# Health Risk Assessment of some Heavy Metals Contents in Sediment and Water at Balanga Dam Gombe State, Nigeria

# ABSTRACT

Heavy metals are occurring in natural waters bodies can be found in both dissolved and particles form which are essential to living organisms, yet may become highly toxic when present in high concentrations.The study was aimed at evaluating heavy metals potential in Balanga Dam reservoir. Four samples of water and sediments where heavy metals were investigated (Cu, Pb, Cr, Cd, As, Ni, Fe, Mn and Zn) by their concentrations using AAS. Heavy metals concentrations in both water and sediment were beyond the recommended permissible limits range 0.002 to 0.004 mg/kg. Hazard Index of Non-carcinogenic in heavy metals in Water were calculated in three pathways; ingestion, inhalation and dermal range; Mn=2.75E-05 to Pb = 1.04E-06 while Hazard Index in Sediments range; Mn=2.52E-06 to As = 1.57E+07. Both water and Sediments showed HI >1 indicated adverse health risk effect. Cancer risk of ingestion pathway in water showed value of Cr = 8.02E-06 > Cd=1.68E-06 > As=2.50E-07 > Pb=1.28E-09 has the least value. Inhalation path way showed Cr = 1.24E-09> Cd=2.48E-10 > As=3.81E-11> Pb=9,328E-13 which was too low. Cancer risk assessment of carcinogenic heavy metals in sediments were also shown in two specific pathways whereby the result indicated the same values with the water pathway. Physicochemical parameters of water and sediments showed the mean pH values of 6.16 and the conductivity have the mean value of 150 μscm-1.Heavy metals investigated in water and sediments showed concentrations beyond permissible limits constituted a threat to aquatic life and human health hazard and cancer risk on human will persisted on body systems of humans and aquatic life at certain prolong time.

**Key Words**: Water, Sediments, Heavy metals, Pollution, Cancer risk, Health index, Toxicity

**Introduction**

Heavy metals are commonly found in natural waters such as rivers, lakes and seas in limited amounts as non-degradable, non-toxic, naturally occurring free elements. Some are essential to living organisms, yet may become highly toxic when present in high concentrations (Bai *et al.*, 2011). Source of heavy metals from many continental ecosystems according to reliable environmental study emanated from industrial effluents. Heavy metal contamination from water bodies were dually investigated as a serious pollution menace to developed cities, Thus, purification water treatment process and infrastructural products contradicted with alarming population growth and urbanization especially in developing countries such as Nigeria (Ahmad *et al.* 2010).

Sediment serves as a pollutant accumulator and a source of heavy metals pollution in an aquatic environment. The heavy metals deposited in the sediments became suspended and absorbed particles which formed habitat for aquatic life, resulting to food chain stage in water pollution in cycle. Their dissolved particles converted to serious pollution sources in the aquatic environment that have significant threats. The effects toxicity of heavy metals persisted in the environment by accumulation in the aquatic ecosystem beyond permissible limits. (Anyanwu *et al*., 2022). Many of these heavy metals pollutants contain carbon-based compounds and nutrients, which are agents of diseases to organisms, poses significant hazards to humans and aquatic life. Toxic heavy metals accumulated in the apparent sediments, thereby provided tiny particles with major constituents on prolong depositions (Bai *et al*., 2011). Heavy metals concentrations analysis frequently revealed their higher contaminations and toxicity levels in many environments and ecosystems in general (Kumar *et al*., 2020).

Water is a vital source to organism’s survival which is also necessary for several human activities and life’s existence, including drinking, healthcare, agriculture, economics, and industrial applications. Alarming population growth across the world lack of safe drinkable water due to pollution of water bodies by human activities (Taka *et al*., 2017). Human population increase in whole world contradicted economic advancement with poor portable drinking water became threats to global warming. Factors responsible for potable a drinking water deficiencies and water resources contaminations were reliable on weathering, erosion, industrial effluences, domestic wastes, and constant applications of pesticides and herbicides, (Amin *et al*., 2014). The population of people lacking access potable water and proper sanitation have been multiply annually based on world environmental data (Taka *et al*., 2017). Modern policies on effective portal water accomplishments by resolving scarcity of portable water resources incorporated the treatment of wastewater effluents (Ahmed *et al*., 2011), where by freshwater constituted less than 1% of the entire world accessible water in the ecosystems (Huang *et al*., 2019).

