Adamawa State University Journal of Scientific Research (ADSUJSR)
Volume 11 Issue 1, 2023
ISSN: 2705-1900 (Online); ISSN: 2251-0702 (Print)
http://www.adsu.edu.ng

Assessment of Heavy Metals Concentrations in Lake Gwakra, Girei Local Government, Adamawa State, Nigeria

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(Received in October 2023; Accepted in December (2023)

Abstract
This study aimed at evaluating heavy metals of Lake Gwakra for the dry and wet seasons of 2022. Samples were collected from three different locations within the lake using clean one-liter bottles at a depth of 0.3m for laboratory tests. To maintain the cations in solution and prevent bacterial growth, oxidation, and metal precipitation, the composite samples were treated with HNO3. Subsequently, the samples were stored at 4°C to minimize evaporation. Atomic absorption spectroscopy (AAS) was employed to determine the concentrations of the heavy metals which included, iron (Fe), manganese (Mn), cadmium (Cd), chromium (Cr), zinc (Zn), lead (Pb), and copper (Cu). The results revealed that during the dry season, the concentration of iron ranged from 2.20mg/l to 2.24mg/l, while in the wet season, it ranged from 2.70mg/l to 2.90mg/l, both falling within the recommended limits. Manganese concentrations in the dry season ranged from 0.06mg/l to 0.08mg/l, with an average of 0.07mg/l, whereas in the wet season, the average concentration was 0.16mg/l, exceeding the recommended limit. In the dry season, cadmium concentrations varied from 0.11mg/l to 0.13mg/l, averaging at 0.12mg/l, whereas in the wet season, the average concentration was 0.03mg/l, surpassing the recommended limit. Chromium concentrations ranged from 0.45mg/l to 0.48mg/l in the dry season, with an average of 0.47mg/l, and in the wet season, the concentration ranged from 0.43mg/l to 0.45mg/l, averaging at 0.44mg/l, all surpassing the recommended limit. Zinc concentrations in the dry season ranged from 0.12mg/l to 0.14mg/l, with an average of 0.13mg/l among other results of the heavy metals. Regular monitoring protocols to track water quality and identify potential sources of contamination was recommended among others.

Keywords: Heavy Metals, Water contamination, Human health, Water contamination, Lake Gwakra

Introduction
Heavy metals are a major source of pollution in aquatic ecosystems because they can easily infiltrate the food chain of an aquatic ecosystem (Censi et al., 2006; Pandiyan et al., 2020). They are naturally occurring elements with high atomic weights and densities approximately five times that of water (Duffus, 2002). Their presence in water is a global concern due to their bioaccumulation, environmental hazards, and persistence (Goretti et al., 2016;). These metals are released into lakes and other water bodies as a consequence of rapid population growth and anthropogenic activities, such as poorly treated industrial and domestic sewage and intensified agricultural runoff (Yang et al., 2017). Concerns about heavy metal over accumulation and deleterious effects on species and, eventually, people through the food chain have prompted intensive study on heavy metals in aquatic and terrestrial ecosystems (Volpe et al., 2015; Memoli et al. 2017; Kortei et al., 2020).

Heavy metal toxicity in humans has long been recognized, and humans' exposure to these metals is rising in many locations throughout the world (WHO, 2011). Some heavy metals have acute toxicity, whereas others have chronic toxicity following long-term exposure. Heavy metal toxicity manifests itself in a variety of ways. The capacity of Copper (Cu) to switch between Cu(I) and Cu(II) oxidation states in living systems, for example, allows it to operate as a cofactor for numerous oxidative stress-related cuproenzymes such as superoxide dismutase, cytochrome oxidases, and ferroxidases. The propensity of Copper to transition between the oxidation states, however, makes it hazardous because the process produces superoxide and hydroxyl radicals (Harvey and McArdle, 2008;

Stern, 2010). Thus, high exposure to Cu causes cellular and tissue damage in humans, culminating in Wilson disease (Tchounwou et al., 2012). Lead (Pb) causes toxicity through imitating and blocking Calcium (Ca) ions, as well as interacting with proteins. As a result, it affects the central nervous system and vitamin D metabolism, causing reproductive problems, brain and kidney damage, and gastro-intestinal illnesses (Flora et al., 2006; Wani et al., 2015). Therefore, heavy metals have a negative impact on humans, even at low concentrations, because they can cause abnormal fetal development, procreation failure, immune deficiency, carcinoma, organ dysfunction, physical, mental, and neurological disorders, renal tumor, nephritis, osteoporosis, nasopharyngeal congestion, increased blood pressure associated with cardiovascular diseases, reduced life expectancy, and, in some cases, death (Hamadani et al. 2020; Mohanta et al., 2020; Sánchez et al., 2022).

