

Assessment of some heavy metals distribution and their possible human health risks: A case study of parts of Langtang south area, middle Benue trough, Nigeria

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Abstract: An investigation on the distribution of heavy metals in some parts of Langtang South area located within the middle Benue Trough of Nigeria was carried out with the aim of determining their concentration levels for principally environmental assessment and for future mineral exploration studies. The area is characterized by four (4) lithologic formations; Asu River Group, Awe formation, Keana formation and Lafia formation. The area is endowed with abundant Pb-ZnS and BaSO₄ mineralizations. Geochemical analysis of soil samples collected from the area revealed the following heavy metal concentrations; Co = 0.022 - 30.09ppm; Cr = up to 21.64ppm; Ni = 0.02 - 50.67ppm; Cu = 0.39 - 63.77ppm; Zn = 0.04 - 3468ppm; As = up to 465.7ppm; Pb = 0.012 - 9322ppm, Cd = up to 17.74ppm. It is also observed that Co, Cr, Zn, As, Cd, Ni and Cu have relatively low spatial distribution pattern in Agri and Bolya villages as well as its surroundings while high spatial distribution pattern of these elements are observed in Jigawa ba da Goshi. However, Pb is observed to have high spatial distribution pattern in almost all northern parts of the mapped area including Agri, Jigawa ba da Goshi and Bolya villages. The concentrations of heavy metals in water samples decreases in the order Cu(223μg/l) > As(75.3μg/l) > Co(28μg/l) > Ni(27.8μg/l) > Pb(14.3μg/l) > Cr(6.8μg/l) > Zn(2.008μg/l) > Cd(1μg/l) and these are greater than the recommended no-effect values in water. The calculated daily intake of metal showed that the heavy metals portent potential human health risks in decreasing order of Cu > As > Cd. Health risk index found for these heavy metals was less than one suggesting that the consumption of such waters is safe and therefore pose no human health risks. However, the cumulative intake of such heavy metals over a long period of time may cause serious human health problems.

Keywords: Heavy Metals, Health Risks, Middle Benue Trough, Langtang South

1. Introduction

Many people are oblivious of the danger posed as a result of their interactions with the environment. The environment being the storehouse of many metals release them through a range of media including stream sediments, soils and waters [1]; [2]. These metals find their way into natural water bodies, or are remobilized into soils [3]. They originated from both natural and anthropogenic sources containing heavy metals which accumulate in the media and subsequently enter the human body through several pathways including food and water intake, dermal contact and inhalation [4], [5], [6]. It is

imperative to understand that once they enter into the system, they are deposited in bones and fat tissues, overlapping noble minerals and cause several diseases and to some extent death [7]. They are often problematic environmental pollutants, with well-known toxic effects on living systems [8]; [9] especially when they are more than the standard required for consumption in the area. High concentrations of heavy metals such as Cd, Cr, Cu, Mn, Ni, Pb and Zn causes wide range diseases in humans such as abdominal pain, hypertension, cardiovascular diseases, immune dysfunction, liver diseases, anorexia, and kidney related disorders, as well as various kinds of cancers due to excessive intake in contaminated food and drinking water.

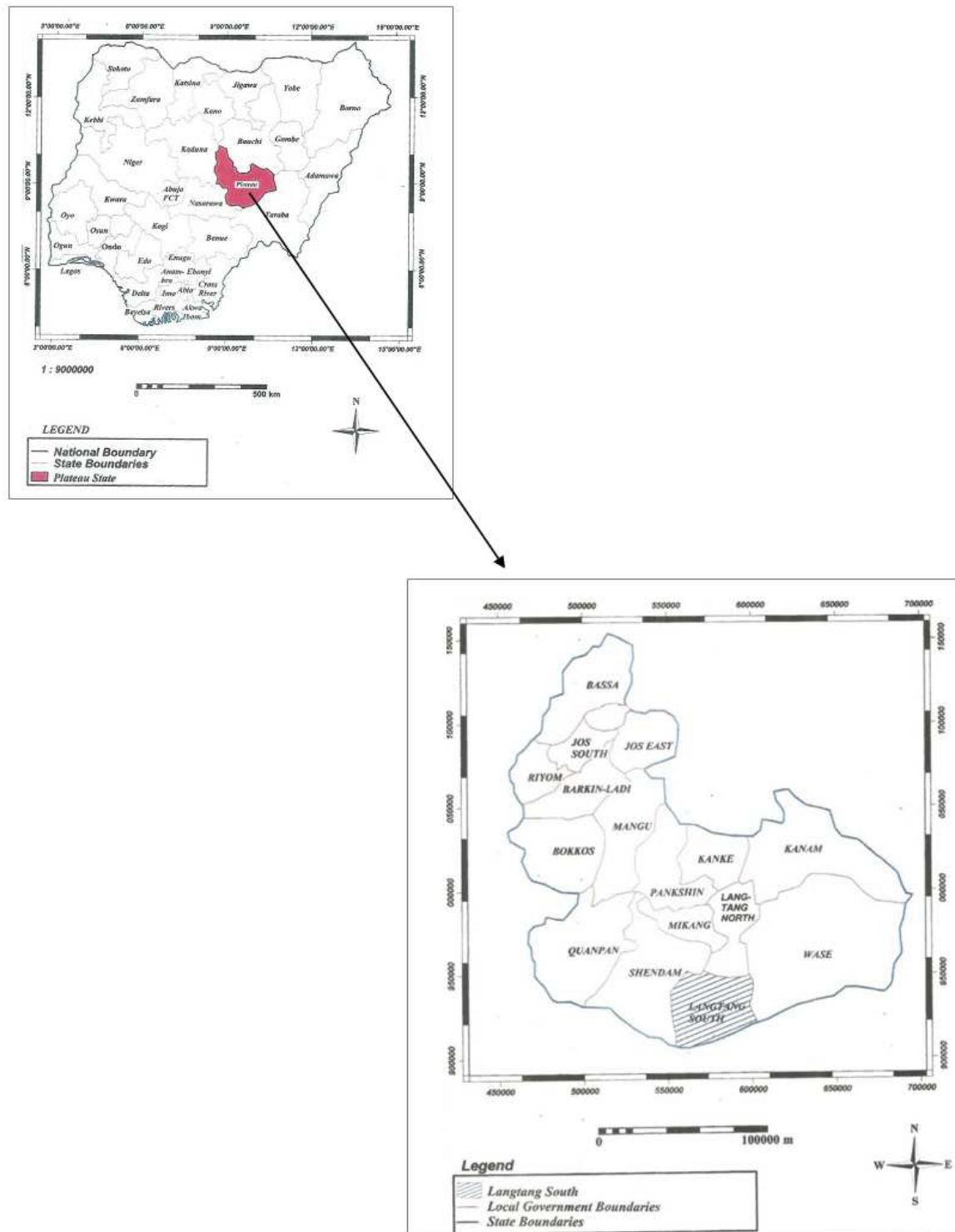


Figure 1. Location of the study area

They study area is faced with the scarcity and inadequacy in portable water supply, hence, surface and shallow water have become the most available source that is directly used for human consumption and domestic uses and as such increases the chance of heavy metal intake. Also, the polluted soil/stream sediments are use for the cultivation of crops and since the toxic metals are non-biodegradable in nature [10], they are transferred and remobilized through the food crops

and directly consumed in the body. Therefore, this study is aimed at establishing and assessing the extent of the distribution of heavy metals and evaluating the health risks indexes in the area since the populace are very vulnerable to the direct exposure of heavy metals in the soils, stream sediments and water.

