.,* 2019). The samples were then acidified with a 3:1 HNO_3-HCl ratio and heated to reduce the volume to 25 ml. The samples were digested using the EPA 3050b method and were followed by analysis of the heavy metals, which include lead, cadmium, mercury, arsenic, nickel, zinc, and chromium, using an inductively coupled plasma atomic absorption spectrometer (AAS) in the laboratory. The preparation of different analytes with Merk-Millipore ICP multi-element standard solution was carried out. The limit of qualification (LCQ) and limit of detection (LOD) were obtained, and corrections were made to the concentrations of each heavy metal in accordance with the percentage of recovery for each analyte. However, mercury analyzers were used to quantify the mercury according to the EPA 7473 method. The results of the concentration of heavy metal present in the selected samples were carefully examined and compared with the standard range set by the World Health Organization (WHO), the United States Environment Protection Agency (USEPA), and the Standard Organisation of Nigeria (SON) for heavy metal presence in drinking water samples. The result was further used to evaluate the potential human health risk associated with exposure to heavy metals in drinking water sourced from Erelu Dam.

RESULTS AND DISCUSSION

Very safe and portable water forms the basis of human health; however, it becomes unwanted when it is polluted and then causes a negative impact on human health after consumption. The harmful effect can give rise to different diseases like cancer, kidney problems, and dental diseases, among others (Rozana *et al.,* 2020; Afrasiab 2014). This research focuses on determining the concentration of heavy metals (Pb, Hg, Cd, As, Ni, Cr, and Zn) in the water samples obtained in the study area. Table 1 shows the results of the concentration detected in all the water samples (sludge water, treated water, stream water, and river water) and the corresponding standard values of the respective metals. To assess the significance of these findings, we need to compare the metal concentrations with the standards values set by regulatory bodies such as the Standards Organization of Nigeria (SON), the World Health Organization (WHO) for drinking water, and USEPA.

Figure 2 shows the comparison between the lead concentration with national and international standard values. The concentration recorded for lead in all the water samples ranges between 0.008 mg/l and 26.89 mg/l. Lead concentration in all the water samples exceeded the permissible limit of SON, USEPA, and WHO except the treated water sample. Only the treated water sample falls within the acceptable limit of standard values; hence, continuous intake of stream water and river water in these areas may affect the mental development of the infant in these areas. High concentrations of lead may be as a result of leaching from the metal pipes used in the distribution of water or corrosion from the pipe that is coated with zinc (Chinyere *et al.,* 2019; Budhlani and Nagarnaik 2006; Dilebo *et al.,* 2023). Both SON, WHO, and USEPA have established a maximum allowable concentration of lead in drinking water as 0.01 mg/l, 0.01 mg/l, and 0.05 mg/l, respectively (SON 2015; WHO 2003, 2017; USEPA 2009).

Figure 4 shows the comparison result of cadmium concentration in all the water samples analyzed as presented in Table 1. The analyses display concentration ranges between 0.003 mg/l and 0.45 mg/l, which exceeded the permissible standard limits of USEPA (0.005 mg/l), SON (0.003 mg/l), and WHO (0.003 mg/l) guidelines (SON 2015; USEPA 2009). According to Gebresilasie *et al.* (2021 and Chinyere *et al.* (2019), in their research, it was stated that the high concentration of cadmium in water is attributed to industrial activities in the area, and it may also be attributed to the corrosive nature of the metal pipes and plumbing systems. It has been researched that excessive intake of cadmium may result in diarrhea and vomiting, among other negative health impacts (USEPA 2009; WHO 2003; and Radulescu *et al.,* 2014).

The results of arsenic concentration as compared with SON, USEPA, and WHO were presented in figure 5. The analysis shows concentrations between 0.006 mg/l and 23.88 mg/l, which significantly exceeded the regulatory limits of USEPA, SON, and WHO with permissible limits of 0.01 mg/l, 0.05 mg/l, and 0.01 mg/l, respectively (Johnson *et al.,* 2018). Only the treated water with concentration (0.006 mg/l) is eligible for drinking.

