Potential Health Risks Associated with the Release of Trace Elements in the Luku Gold Mining Area, Minna, North-Central Nigeria

Ako T. A.[1]; Alabi, A. A.[1]; Mamodu A[1].; Abba F. M[1].; Chukwu. J. N.[1] and Kolawole M. S.[2]
1. Department of Geology, Federal University of Technology, Minna, Nigeria
2. Earth Sciences Department, Kogi State University, Anyigba, Nigeria

Abstract

Mining of solid minerals is one of the world's most valuable resources. Mining activities such as gold mining are usually associated with dangers which serve as threat to man, animals, water and land. This work aims at evaluating the health risk associated with release of trace elements as a result of mining of gold in Luku, Minna, North Central Nigeria. Soil samples collected from the study area were analysed for trace elements using X-ray Fluorescence (XRF) method at the National Geo-science Research Laboratory (NGRL), of Nigerian Geological Survey Agency (NGSA), Kaduna. Field observations reveal that mining activities have destroyed the quality and availability of surface and ground water in the area due to panning for gold and the use of chemicals for extraction of gold from its ores. Results of chemical analyses show that the mean concentrations of Pb (85.73 ppm), As (9.27 ppm), Cu (56.46 ppm), Ni (58.55), Cd (1.73 ppm) and Ag (0.73 ppm) in the soil were more than the comparable crustal values of the elements. Also, Co (10.91 ppm) and Mo (0.1 pmm) had concentrations slightly above the crustal values while those of Zn (31 ppm) and Mn (283.73 ppm) were below these values. The order of average concentration of the elements is as follows: Mn > Pb > Ni >Cu >Zn >Co > As >Cd >Mo > Hg. Consumption of water and plants with high concentrations of these elements by man can lead to possible health implications such as stomach aches, dizziness, nose, mouth and eye irritations, liver and kidney damage, cardiovascular diseases, liver cancer and even death. It is recommended that environmental impact assessment (EIA) of the area be carried out at the commencement of mining operations.

Keywords: Health risks, Medical geology, Mining activities, North Central Nigeria, Pollutants, Trace elements.

1. Introduction

Nigeria is blessed with lots of solid mineral resources and these mineral resources occur in the three main geological units in the country. The basement complex hosts gold, iron ore, cassiterite, talc, feldspar, the sedimentary basins coal, gypsum, diatomite, limestone, while the Younger Granites host cassiterite, columbite, lead (Obaje, 2009, Ezeaku, 2011). The geology of an area has a direct effect on the regional inputs of elements into the soil, water and air. These inputs, in turn, depending on composition, may result in adverse health effects in humans, animals and/or plants. Health problems related to a region's geology are visible in both animals and man on almost every continent, and can range from lead contaminated ground and surface water in Zamfara State, in Nigeria, (Medecins Sans Frontieres (MSF), 2010) to molybdenosis in Canadian cattle (Hastings *et al.*, 1999).

Extraction of these mineral resources has become of outmost importance in many developing countries. Mineral resources are the major source of the nation's economy and usually undergo the different stages of exploration, mining and processing before they can be made to be productive (Adekoya, 2003, Ajakaiye, 1985). In theory, the activities of mining can be feasible if it does not change the nature of the area and shows an increasing growth in all aspect of the society.

Mining of minerals may be economically captivating but usually associated with unfavorable environmental hazards, which have drawn international attention due to the environmental impact imposed on the land (Maponga, 1995 and Dreschler, 2001). Generally, effects of mining on the environment could be short or long, temporary or permanent, harmful or beneficial, irreparable or reparable and irreversible or reversible and it affects all areas of the environment. The different stages of mineral development are usually linked with environmental hazards and damages. According to Khandare, (2012) and Bunnell *et al.*, (2007), every day, human beings interact directly with nature by way of eating, drinking and breathing, and in the process ingest minerals and trace elements. The material consumed is mostly harmless and even beneficial, supplying essential nutrients to the body. However, the interaction with minerals and trace elements can sometimes have devastating, even fatal effects. All these interactions are covered under the realm of medical geology. Bunnell *et al.*, (2007) have defined Medical Geology as, the study of the impacts of geologic materials and processes on animal and human health and is a dynamic emerging discipline bringing together the geoscience, biomedical, and public health communities to solve a wide range of environmental health problems. Medical Geology describes both deficiency and toxicity of trace element exposure. However, in this study, only effects of toxicity of these elements are discussed.

