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Exploration of concentration and variation of heavy metals in some borehole water from basement formation In Charanchi local government, Katsina state of Nigeria

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Abstract

Heavy metals such as lead, arsenic, and cadmium can contaminate water sources and pose serious health risks when consumed. Considering their potential health implications, this research aims to investigate the concentration and variation of heavy metals in some borehole water from basement formation in Charanchi local government area of Katsina state. The objectives are to identify heavy metals and their levels of concentration, understand the variation of heavy metals across the study area, and compare the result with the internationally accepted standard concentration value. Twenty borehole water samples were collected, and the coordinates of the various locations were taken using a handheld GPS. Microwave plasma Atomic Emission spectrometer (MP-AES) was used to analyze the concentration of the five heavy metals (Cd, As, Co, Pb, and Cr), and the mean concentration in part per million (ppm) was obtained using statistical analysis. The results obtained show that Charanchi local government Borehole's water has an average heavy metal (Cd, As, Co, Pb and Cr) concentration of 0.0301, 14.058, 0.303, 0.113 and 0.050 (ppm) respectively. The differences were obtained by comparing the mean concentration of the heavy metals in the study area with that of the World Health Organization (W.H.O) and NAFDAC threshold limit standard. It was observed that the samples were contaminated with arsenic (As) metal which has high-risk implications. There is a 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, especially arsenic in the study area.

Keywords: MP-AES; Heavy metals; NAFDAC; Threshold limit; W.H.O; Pollution

1. Introduction

Katsina State, located in northern Nigeria, is characterized by diverse geological formations and mineral deposits. The region's geology plays a significant role in influencing the composition of groundwater and the potential for contaminants such as heavy metals. Heavy metals are defined as any metallic chemical element that has a relatively high density and toxic or poisonous at low concentrations. They also include large group of elements that are important for both industry and biology and have an atomic density of more than 6g/cm^3 (Iyaka and Kakulu, 2019). Heavy metals are deleterious due to their long biological half-lives, non-biodegradable nature, and their ability to accumulate in different body parts (Kankara *et al*, 2021). Heavy metals are characterized by persistence and biomagnification effects that can cause adverse impacts on the aquatic ecosystems (kumar *et al,* 2022). The level of heavy metals in an aquatic system is an important indicator of the health of the aquatic ecosystem (kumar *et al,* 2022). The heavy metals in aquatic systems originate from both natural sources (mainly atmospheric deposition, erosion, leaching and weathering of rocks). This can be found in a variety of forms, such as minerals that are attached to airborne particles, encased in organic or inorganic compound found in soil, rocks, and sand. (Samaila *et al*, 2023). Heavy metal pollution causes a noteworthy threat in agricultural fields (Bhagure and Mirgane, 2010).

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Water is one of the most abundant substances on earth and is a principal constituent of all living things. It is important for water meant for ingestion to be free from all kinds of contamination (Olayiwola, 2013). Anthropogenic activity leads to the accumulation of heavy metals in an environment which leads to environmental pollution (Sultan *et al*., 2017*)*. Food is also one of the major sources of ingestion of heavy metals in humans, particularly all categories of vegetables. One of the most essential aspects of food quality assurance is the assessment of heavy metal contamination of the food items which water is not excluded (Rafi and Gowda, 2017). There is growing concern all over the world as the accumulation of metals increases the direct and indirect risk to human beings. (Vysetti *et al*., 2014). In the last decade, more emphasis has been placed on measuring heavy metal concentration in water and soil because most of the heavy metal in plants comes from water and soil. (Xiang *et al*., 2021). Conducting this study will create awareness regarding the levels of these contaminants in the area. The absence of prior studies emphasizes the need for comprehensive research like this to understand the current state of water quality to heavy metals in charanchi.

1.1. The Study area

The study area is Charanchi local government area located in katsina state. Its landscape is characterized by savannah vegetation and semi-arid climate. The region witnesses distinct heat and dry seasons. It is bound by longitude: 07°30′0″E and latitude: 12°28′39″N (Figure 1.) The elevation ranges from 490 to 579m as shown in Figure 2.