**Methodology**

**2.1 Study Area**

This study was conducted at Balanga Dam Reservoir in Balanga Local Goverbnment Area of Gombe State, which is located in the center part of north-eastern part of Nigeria latitude (110 20′E to 110 40′E) and between longitudes (090 40′N to 100 00′N). The area was engulf in between mountain ranges along Talasse road leading along Degri to Kulani road leading to Cham in Gombe state Nigeria.



Figure 1 map of Balanga Dam Reservoir showing Study Area

 **2.2 Sample Collection**

***2.2.1 Soil sampling***

 The Soil Sediments samples for this research work are collected in Four different sampling points, Samples of soil are identified and names as S1 = Soil at bank of the Eastern site of the Dam, S2 = Soil at the western site of the Dam, S3= Southwestern site of the reservoir and S4= Soil at the farmland away from Dam site. Each of the sample area soil were collected at various deep of the soil layers to have comprehensive segments compositions. All the layers are mixed together to form representative fractions suitable for the analysis as adopted by Usman *et al*., (2022).

***2.2.2 Water sampling***

Water samples were collected by at the bank of the reservoir nearly midle depth of one meter in the sampling location using a plastic bottles. The sample was collected from four locations at Inlet WI= Eastern site, W2= western site, Outlet W3= southwestern site and W4=northern site of the Dam at different points intervals of about 200 meters apart which are meant for analysis. Every sampling locations, was allocated a separate sampling clean bottles before collection of the sample. The samples were left to settled, then 2 cm3 of concentrated HNO3 was poured into 100 cm3 of the samples that prevented metal adsorption onto the inner surface of the sampling bottle. The methods was adopted with slight modifications by Modibbo *et al*., (2024).

**2.3 Sample Preparation for AAS Analysis**

Initially, 10 cm3 of 1M HNO3 was added to 1.00 g of both water and sediments sample in 25 x 150 mm glass digestion tube. Samples of both water and sediment were subjected to direct heating on heating mantle at 95 ± 10 °C for 15 minutes. The samples were cooled and 5 cm3 of HNO3 was added and reheated for another 30 minutes. The digests were again allowed to cool, then 2 cm3 of distilled water and 3 cm3 of 30 % H2O2 was added and heated to 95 ± 5 °C. After the digests were cooled again, another 1 cm3 of 30 % H2O2 was added. Heating continued until the sample volumes reduced to approximately 5 cm3. The digests were then allowed to cool again before being diluted to 50 cm3 with distilled water. Prior to analysis, the tomatoes digests were further diluted for analysis of metals content as adopted by (Usman *et al*., 2022)

**2.4 Determination of pH values of Soil Sediments**

pH Values of both Sample of 2 g of grounded soil was mixed up with 50 cm3 of distilled water was poured into a 250 cm3 conical flask then 20 cm3 of Buffer 7.0 solutions was added that mixed up the solutions. Then pH meter (3150 Jen way) was calibrated with the buffer solutions (7.0) added and inserted into the solution immediately. The probe was then left standing in distilled water for 6 hours, the pH values of the onion samples collected from three samples locations were recorded at an hourly basis for 6 hours as reported by Usman *et al*., (2022).

**2.5 Conductivity Test of Soils Sediments**

About 3g of each of the soil samples was soaked with 50ml of distilled water in an extraction bottle and shaken with mechanical shaker (Griffin flask shaker) for 1hr. The suspension was filtered twice to remove turbidity and two drops of 0.1% Na2PO3 was added to the filtrate. Probe of conductivity meter was inserted and values are recorded in NScm-1 at interval of an hour for 4 hours. Voltage was applied between two electrodes in a probe immersed in the sample water. The drop in voltage caused by the resistance of the water was used to determine the conductivity per centimeter (Usman *et al*., 2022)

**2.6 Health Risks Assessment**

Health risks assessment of carcinogenic and non-carcinogenic risk through Heavy metals present in soil and sediments around Balanga Dam Gombe has been determined using exposure pathways of inhalation, ingestion and dermal to determined health risk of human as evidence for taking decision, (Saheh *et al*., 2025) and the methods adopted was through (Usman *et al*., 2020) which are mention below.