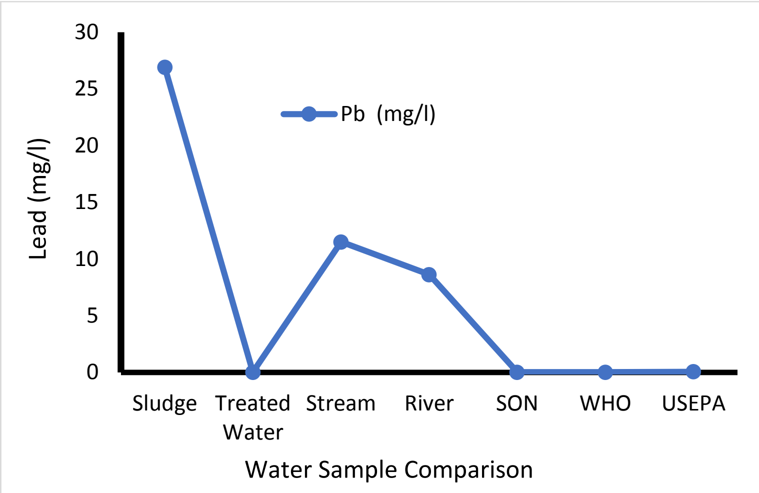

Fig. 2: Comparing lead with permissible limits of SON, WHO, and USEPA;