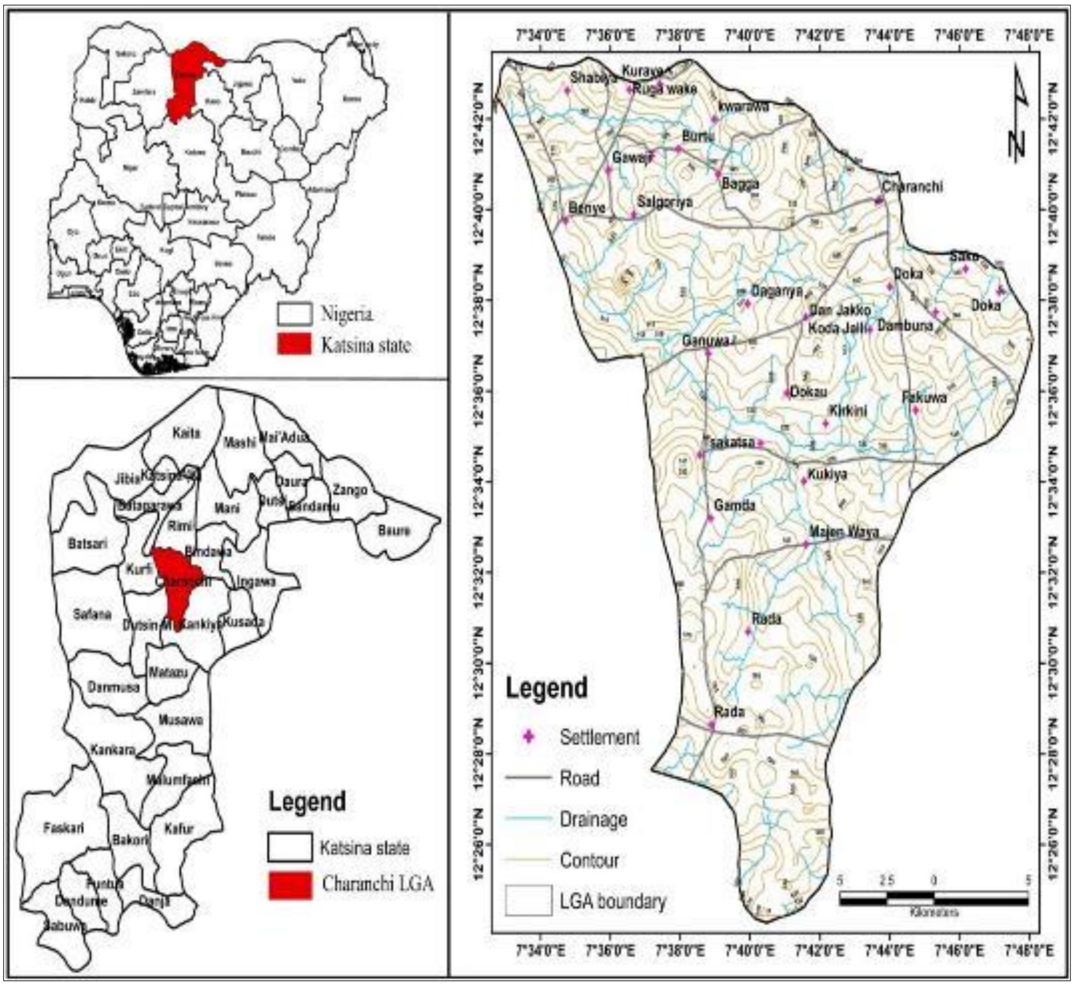

Figure 1 Showing the map of the study area

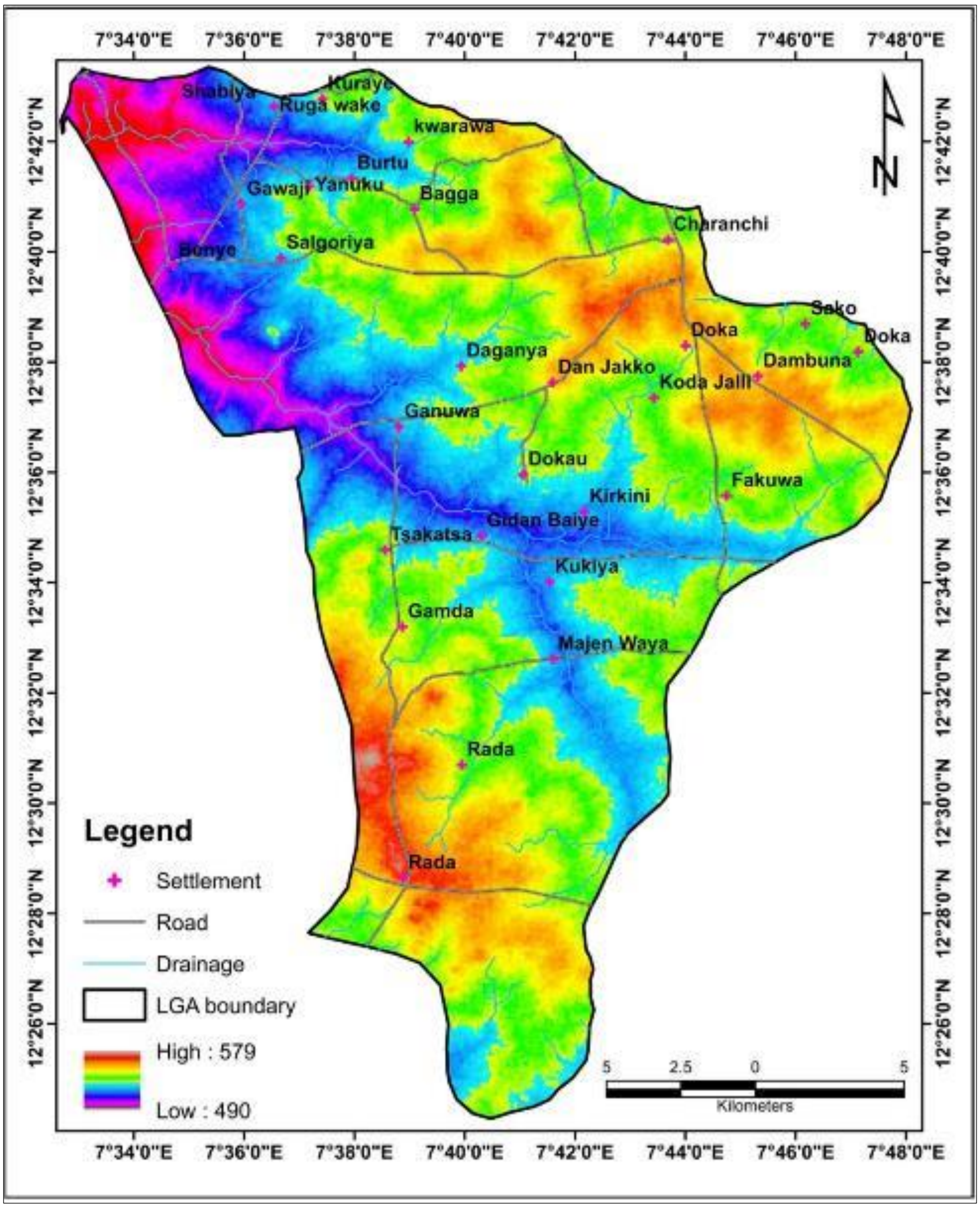

Figure 2 Elevation map of the study area

1.2. Regional Geology of the Study Area

Generally, the geology of the north-western region which Katsina State is part of consists of the following main units: migmatite - gneiss Basement Complex, younger metasediments and metavolcanics, granites, younger granite, igneous rocks, and sedimentary rocks (Figure 3). Parts of the State are underlain by granites with lateritic capping in some of them. There are also the Daura Igneous Complex rocks and the Gundumi and Chad sedimentary formations (Kogbe, 1975). Outcrops consist almost entirely of resistant migmatites, quartzites, conglomerates and granites, although there is small exposure of softer gneisses and semi-pelitic rocks in some stream channels. Rocks of the migmatite-gneiss basement complex constitutes the majority to real extent (McCurry, 1970). The younger metasediments are the second most abundant rock type (occupying about 33% of the State), while most of the western part is underlain by the granites. Others include the Chad Sedimentary Formation and the Gundumi Formation which occupy about 15% of the total area of Katsina State. The least exposed rocks are the Daura Younger Granite rocks located in Zango LGA of the State. The contact relationship between most of the rocks could only be inferred because exact contacts between the rocks have been concealed by overlying material (Rahaman, 1971).

