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Appraisal of Geochemical Composition of the Mined Rock Materials Used For Small Scale Gold Extraction in Some Communities of Zamfara State, Nigeria

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Abstract: *Infant deaths and illnesses attributed to acute lead poisoning at Yargalma and Tunga Guru in Bukkuyum LGA and Dareta, Abare and Tunga Daji in Anka LGA of Zamfara State, was reported and a rapid assessment of the sources of lead that could have contributed to the poisoning in the affected villages was carried out. The geology and hydrogeology of the area especially the locations where the rock materials used for the small scale gold mining was assessed and rock samples collected for geochemical assessment and thin section to determine the major chemical and mineralogical constituents of the rock materials used for the mining activities. The water levels in the wells measured during the survey ranged from 4.9 - 9.85 m and the aquifers in the hand dug wells are mainly the weathered regoliths with fractures in the transmission zone and fresh basement. The geochemical analysis carried out on samples from all the locations indicated high level of lead ranging from 49.01 – 350,200 ppm in addition to the occurrence of chromium, silver and other trace metals associated with the gold mineralization. Community members involved in the mining activities undertake the processing of the mining materials within and outside their households and the processing of mining materials includes crushing, grinding and washing with resultant high dust from the materials being processed. This could have resulted to the high contacts of mining rocks in the communities with possible pollution. There is the need to provide the communities with technical support to use safe and better mining methods to prevent direct contacts of the mining materials.*
Keywords*: Geochemical composition, hydrogeology, lead poisoning, mining, rock minerals*

I. Introduction

Soil contaminated with lead is not only a source of worry in developing countries, but also a persistent health problem in western countries for decades [1]. Because of its health concerns, lead is no longer being used as additives to gasoline and house paints [2, 3]. People can be exposed to small quantities of lead by breathing air, drinking water, eating food, or swallowing dust or dirt that contains lead [3]. For adults, the food is the source of most general low-level environmental acquaintance to lead [4]. Children are more prone to lead than adults [4]. Children are commonly exposed to lead from hand-to-mouth activities involving contaminated dust and soils around older homes that contain lead-based paint or from eating paint chips that contain lead [5]. Workers may be exposed in industries use lead as material for manufacturing. Workers can also be routes through which household members become victims by carrying lead home on their clothes [6].

No safe blood lead level has been identified. For infants and young children, lead levels of 10 micrograms or more in a deciliter of blood are levels of worry and can damage ability to learn and faced the most danger from exposure to lead because of being in their early stages of growth and development are more prone to harm than do adults' bodies. Lead can cause everlasting impact on pregnant women and women of reproductive age. Therefore, they should evade exposure to lead because lead consumed by a mother can result in malfunctioning of organs and deformity to the unborn foetus [6]. In men, these effects can result to reproductive and sexual abnormality [7]. At much higher blood lead levels lead can damage people's kidneys, blood, and nervous system and progress to coma, convulsions, or even death [8, 9].

An episode of lead contamination that resulted in the outbreak of acute lead poisoning in Zamfara State, Nigeria reported illness and deaths among children mostly under 5 years old in some communities in Bukkuyum and Anka Local Government Areas (LGAs) of Zamfara State, prompted a joint investigation by the Centre for Disease Control (CDC) and World Health Organisation (WHO) [10]. Based on the findings of this report and consultations with United Nations International Children’s Emergency Fund (UNICEF) and Zamfara State Ministry of Water Resources, the National Water Resources Institute Kaduna, decided to carry out an assessment of the possible sources of the pollution, the geology and hydrogeology of the affected communities. In addition, the geochemical constituent of the mined rock materials was also collected for analysis. This paper presents the findings of hydrogeological and geochemical assessment of the mined rocks used for the gold extraction activities in the area.

1.1 Geology of the study area

Geologically, the areas lie within the basement rocks of the Anka schist belts (Fig. 1). It lies west of the Maru belt, the two being separated by the Pan-African Maichi granodiorite and by a probably older gabbro-granite-pegmatite complex [11], [12], [13]. Field studies identified quartzites, schist and phyllites [14], as the dominate rocks of the areas where the materials for artesian mining are obtained. Occurrence of gold in placers and primary veins of quartzites, phyllite and schists are quite common at Kwali and Gwashi (Bukkuyyum LGA) and Sunke and Lambargudu (Anka LGA). The primary gold mineralization is associated with veins and lenses of the quartzites, phyllites.