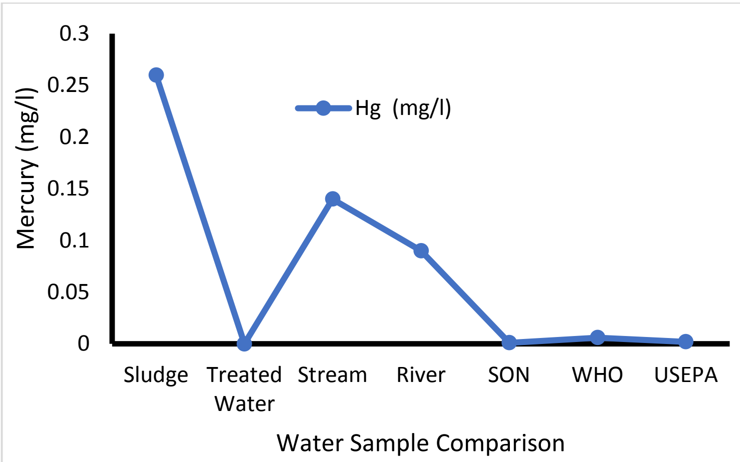

Fig. 3: Comparing mercury with permissible limits of SON, WHO, and USEPA

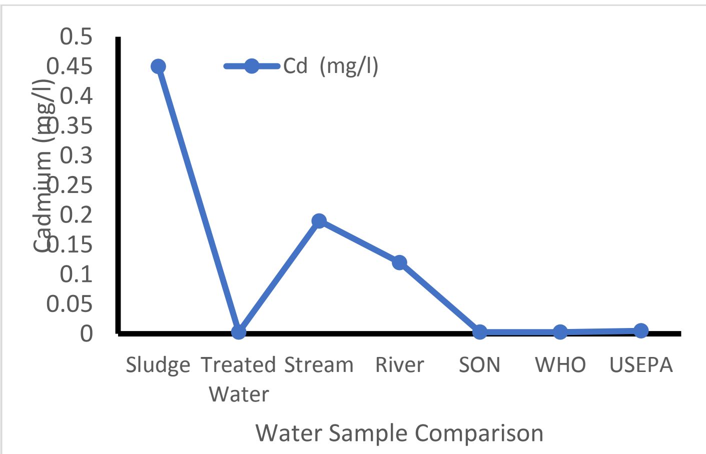

Fig. 4: Comparing cadmium with permissible limits of SON, WHO, and USEPA

The concentration of nickel in all the samples was presented in figure 6, which also shows their comparison with the regulatory limits of SON, WHO, and USEPA. The range of nickel concentration in the analyzed water samples is ranged between 0.017 mg/l and 36.41 mg/l and has exceeded the set regulatory limit (with the exception of treated water samples) for nickel at 0.02 mg/l (SON), 0.07 mg/l (WHO), and 0.2 mg/l (USEPA). However, a study by Rodriguez *et al.* (2019) suggests that exposure to nickel in drinking water can have adverse health effects, so the use of river and stream water in this study area should be discouraged. Figure 7 is the graphical results of comparing chromium concentration in the collected samples with national and international standard limits. The concentration of chromium in analyzed water samples is between 0.012 mg/l and 46.56 mg/l. Except for the values of treated water samples, all other values exceeded the regulatory standards of SON, WHO, and USEPA with their permissible values of 0.05 mg/l, 0.05 mg/l, and 0.1 mg/l, respectively (Johnson *et al.,* 2018). The high chromium content in the analyzed water may be attributed to waste input, runoff from industrial areas into the dam.