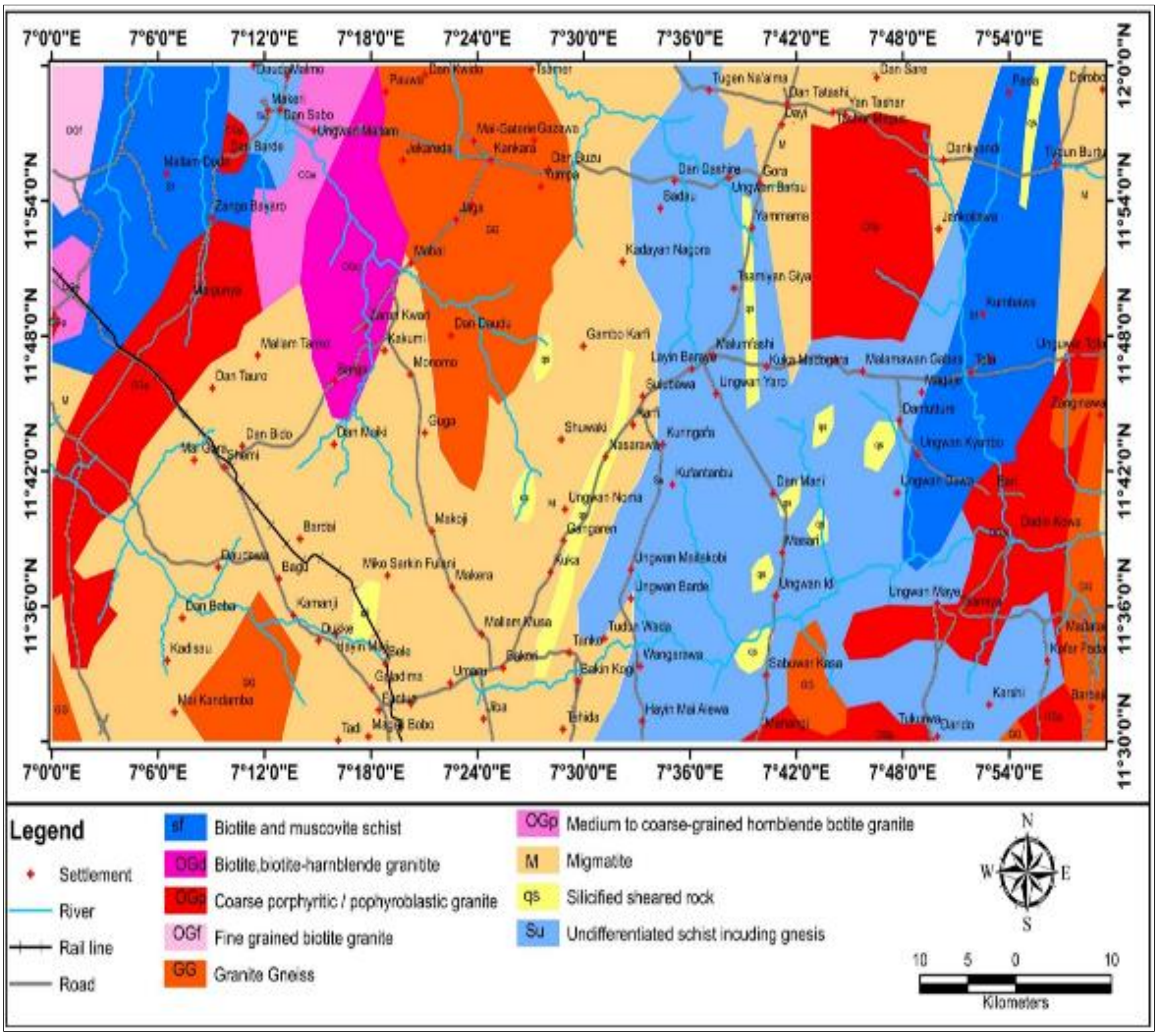

Figure 3 Geological map of the study area

2. Material and methods

The materials used in this study were conical flasks, plastic containers, 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 and Sample collection map for Charanchi local government (Figure 4).

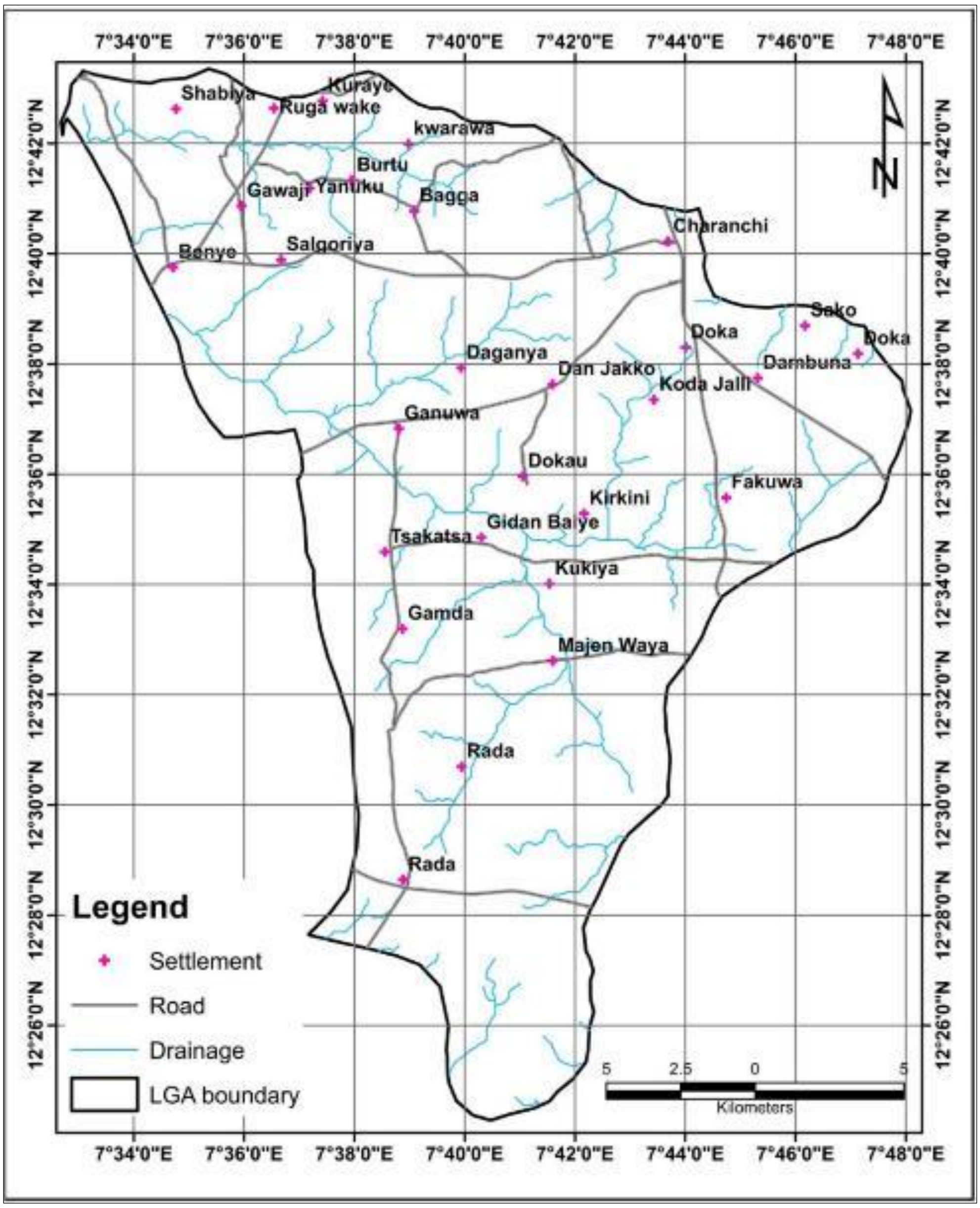

Figure 4 Sample collection map for Charanchi local government

2.1. Samples Collection

A total of 20 Borehole water samples were collected using 2L sampling bottles. The samples were collected after the boreholes were allowed to run for about 5-10 minutes before collection. The bottles were filled and sealed after concentrated HNO_3 acid was added to prevent absorption and precipitation of particulates on the container's wall. A handheld GPS device was used to record the corresponding coordinates of the locations where the samples were collected. The collected samples were then transported to the laboratory for preparation.

2.2. Samples Preparation

100ml of the water sample was measured with a measuring cylinder,5ml concentrated Nitric acid, and a few drops of hydrogen peroxide were added to it. The solution was then transferred into a conical flask and heated on the hot plate for two hours. It was then transferred into a 100ml volumetric flask and deionized water was added to fill up to the mark where it was filtered and transferred into the pre-cleaned sample bottles and taken for further MP-AES analysis. The same procedure was repeated for each of the water samples.

