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Exploration of Heavy Metals Concentration and Variation in Some Selected Borehole Water from Daura Local Government, Katsina State, Nigeria.

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ABSTRACT
Heavy metals such as cadmium lead, and arsenic can contaminate water sources and pose serious health risks when consumed. Considering their potential health implications, this research aim to investigate the presence and explore the variation in heavy metals concentration of some Borehole's water across Daura local government area of katsina state, and compare the result with the internationally accepted standard concentration value. In this regard, a total of twenty borehole water samples was collected from the site in questioned based on the sediment of the area and the coordinates of the various location used in collecting the samples were recorded. Microwave plasma Atomic Emission spectrometer (MP-AES) was used to obtain the concentration of the five examined heavy metals (Cd, As, Co, Pb and Cr), the mean concentration in part per million (ppm*)* was obtained using statistical analysis. The results obtained, shows that Daura local government Borehole's water have an average heavy metal (Cd, As, Co, Pb and Cr) concentration of 0.001, 0.079, 00.298, 0.329 and 0.055 ppm respectively. The differences were seen by comparing the mean concentration of the heavy metals in the study area with world health organization (W.H.O) and NAFDAC threshold limit standard, it was observed that the samples were contaminated with heavy metals which has high risk implication. There is need for urgent intervention and remediation measures by the authority concerned. It was recommended that Water treatment processes should be considered to reduce heavy metal levels at Daura area and Dumpsite should be built in the area so that people should not be dumping refuse and west product anywhere in order to maintain environment stable and free from pollutant.

Keywords:
Pollution,
Threshold limit Mp-Aes,
NAFDAC,
Heavy metals,
W.H.O

INTRODUCTION

Heavy metals are described as elements possessing high atomic numbers and atomic weights (Samaila et al., 2022). They are a broad category of elements with atomic densities exceeding 6 g/cm³ and hold significant roles in both biological systems and industrial processes (Uba et al., 2021).; (passed up the food chain to humans). Over 20 heavy metals have been identified, including aluminium, arsenic, cadmium, chromium, cobalt, lead, manganese, mercury, nickel, selenium, tin, vanadium, zinc, and platinum (Uba et al., 2020). These metals exist in various forms—such as minerals bound to airborne particles, embedded in organic or inorganic compounds, and present in soil, rocks, and sand (Samaila et al., 2023).

Heavy metal contamination poses a significant risk to agricultural lands (Bhagure & Mirgane, 2010). Notably, soil pollution from heavy metals has emerged as a growing environmental concern. Over the past 50 years, more than 30,000 tons of chromium and 800,000 tons of lead have been introduced into the global environment, with most of these pollutants accumulating in soil, resulting in severe contamination (Xiang et al., 2021).

Water is one of the most plentiful substances on Earth and serves as a fundamental component of all living organisms. To ensure safety, water intended for consumption must be free from any form of contamination (Olayiwola, 2013).

Human activities contribute to the buildup of heavy metals in the environment, leading to pollution (Sultan et al., 2017). Food, especially various types of vegetables, represents the primary pathway through which humans ingest heavy metals. Evaluating the presence of heavy metals in food products is a crucial part of food quality control (Rafi & Gowda, 2017). Globally, there is increasing concern about the accumulation of heavy metals due to the significant health risks they pose, both directly and indirectly, to humans (Vysetti et al., 2014).

Katsina State, situated in northern Nigeria, features a variety of geological formations and mineral resources. These geological characteristics significantly influence the composition of groundwater and the likelihood of metal contamination (Rahib et al., 2015). Heavy metals refer to metallic elements that possess high density and are toxic even at low concentrations. They encompass a wide range of elements that are vital in both industrial and biological contexts, typically having an atomic density exceeding 6 g/cm³ (Iyaka et al., 2019). Their harmful nature stems from their persistence in the environment, resistance to degradation, long biological half-lives, and tendency to accumulate in various human organs (Kankara et al., 2021).

Heavy metals like lead, arsenic, and cadmium have the potential to contaminate water supplies and pose significant health hazards when ingested (Shamsuddin et al., 2018). Given these health concerns, it is essential to examine the presence, concentration, and variation of certain heavy metals in borehole water in Daura. This study aims to assess the levels of heavy metals in borehole water samples using Microwave Plasma–Atomic Emission Spectroscopy (MP-AES), estimate the intake of these metals through drinking water, and compare the findings with international safety standards. Although previous studies have been conducted in the area, the lack of focus on geological factors contributing to heavy metal accumulation highlights the importance of this research in providing a more thorough understanding of the current water quality status in Daura.

The study areas

The study area is Daura Local government areas in Katsina State. Its landscapes are characterized by Savanah vegetation and semi arid climate yusuf and Nuraddeen, (2020). The region witnessed distinct wet and dry seasons. Daura is bounded approximately by Latitude 11º33' 14.76º and Longitude of 11º 24' 22º E (Figure 1). The elevation of Daura ranges from 441.4 to 487.3m as shown in Figure 2.