**Ingestion**

ADing (mg/kg-1 day-1) =  (Usman *et al*., 2020)

**Inhalation**

ADinh (mg/kg-1 day-1) = 

 (Usman *et al*., 2020)(Saheh *et al*., 2025)

**Dermal**

ADder (mg/kg-1 day-1) =  (Usman *et al*., 2020)

Where AD (mg/kg-1 day-1) is the absorbed dose of exposure to through ingestion (ADing), inhalation (ADinh), and dermal contact (ADder)

CS = Chemical concentration in a sample (mg/kg)

IRing = Ingestion rate (mg soil/day): 100 mg/day

FI = Fraction ingestion from contaminated source: 1 at reasonable maximum exposure

EF: Exposure frequency: 350 days for non- carcinogenic effect

SA= Exposure skin area: 5700cm3

AF: Soil to skin adherence factor (mg/cm3)0.07 mg/cm3

ABS: Absorption factor (mg/cm3)0.03(As) 1

BW: Body weight in (Kg); 70kg for adult average

PEF: Particle Emission factor: 1.36 x 109 m3.kg-1

AT: Average. 365 x ED for non-carcinogenic effect and 365 x 70 for carcinogenic effect

 CF: conversion factor (10-6) (USEPA, 2011) and (Saheh *et al*., 2025**)**

**Results and Discussions**

**3.1 pH Values of Water Samples**

The pH Values of the sample water was represented on Figure 2 whereby the sampling area W2 showed the highest mean acidity of 6.86 at varying range of one to four hours of measurements. On the other hand W4 exhibited the highest mean alkalinity value of 7.26. The result obtained showed that the acidity values change in the order of W2= 6.86 > W3 = 7.13 >W1 = 7.24 > W4 = 7.25 respectively. The result obtained was related to the findings of Usman *et al*., (2020), However, the result obtained was contrary to pH values range of 7.35 to 7.89 in waste water as reported by Saheh *et al*., (2025), Also the pH of water at Balanga Dam was contrary to the pH water of water range 4.8 5.0 at reported by Faleye *et al*., 2024

Figure 2 pH Values of Water Sample

**3.2 pH Values of Sediments Samples**

The pH Values of the sediments sample was represented on Figure 3 whereby the sampling area S2 showed the highest mean acidity of 5.40 at varying range of one to four hours of measurements. On the other hand S4 exhibited the highest mean alkalinity value of 6.85. The result obtained showed that the acidity values decreased in the order of S2= 5.4 > S3 = 6.25 >S1 = 6.66 > S4 = 6.85 respectively. The result obtained was related to the findings of Usman *et al*. (2020) while pH of Sediments obtained contradicted the range of pH values of 5.29 to 6.59 obtained by the findings Sardique *et al*.,(2025)

Figure 3 pH Values of Sediments Samples

**3.3 Conductivity of Water Samples**

The conductivity values of the water sample was represented on figure 4 in which the conductivity was recorded at varying range of one to four hours. The result showed sampling area W2 with highest conductivity of 290 μscm-¹ followed by W4 and W3 in decreasing order. Also W1 exhibited the lower conductivity value of WI = 145 μscm-¹. The result obtained showed that the conductivity values decreased in order of W2=290 μscm-¹ > W4=200 μscm-¹ > W3=180 μscm-¹ > W1=145 μscm-¹ respectively. The result obtained was related to the findings of Usman *et al*., (2020)