The rising levels of heavy metal exposure in air, water, and food are posing a growing threat to human health, particularly in vulnerable populations. Chronic exposure can lead to a range of adverse health effects, including neurological damage, organ dysfunction, and even cancer. Therefore, effective awareness of the public on the effects of these heavy metals is highly required.

Materials and Method

Study Area

The Lake Gwakra is the main destination of the Jibiro drainage system. The lake is situated on the right bank of the River Benue (Upper Benue Trough) at Gwakra, Girei Local Government Area of Adamawa State. It is located between latitudes 09°24′09″N and 09°25′07″N of the Equator and between longitudes 12°23′04″E and 12°24′11″E of the prime Meridian (Figure 1). It covers a total surface area of 1.41Km^2, with its surrounding flood plains making up a substantial irrigation area.

The study area has a humid tropical climate with distinct wet and dry seasons controlled by the yearly fluctuations of the Inter-Tropical Convergence Zone (ITCZ). The dry season which makes up the irrigation farming period runs from December to May. The lake area and its entire irrigable land are characterized by the Gleyic cambisols (FAO) or Typic topoqualfs (USDA)-213 soil type. This is a mineral hydromorphic and juvenile soil of recent riverine and lacusterine alluvium (Areola 1983). According to Usman (2005), the soil colour ranges from dark brown (10yr3/2) to very dark grey (10yr3/1) with loamy, sandy-loam and silty loam textural characteristics. He further noted that the soil type is also of low to high cation exchange capacity with pH values ranging from 5.9 to 4.9 indicating slightly acidic to very strongly acidic conditions. Being characterized by high water-holding capacity and nutrients content the soil type is naturally fertile enough to support substantial agricultural productivity. The major sources of water for the lake are the Jibiro Drainage System and episodic inundations from the River Benue during flood periods. With a surface area of about 1.41Km^2 and a mean depth of 1.46m (Yonnana et. al., 2015), the lake basin is capable of storing over 2.0 mcm of water annually (Yonnana et. al., 2015). Which could support substantial irrigation agriculture and other socioeconomic activities as fishing and recreation.

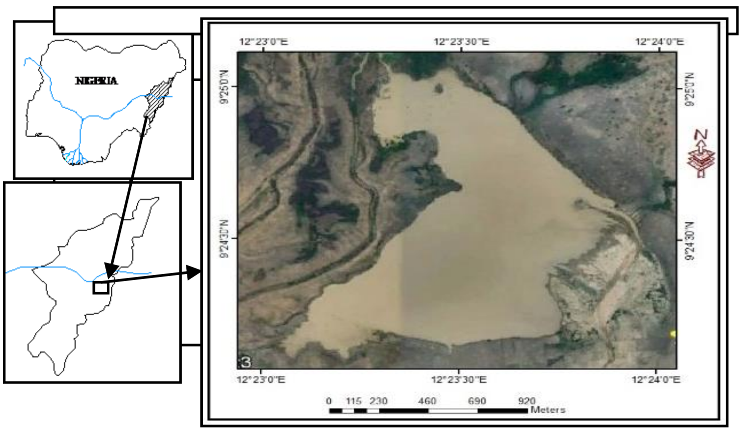

Figure 1: The Study Area

ADSUJSR, 11(1): 140-147, December, 2023
ISSN: 2705-1900 (Online); ISSN: 2251-0702 (Print)
http://www.adsu.edu.ng

The study was conducted on water samples collected in the dry season (January, February, and March) and wet season (July, August and September) of the year 2022. The water samples were taken at three different locations throughout the lake in clean one-liter bottles at a depth of 0.3m in accordance with Maitera et al., (2011) and APHA (2005). The three samples from lake were then put into a container, and a composite sample of one liter was taken, treated with 10ml of HNO_3, and transported to the laboratory for tests in order to keep the cations in solution and slow down bacterial growth, block oxidation reactions and prevent precipitation of the metals. The bottles were then stored at 4°C using ice block to prevent change in volume due to evaporation. The heavy metals in all of the water samples were determined using atomic absorption spectroscopy (AAS). As a radiation source, hollow cathode lamps for Cu, Cr, Cd, Co, Ni, Pb, Zn, and Fe were employed, with air acetylene as the fuel. All samples and standards were tested in duplicate. Atomic absorption spectrometry is an analytical technique that measures the concentrations of elements qualitatively and quantitatively.