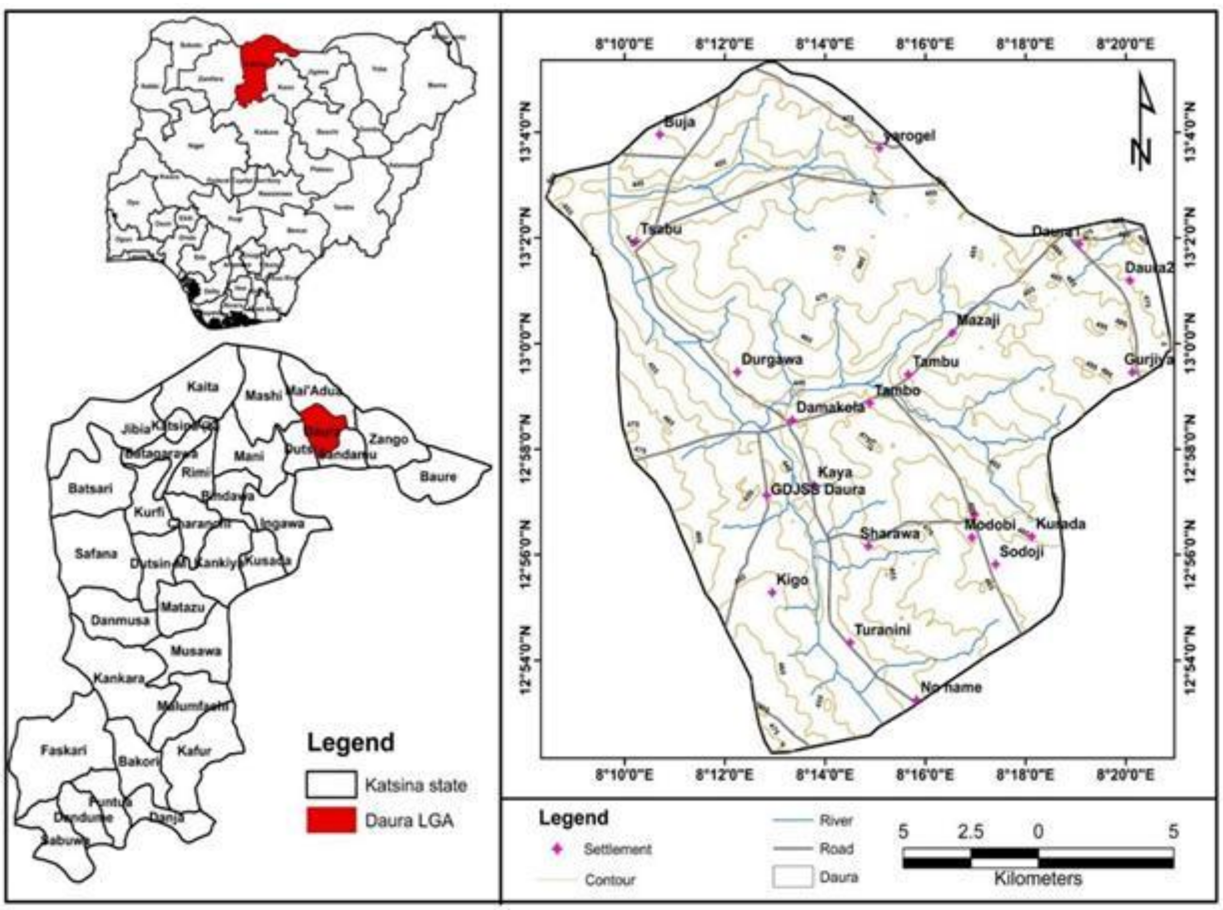

Figure 1 Map showing the location of Daura (This research).