Gold mining is a significant resource in the nation's wealth and the extraction of this mineral resource is usually harmful as it destroys the ecosystem, causes problems for the people living around the area and it can also lead to migration of living organisms. Heavy metals such as lead, arsenic, copper, mercury, nickel and cobalt may be released to the environment due to the mining of gold and these elements may get into the food chain. If their concentrations are above background levels in the environment, they become harmful to living organisms (man and animal) and may lead to serious health implications (Duruibe *et al.*, 2007, Ogezi, 2005). Other effects include erosion and deforestation, landscape destruction, garbage and solid waste, improper closure and uncontrolled activities in protected areas.

Gold mining is generally an important tool for employment, foreign exchange and economic development (e.g., Obaje, 2009 and Ezeaku, 2011). The boost that is being enjoyed by the mining industries in Nigeria today equally leads to negative effects such as environmental damage, increase in health and safety issues, for example, the lead poisoning in Zamfara State and the mine collapse in Kabusa caused by the mining of gold (Obrike *et al.*, 2011). On the Jos plateau of Nigeria, historical mining of placer cassiterite and associated columbite using open cast method has led to a post mining environmental effect of scarred landscape, formation of heaps of mine spoils and artificial lakes in addition to contamination of the soils and water in the affected areas (Gyang and Ashano, 2011).

The study of gold sites in the Migori Gold Belt, Kenya, revealed that the concentrations of heavy metals, mainly Hg, Pb and As are above acceptable levels. Tailings at the panning sites recorded values of 6.5 – 510 mg kg^{-1} Pb, 0.06 – 76.0 mg kg^{-1} As and 0.46 – 1920 mg kg^{-1} Hg. Stream sediments had values of 3.0 – 11075 mg kg^{-1} Pb, 0.014 – 1.87 mg kg^{-1} As and 0.28 – 348 mg kg^{-1} Hg. The highest metal contamination was recorded in sediments from the Macalder stream (11075 mg kg^{-1} Pb), Nairobi mine tailings (76.0 mg kg^{-1} As) and Mickey tailings (1920 mg kg^{-1} Hg). Mercury has a long residence time in the environment and this makes its emissions from artisan mining a threat to health. Inhaling large amounts of siliceous dust, careless handling of mercury during gold panning and Au/Hg amalgam processing, existence of water logged pits and trenches; and large number of miners sharing poor quality air in the mines are the major causes of health hazards among miners. The amount of mercury used by miners for gold amalgamation during peak mining periods varies from 150 to 200 kg per month. Out of this, about 40% are lost during panning and 60% lost during heating Au/Hg amalgam. The use of pressure burners to weaken the reef is a deadly mining procedure as hot particles of Pb, As and other sulphide minerals burn the body. Burns become septic. This, apparently, leads to death within 2–3 years (Ogola *et al.*, 2002).

Gold mining activities usually have hazardous effect on the environment and living organism. It can also have a negative impact on both surface and ground water. The use of chemicals such as mercury and cyanide in the extraction of gold from other materials are equally dangerous to the environment. When these chemicals seep into the ground they tend to contaminate the soil and ground water, and can also pollute surface water when washed into the rivers. When water and food that are grown from such soils are consumed, death of living organisms may result (Ezeaku, 2011).

Ako *et al.*, (2014a) and Ako *et al.*, (2014b) carried out the environment impact of mining of gold, sand and gravel in Luku and reported very high concentrations of trace elements in the soils but did not evaluate the health risks that may likely be associated with these elements. This study, therefore, looks at the likely health problems posed by the release of trace elements due to gold mining activities in Luku, Minna, North Central Nigeria.

The study area is located in Luku, Niger State North Central Nigeria. It is situated 5km east of Maitumbi town and lies between Latitudes 9° 38N to 9° 39N and Longitudes 6° 36'E to 6° 37'E covering a total area of 1.12km^2 (Figure 1). It lies within the Kusheriki - Minna schist belt which is known to host gold mineralisation. Apart from mining of gold, sand and gravel, farming of crops like yams, millet, guinea corn and groundnuts are usually cultivated by the farmers in the area. It is also used for cattle rearing and provides the source of drinking water through the rivers that flow through the area.