2. The Study Area

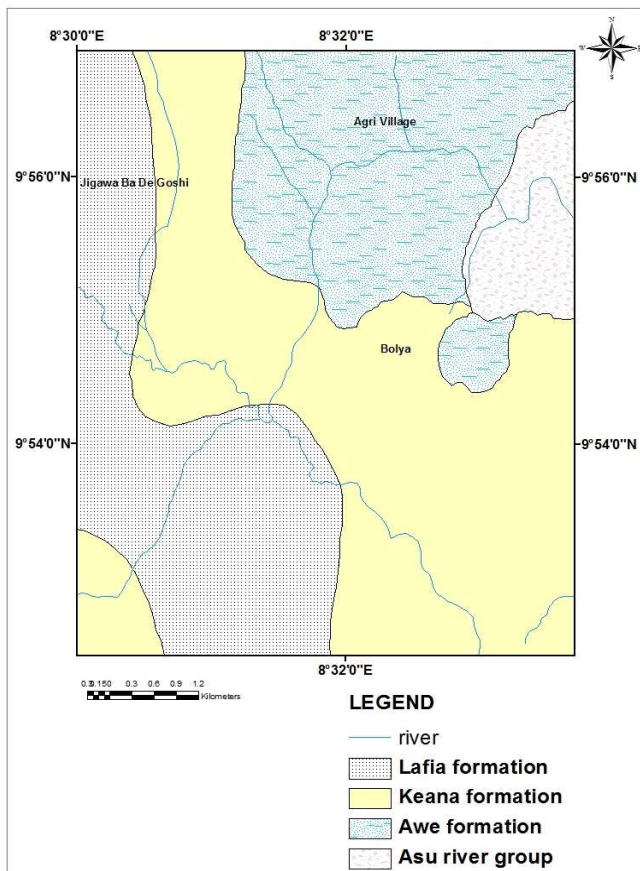


Figure 2. The geology of the study area

The study area is located within Shendam sheet 212 SE and covers an area of 54km² on Latitude 9° 52' 28" to 9° 57' North and Longitude 8° 30' to 8° 33' 42" East (Figure 1). The area is accessible through Mabudi major and minor roads like the Timya to Yamini minor, Jigawa ba de Goshi, Taka lafiya etc. The area is characterized by Guinea savannah with variety of tall as well as short grasses and trees [11]. Agricultural activity is the major occupation of the area with animal rearing and crop productions. The climatic conditions of the area is very typical of the tropics with two distinct rainy seasons; dry and wet seasons with relatively high temperature ranging from 30°C to 33°C witness especially during the dry season. The topography is relatively low with gentle slope towards the valley in the central portion. The drainage pattern is dendritic with major river (Gamakai) flowing in a south east direction which is been fed by several tributaries. However, the rivers are seasonal which prompted the construction of an artificial dam in the area. Surface water is usually polluted due to the presence of cattle and dust from trees leading to contamination of the water. Regrettably, it's this water source that becomes the major water supply to the populace during the dry season. The settlement pattern is characterized and controlled by the availability of the seasonal water bodies and soil fertility forming a nucleated or dispersed settlement. The soil is invariably sandy, loose and coarse grained and often very thick.

3. The Geology of the Study Area

The study area is located within the Middle Benue Trough i.e. at the middle portion of the Nigerian Benue Trough. The Benue Trough itself is a rift basin in Central West Africa that extends NNE–SSW for about 800km in length and 150km in width with Cretaceous-Tertiary Sediments [12]. The Middle Benue Trough is characterized by six (6) lithogenic formations though four (4) are observed in the study area (Figure 2); Asu River Group, Awe formation, Keana formation, Ezeaku formation, Agwu formation and Lafia formation [13]. However, the volcanics are seldom observed in most parts of the basin but extrude especially at the north-eastern parts. The Asu River formation is Mid-late Albian in age and composed of dark micaceous siltstone, fissile shales, mudstone and subordinate clays. They are the oldest known marine geological formation within the basin. The Awe formation is Cenomanian to Turanian in age and overlies the Asu River formation. It is composed of calcareous sandstone, carbonaceous shales and clays. The Keana formation is Campanian to Maastrichian and overlies the Asu River formation. Its lithology consists of whitish coarse feldspathic gritty sandstone which is massive and heavy as a result of water current. Ezeaku formation is Turonian and overlies the Keana formation. It is composed of calcareous shales, micaceous and friable sandstones. It inter-fingers in the transition environment. Agwu formation is Conanian in age and overlies the Ezeaku formation. It is composed of limestone, shales and coal seams and observed around the Lafia-Obi area with thickness covers of not more than 700m [11]. The Lafia formation is Maastrichian in age and deposited within the continental (fluvatile environment). It overlies unconformably on the Agwu formation. It is the youngest formation in the Middle Benue Trough and consists of ferruginized sandstones, red loose sands, flaggy mudstones, clays and clay stone.

4. Geomorphology, Soil and Land Use

The study area is characterized by undulating landscape of low relief which is between 250-300m. Other topographic features include valleys, tributaries and undulating hills. The drainage pattern in the study area is dendritic. The major river Gamakai drains the area in a NNE-SWW flow direction. Human activities such as farming and overgrazing in this area are predominantly dependant on the existence of these tributaries. The area of study is predominantly composed of lowlands with few denudated low lying conical hills which area characterized by flat tops. The soil varies from place to place both in textures and colour depending on the underlying strata. They are invariably sandy, loose and coarse grained and often the covering is thick in some areas, the sand are thick enough to be quarried for construction purposes. Laterization is also observed along most river channels.

5. Materials and Methods

The topographic map of the study area (Shendam sheet 212) was digitized in ArcGIS and gridded for field reconnaissance survey. This reconnaissance survey was to find out exposures and structures and also locate the rivers, streams channels. Stream sediments, soil and water samples were obtained along river channels, farmlands, hand dug wells, stagnant ponds etc. where about 4.5g weight samples of stream sediments and soils were collected at a depth of between 10-15cm for fresh samples and kept in a clear polyethene bags. The samples were then prepared by drying in an oven to remove moisture content and pulverized to powder using an agate mortar and sieve to a size of 80micrometer. About 0.1g of the fines was later dissolved by adding aqua regia to the mixture of hydrochloric acid (HCl) and nitric acid (HNO₃) in a ratio of 3:1 and then heated on a sand bath for about 5-6hours after which deoxidized water in a 100ml volumetric flask is added, filtered out and then loaded for analyses in ICP-OES. Also, the water samples were collected from hand dug wells, stagnant ponds and river channels; and acidified with nitric acid (HNO₃) to preserve the constituents of the water. This was then filtered using filtering cone into a sterilized bottle and then loaded for analyses also in ICP-OES. The analytical techniques employed for all the prepared samples collected from the study area was carried out in the geochemical laboratory of the Department of Geology and Mining, University of Jos. The heavy metals obtained were statistical analyzed in ArcGIS and Microsoft excels to quantify and categorize each element. Subsequently, concentrations of the heavy metals were compared with World Health Organization (WHO) and average crustal abundance standards.

In assessing health risks, the health risk indicators parameters such as chronic daily intakes (CDIs) and health risk indices (HRIs) of metals were calculated for both adults and children from water samples since scarcity of water is eminent and consumption of it is without any treatment and purification. Thus, if the HRI value is less than one, it is considered to be safe for the consumers otherwise it indicate health risks [6], [14].