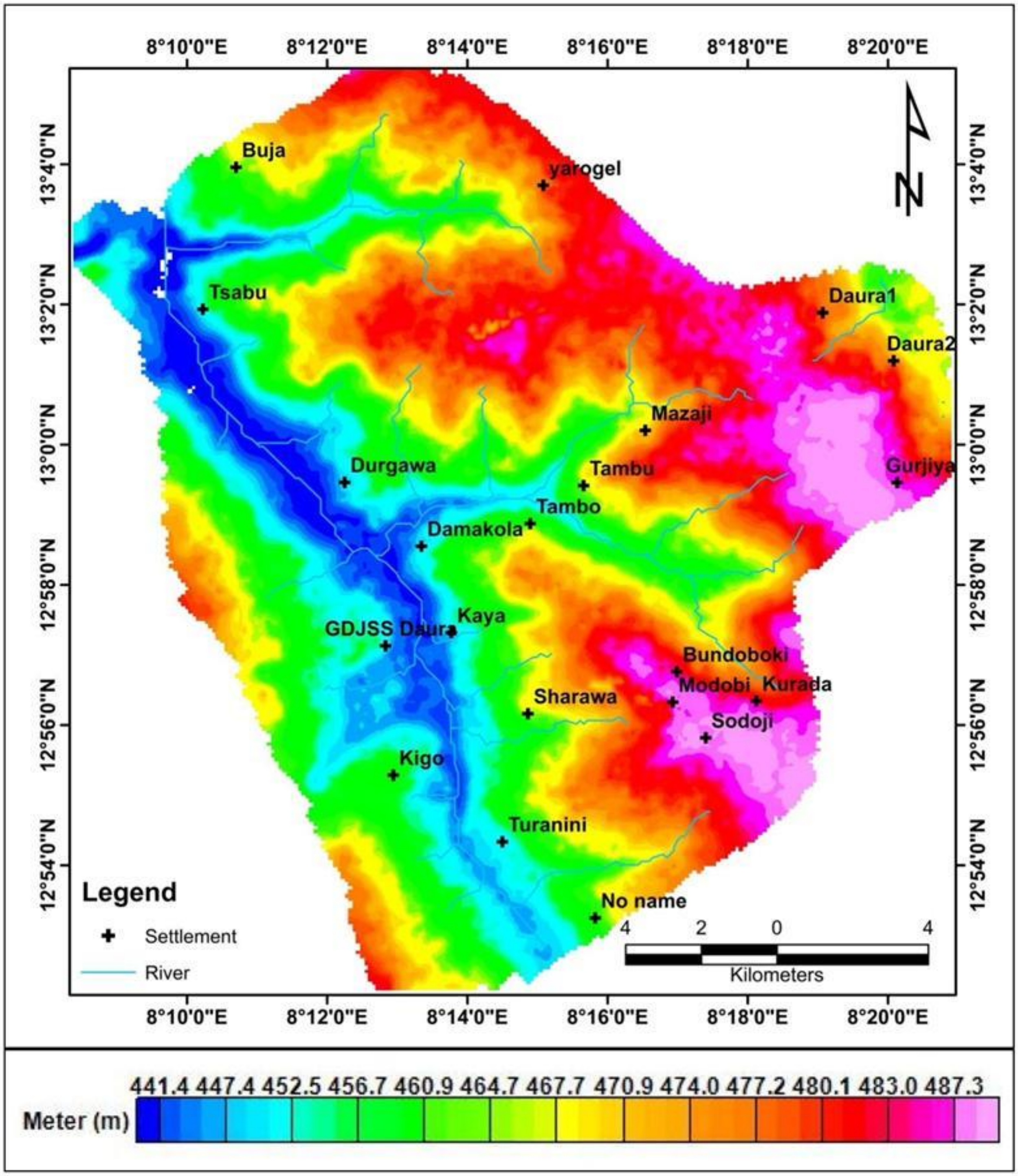

Figure 2. Map showing the elevation of Daura (This research).

MATERIALS AND METHODS

The following materials were used in the research. The Conical flask, plastic container, filter paper, hot plate , sulphuric acid (concentrated), nitric acid (concentrated), distilled water, funnel, 100mL volumetric flask, boiling tube, block digester, Microwave plasma Atomic Emission spectrometer (MP-AES), A handheld GPS device, Sample collection map for Daura (sedimentary formation).

Samples Collection and Preparation

Samples Collection

A total of 20 borehole water samples were obtained using 2-liter sampling bottles. Prior to collection, each borehole was allowed to flow for approximately 5 to 10 minutes, following the designated sample collection map (Figure 3). The bottles were filled and sealed after adding concentrated nitric acid (HNO_3) to prevent the adsorption and settling of particles on the inner walls of the containers. A handheld Global Positioning System (GPS) device was used to record the exact coordinates of each sampling location. After collection, the samples were transported to the laboratory for further processing and analysis.