Figure 4 Conductivity of Water Samples

**3.4 Conductivity of Sediments Samples**

The conductivity values of the sediment sample was represented on the figure of 5 The measurements of conductivity of the sample sediments was recorded at varying range of one to four hours. Whereby the sampling area S2 showed the highest conductivity of 2400 μscm-¹ followed by S4 and S3 .On the other hand S1 exhibited the lower value of 800 μscm-¹.The result obtained showed that the conductivity values was expressed in decreased i order of S2=2400 μscm-¹ > S4=2000 μscm-¹ > S3=1900 μscm-¹ > S1=800 μscm-¹ respectively. The result obtained was related to the findings of Usman *et al*., (2020)

Figure 5 Conductivity of Sediments Samples

**3.5 Daily Exposure Dose Total Non- Carcinogenic Heavy metals in Water sample**

Figure 6 showed the concentration of daily dose non-carcinogenic heavy metals in water sample in all the three pathways( ingestion, inhalation and dermal). Whereby manganese has the highest concentration of health risk with the value of 6.25E-07 followed by Fe=3.31E-07, Zn=2.59E-07, Ni=2.42E-07, Cu=1.44E-07, Pb=8.54E-08, Cr=6.11E-08, Cd=4.83E-08, As= 3.93E-08,while the least or lower amount kept in As= 3.93E-08.The result indicated that the daily exposure dose of non-carcinogenic heavy metals of the water sample analyzed were expressed in decreasing order of Mn > Fe > Zn > Ni > Cu >Pb > Cr > Cd > As respectively. The result indicated slight exposure.

Figure 6 Daily Exposure Dose Total Non- Carcinogenic Heavy metals in Water

**3.6 Daily Exposure dose Total Carcinogenic Heavy metals in Water sample**

Figure 7 showed the concentration of daily dose exposure of carcinogenic heavy metals in water sample specifically in two pathways (ingestion and inhalation) whereby the result indicated that As showed highest carcinogenic effect; As=1.53E-07 followed by Cr=1.198E-07, Pb=8.21E-08 and Cd=8.29E-08.The result obtained showed that the daily exposure dose of carcinogenic heavy metals in water sample examined were expressed in decreasing order of As >Cr > Pb > Cd respectively. The result obtained was almost the same with the findings of Usman *et al*., (2024)

Figure 7 Daily exposure dose total carcinogenic heavy metals in water sample

**3.7 Hazard Quotient Risks of Non-Carcinogenic Heavy metals in Water**

Figure 8 showed the result of HQ risk of non-carcinogenic heavy metals in water sample in which Cd has the highest value of 2.49E-03 followed by As=7.26E-04, Cr=6.26E-04, Pb=3.07+00, Mn=2.00E-04, Ni=6.14E-05, Cu=1.78E-00 where Fe and Zn have the least values or no effect. This representation showed that the values of the heavy metals of HQ in water sample decreased in order of Cd > As > Cr > Pb > Mn > Ni > Cu > Fe > Zn respectively. The result obtained was almost related to the findings of Usman *et al.,* (2024). The result obtained showed As and Cr as the highest while Fe and Zn as the least HQ was contrary to Zn and Cd while Zn formed the least HQ of Heavy metals in as reported by Feleye *et al*., (2024).

Figure 8 Hazard Quotient risk of non-carcinogenic heavy metals in water

**3.8 Cancer Risks Assessment of Carcinogenic Heavy metals in Water**

Figure 9 explored the cancer risk assessment of carcinogenic heavy metals in water in two specific pathways (ingestion and inhalation) where the result showed that Cr has the highest level of cancer risk of ingestion pathway with the value of 8.02E-06 followed by Cd=1.68E-06, As=2.50E-07 where Pb=1,28E-09 has the least value or no significant effect. This indicated that the cancer risk of heavy metals were expressed decreasing order of Cr >Cd >As> Pb respectively, which was similar as reported by Usman at al. (2022) but contradicted result obtained of ingestion in adults range from 1.32E-05 mg/kg to 6.59 E03 mg/kg of Cd to Cr as reported by Saheh *et al*., (2025).Also the cancer risk assessment of carcinogenic heavy metals in inhalation pathway showed order of Cd< Pb< As< Cr respectively, which contradicted result obtained in adults range from 5.89E-07 mg/kg to 2.78 E-04 mg/kg of Cr to Cd as reported by Saheh *et al*., (2025)