Therefore, the equation below was used for estimating the chronic daily intake, CDI of the study area from the water sample according to [15]

$$CDI = (C_m \times D_w) / W_b \quad (1)$$

Where, C_m ($\mu\text{g/L}$) is the heavy metal concentration in water

D_w (L/day) is the average daily intake of water

W_b (kg) is the average body weights

A health risk index of the heavy metals was also estimated by Equation (2) [10]; [16].

$$HRI = CDI / R_fD \quad (2)$$

Where, R_fD is the oral toxicity reference dose ($\mu\text{g}/(\text{kg}\cdot\text{day})$)

6. Results

The results obtained from the geochemical analyses for heavy metals of stream sediments, soils and water samples are presented in table 1. Figures 3a and b, 4a and b, 5a and b, 6a and b, 7a and b, 8a and b, 9a and b and; 10a and b show the relative distribution of the concentrations of the analyzed heavy metals in the samples with their respective prediction pattern map. Comparison of the heavy metals in water samples with WHO permissible values [17] (Table 1) are presented thus in figures 11, 12, 13, 14, 15, 16, 17 and 18. Figures 19, 20, 21, 22, 23, 24, 25 and 26 give the comparison between the various concentrations of the heavy metals in the soil and stream sediment samples with that of average crustal abundance of the metals (Table 2). Table 3 present calculated estimates of the mean concentrations of the heavy metals, chronic daily intake and the health risks indexes of water consumption the study area.

Table 2. WHO guidelines for drinking-water quality (2008) and International Standard for Abundance of element in average crustal rocks (Green and Taylor, 1978)

Element (symbols)	Standard health guideline by the WHO in mg/l	Average Abundance
Arsenic, As	0.01	2ppm
Calcium, Ca	15	3.3%
Cadmium, Cd	0.003	0.1ppm
Cobalt, Co	0.001	25ppm
Copper, Cu	0.10	50ppm
Chromium, Cr	0.02	100ppm
Iron, Fe	4.4	4.65ppm
Magnesium, Mg	2.7	1.7%
Nickel, Ni	0.01	75ppm
Lead, Pb	0.01	10ppm
Zinc, Zn	0.2	10ppm

Table 1. Geochemical Analyses of heavy metals in the study area

S/N	Sample name	Sample type	Long. (E)	Lat. (N)	Co (ppm)	Cr (ppm)	Ni (ppm)	Cu (ppm)	Zn (ppm)	As (ppm)	Pb (ppm)	Cd (ppm)
1	TOB 1	Stream sediments	8.510281	9.944008	19.9	21.64	36.68	63.77	09.02	168.7	111.6	17.74
3	TOB 4	Stream sediments	8.529783	9.921025	30.09	13.25	50.67	45.04	2781	321.9	118.3	<DL
4	TOB 5	Stream sediments	8.524253	9.904	12.88	<DL	28.92	21.19	3468	465.7	64.27	<DL
6	TOB 12	Stream sediments	8.506717	9.916683	22.67	<DL	23.73	33.31	2602	156.2	73.03	<DL
8	JJM3	Soil	8.525	9.880556	9.866	<DL	16.76	30.14	2918	113.7	84.89	0.178
9	JJM4	Stream sediments	8.541194	9.947619	2.82	<DL	4.74	10.25	2077	<DL	9322	<DL
10	JJM6	Stream sediments	8.539611	9.945936	1.466	<DL	19.13	42.22	1735	<DL	54.62	<DL