2.3. Samples Analysis

The heavy metals analysis was carried out using a Microwave Plasma Atomic Emission spectrometer (MP-AES) at the Center for Dry Lab, Department of Agriculture, Bayero University. The basic principle is that once an atom of a specific element is excited by providing it an external energy it emits radiation (light) in a characteristic pattern of wavelengths forming an emission spectrum, as it returns to the ground state. Different concentrations of standard solutions were run on the instrument to obtain the calibration curves for each metal using measured Emission and the corresponding concentration. The instrument was set to zero by reading a reagent blank. Each of the prepared samples was aspirated into the instrument and read three (3) times, the average value of the concentration was taken for each metal in each sample. The values obtained in the standard materials in this work were compared with the certified values. Distilled and Deionized water was used throughout the experiment and all reagents used are of analytical grades.

2.4. WHO And NAFDAC Threshold Limit

There are maximum acceptable limits of heavy metal contamination accepted by the world organizations which are used to serve as a global standard worldwide. The two (2) organizations taken into consideration are the World Health Organization (WHO) and the National Agency for Food and Drugs Administration and Control (NAFDAC) Nigeria. Table 1 indicates the acceptable concentration limit/ranges of heavy metals in drinking water by the WHO and NAFDAC.

Table 1 Table of WHO and NAFDAC Threshold Limit (Lavanya *et al,*2021)

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

3. Results and discussion

The location, sample codeS, longitude and latitude of the study area are depicted in (Table 2)

Table 2 Table of Charanchi Sample Collection location, sample codes and their coordinates

S/N	Name Of Location	Sample Codes	Longitude	Latitude
1	Burtu	C1	12^0 42` 0’’ N	7^0 38` 0” E
2	Salgoriya	C2	12^0 40` 0’’ N	7^0 37` 0” E
3	Baggai	C3	12^0 41` 0’’ N	7^0 40` 0” E
4	Daganya	C4	12^0 38` 0’’ N	7^0 41` 0” E
5	Fakuwa	C5	12^0 36` 0’’ N	7^0 46` 0” E
6	Dan Jakko	C6	12^0 38` 0’’ N	7^0 42` 0” E
7	Doka	C7	12^0 39` 0’’ N	7^0 48` 0” E
8	Dokau	C8	12^0 37` 0’’ N	7^0 41` 0” E

9	Kirkini	C9	12^0 35` 0”N	7^0 44` 0” E
10	Gidan Baiye	C10	12^0 37` 0” N	7^0 42` 0” E
11	Kwarawa	C11	12^0 43` 0” N	7^0 41.5` 0” E
12	Sako	C12	12^0 49.3` 0” N	7^0 46` 0” E
13	Ganuwa	C13	12^0 37^0 `0” N	7^0 40` 0” E
14	Gamda	C14	12^0 33.8` 0” N	7^0 40` 0” E
15	Kukiya	C15	12^0 34.3` 0” N	7^0 42` 0” E
16	Tsakatsa	C16	12^0 35` 0” N	7^0 35` 0” E
17	Majen Wayya	C17	12^0 33` 0” N	7^0 42` 0” E
18	Charanchi	C18	12^0 41` 0” N	7^0 44` 0” E
19	Banye	C19	12^0 40` 0” N	7^0 35` 0” E
20	Dambuna	C20	12^0 38` 0” N	7^0 46` 0” E

Table 3 shows the results from the Microwave Plasma Atomic Emission spectrometer (MP-AES). It can be observed that there is a variation in concentration across the samples.

Table 4 shows the various mean concentrations of heavy metals in the study Area. Arsenic tends to have a high mean concentration among the samples with a mean value of 14.0580 followed by lead with a mean value of 0.1130 and the least heavy metal with a low mean value is Cd which has a mean concentration of - 0.0305.

Table 3 Table of The Heavy Metals Concentration of Charanchi

Sample Code	Cd (228.802 nm)	As (193.695 nm)	Co (340.512 nm)	Pb (405.781 nm)	Cr (425.433 nm)
Sample C1	0.01 (ppm)	11.50 (ppm)	0.07 (ppm)	0.14 (ppm)	0.15 (ppm)
Sample C2	0.00 (ppm)	89.52 (ppm)	2.15 (ppm)	0.22 (ppm)	0.06 (ppm)
Sample C3	-0.02 (ppm)	5.44 (ppm)	0.38 (ppm)	0.28 (ppm)	0.17 (ppm)
Sample C4	-0.03 (ppm)	8.84 (ppm)	0.21 (ppm)	0.26 (ppm)	0.06 (ppm)
Sample C5	-0.04 (ppm)	13.70 (ppm)	0.04 (ppm)	0.03 (ppm)	0.04 (ppm)
Sample C6	-0.05 (ppm)	12.04 (ppm)	0.09 (ppm)	0.02 (ppm)	0.02 (ppm)
Sample C7	-0.05 (ppm)	3.81 (ppm)	1.00 (ppm)	-0.10 (ppm)	0.02 (ppm)
Sample C8	-0.03 (ppm)	9.42 (ppm)	0.07 (ppm)	0.13 (ppm)	0.04 (ppm)
Sample C9	-0.04 (ppm)	9.51 (ppm)	0.24 (ppm)	0.14 (ppm)	0.07 (ppm)
Sample C10	-0.04 (ppm)	21.31 (ppm)	0.29 (ppm)	-0.13 (ppm)	0.04 (ppm)
Sample C11	-0.05 (ppm)	-0.25 (ppm)	0.13 (ppm)	0.21 (ppm)	0.07 (ppm)
Sample C12	-0.04 (ppm)	7.68 (ppm)	0.10 (ppm)	0.22 (ppm)	0.04 (ppm)
Sample C13	-0.03 (ppm)	5.95 (ppm)	0.04 (ppm)	0.02 (ppm)	0.00 (ppm)
Sample C14	-0.06 (ppm)	10.86 (ppm)	0.06 (ppm)	0.18 (ppm)	0.03 (ppm)
Sample C15	-0.05 (ppm)	-0.63 (ppm)	0.07 (ppm)	0.26 (ppm)	0.02 (ppm)
Sample C16	-0.03 (ppm)	4.04 (ppm)	0.06 (ppm)	0.16 (ppm)	0.04 (ppm)
Sample C17	-0.02 (ppm)	2.05 (ppm)	0.12 (ppm)	-0.01 (ppm)	0.02 (ppm)
Sample C18	-0.01 (ppm)	21.63 (ppm)	0.26 (ppm)	0.06 (ppm)	0.02 (ppm)

Sample C19	0.00 (ppm)	21.42 (ppm)	0.43 (ppm)	0.02 (ppm)	0.02 (ppm)
Sample C20	-0.03 (ppm)	23.95 (ppm)	0.25 (ppm)	0.15 (ppm)	0.07 (ppm)

Table 4 Table of Mean Concentration of the Heavy Metals at Charanchi

S/N	Heavy Metals	Mean	Std. Deviation
1	Cd	-.0305	.01905
2	As	14.0580	19.20925
3	Co	.3030	.48699
4	Pb	.1130	.11886
5	Cr	.0500	.04267

Figure 5 shows the mean concentration and presence of heavy metals (Cd, As, Co, Pb and Cr) in the water sample collected from Charanchi; It further shows that the area with higher concentration of cadmium and arsenic when compared to the standard limit of NAFDAC and WHO, which could indicate a potential source of contamination in the area. The significantly higher arsenic level at Charanchi is a concern, as it can have health effects. Cobalt, lead and chromium concentrations were within the limit in the study area, suggesting a consistent geological or environmental factor.