Table 3.1 Cancer Risk Total of Carcinogenic Heavy metals in Water

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Metals | Pb | Cr | Cd | As |
| CR ing | 1.28E-09 | 8.24E-06 | 1.68E-06 | 2.60E-07 |
| CR inh | 9.32E-13 | 1.24E-09 | 2.48E-10 | 3.81E-11 |

Figure 9 cancer risk of carcinogenic heavy metals in water sample

**3.9 Hazard Index of Water samples**

Figure 10 showed that the Hazard Index of Non-carcinogenic heavy metals where by Mn showed the highest value of 2.52E-06followed by Fe = 1.32E-06, Ni = 9.68E-07, Zn = 1.03E-06, Cu = 5.76E-07, Pb = 3.42E-07, Cr = 2.44E-07, Cd = 1.83E-07 and As = 1.57E-07. This representation indicated that the values of heavy metals of no carcinogenic of hazard index in water samples decreased in order of Mn > Fe > Ni > Zn > Cu > Pb > Cr > Cd > As respectively. The result obtained were closely related to the findings of Usman *et al*. (2022). However the HI obtained range from 2.52E-06 in Mn to 1.57E-07 in As which contradicted HI value range water from 19.51 mg/kg to 14.61mg/kg as investigated by Saheh *et al*., (2025). The result obtained also HI of 00.00 in As to 5.17E-04 in Fe as reported by Feleye *et al*.,(2025)

Table 3.2 Hazard Index of Non- Carcinogenic Heavy metals in water

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Metals | Cu | Pb | Cr | Cd | As | Ni | Fe | Mn | Zn |
| Ing Tot. | 5.19E-07 | 2.12E-07 | 2.11E-07 | 1.70E-07 | 1.14E-07 | 8.67E-07 | 1.19E-06 | 2.20E-06 | 9.39E-07 |
| Ihl tot. | 1.23E-10 | 1.05E-09 | 4.09E-11 | 2.85E-11 | 5.24E-11 | 1.24E-10 | 1.63E-10 | 3.71E-10 | 1.61E-10 |
| Derm tot. | 5.71E-08 | 1.29E-07 | 3.33E-08 | 2.32E-08 | 4.26E-08 | 1.01E-07 | 1.33E-07 | 3.02E-07 | 9.43E-08 |
| HI | 5.76E-07 | 3.42E-07 | 2.44E-07 | 1.93E-07 | 1.57E-07 | 9.68E-07 | 1.32E-06 | 2.50E-06 | 1.03E-06 |

Figure 10 Hazard Index of Water samples

**3.10 Hazard Index of Water samples in Three Pathways**

Figure 11 showed that the Hazard Index in Three Pathways (Ingestion, Inhalation and Dermal) in which that the ingestion has the greeter value of 6.42E-06 followed by Dermal = 9.16E-07. Inhalation = 2.11E-09 served as the least value of HI effects. The result showed that Ingestion > Dermal > Inhalation respectively. The result indicated that HI of heavy metals in water were access to pollution rate through ingestion of water than inhalation and dermal effect. The result of high ingestion effect in water were similar to work of Usman *et al*. (2022).

Figure 11 Hazard Index of Water samples in Three Pathways

**3.11 Daily Exposure dose Total Non- Carcinogenic Heavy metals in Sediments Sample**

Figure12 showed the concentration of daily dose non-carcinogenic heavy metals in sediments sample in all the three pathways( ingestion, inhalation and dermal) whereby Fe has the highest concentration of likelihood daily exposure health risk with the value of 7.68E-06 followed by Mn=7.95E-06, Zn=5.61E-06, Ni=2.03E-06, Cu=6.59E-07, Cr=4.86E-07, Cd=4.97E-07, Pb=2.60E-07 while the least or lower amount kept in As=2.89E-07.The result indicated that the daily exposure dose of non-carcinogenic heavy metals of the sediments sample analyzed were expressed in decreasing order of Fe > Mn >Zn >Ni >Cu >Cr >Cd >Pb >As respectively. The result obtained were similar to the work Usman *et al*. (2020)