The typical schist belt at Lambargudu is oriented in NS, NE-SW direction. It is primarily a mixed quartzite, phyllites and schists mixed with dark shinning galena crystals and reddish brown sulphide and iron. All the miners in the communities visited said the raw materials for the gold mining activities were collected from Nagaku, Kwali and Gwashi in Bukkumyu LGA and from Sunke and Lambargudu in Anka LGA, all in Zamfara State.

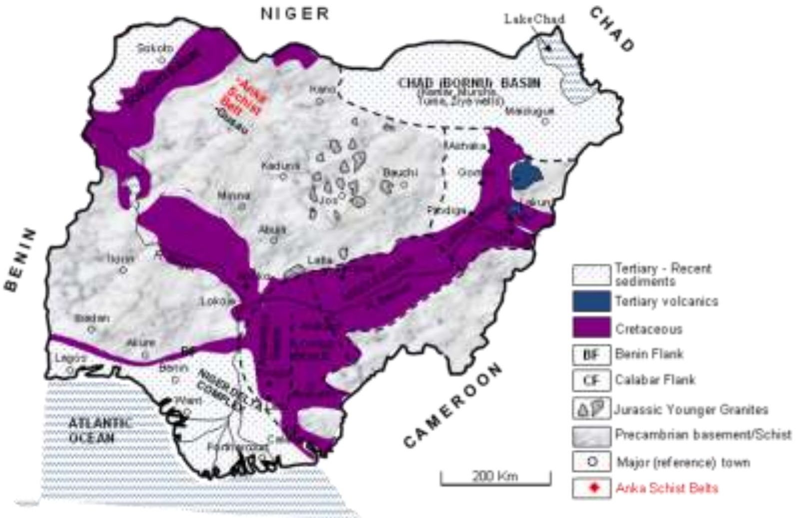

Figure 1. Geological map of Nigeria showing the location of the Anka schist belt with gold mineralization

Figure 2. Mining sites at Lambargudu in Anka LGA

II. Methodology

2.1 Geological and hydrogeological assessments

In each village visited, the geology and hydrogeology of the area were rapidly appraised. In addition, the locations of the mined rocks processing activities (now relocated to the outskirt of the villages), the processing procedures, the equipment and facilities being used and the rocks being processed were assessed. Samples of the rock materials (from different mines) processed were collected for geochemical analysis. Lambargudu mine site some 5 km to the south of Dareta village was assessed and samples collected for analyses. This was one of the sources of the rocks processed at both Dareta and Abare in Anka LGA (Fig. 2). The rocks samples were collected for analyses, to determine the major mineralogical constituents of the rocks (i.e. thin section) and to determine the major elements in the rocks (i.e. geochemical analyses).

2.2 Hand and thin section (microscopic descriptions)

Description and microscopic analyses of the rock samples collected from the mining sites at Lambargudu and samples from other mining locations collected from the miners at Yargalma village (Bukkuyum LGA) were described at site and thin sections were prepared in the laboratory for microscopic examination [15].

2.3 Laboratory geochemical analyses

The rock samples were prepared by crushing and digestion. The Inductively Coupled Plasma Optical Emission Spectrometry method was used for the analyses of the samples [16].

III. Results And Discussion

3.1 Hydrogeology and static water levels

The aquifers in the hand-dug wells are mainly the weathered regoliths and the fractures in the transmission zone. The weathered granular sandy zone is composed of coarse-grained sands, which form a level below the loose clayey alterite. The granular sands may consist of sands or gravels derived from the disintegrations of the crystalline rock. There are good prospects for groundwater production in the horizon of the intermediate zones with an average thickness of about 6 m. [17], [18], [19]. The majority of hand-dug wells in the study area terminate in this part of the zone. The aquifers of the basement are quite productive and highly sustainable for domestic water supply fitted with hand pumps and moderate submersible pumps capacity. The water levels in the wells measured during the survey ranged from 4.9 -9.85 m. Most of the wells were hand dug and not lined.