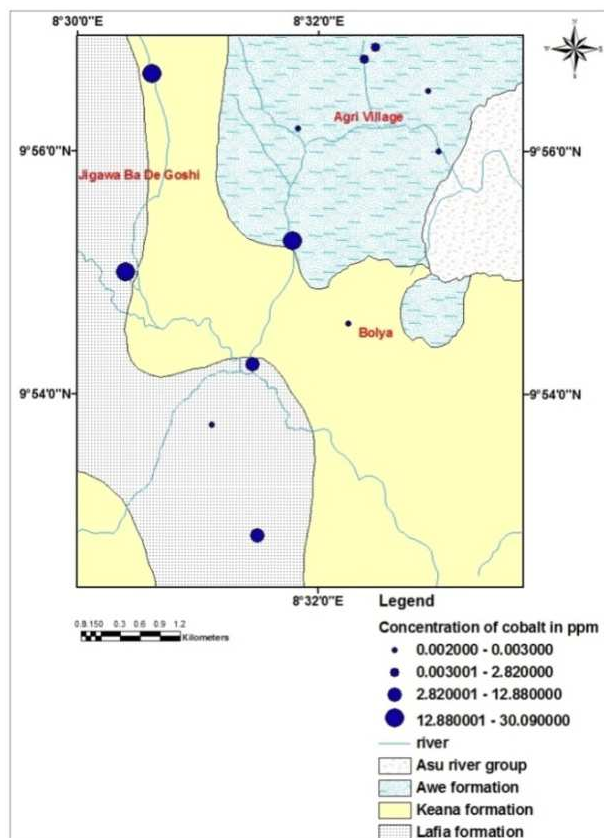


Fig 3a. Cobalt concentration map of the study area

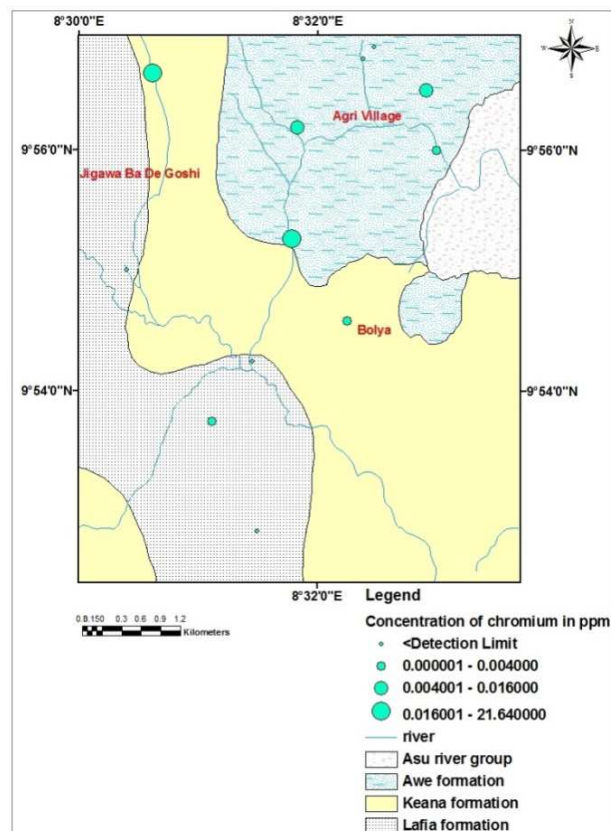


Fig 4a. Chromium concentration map of the study area

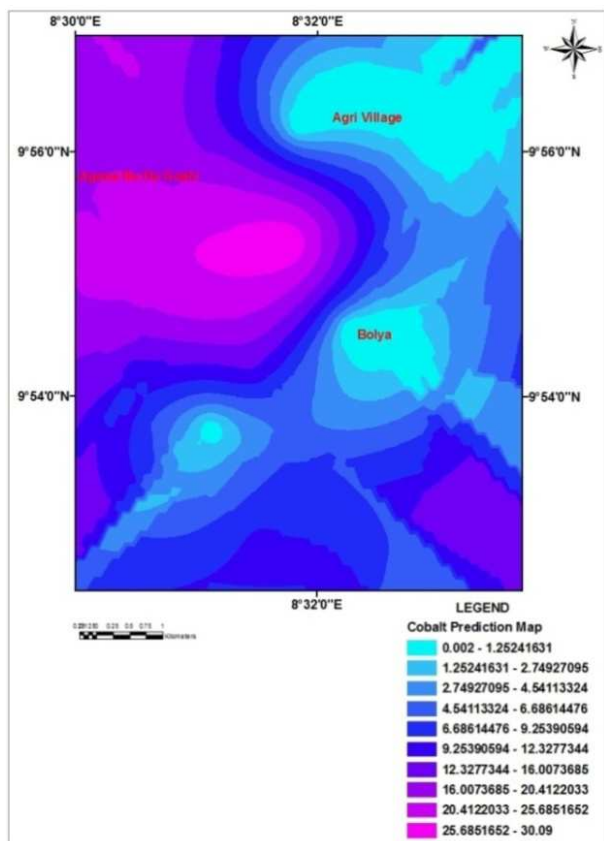


Fig 3b. Cobalt prediction map of the study area

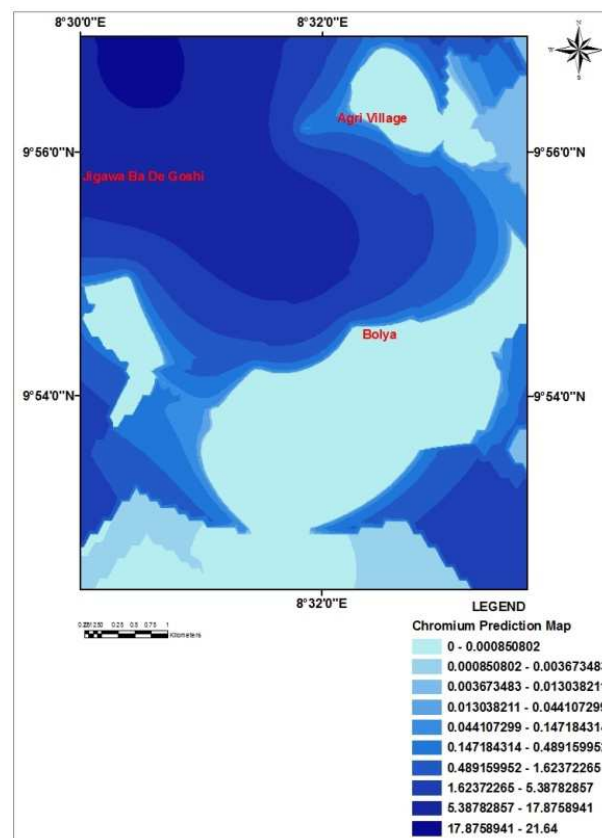