Figure 12 Daily dose Total Non- Carcinogenic Heavy metals in Sediments

**3.12 Daily Exposure dose Total Carcinogenic Heavy metals in sediment**

Figure 13 showed the concentration of daily dose exposure of carcinogenic heavy metals in sediment sample specifically in two pathways (ingestion and inhalation) whereby the result indicated that the highest carcinogenic effect ; Cd=2.67E-07 followed by Cr=2.06E-07, As=1.73E-07 and Pb=1.51E-07. The result obtained showed that the daily exposure dose of carcinogenic heavy metals in sediment sample examined were expressed in decreasing order of Cd > Cr > As > Pb respectively. As adopted by Usman *et al*., (2020)

Figure 13 Daily Exposure dose Total Carcinogenic Heavy metals in Sediment sample

**3.13 Hazard Quotient Risks of Non-Carcinogenic Heavy metals in Sediments**

The hazard quotient (HQ) represents the potential non- carcinogenic risk for an individual heavy metal. The HQ is the ratio of mean daily exposure dose (AD) to the reference dose (RfD) in mg/kg/day

HQ = $\frac{AD}{RfD}$ (Saheh *et al*., 2025)

The RfDing (mg/kg/day),of heavy metals values are; Cd = 1.00 x 10-3, Cr = 3.00 x 10-3 , Co = 3.00 x 10-4 Cu = 4.00x10-2 Pb = 3.5 x10-3 , Zn = 3.00 x10-1 (Usman *et al*., 2022), Mn = 1.40 x10-1 ,As = 3.00 x 10-4 (Usman *et al*., 2022) Ni = 2.00x 10-2 (Caspah *et al*., 2016) Fe = 7.00x 10-1(Usman *et al*., 2020).

The RfDinh (mg/kg/day), constant values are; Cd = 1.00 x 10-3, Cr = 2.86 x 10-5, Co = 5.71 x 10-6, Cu = 4.02 x 10-2, Pb = 3.52 x 10-3, Zn = 3.00 x 10-1, (Zheng *et al*., 2015), Mn = 1.84 x 10-5, As = 3.00 x 10-4, Ni = 0 (Caspah *et al*., 2016) Fe = 8.25 (Patrick *et al*., 2014)

The RfDderm(mg/kg/day),constants values are; Cd = 1.00 x 10,-5 Cr = 6.00 x 10-5 , Co = 3.00 x 10-2 Cu = 1.20x10-2 Pb = 5.25 x10-4 , Zn = 6.00 x10-2 (Zheng *et al*., 2015), Mn = 1.84 x10-3 ,As = 1.23 x 10-4 Ni = 5.6 x 10-3(Caspah *et al*., 2016). Fe = 7.00 x 10-1 (Usman *et al*., 2022)

Figure 14 showed the result of HQ risk of non-carcinogenic heavy metals in sediment sample in which Cd has the highest value of 7.96E-03 followed by As=1.78E-03, Cr=1.12E-03, Mn=5.74E-04, Pb=1.55E-04, Ni=1.37E-04, Cu=2.49E-04, Fe=1.19E-05 and Zn =3.32E-05.This showed that the values of the heavy metals HQ in sediment sample decreased in order of Cd > As > Cr > Mn > Pb > Ni > Cu > Fe > Zn respectively. The result obtained is closely related to the findings of Usman *et al*., (2020).