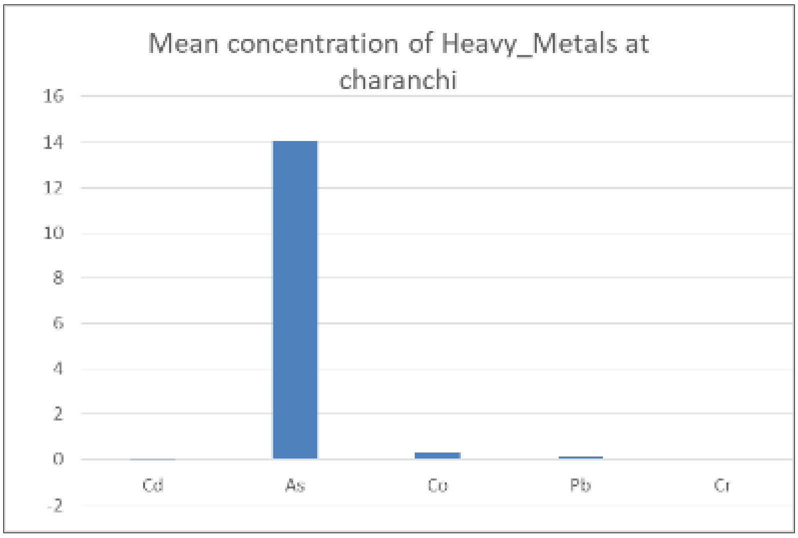

Figure 5 The mean concentration of Heavy Metals at Charanchi

Figure 6 is the contour map of the study area showing the variation in Arsenic concentration across the area.

Regions like Banye, Salgonya, and Daganya in the North-western part show the highest arsenic concentrations (greater than 7.59 ppm), marked in reddish, yellowish and greenish. These areas are typically at lower elevations.

Locations such as Dambuna and Dan Jakko have moderate arsenic concentrations (3.45 to 5.74 ppm), indicated by orange shades.

Areas like Fakuna and Tsakatsa in the North-eastern part exhibit the lowest arsenic concentrations (0.6761 to 1.75 ppm), depicted in green.

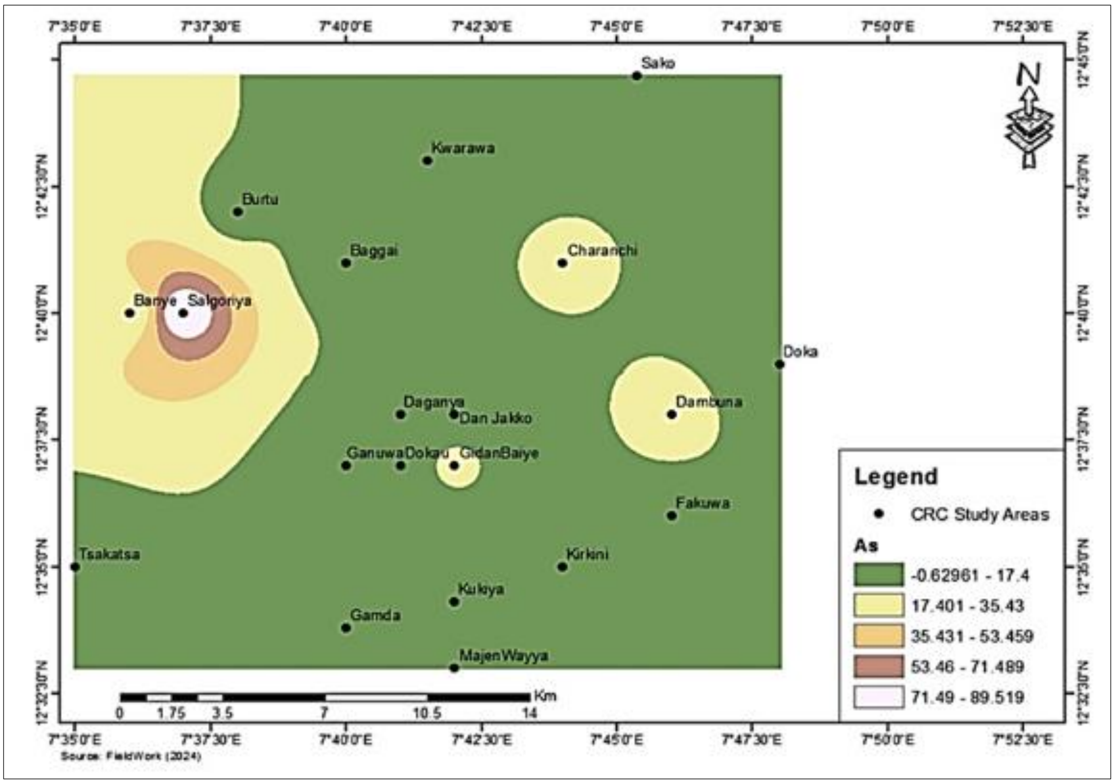

Figure 6 Contour Map showing the variation Concentration of Arsenic in the study area