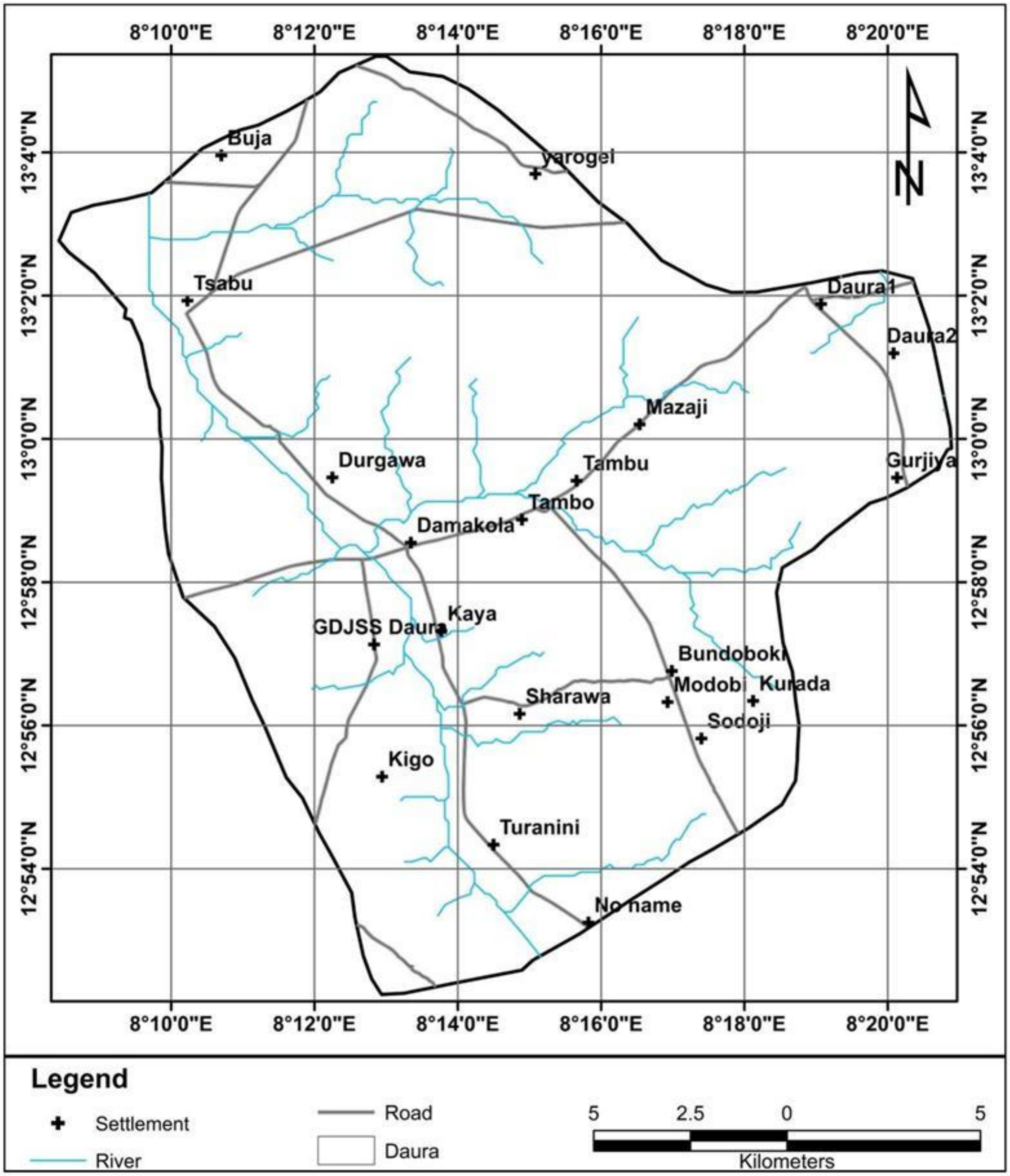

Figure 3. Sample collection map Daura local government (This research).

Samples Preparation

A 100 ml portion of the water sample was measured using a measuring cylinder, after which 5 ml of concentrated nitric acid and a few drops of hydrogen peroxide were added, following the method described by Ibrahim et al. (2017). The mixture was then poured into a conical flask and heated on a hot plate at 105°C for two hours. After heating, the solution was transferred into a 100 ml volumetric flask and topped up to the mark with deionized water. It was subsequently filtered and poured into pre-cleaned sample bottles for further analysis using Microwave Plasma-Atomic Emission Spectroscopy (MP-AES). This procedure was applied to each water sample, as reported by Yang et al. (2017) and Adelekan & Abegunde (2011).

Samples Analysis

The analysis of heavy metals was conducted using a Microwave Plasma Atomic Emission Spectrometer (MP-AES) located at the Centre for Dryland Agriculture, Bayero University. Calibration curves for each metal were generated by running standard solutions of varying concentrations and recording their emission intensities. A reagent blank was used to zero the instrument before sample analysis. Each prepared water sample was introduced into the instrument and measured three times, with the average concentration value recorded for each metal. The results obtained from the standard reference materials were compared with their certified values. Throughout the procedure, only distilled and deionized water was used, and all reagents were of analytical grade, in accordance with the methods described by Ogarekpe et al. (2023) and Mohammed et al. (2024).

WHO And NAFDAC Threshold Limit

Various international organizations have established maximum permissible limits for heavy metal contamination, which serve as global standards. This study considers the guidelines set by two key bodies: the World Health Organization (WHO) and Nigeria's National Agency for Food and Drug Administration and Control (NAFDAC). Table 5 presents the recommended limits for heavy metals in drinking water, as outlined by WHO (2011) and NAFDAC (Vysetti et al., 2014).

