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ASSESSMENT OF LEAD AND CADMIUM CONCENTRATION ALONG THE FLOW PATH OF THE CHANCHANGA DAM, MINNA NORTH CENTRAL, NIGERIA

by

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Abstract
This study analyzed the levels of Cadmium (Cd) and Lead (Pb) in Chanchaga Dam in Minna, Niger State, Nigeria. Water samples from different locations within the dam path (Upper, Middle and Down) were collected and tested using the Per chloric and Nitric acid digestion method and Atomic Absorption Spectroscopy (AAS) analysis. The study also examined the physical and chemical properties of the water including pH, total organic matter, and electrical conductivity. The results revealed that Cd concentrations were 0.006 mg/l, 0.004 mg/l and 0.014 mg/l in the upper, middle and lower side of the dam respectively. For Pb, the concentrations were 0.8375 mg/l, 0.7865 mg/l and 0.9630 mg/l in the upper, middle and lower side of the dam. Statistical analysis showed no significant three-way interaction between the different river locations. Furthermore, there were no significant differences between the upper and middle, upper and lower and middle and lower side of the dam. The study concluded that consuming water directly from Chanchaga Dam could pose health risks due to Cd and Pb levels surpassing the limits set by the World Health Organization (0.003 mg/l for Cd and 0.010 mg/l for Pb). It is therefore recommended that continuous monitoring of the water source to regulate the accumulation of these elements and improve water quality is essential. This study contributes valuable information about Chanchaga Dam, serving as a reference for future studies and emphasizing the importance of monitoring and enhancing the overall quality of the water.

Keywords: Lead, Cadmium, Concentration & Chanchaga Dam,

Introduction

Water is a fundamental resource for human health and well-being, yet approximately 780 million people globally lack access to clean water leading to millions of deaths annually from water-related health disorders (UN Water, 2013). This study aims at investigating the concentration of heavy metals specifically lead (Pb) and cadmium (Cd) in the water of Chanchaga Dam in Minna, Niger State, Nigeria. This is motivated by the increasing pollution and high level of anthropogenic activities particularly from automobile workshops that discharge hazardous waste into nearby water bodies.

Access to clean water is essential for maintaining good health. However, many individuals lack sufficient access resulting in millions of deaths each year from water-related diseases. Both manufacturing and agriculture significantly contribute to water pollution particularly through the introduction of toxic heavy metals that can accumulate in water bodies and pose risks when present in elevated concentrations (Magadza, 2003; Liu *et al.*, 2013).

Aquatic systems including rivers, lakes and coastal waters are crucial habitats for a wide variety of flora and fauna. Heavy metal contamination disrupts the delicate ecological balance of these ecosystems resulting in a decline in biodiversity and the potential collapse of food chains. Many aquatic organisms such as fish and shellfish can accumulate these toxic metals in their tissues through a process known as bioaccumulation. As a result, when humans consume contaminated seafood, they may be exposed to harmful levels of heavy metals which pose serious health risks (Cobbina*et al.,* 2013).

Prolonged exposure to these metals can lead to serious health issues ranging from acute poisoning to chronic diseases. For instance, lead exposure is known to cause neurological damage particularly in children resulting in cognitive and developmental impairments. Mercury poisoning can adversely affect the nervous system leading to behavioural changes and impaired motor skills. Cadmium exposure has been associated with kidney damage while arsenic is recognized as a carcinogen, increasing the risk of various cancers (Yu *et al.*, 2011).

Human activities, particularly in the manufacturing and agricultural sectors significantly contribute to water pollution by discharging contaminated effluents into aquatic environments (Magadza, 2003). Among these pollutants are toxic heavy metals which can accumulate in water bodies and pose serious risks to both human health and aquatic ecosystems (Alloway, 1990). When present at elevated concentrations, these metals can become highly detrimental, underscoring the necessity for continuous monitoring and assessment of freshwater quality to ensure its safety for consumption and ecological balance (Liu *et al.,* 2013).