Table 3.3 Hazard Qoutent of Non-Carcinogenic Heavy metals in Sediments

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Metals | Cu | Pb | Cr | Cd | As | Ni | Fe | Mn | Zn |
| HQ ing | 1.65E-05 | 7.43E-05 | 1.62E-04 | 4.97E-04 | 9.63E-04 | 1.02E-04 | 1.10E-05 | 4.96E-05 | 1.87E-05 |
| HQ inh | 2.84E-09 | 1.47E-08 | 1.83E-06 | 9.16E-08 | 1.97E-07 | 0.00E+00 | 1.11E-10 | 5.76E-05 | 3.57E-09 |
| HQ derm | 8.42E-06 | 8.04E-05 | 9.58E-04 | 7.46E-03 | 8.13E-04 | 3.52E-05 | 8.96E-07 | 4.67E-04 | 1.45E-05 |
| HQ Tot | 2.49E-05 | 1.55E-04 | 1.12E-03 | 7.96E-03 | 1.78E-03 | 1.37E-04 | 1.19E-05 | 5.74E-04 | 3.32E-05 |

Figure 14 HQ Total for Non Carcinogenic Heavy metals in Sediments

**3.14 Cancer Risks Assessment of Carcinogenic Heavy metals in Sediments**

The carcinogenic cancer risk assessment was determined by multiplying daily exposure dose by their corresponding slope factor of individual carcinogenic heavy metals to arrive at cancer risk values. Slope factor for ingestion in mg/kgday-1 of As = 1.50E + 00, Pb = 8.50E -03, Cr = 5.0E – 01, Ni = 0, while slope factor for inhalation of carcinogenic heavy metals are As = 1.50 E + 01, Pb = 4.20 E – 02, Cd= 6.30 E + 00, Cr = 4.10 E + 01 (Caspah *et al*., 2016).

Figure 15 explored the cancer risk assessment of carcinogenic heavy metals in sediment in two specific pathways (ingestion and inhalation) whereby the result indicated that Cr has the highest level of cancer risk in ingestion with the value of 8.24E-06 followed by Cd=1.68E-06, As=2.60-07 where Pb has the least value of 1.28E-09 which were represented in decreased order of Cr > Cd > As >Pb respectively. The inhalation pathway showed negligible effect on the process. The cancer risk shown on these four carcinogenic heavy metals were similar to finding of Usman *et al.*, (2020). However the CR obtained in sediments contradicted the range CR of 14.20 to 217.72 in all sampling sites as investigated by Sadique *et al*., (2025)

Figure 15 Cancer Risks Assessment of Carcinogenic Heavy metals in Sediments

**3.15 Hazard Index of Sediment Samples**

Hazard Index (HI) represents the functional non- carcinogenic risk assessment of many heavy metals through major pathways present in the sample, which is given as; Total Hazard Index (Hit = HI ing. + HI inh. + HI derm.) Which is the sum of all HI in three pathways. HI = $\sum\_{}^{}HQi$ where Q = Hazard Quotient, i = different heavy metals in the sample. Otherwise

HI = $\sum\_{}^{}HQ$=HQing+HQdermal+HQinh (Saheh *et al*., 2024)

 HI$ \leq $1 no adverse health risk, HI $\geq 1 $1there is likely adverse health risk effects. As reported by (Usman *et al*., 2022).

Figure 16 showed that the Hazard Index of Non-carcinogenic in heavy metals where by Fe revealed the highest value of 3.07E-05followed by Mn = 2.75E-05, Zn = 2.55E-05, Ni = 8.12E-06, Cu = 2.64E-06, Cr = 1.99E-06, Cr = 1.94E-06, Cd = 1.99E-06, As = 1.16E-06 and Pb = 1.04E-06. This indicated that the values of heavy metals of non-carcinogenic showed hazard index of HI>1 which represented likely adverse health risks in sediments samples decreased in order of Fe > Mn > Zn > Ni > Cu > Cr > Cd > As > Pb respectively. As related to the findings of Usman *et al*. (2022). However, the trend in toxicity contradicted the trend showed Mn and V as the highest while Cd >Cr formed the least toxic as reported Saltana *et al*., 2017). The result obtained was contrary to HI in soil dust which range 1.9E-01 in Mn to 5.9E-01 in Vanadium as reported by Arifa *et al*., (2015).