Results and Discussion

Table 1: Heavy metals Concentration in Lake Gwakra

Parameter	January	February	March	Mean	July	August	September	Mean
Fe	2.24	2.22	2.20	2.22	2.27	2.29	2.27	2.28
Mn	0.06	0.07	0.08	0.07	0.17	0.16	0.16	0.16
Cd	0.11	0.13	0.12	0.12	0.03	0.03	0.03	0.03
Cr	0.48	0.47	0.45	0.47	0.43	0.45	0.44	0.44
Ni	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Zn	0.12	0.12	0.14	0.13	0.14	0.13	0.15	0.14
Pb	0.02	0.03	0.02	0.02	0.03	0.03	0.03	0.03
Cu	0.30	0.31	0.30	0.30	0.30	0.30	0.31	0.30

Iron (Fe)

The detection of iron in the water is an indication of possible contamination from the geology of the water channel and rock mineral type present as well as waste inflows. The implication of high concentration of iron in the water is that it can lead to the formation of blue baby syndrome in babies and goiter in adults (Shyamala *et al.*, 2008). In this study the concentration of iron ranged from 2.20mg/l to 2.24mg/l in the dry season (January, February and March) with an average concentration of 2.22mg/l (Table 1) and from 2.70 to 2.90mg/l with an average concentration of 2.28mg/l in the rainy season (July, August and September). These concentrations were found to be within the standard recommended limit (0.30 mg/l) in water for human use as provided by the WHO, (2011). The results obtained is in agreement of the findings of Igwenyi, (2017) who analyses water sources in Ikwo Local Government Area of Ebonyi State, Nigeria

Manganese (Mn)

Manganese is an essential trace element abundantly present in earth crust in the form of oxides and hydroxides. Manganese commonly finds its way into the water through activities such as industrial emissions, soil erosion, volcanic emissions and the burning human activities (Maqbul, 2021). In this study, the concentration of iron ranged from 0.06mg/l to 0.08mg/l in the dry season (January, February and March) with an average concentration of 0.07mg/l and in the rainy season (July, August and September), the average concentration of 0.16mg/l (Table 1) which is higher than the standard recommended limit of 0.05 mg/l manganese in the water as given by WHO, (2011). This finding is similar to the study conducted by Khan and Yousaf, (2020) found that the iron concentration in groundwater ranged from 0.12 mg/L to 0.87 mg/L, with an average of 0.45 mg/L. This value is significantly higher than the WHO recommended limit. The high iron concentration was attributed to geological factors and anthropogenic activities such as irrigation and industrial waste disposal.

Cadmium (Cd)

Cadmium is uniformly distributed in trace amounts in the earth's crust and is highly toxic as well as responsible for several cases of food poisoning (Maqbul *et al.*, 2021). Satarug *et al.*, (2003) reported the possible sources of Cd globally may be due to the disposal of various electronic wastes along with the solid waste and it may be associated with the possibility of rock–the water interaction in deep aquifers along with the runoff from residential houses. In this research, the cadmium concentrations ranged from 0.11mg/l to 0.13mg/l in the dry season (January, February and March) with an average concentration of 0.12mg/l. An average concentration of 0.03mg/l was obtained for the rainy season (July, August and September). concentrations has This concentration value was found to be higher than the standard recommended limit of 0.005 mg/l (Table 1) in water for human consumption as provided by the WHO, 2011. Similar results were revealed by Ringim et al., (2015) which found cadmium concentrations in irrigation water ranging from 0.11mg/l to 0.453mg/l, exceeding WHO and national standards.

Chromium (Cr)

In water, chromium occurs in the form of hydroxides and complexes although its concentration depends on the type of the water involved (WHO, 2003). The sources of chromium in environment are both natural and anthropogenic. Natural sources include burning of oil and coal, petroleum from ferro chromate refractory material, chromium steels, pigments oxidants, catalyst and chemical fertilizers (Pillay *et al*., 2003). In this study the concentration of chromium ranged from 0.45mg/l to 0.48mg/l in dry season (January, February and March) with an average concentration of 0.47mg/l and in the rainy season (July, August and September), the concentration ranged from 0.43 to 0.45mg/l with an average concentration of 0.44mg/l (Table 1). This average is above the standard recommended limit of 0.05 mg/l chromium concentration in the water as given by WHO, (2003). Gastrointestinal and neurological damage are two health consequences of acute inhalation exposure to very high concentrations of chromium, whereas dermal exposure results in skin burns in humans as opined by ATSDR, (1998). The finding is similar to the study conducted by Singh et al., 2015 in India which reported chromium levels in groundwater samples ranging from 0.05mg/l to 0.7mg/l, exceeding the permissible limit for drinking water.