In a study conducted by Islam *et al.* (2015) on the Korotoa River in Bangladesh, he identified six heavy metals in the water with concentrations exceeding safe drinking water standards. This contamination not only compromised the quality of the water but also adversely affected the sediment quality leading to significant health issues among local residents. Similarly, Yu *et al.* (2011), highlighted that heavy metal pollution in sediments has resulted in widespread water quality problems across various countries, indicating a global challenge that requires urgent attention and action. The implications of heavy metal contamination are profound, affecting not only the health of individuals but also the integrity of ecosystems and the sustainability of water resources. Therefore, addressing this issue is critical for public health, environmental protection, and the overall well-being of communities worldwide**.**

The primary objective of this study is to determine the concentration of Pb and Cd on different points along the Chanchaga Dam at upper, middle and lower courses, and to analyze the physical and chemical properties of the water samples, including total organic carbon (TOC) and pH levels.

Description of the Study Area

The study area is situated in Chachanga with geographic coordinates of latitude 9°32′6″N and longitude 6°34′55″E. The region experiences an average annual temperature of 35°C and receives an average annual precipitation of 1209.7 mm. It is located within the southern guinea savanna zone of Nigeria. The major rivers in Minna include Bosoo River, Chachanga River and Tagwai River. These rivers are connected to outlets and channels that are utilized for irrigating agricultural farms during the dry season. However, this water may be contaminated with pollutants as both domestic and industrial waste water are discharged into these water bodies (Wogu and Okaka, 2011).

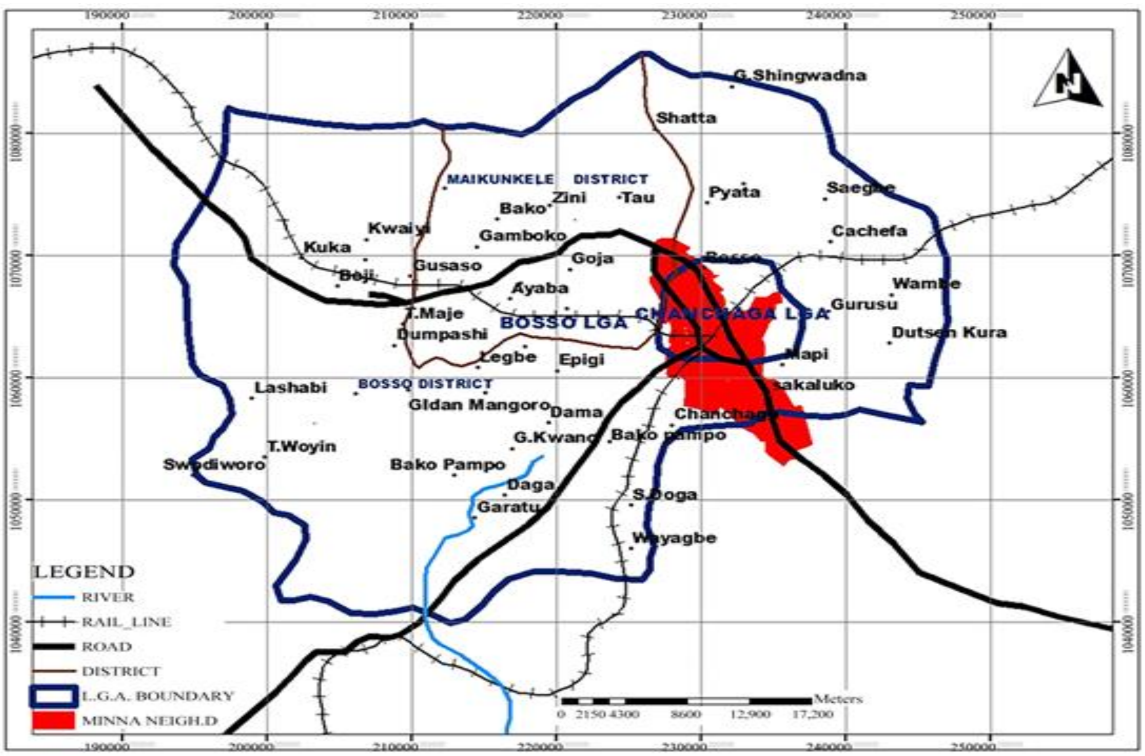

Figure 1: Map of Minna showing the study area.

Source: Idowu *et al.*, 2020

Experimental Design

The experimental design involves collecting water samples from three distinct locations along the Chanchaga Dam: the upper, middle and lower sections. Each sampling point was replicated three times to ensure the reliability of the data.