Fig 4b. Chromium prediction map of the study area

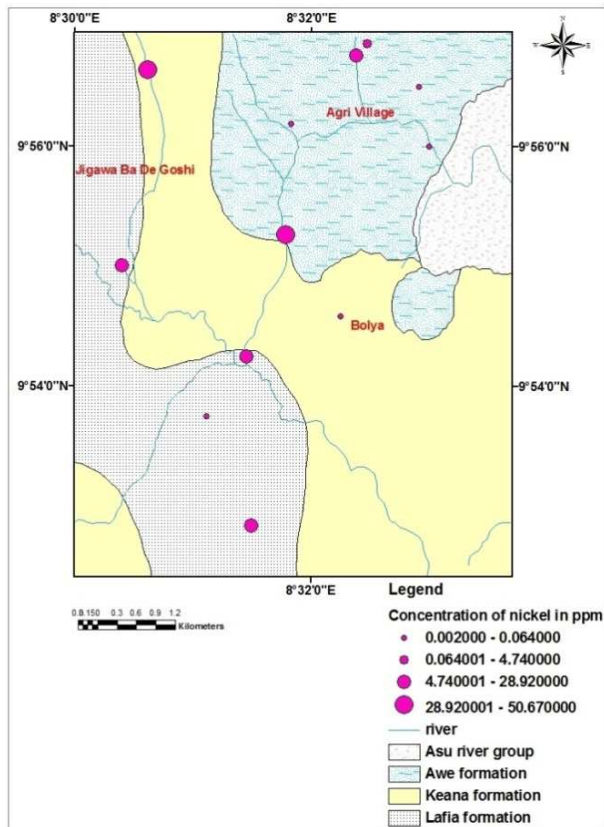


Fig 5a. Nickel concentration map of the study area

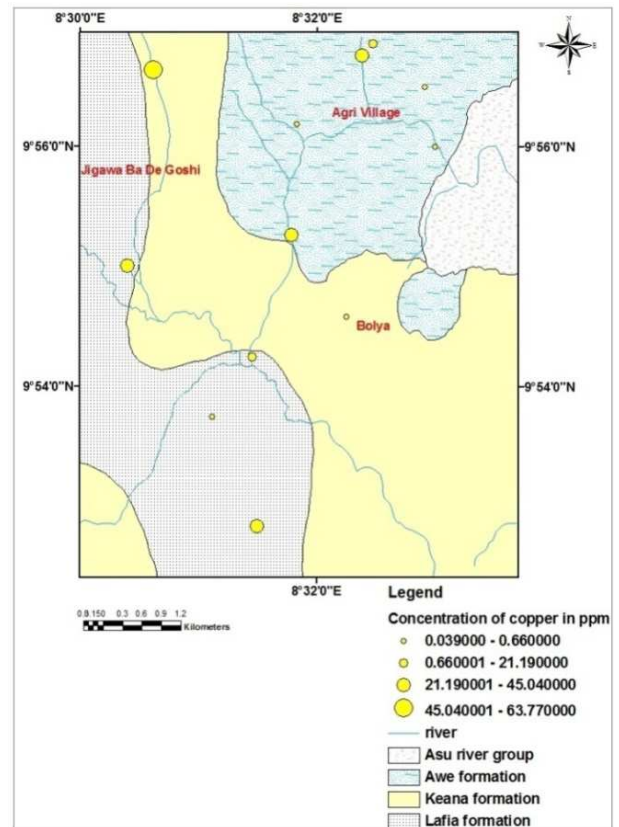


Fig 6a. Copper concentration map of the study area

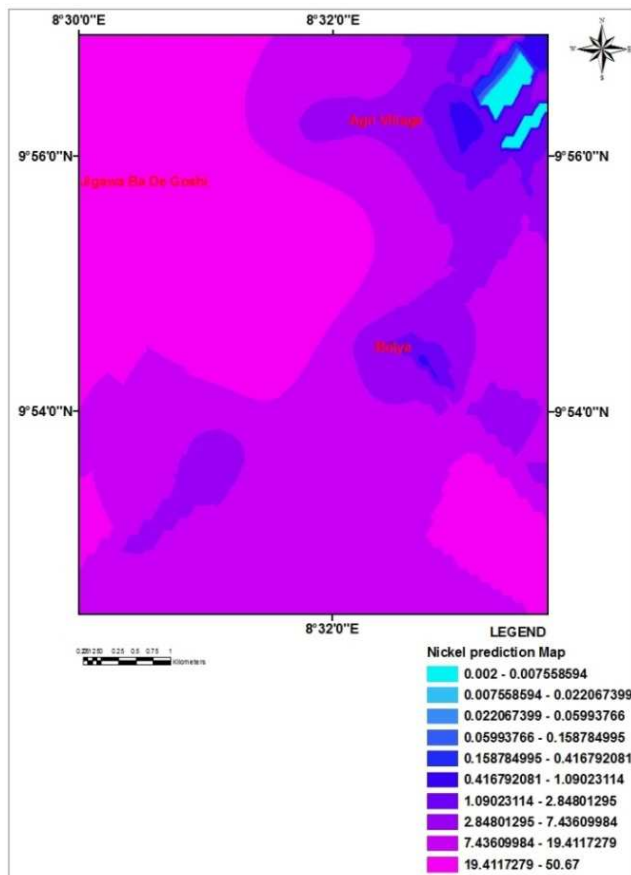


Fig 5b. Nickel prediction map of the study area

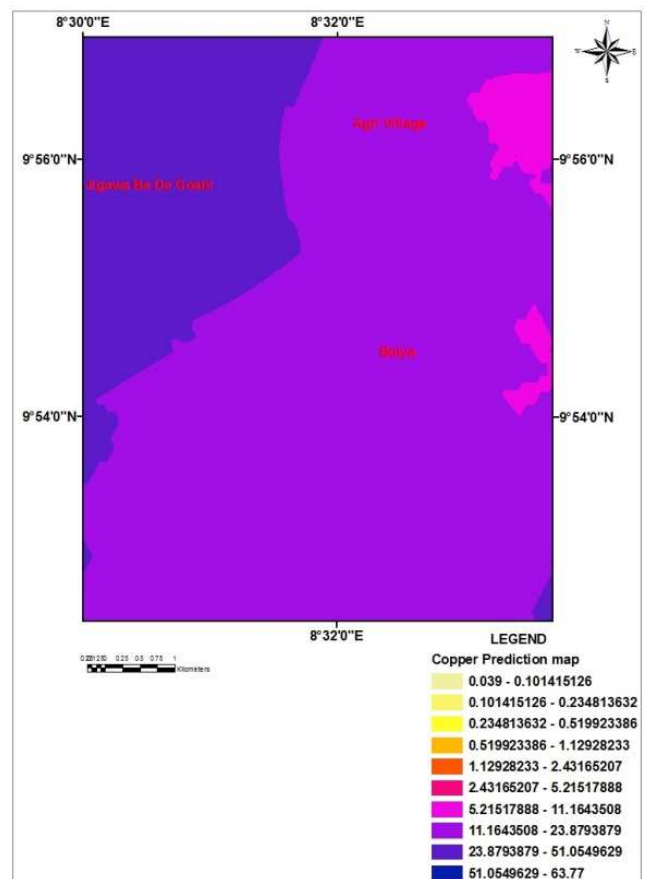