TABLE 1: Table of WHO and NAFDAC Threshold Limit

S/N	HEAVY METALS	W.H.O THRESHOLD LIMIT	NAFDAC THRESHOLD LIMIT
1	Arsenic	50	5
2	Magnesium	50	30
3	lead	0.01	0.0
4	Cadmium	0.003	0.0
5	Mercury	0.01	0.0
6	Silver	0.0	0.0
7	Nickel	0.08	0.08
8	Chromium	1.0	1.0
9	Zinc	3.0	3.0
10	Copper	0.03	0.03

(Lavanya et al., 2021)

RESULTS AND DISCUSSION

Table 2. shows the results of the concentration of the analysis from Microwave plasma Atomic Emission spectrometer (MP-AES). It can be observed that there are variation of concentration across the samples collected from Daura.

TABLE 2: Table of the heavy metals concentration of Daura

S/N	Sample Code	**Cd** (ppm)	**As** (ppm))	**Co** (ppm)	**Pb** (ppm)	**Cr** (ppm)
1	Sample D1	0.10	29.80	1.33	0.52	0.11
2	Sample D2	0.05	14.21	0.87	0.46	0.08
3	Sample D3	0.00	3.54	0.54	0.56	0.09
4	Sample D4	0.05	0.45	0.40	0.33	0.06
5	Sample D5	0.00	5.94	0.56	0.29	0.05
6	Sample D6	0.00	12.30	0.54	0.41	0.02
7	Sample D7	0.03	40.98	0.61	0.21	0.04
8	Sample D8	0.00	2.12	0.04	0.15	0.04
9	Sample D9	0.02	4.80	0.06	0.13	0.04
10	Sample D10	0.00	0.09	0.02	0.19	0.04
11	Sample D11	0.01	2.41	0.01	0.21	0.04

12	Sample D12	0.00	27.10	0.09	0.20	0.04
13	Sample D13	0.01	0.80	0.02	0.21	0.05
14	Sample D14	0.01	4.59	0.07	0.16	0.05
15	Sample D15	0.01	4.80	0.16	0.32	0.07
16	Sample D16	0.00	10.08	0.18	0.24	0.06
17	Sample D17	0.00	1.72	0.13	0.27	0.06
18	Sample D18	0.02	6.86	0.20	0.51	0.06
19	Sample D19	0.02	8.06	0.01	0.93	0.05
20	Sample D20	0.01	0.00	0.14	0.29	0.05

Table 3 depicted that Lead was found to have a high mean concentration across the samples with mean value of 0.3295 followed by cobalt with mean value of 0.2980 and the least heavy metal with low mean value is Cd which is having mean concentration of 0.0010. Thus, it is concluded that lead is having the high concentration among the heavy metals across the 20 samples.

TABLE 3: table of mean concentration of the heavy metals at Daura

S/N	heavy_metals	Mean Concentration (ppm)	Std. Deviation
1	Cadmium Cd	0.0010	0.03042
2	Arsenic As	0.0795	14.38684
3	Cobalt Co	0.2980	0.35036
4	Lead Pb	0.3295	0.19204
5	Chromium Cr	0.0550	0.02039

The location, sample codes, longitude and latitude of the Daura is depicted in Table 3**.**

TABLE 4: Table of Daura sample collection location, sample codes and their coodinates

S/N	NAME OF LOCATION	SAMPLE CODES	LONGITUDE	LATITUDE
1.	GDJSS Daura	D1	12^{0} 57` 0” N	8^{0} 13` 0” E
2.	Daura 1	D2	13^{0} 2` 0’’ N	8^{0} 19` 0” E
3.	Daura 2	D3	13^{0} 1` 0’’ N	8^{0} 20` 0” E
4.	Mazaji	D4	13^{0} 00` 0’’ N	8^{0} 17` 0” E
5.	Danakola	D5	12^{0} 59 `0’’ N	8^{0} 13` 0” E
6.	Buja	D6	13^{0} 4` 0’’ N	8^{0} 11` 0” E
7.	Yarogel	D7	13^{0} 3` 0’’ N	8^{0} 15` 0” E
8.	Tsabu	D8	13^{0} 2` 0’’ N	8^{0} 10` 0” E
9.	Durgawa	D9	13^{0} 0 `0’’ N	8^{0} 12` 0” E
10.	Tambo	D10	12^{0} 59 `0’’ N	8^{0} 16` 0” E
11.	Kaya	D11	12^{0} 58 `0’’ N	8^{0} 14` 0” E
12.	Kigo	D12	12^{0} 55 `0’’ N	8^{0} 13` 0” E
13.	Sharawa	D13	12^{0} 56 `0’’ N	8^{0} 15` 0” E
14.	Turanini	D14	12^{0} 54 `0’’ N	8^{0} 16` 0” E
15.	BundoBoki	D15	12^{0} 57 `0’’ N	8^{0} 17` 0” E
16.	Modobi	D16	12^{0} 56 `0’’ N	8^{0} 17` 0” E
17.	Kurada	D17	12^{0} 57 `0’’ N	8^{0} 17` 0” E
18.	Sodoji	D18	12^{0} 57 `0’’ N	8^{0} 18` 0” E
19.	Gurjia	D19	13^{0} 0 `0’’ N	8^{0} 20` 0” E
20.	Tambu	D20	13^{0} 0 `0’’ N	8^{0} 16` 0” E