Water Sampling Procedure

Water sampling operation was carried out in the morning at three distinct locations within the dam: the upper, middle, and lower sections. Clean air-dried bottles were utilized to collect the samples which were subsequently analyzed in the laboratory for electrical conductivity, pH and total organic carbon. The assessment of physical and chemical properties followed the standard methods outlined by the American Public Health Association (APHA, 2005) for both fresh and waste water analysis.

Laboratory Analysis Methods

Hydrogen Ion Concentration (pH)

The pH of the water samples was determined using the potentiometric method with a REX Model: 25 pH meter. Fifty milliliters of each water sample were placed in separate beakers and the pH meter was calibrated using buffer solutions with pH values of 9, 7 and 4. The calibrated pH meter was then immersed in the water sample and readings were recorded once the meter stabilized.

Total Organic Carbon

To assess the total organic carbon, the Walkley and Black method was employed. Ten milliliters of each water sample was measured into different conical flasks followed by the addition of 1 ml of sulfuric acid and 5 ml of potassium dichromate. The solutions were allowed to sit undisturbed for 30 minutes after which three drops of ferroin indicator were added. The solutions were then titrated against a 0.5 molarity solution of ferrous sulfate.

Heavy Metals (Wet Digestion and AAS Analysis)

The analytical method used in this study involved the wet digestion of samples followed by analysis using an atomic absorption spectrophotometer (AAS) specifically the BUCK Model: 230 instrument. This approach aimed to quantify the concentration of each heavy metal in the samples. To minimize interferences, the organic components of the samples were decomposed through acid digestion allowing for the breakdown of metal-containing compounds into free metal ions that could be accurately measured using AAS. A mixture of per chloric and nitric acid was employed for this purpose which is a widely accepted reagent for flame, electro-thermal atomic absorption and ICP-MS analyses (Hoenig and Kersabiec, 1996). In the acid digestion process, 100 ml of each sample was measured into separate conical flasks and heated with a mixture of 5 ml of concentrated nitric and per chloric acid until a clear solution obtained (Eaton *et al.*, 2005). After cooling, the solutions were adjusted to a final volume of 50 ml using distilled water and then filtered through properly aligned funnels with Whatman No. 42 filter papers into sample bottles.

Statistical Analyses

A three-way ANOVA analysis was performed using SPSS version 22. This analysis was conducted separately for each dependent variable through the General Linear Model Univariate procedure. The experimental design includes collecting samples from the upper, middle and lower sections of the dam with three replications for each section. The data were described using mean and standard deviation which provided insights into the values of Total Organic Carbon, pH, and Electrical Conductivity.

Instrumentation Principles of AAS Operation

The AAS measures the concentration of specific elements in a sample by atomizing the sample and passing a beam of electromagnetic radiation through it. The amount of light absorbed by the atoms in the sample was directly proportional to the concentration of the element being analyzed. The AAS consists of several key components: a hollow cathode lamp as the light source, an atomizer for sample vaporization, a mono-chromator for wavelength selection, a detector for measuring light absorption and a recorder for data output.

Method Validation and Quality Control

To ensure the reliability of the analytical methods, several validation parameters was assessed including instrumental detection limit

(IDL), limit of detection (LOD), limit of quantification (LOQ) and precision (Prichard *et al.*, 2007). The IDL was calculated as three times the standard deviation of the blank signal. The LOD was determined from the analysis of blanks processed in the same manner as the samples while the LOQ was established as ten times the standard deviation of the method blank.

Assurance of Quality of Analysis

To maintain the quality of the analysis, strict protocols were followed including the use of clean glassware and high-quality reagents. Successful water sampling requires careful handling to ensure minimal disturbance of the sample stratification. Sampling focus on muddy areas as trace metals are often associated with fine sediments. Calibration of standards for the preparation of the calibration curve was conducted to cover a range of concentrations relevant to practical conditions ensuring that the analytical precision is achievable throughout the entire range of concentrations (Cheri and Tavassoli, 2011).