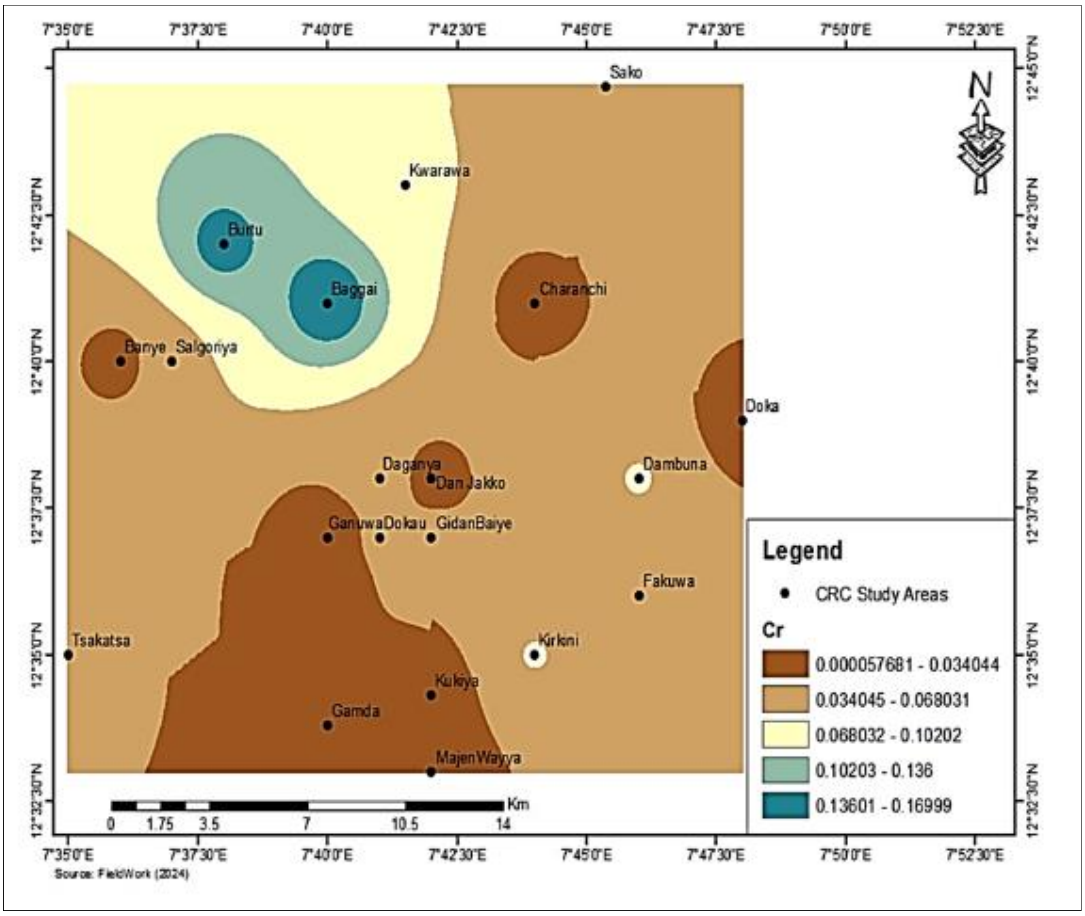

Figure 7 Contour Map showing the variation of Concentration of Chromium in study Area

Figure 7 is the contour map that shows the distribution of chromium concentration across different elevations.

Regions like Kukiya and Majen Waya located at southern part show the highest concentration chromium concentrations (0.13901 - 0.16969 ppm), marked in dark blue. These areas are typically at lower elevations.

Locations such as Ganuwa and Daganya located in the Northern part have moderate chromium concentrations (0.068032 - 0.10202 ppm), indicated by medium shades.

Areas like Doka and Fakuwa located at North-Eastern part exhibit the lowest chromium concentrations (0.0003654 - 0.063034 ppm), shown in light brown.

Figure 8 is a contour map that shows the distribution of cadmium concentration across different elevations.

Regions like doka and charanchi located in the Northern-Eastern part show the highest cadmium concentrations (0.05676 - 0.04397 ppm), marked in dark shades. These areas are typically at lower elevations.

Locations such as Kwarawa and Bagga located at Northern part have moderate cadmium concentrations (-0.03116 - -0.01837 ppm), indicated by medium shades.

Areas like Tsakatsa and Gidan baiye located at western part exhibit the lowest cadmium concentrations (-0.04396 - -0.03117ppm), shown in light shades.

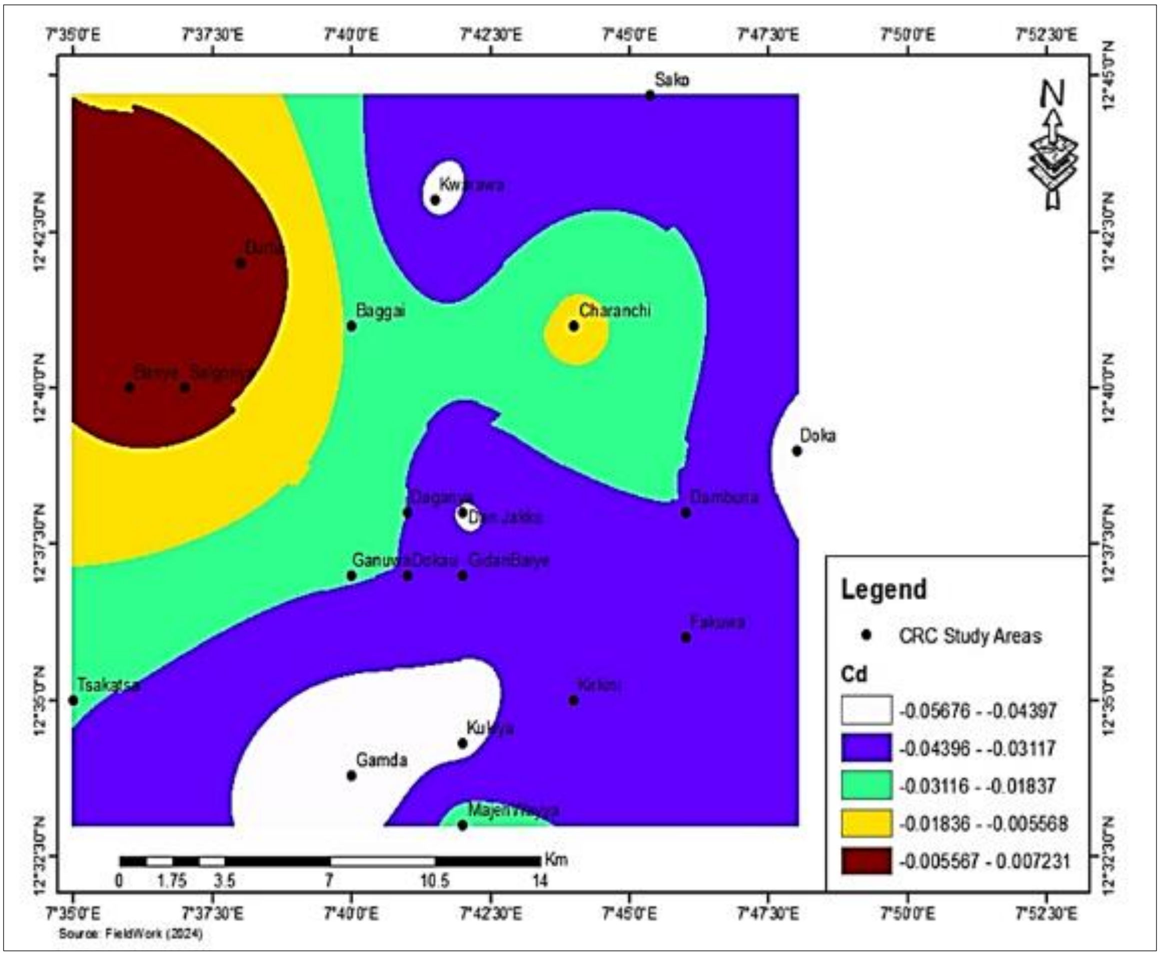

Figure 8 Contour Map showing the variation Concentration of Cadmium in the study Area

Figure 9 is the contour map that shows the distribution of cobalt concentration across different elevations.

Regions like Kavumu and Bujumbura located at western part show the highest cobalt concentrations (0.46204 to 0.48204 ppm), marked in dark blue. These areas are typically at lower elevations.