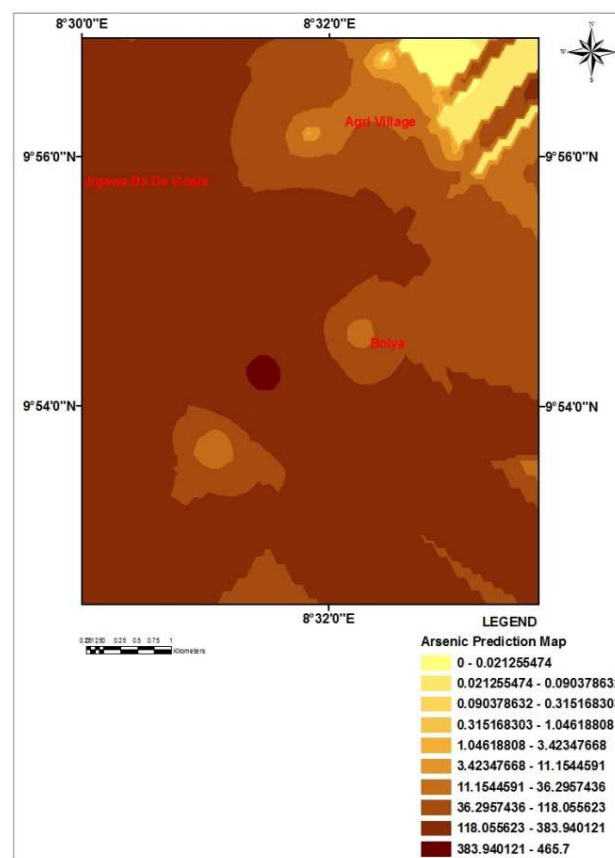
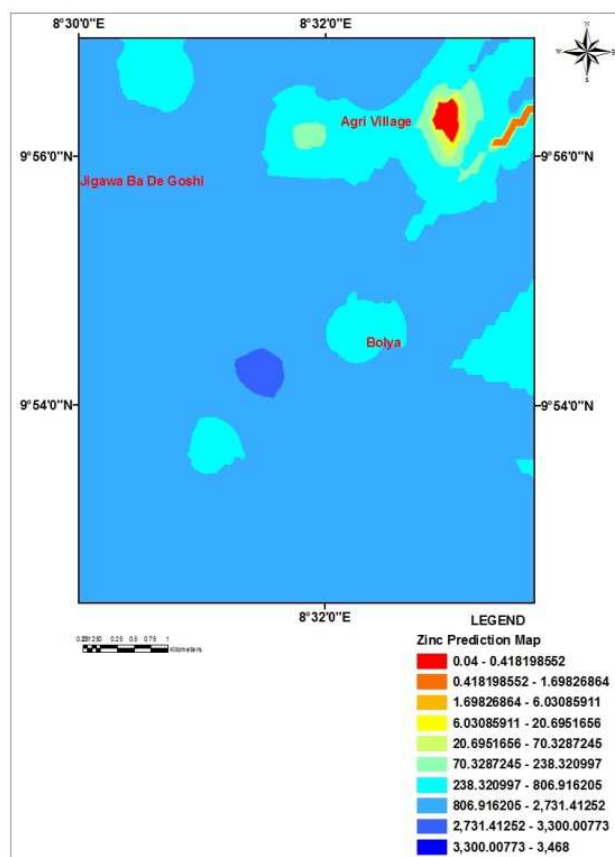
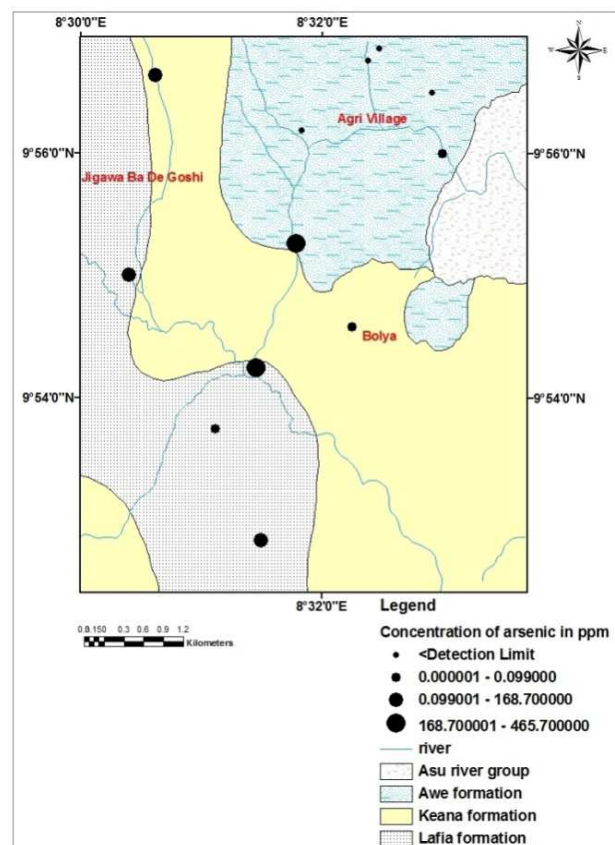
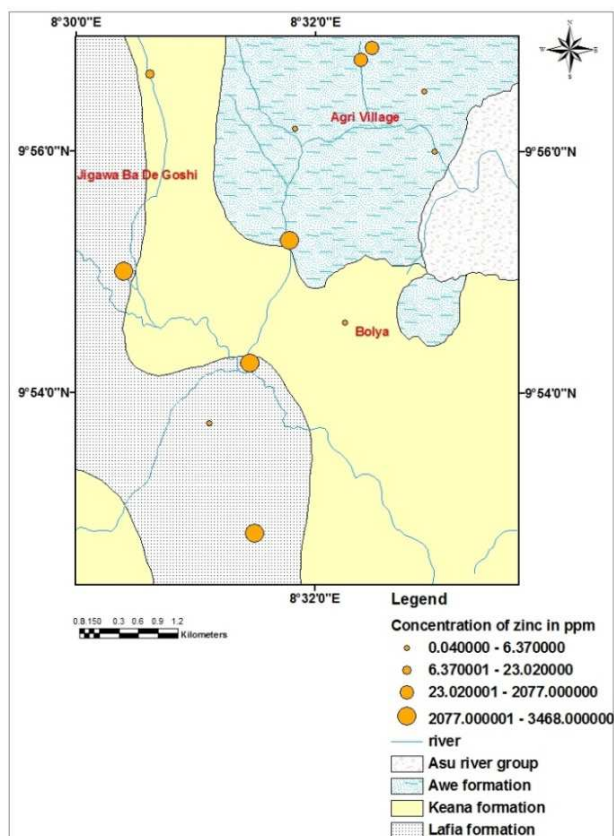
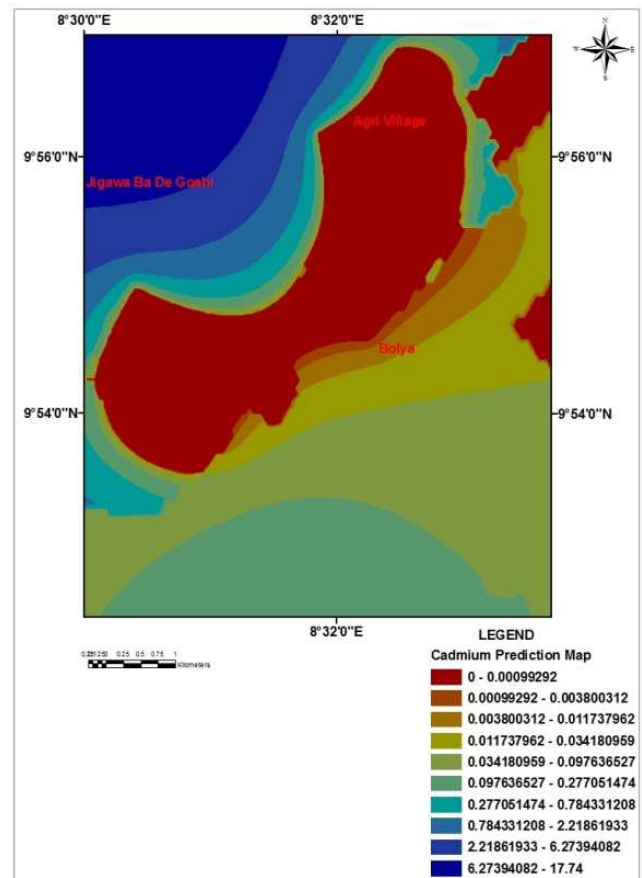
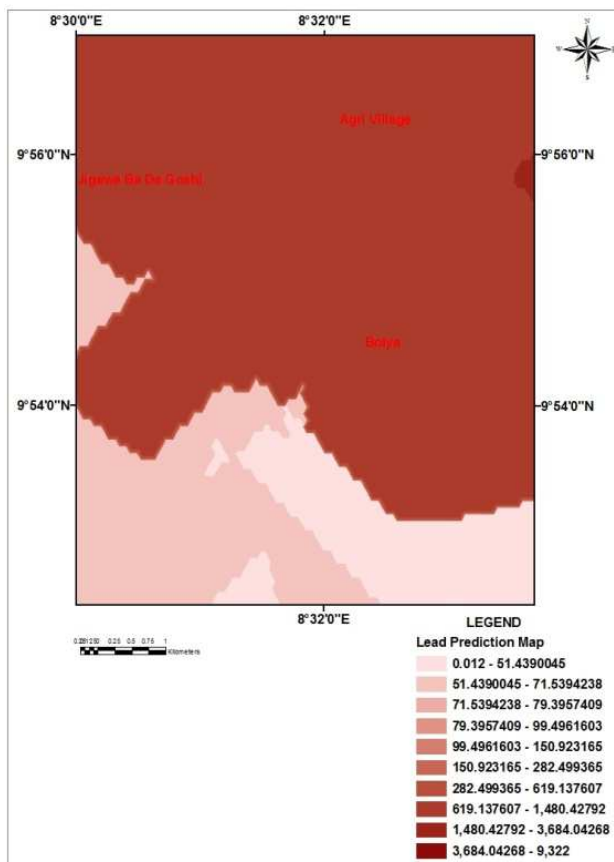
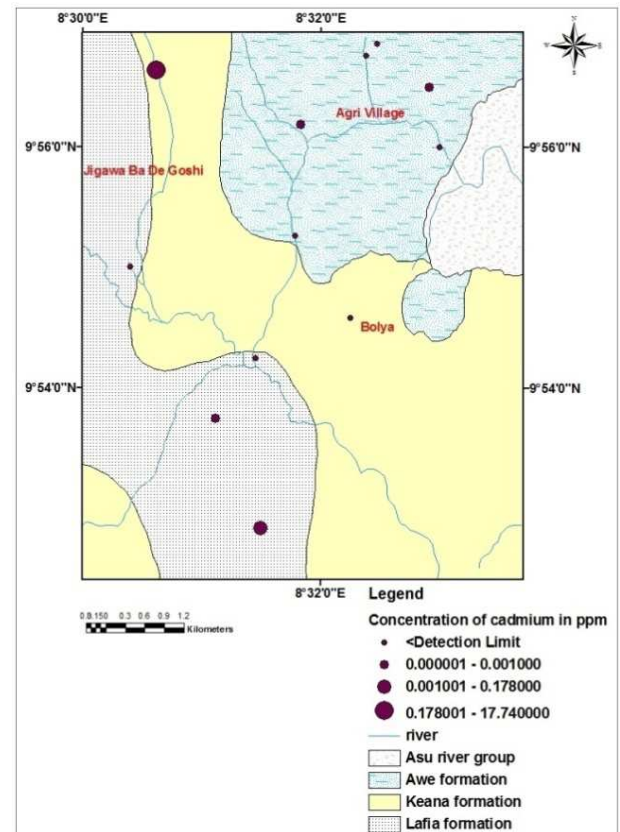
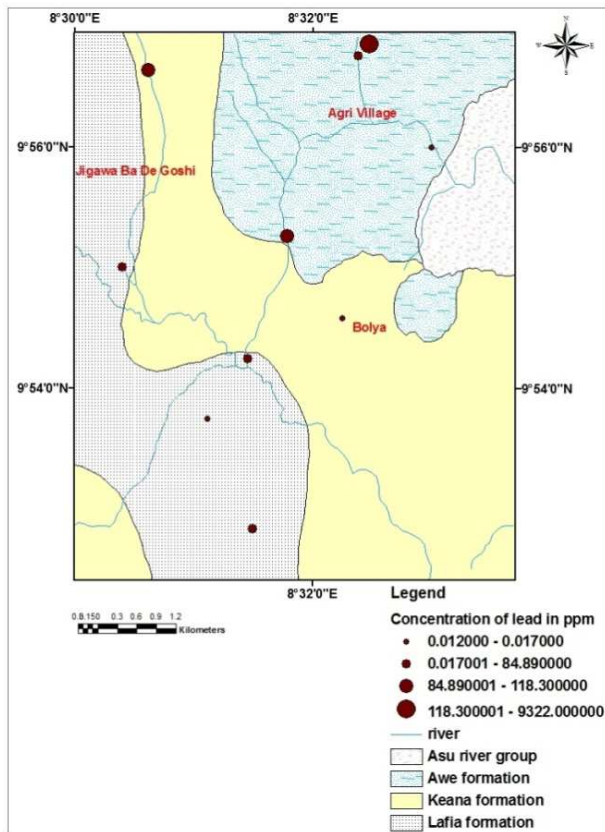