Result of Analysis of Water Samples

Table 1: Result of Laboratory Analysis of Water Samples

STATIONS	TOC(mg/1)	pH	E.C(μm/s)
A1	0.004	7.54	94
A2	0.001	7.63	99
A3	0.004	7.60	95
MEAN	**0.003**	**7.59**	**96**
SD	**0.002**	**0.05**	**2.65**
B1	0.004	7.51	103
B2	0.004	7.32	110
B3	0.004	7.43	110
MEAN	0.004	7.42	107.6
SD	0.0002	0.10	404
C1	0.0111	7.29	145
C2	0.009	7.30	125
C3	0.007	7.76	112
MEAN	**0.0090**	**7.45**	**127.3**
SD	**0.0030**	**0.27**	**16.62**

The concentration of TOC was highest in the lower course of the dam, with a mean value of 0.0090 (mg/l). The middle course had a mean concentration value of 0.004 (mg/1), and the upper course had the lowest concentration value of 0.003 (mg/l).The pH concentration was highest in the upper course of the dam, with a mean value of 7.59. The lower course had a mean value of 7.45, and the middle course had the lowest concentration value of 7.42. The highest pH values on the upper and lower courses of the dam suggest that the highest concentrations of Cd and Pb is expected in these areas due to the predominant negative charges from (OH-) or organic matter content, which attract positively charged elements. Thus, there is a direct relationship between pH and TOC, as an increase in pH values corresponds to an increase in TOC and vice versa. Concentration of lead and cadmium in comparison with (WHO, 2008) is shown in Table 2.

Table 2: Concentrations of lead (Pb) and cadmium (Cd) and comparison with WHO

Pb (mg/l)	WHO (2008)	Cd (mg/l)	WHO (2008)
0.83	0.01	0.015	0.003

Electrical conductivity (E.C) measures the water's ability to conduct electricity which is directly related to the concentration of ions, dissolved salts and inorganic materials in the water. However, for the concentration of heavy metals (HMs) in the water from the experimental site, E.C is of little relevance. The highest mean E.C value of 127.3333 (μm/s) was recorded in the lower course of the dam, followed by 107.6667 (μm/s) in the middle course and the lowest mean value of 96 (μm/s) was observed in the upper course of the dam.

Table 3: The effect of flow path on the concentration of (Cd and Pb) in the dam

HM Concentrations/River morphology	Upper River	Mid-River	Lower River	Significance
Cd	0.006 0 ± 0042	0.004 ± 0.0042	0.014 ± 0.0014	p>0.05
Pb	0.84 ± 0.1	0.79 ± 0.05	0.96 ± 0.054	p>0.05
UR*MR for (Cd and Pb)	-	-	-	p>0.05
UR*LR for (Cd and Pb)	-	-	-	p>0.05
MR*LR for (Cd and Pb)	-	-	-	p>0.05
UR*MR*LR (Cd)	-	-	-	p>0.05
UR*MR*LR (Pb)	-	-	-	p>0.05

MEAN±SD

A three-way ANOVA was conducted to determine the effect of river morphology; upper River (UR), mid-River (MR) and Lower River (LR) on the concentration of Cd and Pb in the dam. Data represent mean ± standard deviation. There was no statistically significant three-way interaction between the UR, MR and LR (P>0.05). Thus, suggesting that the concentration of Cd and Pb in the UR does not influence the concentration of Cd and Pb in the MR and LR. Similarly, results for the simple two–way interaction and simple main effects showed that there were no statistically significant mean differences between the UR and MR, UR and LR, MR and LR (P>0.05).

Discussion of Results

The accumulation of heavy metals in sediments containing organic matter and clays can occur and their concentrations in water samples were analyzed. The Chanchaga dam in Minna, Niger State, Nigeria showed higher mean concentrations of lead (Pb) and cadmium (Cd). The high Pb concentration in the dam may be attributed to the widespread use of lead materials in the study area. Overall, the presence of specific rock formations and anthropogenic activities significantly influenced the levels of heavy metals in the study area. These findings emphasize the critical importance of monitoring and addressing heavy metal pollution to safeguard water resources and mitigate associated health risks.

Conclusion and Recommendations

Generally, this study revealed that the levels of Pb and Cd in water from Chanchaga dam exceeded the World Health Organization (WHO, 2008) stipulated limits of 0.010 mg/l for Pb and 0.003 mg/l for Cd in drinking water. Thus, direct intake of this water might result in an outbreak of water-related health challenges. Continuous monitoring of the quality of this water is highly recommended. Therefore, it is crucial to implement regulations to curb these unauthorized environmental practices in order to protect natural resources from depletion.

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