Zin (Zn)

Zinc leaks from zinc pipes and rain pipes, consequential to circulation of carbon-rich the water. Increase concentration of zinc may cause toxicity leading to stomach aches, vomiting, fevers and diarrhea (Wang and Dou 1998; Maqbul et al., 2021). In this study the concentrations of zinc ranged from 0.12mg/l to 0.14mg/l in dry season (January, February and March) with an average concentration of 0.13mg/l and in the rainy season (July, August and September), they ranged from 0.13 to 0.15mg/l with an average concentration of 0.14mg/l (Table 1). This value falls within the standard recommended limit of 5.0 mg/l zinc concentration in the water as given by the WHO, (2003). Samuel et al., (2015) reported a similar result in their study; which assessed the levels of heavy metals in drinking water sources in two small-scale mining communities (Nangodi and Tinga) in northern Ghana.

Lead (Pb)

Lead is a naturally occurring toxic metal used in many domestic products and enters into the water through the corrosion of pipes. Oluwande *et al.* (1983) observed that human activities such as mining, industries and natural ways such as leaching and the erosion of soils by rainfall push or move these heavy metals down the water bodies. Lead is well known for being poisonous for mammals and there are fears that human body burdens below those at which clinical symptoms of lead toxicity appear may cause mental impairment in young children (Olewinska, *et al.*, 2010). In this study the concentration of Pb ranged from 0.02mg/l to 0.03mg/l in the dry season (January, February and March) with an average concentration of 0.02mg/l and in the rainy season (July, August and September), the average concentration of 0.03mg/l (Table 1) which is above the standard recommended limit of 0.01mg/l lead concentration in water as given by the WHO, (20011) was obtained. This result is in agreement with the average result of Oladoja et al., (2011) reported lead concentrations in well water ranging from 0.02 to 0.04 mg/l, exceeding the WHO limit of 0.01 mg/l. The lead was attributed to corrosion of lead pipes and industrial activities.

Copper (Cu)

Copper is an essential element for the living organisms including the human and small amount is necessary in human diet to ensure good health (Iroha *et al*., 2020). Excessive intake of copper causes wide spread capillary damage, gastrointestinal irritation and damage to the surrounding tissues (Shyamala *et al*., 2008). In this study the concentration of Cu ranged from 0.30mg/l to 0.31mg/l in dry season (January, February and March) with an average concentration of 0.30mg/l and in the rainy season (July, August and September), the concentration ranged from 0.30mg/l to 0.31mg/l with an average concentration of 0.30mg/l (Table 1). The average concentration of the copper in this research is higher than the findings of Ekanem et al., 2012 which observed Cu concentrations in a Nigerian river ranging from 0.06mg/l to 0.18mg/l in the dry season and 0.22mg/l to 0.45mg/l in the rainy season, showing a clear increase during wetter months .

Conclusion

The study conducted on water samples collected from the lake during the dry and wet seasons of 2022 revealed varying concentrations of heavy metals. The concentrations of iron, zinc, and copper were within the recommended limits, indicating acceptable levels of these metals in the water. However, manganese, cadmium, chromium, and lead concentrations exceeded the recommended limits, indicating potential contamination and posing risks to human health. The presence of elevated levels of manganese, cadmium, chromium, and lead in the lake water is concerning, as these metals have known toxic effects on humans. Long-term exposure to these metals can lead to various health issues, including gastrointestinal problems, neurological damage, skin burns, and mental impairment. The findings of this study highlight the need for remedial actions to reduce the heavy metal contamination in the lake and protect public health. To address the issue of heavy metal contamination in the lake, it is recommended to establish regular monitoring protocols to track water quality and identify potential sources of contamination. Effective water treatment techniques should be implemented to remove or reduce heavy metal content. Public awareness campaigns should be conducted to educate the community about the risks of heavy metal pollution and promote responsible practices. Strengthening and enforcing regulations regarding heavy metal pollution is crucial, and further research should be conducted to gain a better understanding of the sources and dynamics of heavy metals in the lake ecosystem, guiding future management strategies.

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