Fig 6b. Copper prediction map of the study area





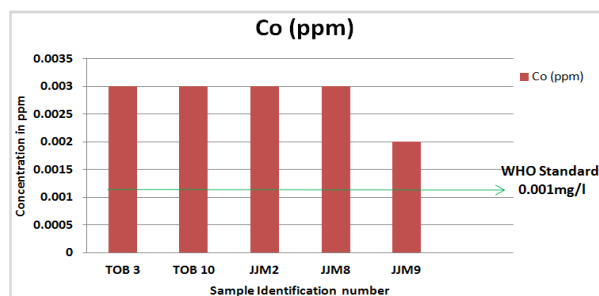


Fig 11. Comparing cobalt concentrations in water with WHO standard

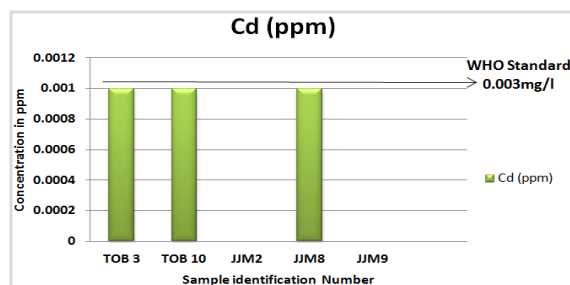


Fig 16. Comparing cadmium concentrations in water with WHO standard

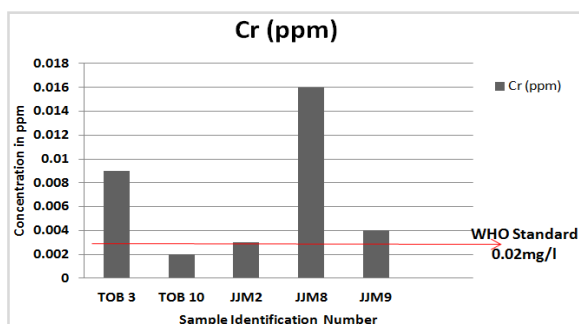


Fig 12. Comparing chromium concentrations in water with WHO standard

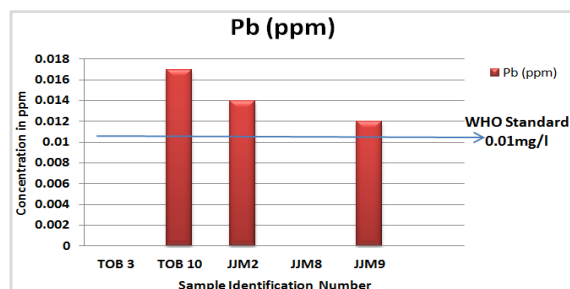


Fig 17. Comparing lead concentrations in water with WHO standard

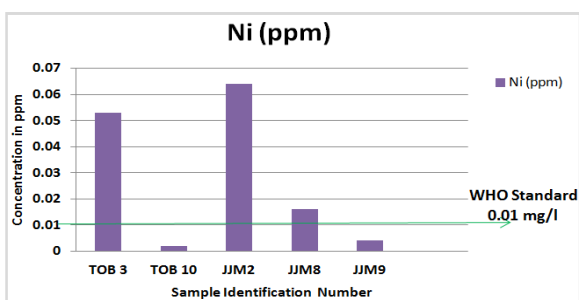


Fig 13. Comparing nickel concentrations in water with WHO standard

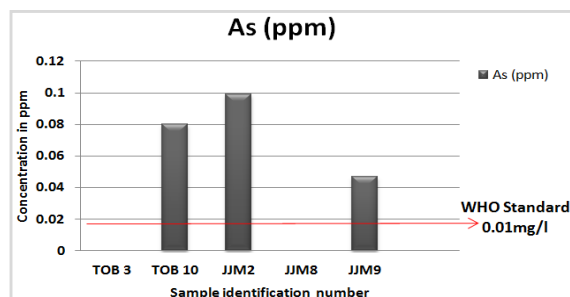


Fig 18. Comparing arsenic concentrations in water with WHO standard

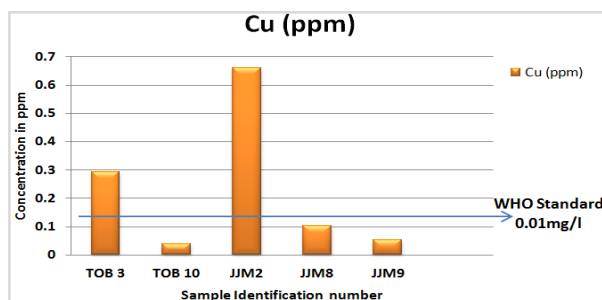


Fig 14. Comparing nickel concentrations in water with WHO standard

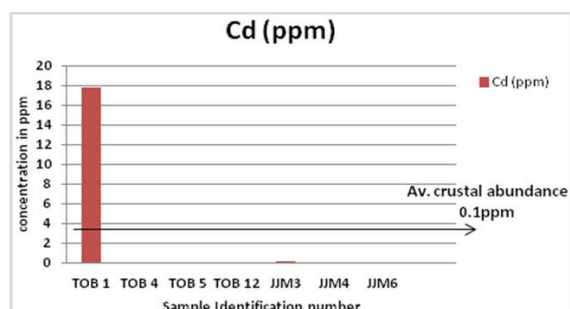


Fig 19. Comparing iron concentration in sediments with standard average crustal abundance

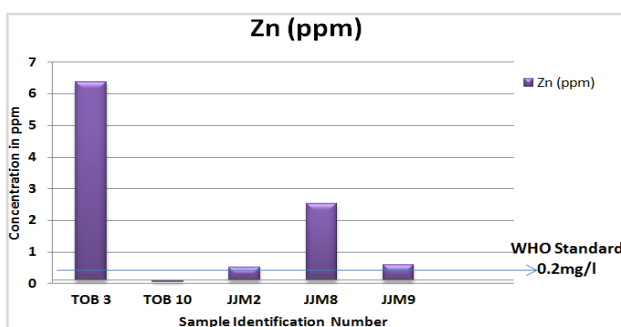


Fig 15. Comparing zinc concentrations in water with WHO standard

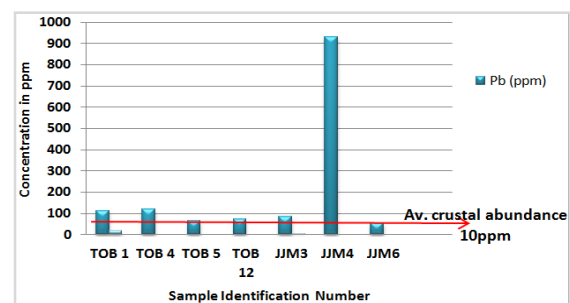


Fig 20. Comparing lead concentrations with standard average crustal abundance

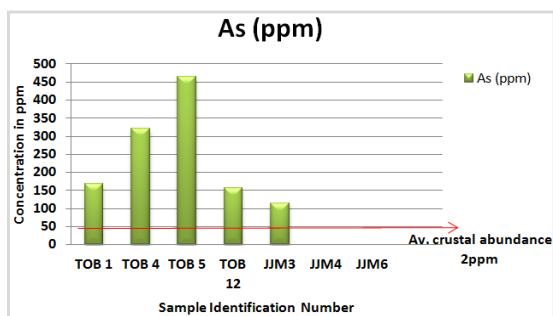


Fig 21. Comparing arsenic concentrations with standard average crustal abundance

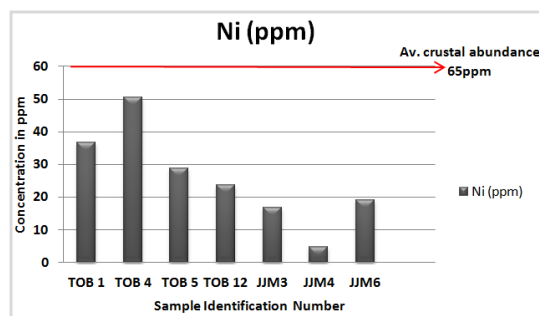


Fig 24. Comparing nickel concentrations with standard average crustal abundance

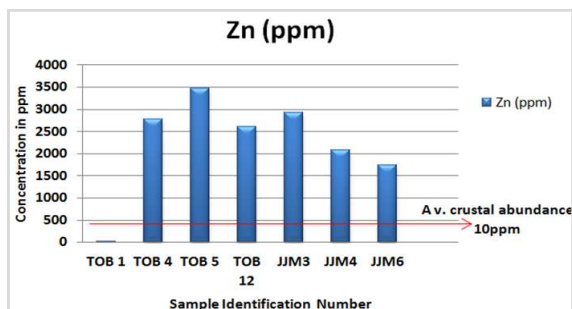


Fig 22. Comparing zinc concentrations with standard average crustal abundance

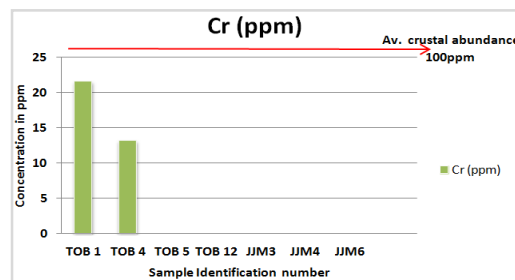


Fig 25. Comparing chromium concentrations with standard average crustal abundance