Table 3.4 Hazard Index of Non-Carcinogenic Heavy metals in Sediments

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Metals | Cu | Pb | Cr | Cd | As | Ni | Fe | Mn | Zn |
| Ing tot | 2.23E-06 | 8.70E-07 | 1.71E-06 | 1.69E-06 | 7.56E-07 | 7.33E-06 | 2.82E-05 | 2.43E-05 | 1.90E-05 |
| Ihl tot | 4.58E-10 | 2.07E-10 | 2.82E-10 | 3.66E-10 | 2.37E-10 | 1.25E-09 | 3.79E-09 | 4.23E-09 | 4.26E-09 |
| Derm tot | 4.05E-07 | 1.69E-07 | 2.30E-07 | 2.98E-07 | 4.00E-07 | 7.87E-07 | 2.51E-06 | 3.44E-06 | 3.47E-06 |
| HI | 2.64E-06 | 1.04E-06 | 1.94E-06 | 1.99E-06 | 1.16E-06 | 8.12E-06 | 3.07E-05 | 2.77E-05 | 2.25E-05 |

 Figure 16 Hazard Index of sediment samples

**3.16 Hazard Index of Sediment samples in Three Pathways**

Figure 17 showed that the Hazard Index of sediment sample in Three Pathways (Ingestion, Inhalation and Dermal) in which that the ingestion has the greeter value of 8.61E-05 followed by Dermal = 1.17E-05 while inhalation=1.51E-08 with the least value of effect on the process pathway. The result obtained were represented in decreasing order of Ingestion > Dermal > Inhalation respectively. The work obtained is similar to the findings of Usman *et al*. (2022).

Figure 17 Hazard Index of Sediment samples in Three Pathways

**3.17 Comparative Hazard Index of Water and Sediments Samples**

The Hazard index of water and Sediments were represented on Figure 18 which showed Water HI range of Mn=2.75E-05 to Pb = 1.04E-06 indicated that all the heavy elements showed HI >1 indicated adverse health risk effect sediments. On the other hand Hazard Index in Sediments range; Mn=2.52E-06 to As = 1.57E+07 also showed HI >1 indicated adverse health risk effect in water. Both water and sediments investigated showed adverse health risks effects.

Table 3.5 Comparative Hazard Index of Water and Sediments Samples

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Metals | Cu | Pb | Cr | Cd | As | Ni | Fe | Mn | Zn |
| HI Water | 5.76E-07 | 3.42E-07 | 2.44E-07 | 1.93E-07 | 1.57E-07 | 9.68E-07 | 1.32E-06 | 2.50E-06 | 1.03E-06 |
| HI Sed. | 2.64E-06 | 1.04E-06 | 1.94E-06 | 1.99E-06 | 1.16E-06 | 8.12E-06 | 3.07E-05 | 2.77E-05 | 2.25E-05 |

Figure 18 Comparative Hazard Index of Water and Sediments Samples

**Conclusion**

The study provided comprehensive environmental health risks posed by heavy metals in the water and sediments samples from Balanga Dam. The result showed that effects of heavy metals Hazard Index of Non-carcinogenic in heavy metals in Water range of Mn=2.75E-05 to Pb = 1.04E-06 indicated that all the heavy elements showed HI >1 indicated adverse health risk effect sediments.

 Hazard Index in Sediments range; Mn=2.52E-06 to As = 1.57E+07 also showed HI>1 indicated adverse health risk effect in both water and Sediments simultaneously.

The pH values showed a range from W2 (pH = 6.86) slightly acidic to W4 (pH = 7.26) slightly alkaline. Sediment samples exhibited more acidic values, with S2 showing the highest acidity (pH = 5.40) and S4 exhibited highest alkalinity (pH = 6.85). Thus, water samples were slightly acidic while the sediment samples investigated are moderately alkaline. All are within safe limits while non-carcinogenic effects, certain metals, particularly cadmium, arsenic, and chromium, are of concern due to their carcinogenic potential. The study revealed that emphases on minimal direct human and contact with contaminated water and sediment of Balanga Dam water. Daily dose may possessed high cancer risk of carcinogenic heavy metals and health risks of non- carcinogenic upon prolong dose of 35 years of exposure.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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Details of the AI usage are given below:

1.

2.

3.

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