Locations such as Kwarawa and Charanchi located in the Northern part have moderate cobalt concentrations (0.44205 to 0.46203 pmm), indicated by medium blue shades.

Areas like Tsakatsa and Fakuwa located in the Eastern part exhibit the lowest cobalt concentrations (0.38208 to 0.40206 pmm), shown in yellow.

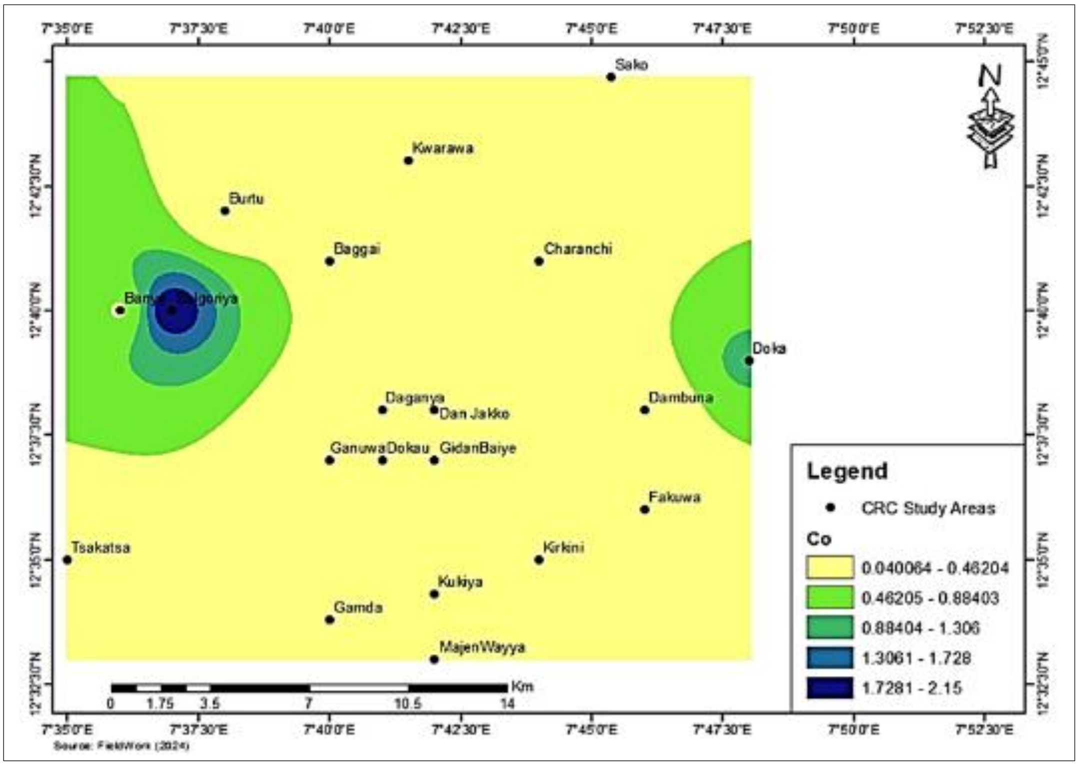

Figure 9 Contour Map showing the variation of Concentration of Cobalt element in the study area

Figure 10 is the contour map showing the distribution of lead concentration across different elevations.

Regions like Danjakko and Daganya located in the North-western part show the highest lead concentrations (0.279605 - 0.759390 ppm), marked in dark shades. These areas are typically at lower elevations.

Locations such as Dokau and Kirkini located at Eastern part have moderate lead concentrations (0.11603 - 0.19799ppm), indicated by medium shades.

Areas like Tsakatsa and Fakuwa located at Eastern part exhibit the lowest lead concentrations (0.012987 - 0.043290 ppm), shown in light shades.

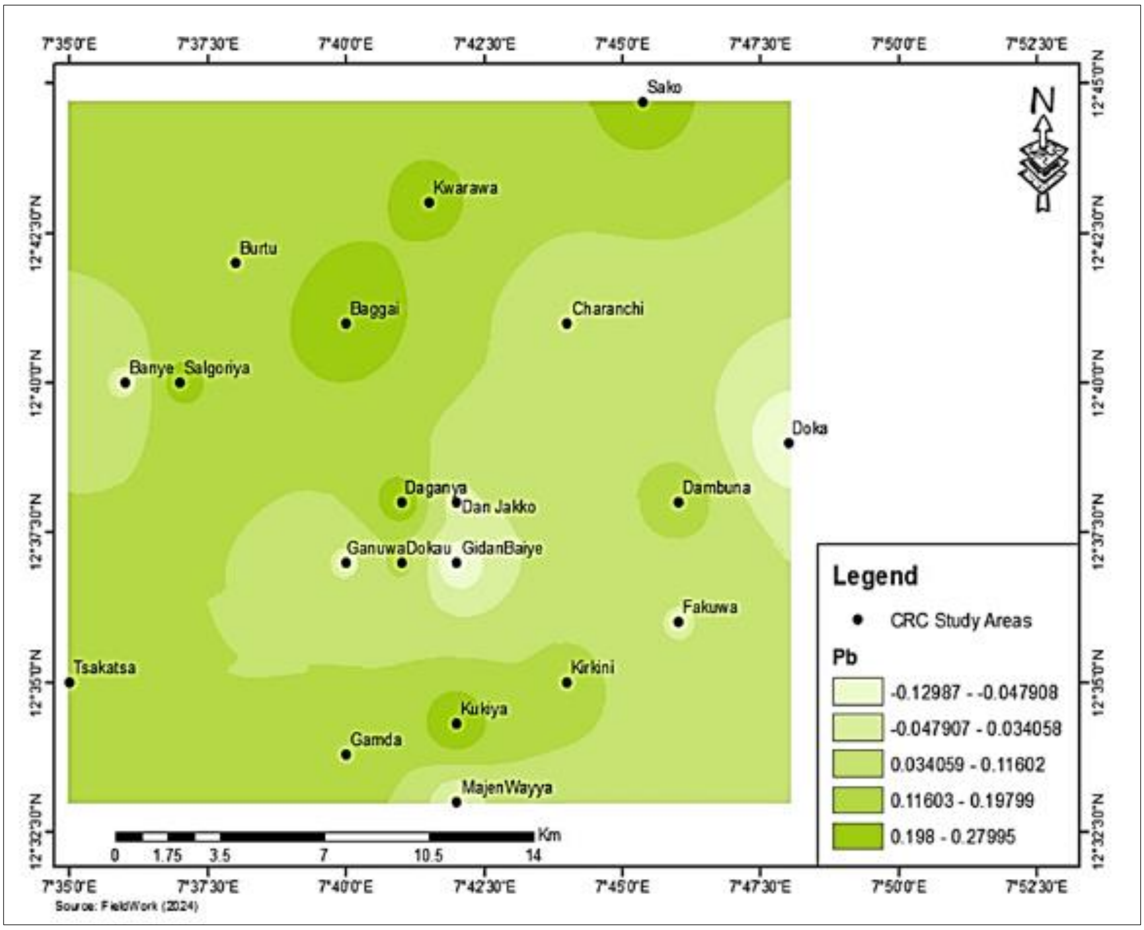

Figure 10 Contour map showing the variation of concentration of Lead element in the study Area