Table 3 compares the concentration of five heavy metals (Cadmium, Arsenic, Cobalt, Lead, and Chromium) in Daura with the World Health Organization (WHO, 2011) and National Agency for Food and Drug Administration and Control (NAFDAC) standards. It shows that :

Cadmium (Cd) concentration in Daura has the value of 0.0010 ppm which is below WHO and NAFDAC permissible limits.

Arsenic (As) concentration in Daura is 0.0795 ppm which exceeds both WHO and NAFDAC limits. Arsenic is one of the most dangerous heavy metals due to its carcinogenic properties. The WHO standard for arsenic is 0.010 ppm, while NAFDAC's stricter standard is 0.0013 ppm. The concentration of arsenic in the study area (0.0795 ppm) is nearly 8 times higher than the WHO limit and over 60 times higher than the NAFDAC permissible limit.

Cobalt (Co) concentration in Daura is 0.2980 ppm and it is above WHO and NAFDAC permissible limits. Cobalt is an essential trace element in small amounts but becomes toxic at high concentrations. The WHO and NAFDAC permissible limits for cobalt are set at 0.005 ppm. However, cobalt concentrations in the study area (0.2980 ppm) is nearly 60 times above the safe limit.

Lead (Pb) concentration in Daura is 0.3295 ppm which significantly exceeds WHO and NAFDAC permissible limits. However, lead concentration in the area (0.3295 ppm) is over 30 times higher than WHO’s permissible limit.

Chromium (Cr) concentration is 0.0550 ppm slightly exceeded WHO and NAFDAC permissible limits. The concentration of chromium level in the study area (0.0550 ppm) slightly exceeded the acceptable limit.

TABLE 5: Table of comparison of this work result and international standard

S/N	Heavy_Metals	Mean conc at daura(This research) ppm	W.H.O Standard (ppm)	NAFDAC Standard. (ppm)
1	Cd	0.0010	0.003	0.0030
2	As	0.0795	0.010	0.0013
3	Co	0.2980	0.005	0.0050
4	Pb	0.3295	0.010	0.0110
5	Cr	0.0550	0.050	0.0500

Figure 1. show the of heavy mean concentration and presence metals (Cd,As,Co,Pban Cr) in the water sample collected from Daura; it futher shows thatLead (Pb) and cobalt (Co) have the highest concentrations, which are concerning from a health perspective. Lead, in particular, poses significant risks even at low levels, so the presence of 0.3295 ppm warrants investigation into potential sources and public health interventions.Arsenic (As) and chromium (Cr) are also present at moderate levels. While chromium levels are lower and may not pose an immediate threat, arsenic is still concerning as it is a known carcinogen and toxic substance. Chronic exposure could lead to long-term health issues. The absence of measurable cadmium is a positive aspect, as cadmium is highly toxic even in small amounts. However, it’s important to confirm that this lower value is not due to measurement issues and that cadmium isn't being introduced into the environment in other ways that might have been overlooked.