3.2 Hand and Thin Section (microscopic descriptions)

Details description and microscopic analyses of the rock samples collected from the mining sites at Lambargudu and samples from other mining locations collected from the miners at Yargalma are presented below. The major objective is to identify the mineral composition of the source rocks. This will also assist in the interpretation of the geochemical data from the rock samples.

3.2.1 Lambar gudu, Dareta, Anka LGA mining site sample 1

The rock is a light coloured metamorphic rock with sparkling grains of Mica (muscovite) and highly impregnated with galena (phyllites). The rock consists of interlocked quartz grains showing dissolution at the edges. There are a few grains of apatite and altered grains of olivine. The rock is altered and replaced by Galena.

3.2.2 Lambar gudu, Dareta, Anka LGA mining site sample 2

The rock is essentially made up of quartz with dark stains in some places (quartzites), smoky quartz looks. The rock consists essentially of fine grained quartz with large phenoclast of feldspars altered to clayey mineral. There are no alignments of the grains. Accessory grain of apatite is present.

3.2.3 Lambar gudu, Dareta, Anka LGA mining site sample 3

The rock is essentially made up of quartz with pink and grey colorations (quartzites), with quartz grain showing alignment. A few grains of feldspar and apatite all showing alteration is present.

3.2.4 Sunke, Anka LGA sample 1

The rock is a medium grained metamorphic rock with green to yellow and dark mineral (phyllites). This is made up of quartz and clay minerals. The rock is altered and replaced by pyrite.

3.2.5 Sunke, Anka LGA sample 2

The rock is essentially made up of quartz with pinkish colorations giving the rock a pinkish colour (quartzites). The rock consist essentially quartz and feldspars altered to clay minerals. Pyrite occurs around the edges of several grains and alteration products.

3.2.6 Nagako, Anka LGA

The rock is essentially made up of quartz with pink and black colorations. The rock is quartzites, which consist of small grain quartz in the interstices of the large grains of feldspars altered to clay minerals. A few grain and apatite and pyrite are present.

3.2.7 Gwashi, Bukkuyum LGA

The rock is grey to brown in colour with cryptocrystalline texture. This has the texture of a volcanic rock (rhyolites), which may have been metamorphosed. The rock consists essentially of quartz grains showing alignment in a single direction. A few feldspars are also present. All the minerals show incipient alteration.

3.2.8 Kwali, Bukkuyum LGA

The rock is a light pink coloured rock essentially made up of quartz with black stain along fractures and within the rock (quartzites). The rock consists of altered large grains of feldspars and quartz grains distributed in the interstices of the feldspars.

3.3 Geochemical analysis

The result of the geochemical analyses is presented in Table 1. The rock samples were prepared by crushing and digestion. The Inductively Coupled Plasma Optical Emission Spectrometry method was used for the analyses of the samples.

Table 1: Trace elements analyses of rock samples from some mine sites

S/N	Source area	Ag	As	Cd	Co	Cr	Cu	Pb	Se	Tl
		(ppm)								
1.	Lambargudu 1	243.3	403.0	43.74	21.67	804.7	11,220.0	350,200.0	158.8	145.7
2.	Lambargudu 2	5.86	261.9	3.63	110.90	838.4	984.0	21,240.0	0.0	101.2
3.	Sunke 1	66.26	335.7	3.00	130.20	896.9	946.0	10,540.0	0.0	0.0
4.	Sunke 2	6.92	272.7	4.24	180.30	833.5	202.3	798.2	65.85	29.5
5.	Nagako	33.01	272.2	5.63	173.60	843.9	306.5	9,049.0	117.2	63.7
6.	Gwashi	44.73	20,360.00	516.30	81.45	937.1	775.2	48,440.0	0.0	0.0
7.	Kwali	0.0	238.6	3.50	114.10	1,437.0	28.3	49.01	0.0	0.0
Average value		57.15	3,163.44	82.86	116.03	941.6	2,066.0	62,902.3	48.83	48.6

Note: Ag, Silver; As, Arsenic; Cd, Cadmium; Co, Cobalt; Cr, Chromium; Cu, Copper; Pb, Lead; Se, Selenium; TI, Thallium.