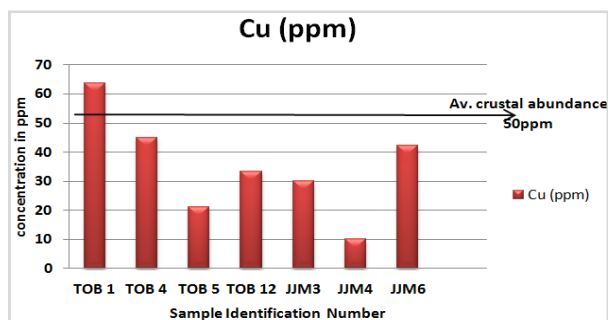


Fig 23. Comparing copper concentrations with standard crustal abundance

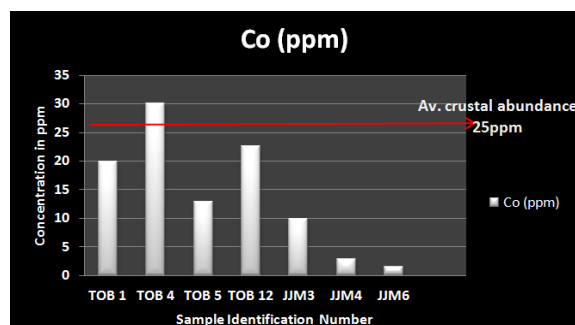


Fig 26. Comparing cobalt concentration in sediments with standard average crustal abundance

Table 3. Chronic daily intake and health risks indexes of heavy metals through drinking water consumption

Mean Concentration (microgram/ litre)		Co	Cr	Ni	Cu	Zn	As	Pb	Cd
		28	6.8	27.8	223	2.008	75.3	14.3	1
Chronic Daily Intake of metals (CDI)	Adults	0.7778	0.1889	0.7722	6.1944	0.5577	2.0833	0.3972	0.0278
	Children	0.8562	0.208	0.8502	6.9725	0.0614	2.3028	0.4373	0.0306
Health Risks Index	Adults	0.3889	1.20E-04	0.0386	0.1674	1.80E-03	0.0417	0.011	0.0556
	Children	0.4281	1.40E-04	0.0425	0.1884	2.00E-04	0.0461	0.0122	0.0612

N.B:

- Assuming that the average daily intake of water, D_w is 2 L/day for adult and 1 L/day for child (US EPA, 2011)
- Assuming that the average body weights, W_b to be 72 kg for adult and 32.7 kg for children (Muhammad et al., 2011; Khan et al., 2010; Jan et al., 2010).
- Oral toxicity reference dose (R_fD , $\mu g / (kg \cdot day)$) for Co, Cr, Ni, Cu, Zn, As, Pb, and Cd are 2, 1500, 20, 37, 300, 50, 36 and 0.5, respectively (Shah et al., 2012; Muhammad et al., 2010; US EPA, 2005, 2011).

7. Discussion

The general concentration of Cobalt in the soil ranges from 0.022 to 30.09ppm. Chromium concentration spans from undetectable limits to 21.64ppm while for nickel, the concentration ranges from between 0.02 to 50.67ppm. The concentration of copper ranges between 0.39 to 63.77ppm and zinc is between 0.04 and 3468ppm. Arsenic concentration falls below detection limit in some sample to

465.7ppm. The concentration of lead is between 0.012 and 9322ppm. Undetectable amount of cadmium is analyzed in the area up to a concentration of 17.74ppm. Its observed in the area that cobalt, chromium, zinc, arsenic, cadmium, nickel and copper have relatively low spatial distribution pattern in Agri and Bolya villages as well as its surroundings while high spatial distribution pattern of these elements are noticed in Jigawa ba da Goshi. However, lead is observed to have high spatial distribution pattern in almost all northern parts of the mapped area including Agri, Jigawa ba da Goshi and Bolya villages.

7.1. Water Samples

Generally, Chromium and Cobalt show high concentrations in all samples of the study area more than the WHO permissible limits [17] for water (0.001mg/l and 0.02mg/l respectively). Nickel concentrations in samples TOB 10 and JJM9 are lower than the WHO permissible limits [17] while in samples TOB 3, JJM 2 and 8 are higher WHO (0.01mg/l). Copper indicate 2 samples (TOB3 and JJM2) that have peaked above the WHO standard of 0.01mg/l. Zinc concentration in the area is generally higher than the WHO standard (0.2mg/l). Cadmium concentration in the study area is below the WHO standard (0.003mg/l) while lead concentration is shown to be high in samples TOB 10, JJM 2 and 9 more than WHO standard (0.01mg/l). Arsenic show Three (3) samples (TOB 10, JJM 2 and JJM9) with concentrations of above WHO permissible limits (0.01)[17].

7.2. Soils and Stream Sediments

The concentrations of cadmium in stream sediments of the study area is generally below the standard average crustal abundance (0.1ppm) except sample TOB 1 which contains 17.74ppm. Lead concentrations are above the standard average crustal abundance (10ppm) in the study area. Only two (2) samples have arsenic concentrations lower than the detection limit while the remaining samples are above the standard average crustal abundance (2ppm). The concentration of zinc in all the stream sediment samples is above the standard average crustal abundance (10ppm) except in sample TOB 1 which is 9.02ppm. Sample TOB 1 has high copper concentration in the area than the remaining samples. The entire concentrations of Nickel and Chromium are below the average standard crustal abundance (65ppm and 100ppm respectively). However, cobalt show that sample TOB 4 to have concentration higher than normal crustal abundance (25ppm).

7.3. Human Health Risks

The analyses show that the concentrations of heavy metals in water samples been the direct most consumed in the study area decreases in the order Cu>As>Co>Ni>Pb>Cr>Zn>Cd and all these toxic metals have concentrations greater than the WHO [17] admissible values for drinking water except cadmium. Health risk indices values obtained for these heavy metals either in children or adult are less than one indicating

that it is safe and do not pose any human health risks. However, the intake of such heavy metals over a long period of time may increase the chance for serious human health problems.

8. Conclusion

This study has revealed that heavy metals such as cobalt, chromium, zinc, arsenic, cadmium, iron, nickel and copper have relatively low spatial distribution pattern in Agri and Bolya villages as well as its surroundings while high spatial distribution pattern of these elements are noticed in Jigawa ba da Goshi. However, lead is observed to have high spatial distribution pattern in almost all northern parts of the mapped area including Agri, Jigawa ba da Goshi and Bolya villages. Thus, the heavy metal concentrations in soils, sediments and water sources are considerably high relative to the recommended WHO values for water as well as the average crustal abundance. Whereas the calculated HRI for these heavy metals in potable water sources show that there is no immediate health risk for both adults and children, a long time intake may cause more serious health risks. On the positive side the spatial distribution of the heavy metals, especially Pb, As and Cu in the soils and sediments have great implications as to future mineral exploration targets.

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