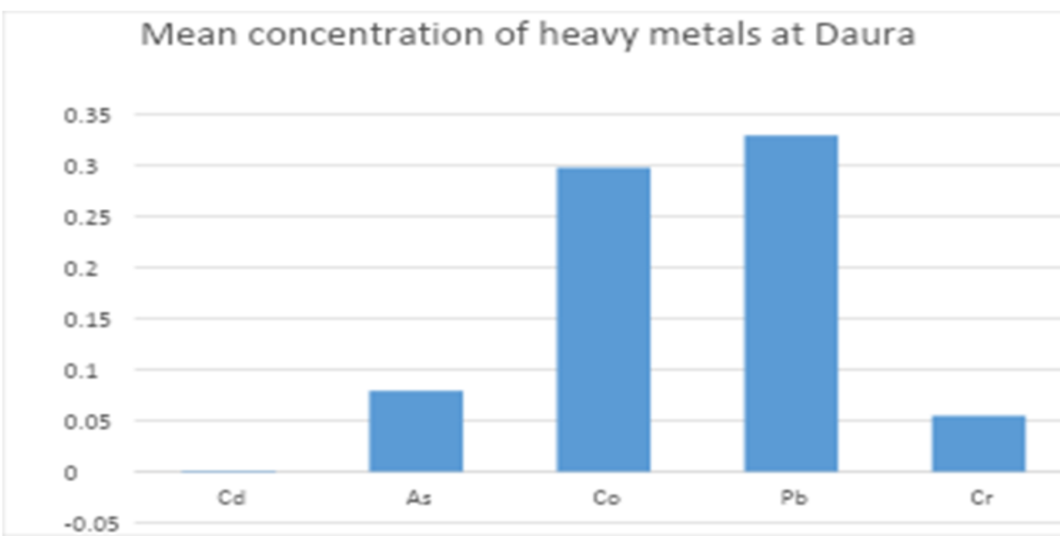

Figure 1. Mean concentration of heavy metals at Daura L.G.A

Figure 2. shows the distribution of lead concentration across different areas. Regions like Daura 1 and Daura 2 located at North-Estern part show the highest lead concentrations (greater than 0.75 ppm). These areas are marked with the darkest colors on the map. Locations such as Tambu and Gurjiya located at Northern part have moderate lead concentrations (0.45 to 0.61 ppm), indicated by lighter shades.

Areas like Tsabu and Durgawa located at North-western partexhibit the lowest lead concentrations (0.13 to 0.29 ppm), shown in the lightest colors.The map suggests that, lead concentration varies significantly across different elevations, with higher elevations generally showing higher concentrations.

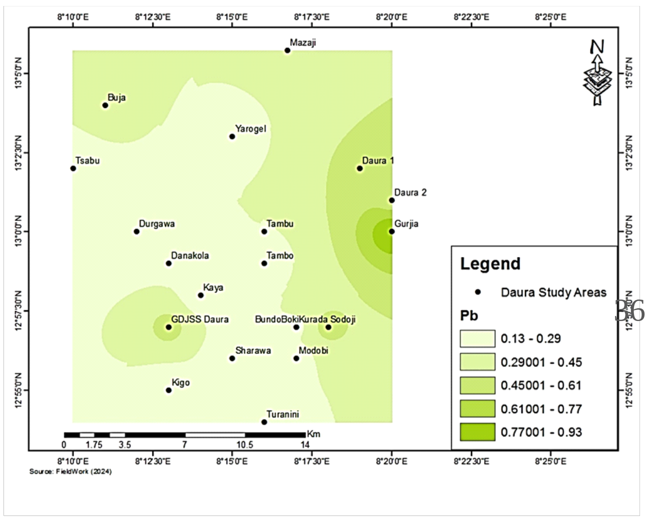

Figure 2. Contour Map showing the variation Concentration of Lead in Daura L.G.A

Figure 3 indicating highlight the distribution of chromium concentration using a contour map across different elevations. Regions like Daura 1 and Daura 2 located at North-Estern part show the highest chromium concentrations (0.09201 to 0.11 ppm), marked in the darkest shades. These areas are typically at lower elevations.

Locations such as Tambu and Gurjiya located at North-Estern part have moderate chromium concentrations (0.05601 to 0.074 ppm), indicated by medium shades.

Areas like Tsabu and Durgawa located at North-western part exhibit the lowest chromium concentrations (0.02001 to 0.038 ppm), shown in the lightest shades.

The map suggests that chromium concentration tends to be higher in lower elevations and decreases as elevation increases.

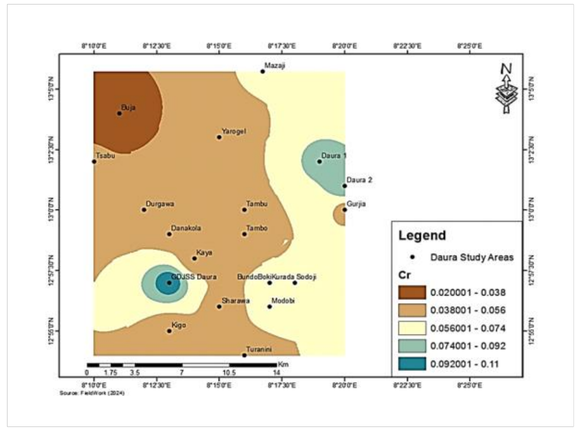

Figure 3. Contour Map showing The variation Concentration of Chromium in Daura L.G.A

Figure 4 is contour map that shows the distribution of cadmium concentration across different elevations. Regions like Mazaj and Tambu located at the Northern part show the highest cadmium concentrations (0.02 to 0.049998 ppm), marked in yellow.

These areas are typically at lower elevations.Locations such as Daura 1 and Daura 2 located at North-Estern part have moderate cadmium concentrations (0.01 to 0.019 ppm), indicated by blue shades.

Areas like Tsabu and Durajka exhibit the lowest cadmium concentrations (0.069 to 0.04 ppm), shown in green.

The map suggests that cadmium concentration tends to be higher in lower elevations and decreases as elevation increases.