3.3.1 Silver (Ag)

In rocks, silver commonly occur in galena, sometimes it accounts for up to 2 %. In the samples analysed, it ranged from trace 0.0 – 243.3 ppm.

3.3.2 Arsenic (As)

Arsenic is frequently present in magnetite and ilmenite as sulphides, arsenides, arsenates and oxide and native element. The values ranged from 238.6 – 20,360.0 ppm in the rock samples from all the sites.

3.3.3 Cadmium (Cd)

Cadmium normally occurs as carbonates, sulphides and oxides, associated with zinc ores, and concentrated in hydrothermal veins and ores. Cadmium concentration in the rock samples ranged from 3.0 – 82.86 ppm.

3.3.4 Cobalt (Co)

This is found in common minerals such as pyrite, pentlandete and pythotite. In igneous rocks is bound in silicate structure and has affinity for sulphur. The values from the rock samples vary from 21.67 – 180.3 ppm.

3.3.5 Chromium (Cr)

Found in oxide and silicate minerals in the upper crust. The values from the rock samples ranged from 804.7 – 1,437 ppm.

3.3.6 Copper (Cu)

The majority of the copper in the crust is in sulphur and contains minerals. In the silicates Copper replaces Fe^{2+} and Mg^{2+} and occurs in sulphides, silenides and tellurides, oxide and lead (Pb). Copper vary from 28.34 – 11,220 ppm in the rock samples analysed.

3.3.7 Lead (Pb)

Galena principally constitutes about 80.6 % of lead (Pb). It is lead grey streak with grayish black colour. Generally, it is trace in igneous rocks. Lead (Pb) replaces potassium (K) in potassium feldspar and calcium in minerals like apatite, pyroxene and aragonites. The lead in the rock samples from all the locations range from 49.01 – 350,200 ppm. It is necessary to note that the higher the values of lead in the samples, there is a corresponding higher values for silver due to their co-existence with gold mineralization.

3.3.8 Selenium (Se)

It is usually trace in sulphide minerals of hydrothermal deposits. It is concentrated in pyrite chalcopyrite, arsenopyrite, Galena and Sphalerites. Only three (3) samples contain selenium with range values of 0.0 – 158.8 ppm.

3.3.9 Thallium (Tl)

Thallium minerals are associated with hydrothermal deposits. It is present as a trace in biotitics potassium, feldspars and amphiboles. It is highly concentration in feldspars and muscovites from pegmatites. The values range from trace 0.0 – 145.7 ppm.

IV. Observations

There is no doubt that the rock samples used for the gold mining activities contained substantial amount of lead as shown in the average values of 62,902.32 ppm and this is shown for all the rock samples analyses for with a range of 49.01 - 350,200 ppm. A report by the US Centre for Disease Control and Prevention (CDC) and World Health Organization (WHO) on environmental analyses carried out on soil/dust collected from the eating and sleeping areas in all the surveyed compounds in Yargalma and Dareta had a lead level exceeding the 400 ppm threshold [10]. However, the values of lead concentration dropped dramatically at a depth of 3 cm inside the compound that are being used for mining activities indicating that the concentration are mainly at the surface of the top soil and derived from the rock samples brought for gold mining from other locations.

V. Conclusions

Results of the field, petrographic and laboratory geochemical analysis indicated the occurrence of high concentration of lead and other trace metals like chromium, silver, arsenic, cadmium and other trace metals associated with the gold mineralization. Some of the major challenges are the mining processes that entail improper mining practices, use of children and women in the mining activities resulting in the pollution of water sources and the mining processes being carried out in homes and the likely mercury pollution of the rivers, streams and the soil due to the use of mercury as a means of gold recovery chemical during the gold processing operations. In order to address some of the identified challenges, the following recommendations are hereby proffered. Basic precautions must be put in place for all mining activities to avoid all sources of pollution. Detailed studies should be carried out in all sites, where mining activities takes place for effective monitoring and pollution control strategy and taking into consideration all sources of water supply to the communities.

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