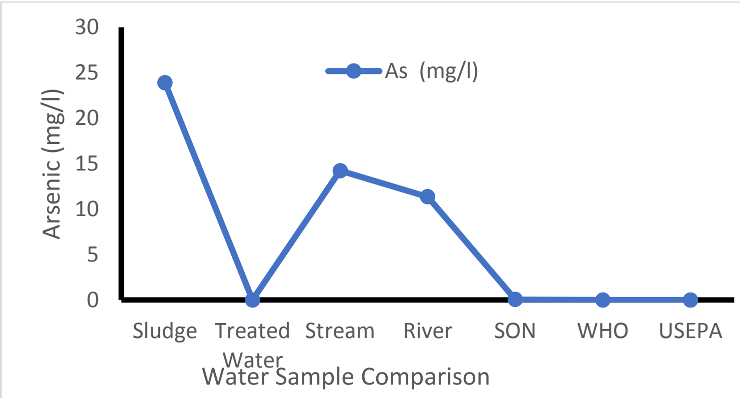

Fig. 5: Comparing arsenic with permissible limits of SON, WHO, and USEPA

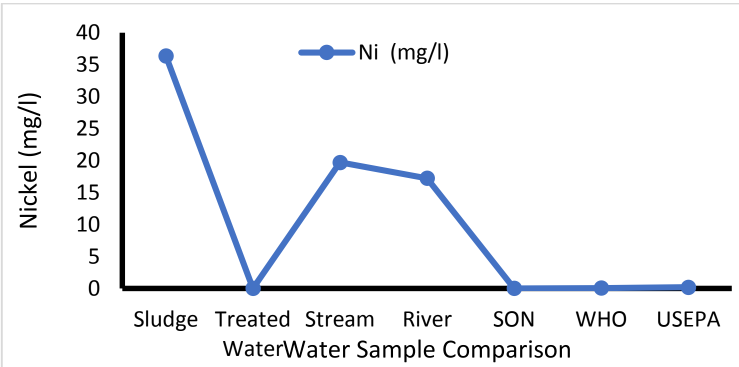

Fig. 6: Comparing nickel with permissible limits of SON, WHO, and USEPA

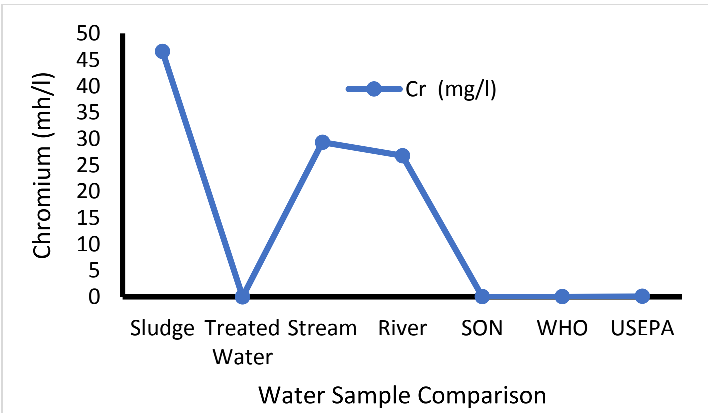

Fig. 7: Comparing chromium with permissible limits of SON, WHO, and USEPA

Figure 8 shows the results of the concentration of zinc in the water samples analyzed. The concentration is between 0.035 mg/l and 58.68 mg/l. With the exception of the values of treated water samples, all other values exceeded the regulatory limits set by USEPA, SON, and WHO for zinc in drinking water (5.0 mg/l, 3.0 mg/l, and 3.0 mg/l, respectively). The concentrations of zinc in sludge, stream, and river samples are notably higher compared to the treated water sample. However, a study by Smith et al. (2020) highlights that a high concentration of zinc in drinking water may lead to health issues. Therefore, the inhabitant should be encouraged to focus on the use of treated water rather than the use of river water and stream water. It is also important to monitor zinc concentrations and take necessary actions to mitigate potential risks.

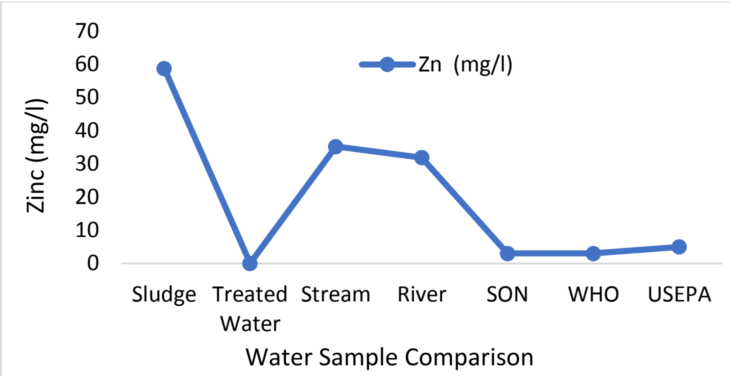

Fig. 8: Comparing zinc with permissible limits of SON, WHO and USEPA

Table 1: Average concentration of heavy metals in the water samples

	Concentration (mg/l)						
Water Sample	Pb	Hg	Cd	As	Ni	Cr	Zn
Sludge	26.89	0.26	0.45	23.88	36.41	46.56	58.68
Treated Water	0.008	0.000	0.003	0.006	0.017	0.012	0.035
Stream	11.50	0.14	0.19	14.22	19.73	29.34	35.23
River	8.62	0.09	0.12	11.36	17.24	26.78	31.90
SON	0.01	0.001	0.003	0.05	0.02	0.05	3.0
WHO	0.01	0.006	0.003	0.01	0.07	0.05	3.0
USEPA	0.05	0.002	0.005	0.01	0.2	0.1	5.0

Conclusion: The findings of the study reveal elevated levels in concentration of lead, mercury, nickel, arsenic, cadmium, and chromium in samples taken from sludge, rivers, and streams, surpassing the regulatory thresholds established by SON, USEPA, and WHO. However, analyses of treated water samples confirmed that metal concentrations remained within the permissible limits for drinking water. The elevated levels in natural water bodies are likely due to anthropogenical activities, including agricultural runoff and detergent discharge from washing near these sources. This highlights the need for awareness campaigns to inform local residents about the health risks associated with consuming untreated river and stream water. Ensuring the availability of treated water is crucial to reducing reliance on these contaminated sources. Encouraging the use of safe, treated water can mitigate potential health hazards, as treated water consistently meets the safety standards set by SON, USEPA, and WHO. I have rewritten this conclusion; it is now less than 150 words as requested. The symbols of the chemical element have been removed. Recommendation has been removed.

Declaration of Conflict Of Interest: The authors declare no conflict of interest.

Data Availability Statement: Data are available upon request from the first corresponding author.

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