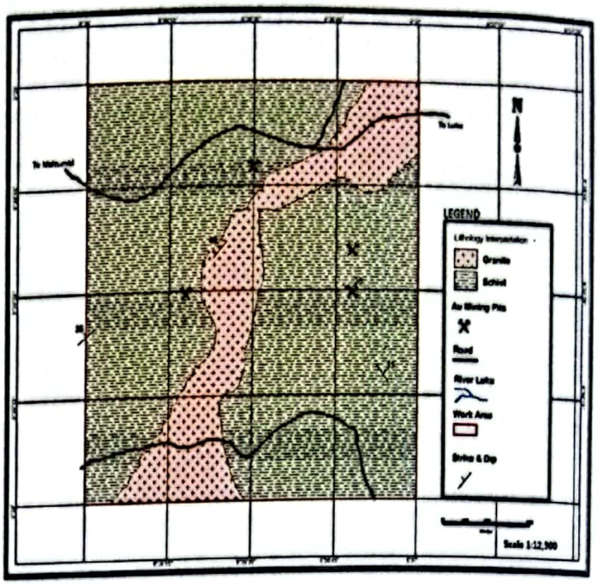

Figure 1: Geological Map of Luku.
Source: Adapted from Ako *et al.*, 2014a

2. Materials and Methods

The method of this study consists of field work and laboratory analysis. The field work involved field study of the effects of mining on the environment which may lead to health effects and collection of soil samples for chemical analysis. Soil samples were collected from the area where the mining activities are taking place. Chemical analysis was done on eleven out of the fifteen soil samples obtained from the field at the National Geo-science Research Laboratory (NGRL), Kaduna. The soil samples were sun-dried for about 24 hours in order to remove moisture. Coning and quartering was carried out by pouring each sample on a cardboard paper and then arranged in cone form. A metal rule was used to divide the coned sample into four equal halves. Two halves were taken off diagonally and then the process was repeated till a representative of the whole bulk sample was obtained. About 50 - 55g of each sample was pulverized using the Ball Milling machine (Retch PM 200 or 400) to fine powder and was sieved using a mesh sieve of 75μm. The sample was re-crushed and re-sieved till every bit passes through the sieve. About 30 - 35g was weighed on the weighing balance and then packaged in the labelled sample bag with details of the specimen before the analyses.

The powdered samples were analysed for trace elements using X-ray Fluorescence (XRF) machine, model: PANalytical, at the National Geo-science Research Laboratory (NGRL), of Nigerian Geological Survey Agency (NGSA), Kaduna. The software used for the analysis was Millipal 4. In this method, about 10g of each the eleven prepared samples was weighed into the sample cup of the X-ray Fluorescence machine and analysed according to the method described by Ezeaku, (2011). The mean concentration of each element in the samples was compared with Wedepohl, (1995) and Taylor and McLennan, (1985) average concentration of elements in upper continental crust. Values that correspond or fall below the expected limit were accepted as safe while values above the limits indicate very high concentrations of such elements in the soil which can cause serious environmental problems to plants and animals including man.

3. Results and Discussion

The results of this research is divided into two based on the manner the study was carried out. These include results from field observations and those from the laboratory analysis of soil samples. The results of chemical analysis are presented in table 1 while a summary of the results and the comparable data by Taylor and McLenna (1985) and Wedepohl (1995) of the upper continental crust are presented in table 2.

3.1 Field Observations

1. Water Pollution and Related Problems

Mining activity has destroyed the quality and availability of surface and groundwater in the area as its activities such as panning and the use of chemicals are some of the major causes of both surface and ground water pollution in the environment. Panning has a direct effect on the river and water bodies, some tailings are deposited directly into the river thereby polluting it (Plate I). As the tailings are deposited into the water, the river channels are diverted. When the rivers are diverted, water accumulates as pools in the open pit, which serves as good breeding space for mosquitoes and other disease causing animals (Plate II). The use of chemicals such as mercury and cyanide during ore processing also constitute the major pollutants of surface and ground water. Improper storage and mishandling of this chemical can also lead to water pollution. The presence of these chemicals can endanger the lives of both aquatic animals and humans.

Plate I: Pollution of Water Bodies due to Panning and Deposition of Mine Tailings

Source: Authors', 2014

Plate II: Pool of Water Accumulation in an Open Pit Created by Mining

Source: Authors', 2014

Similarly, it was reported by Ezeaku, (2011) that water pollution occurred in several mining sites in Nasarawa State (North Central Nigeria) due to seepage from mines which flow into them, resulting in stream pollution. This may lead to change in water taste, odour, colour, hardness which is very dangerous to both plants and animals. Finkelman, (2008) and Galadima *et al.*, (2011) also reported that mining activities in many developing countries are leaving, or have left, a legacy of environmental degradation and serious health problems due to poor water and air quality.