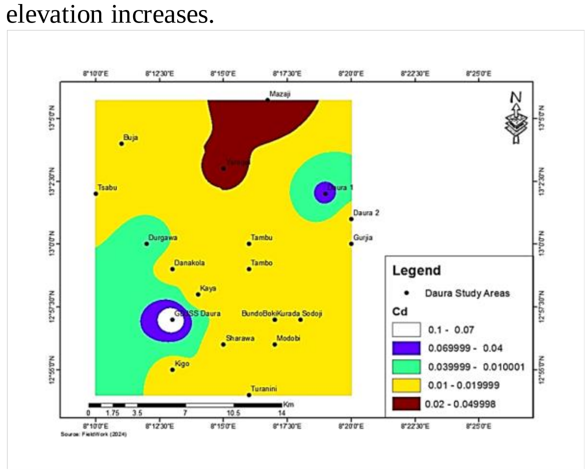

Figure 4. Contour Map showing The variation Concentration of Cadmium in the study Area

Figure 5 contour map shows the distribution of arsenic concentration across different elevations. Regions like Mazaji and the area between Daura 2 and Gurjiya located at North-Estern part show the highest arsenic concentrations (above 0.08 ppm), marked in dark brown. These areas are typically at higher elevations. Locations such as Buja and Tsabu located at North-

Wetern part have moderate arsenic concentrations (0.0.49 to 0.08ppm), indicated by brown shades.

Areas like Tsabu and Guria located at North part exhibit the lowest arsenic concentrations (less than or equal to 0.0298 ppm), shown in light beige.The map suggests that arsenic concentration tends to be higher in higher elevations and decreases as elevation lowers.

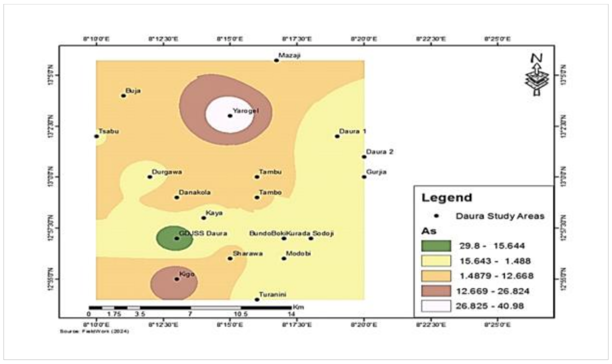

Figure 5. Contour Map showing The variation Concentration of Arsenic in the study Area

Figure 6 shows the distribution of cobalt concentration across different elevations.

Regions like Buja and Yarogel located at the North show the highest cobalt concentrations (above 0.03301 ppm marked in red. These areas are typically at lower elevations. Locations such as Dura 2 and Tambulocated at the North-Estern have moderate cobalt concentrations (0.57401 to 1.062 ppm) indicated by green shades. Areas like sodoji and Kurada located at South-Estern Part exhibit the lowest cobalt concentrations (0.0009954 to 0.258 ppm shown in dark blue.

The map suggests that cobalt concentration tends to be higher in lower elevations and decreases as elevation increases.

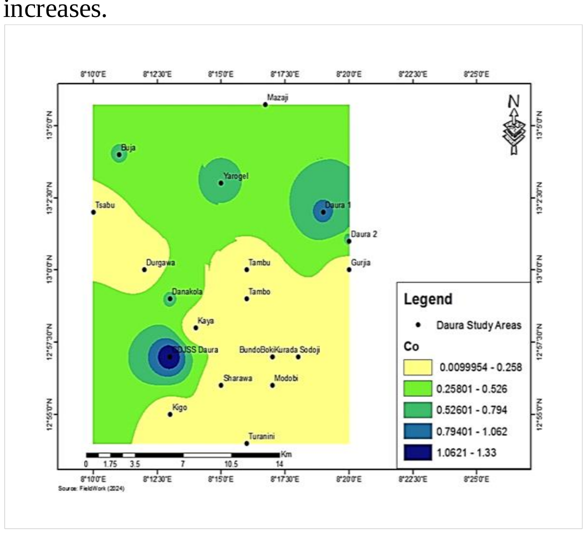

Figure 6. Contour Map showing the variation Concentration of Cobalt in the study Area

CONCLUSION

The concentration levels of heavy metals (Cd, As, Co, Pb, and Cr) in water samples collected from Daura Local Government Area, Katsina State, were analyzed using a Microwave Plasma Atomic Emission Spectrometer (MP-AES). The results were compared with the permissible limits set by the World Health Organization (WHO) and the National Agency for Food and Drug Administration and Control (NAFDAC). The findings clearly indicate that the concentrations of all selected heavy metals exceeded the acceptable limits established by both WHO and NAFDAC, revealing that the metals are present at hazardous levels. Consequently, this points to significant heavy metal pollution in the area, highlighting the urgent need for intervention and remediation by relevant authorities. To help preserve environmental quality, it is strongly discouraged to establish industries or factories in the region. Additionally, implementing water treatment methods is recommended to lower the levels of heavy metal contamination.

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