4. Conclusion

Microwave Plasma Atomic Emission spectrometer (MP-AES) was used to analyze the concentration of heavy metals (Cd, As, Co, Pb and Cr) in water samples collected from Charanchi local government areas of Katsina state. The acquired result was contrasted with the WHO and NAFDAC threshold limit. Comparatively, it is abundantly obvious that the concentration of the chosen heavy metals in the study regions is not above the threshold limit of the World Health Organization (W. H.O.) and the National Agency for Food and Drugs Administration and Control (N.A.F.D.A.C) standards and all the metals discovered have legal concentration with the exception Arsenic in the area. Hence, there is a need for urgent remediation. The variations in concentration may be because of geochemical processes and the topography of the study area. result from

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Adelekan B. A. and Abegunde K. D. (2011). Heavy Metals Contamination of Soil and Ground water at automobile mechanic villages in Ibadan, Nigeria. International Journal of the Physical Sciences vol. 6(5), pp. 1045-1058.

[2] Bhagure G. R. and Mirgane S. R. (2010). Heavy metals Contaminations in groundwater and soils of Thane Region of Maharashtra, Indian. Environ. Monit Assess pp. 1-10

[3] Ibrahim, K. O., Orosun, M. M., Purchase, M. W., & Yusuf, M. A. (2024). Environmental Assessment of Heavy Metal Pollution around Industrial Area in Southwestern, Nigeria. Journal of Sustainable Natural Resources, 5(1), 40-51.

[4] Iyaka, Y.A and Kakulu, S.E. (2019). Heavy metal concentrations in top Agricultural soils around ceramic and pharmaceutical Industries Sites in Niger state, Research journal Environmental and Earth sciences 4(2):171-176, 2012 ISSN: 2041-0492

[5] Kankara, U. M., Rabiu, N., Nuraddeen, N., Garba, Jamila, M. K. and Umar, M. (2021). Assessment Of Heavy Metal Concentration in Vegetables Dried Along Funta-Danja Highway Katsina State, Nigeria. Fudma journal of science. 5(1):467-471.

[6] Kogbe, C.A., (1975). Geology of Northwest Nigeria. A Review of Geology of Nigeria. Elizabethan Publication Co. Lagos.

[7] Kumar, V. V., Rimjhim, S., Garagu, S. A., Valappil, N. N.,and Rakhavan, R. P. (2022). Heavy metal contamination, distribution and source apportionment in the sediments from Kavvayi Estuary, South-west coast of India. Total Environment Research Themes, 3, 100019.

[8] Lavanya kannan, Gokulprasath M, Ragul Gurusamy, Ranjithkumar Selvam, Radha Palaniswamy. (2021). Analysis Of Heavy Metals Contamination in Water: A Review. Ijrar.Org (E-ISSN 2348-1269, P- ISSN 2349-5138

[9] McCurry, P., (1970). The Geology of Degree Sheet 21 (Zaria) Unpublished M.Sc Thesis. Ahmadu Bello University Zaria, Nigeria.

[10] Ogarekpe, N. M., Nnaji, C. C., Oyebode, O. J., Ekpenyong, M. G., Ofem, O. I., Tenebe, I. T., and Asitok, A. D. (2023). Groundwater quality index and potential human health risk assessment of heavy metals in water: A case study of Calabar metropolis, Nigeria. Environmental Nanotechnology, Monitoring & Management, 19, 100780.

[11] Olayiwola, O. A. 2013, Accumulation and contamination of heavy metals in soil and vegetation from industrial Area of Ikirun, Osun state, Nigeria, Global journal of pure and Applied chemistry Research Vol.1 Issue No.1 pp.25-34, june.2013.

[12] Rafi, M., and GowdaT, P. (2017). Determination of heavy metal analysis in vegetable samples of Bengaluru and Tumukur some marketplaces, Karnataka, India (issue 4).

[13] Rahaman, M.A., (1971). Classification of Rocks in the Nigerian Precambrian Basement Complex, (Abs) at 5th Annual Conf. of Nigerian Mining, Geol. and Metall. Soc., Kaduna.

[14] Samaila, A., Bello, S., Salele, S. and Iliyasu, S. R. (2023). Analysis of Some Heavy Metal Background Concentration at Dandagoro Quarters, Katsina, Katsina State, Nigeria. UMYU Scientifica, 2(1), 133 – 139.

[15] Samaila, A.Bello.S., Iliyasu,S.R. and Sani,M.(2022). The background concentration of some heavy metals at nysc orientation camp layout katsina. Fudma journal of science. 2022-0604-1051

[16] Shamsuddin, I. M., Yahaya, K. M., & Shawai, S. A. A. (2018). Determination of level of the concentration of some heavy metals in water from Jibiya dam, Katsina state. MOJ Biorg Org Chem, 2 (5), 243-245.

[17] soils of Thane Region of Maharashtra, India. Environ Monit Assess pp. 1-10

[18] Sultana, M. S., Rana, S., Yamazaki, S., Aono, T., Yoshida, S., and Kanan, S. (2017). Health risk assessment for carcinogenic and non-carcinogenic heavy metal exposures from vegetables and fruits of Bangladesh. Cogent Environmental Science, 3(1), 1291107.

[19] Uba, S., Ajibola, V.O.,Adeosun, O.S., Ikeh, D.C., Mikail, A.H., Awe, J.O.2 and Ruma, M .M. (2021). Quantitative Assessment Of Pollution Status Of Heavy Metals In The Water From Mairua Dam, Faskari Lga, Katsina State, Northwestern Nigeria. Bayero Journal of Pure and Applied Sciences, 14 (2): 95 - 100.

[20] Uba, S.,Mohammed, R. M., Ado, F. M., Abubakar, S., & Isyaku, S. (2020). Risk Assessment of Selected Heavy Metals in Water and Sediment of Shika Dam, Zaria, Nigeria. SLU Journal of Science and Technology, 1 (1), 95-111.

[21] Vysetti, B., Vummiti, D., Roy, P., Taylor, C., Kamala, C. T., Satyanarayanan, M., and Abburi, K. (2014). Analysis of geochemical samples by microwave plasma-AES. Atomic Spectroscopy, 35(2), 65-78.

[22] Xiang, M., Li, Y., Yang, J., Lei, K., Li, Y., Li, F., and Cao, Y. (2021). Heavy metal contamination risk assessment and correlation analysis of heavy metal contents in soil and crops. Environmental Pollution, 278, 116911.

[23] Yang, S., Tomas, D. Xianfeng, C., Qianrui, H. (2017). Risk Assessment of Heavy Metal Pollution in Soils of Gejiu Tin Ore and Other Metal Deposits of Yunnan Province. In IOP Conference Series. Earth and Environmental Science. 95-4-042078.

[24] Yusuf Abdulrashid And Nuraddeen Abdurrahman. (2020). Assessment of some heavy metals in drinking water consume within katsina metropolis 2020-0403-303.