2. Air, Noise and Vibration

The mining operation in the area has affected the air quality through removal of vegetation and emissions of black smokes from mining equipment. Fine dust arising from mining operation can lead to respiratory diseases and can worsen the condition of people with asthma (Plate III).

The production of noise and vibration occur during mining operation through the use of mobile equipment, vibration from the vibrator and air blast. Noise and vibration lead to cracks in building, discomfort, damage of the auditory system, frightening of animals and relocation of man. Similarly, it was reported by Aigbedion, (2005) that air pollution occurred around Sagamu and Ewekoro cement works in Ogun as a result of dust which leads to eye pain and asthmatic attack.

Plate III: Production of Noise and Dust from Machineries at the Mining Site

Source: Authors', 2014

The mining activities in the area have led to the generation of diseases due to pollutants, accidents at mines and consumption of polluted water (Plate IV). The effects of some of these pollutants manifest themselves immediately (cyanide, for example) but others (such as

Plate IV: Human use and Consumption of Water Polluted with Trace Elements

Source: Authors', 2014

Chaanda *et al.*, (2010), reported that barite mined in Azara area is characterized by very poor safety and health standards as a result of numerous spread of diseases and fatal accident. The extraction and processing of gold has given rise to various environmentally related diseases which include, vector-borne diseases such as malaria, respiratory tract diseases such as pulmonary tuberculosis, skin diseases and eye diseases.

Table 1: Results of Chemical Analysis of Soil Samples from the Luku Gold Mining Area (ppm)

Element (ppm)	LSS 1	LSS 3	LSS 4	LSS 5	LSS 6	LSS 7	LSS 9	LSS 10	LSS 11	LSS 13	LSS 14	Mean/average of elements
Pb	330	80	313	53	30	10	20	34	27	36	10	85.727
As	21	9	22	4	1	20	8	5	7	3	2	9.273
Cu	73	55	60	63	40	56	62	62	44	56	50	56.455
Zn	23	20	72	41	21	24	26	47	20	29	18	31
Ni	34	35	21	67	77	86	94	86	47	73	24	58.545
Mn	590	690	520	250	143	180	42	280	56	190	180	283.727
Cd	2	1	4	-	-	-	<1	-	1	1	9	1.727
Co	11	18	13	12	18	-	26	3	14	-	5	10.909
Mo	2	-	-	1	1	-	-	3	-	1	2	0.909
Hg	-	-	2	-	-	-	1	-	-	-	-	0.273
Ag	1	-	2	1	-	1	-	2	1	-	-	0.727

Source: Authors', 2014

Table 2: Summary of the Chemical Parameters Analyzed Compared with the Standard of Upper Continental Crust of Taylor and McLennan (1985) and Wedepohl (1995).

Elements (ppm)	Mean/average of elements (This study)	Taylor and McLennan (1985)	Concentration	Wedepohl (1995)	Concentration
Pb	85.727	20	High	17	High
As	9.273	1.5	High	2.0	High
Cu	56.455	25	High	14.3	High
Zn	31	71	Low	52	Low
Ni	58.545	20	High	18.6	High
Mn	283.727	600	Low	527	Low
Cd	1.727	0.098	High	0.102	High
Co	10.909	10	Moderate	11.6	Moderate
Mo	0.909	1.5	Moderate	1.4	Moderate
Hg	0.273			0.056	Moderate
Ag	0.727	0.05	Moderate	0.055	Moderate

Source: Authors', 2014

3.2 Effects of Concentration of Trace Elements on Man

Results of chemical analyses show that the concentrations of Pb, As, Cu, Ni, Cd and Ag in the soil were more than the comparable crustal values of the elements. Also, Co and Mo had concentrations slightly above the crustal values while those of Zn, Mn and Zr were below these values (Tables 1 and 2). The order of average concentration of the elements is as follows: Mn > Pb > Ni >Cu >Zn >Co > As >Cd >Mo > Hg. The enrichment of trace elements in certain geological formations is related to the source rock, mode of deposition and various chemical factors. The concentration and health risks associated with each of the elements are discussed below. The average concentrations of Zn and Mn were lower compared to the comparable standards and are thus not discussed.

Lead (Pb) has its highest concentration in LSS 1(330ppm) and its lowest concentration in LSS 7 and 14 (10ppm). Its concentration in the soil ranges from 10 to 330ppm with an average of 85.727 ppm. This concentration was observed to be higher than the average in the upper continental crust. It is usually associated with diseases as kidney damage, brain damage, reduced neurophysiological functioning and cancer. According to Donghong *et al*, (2007), Pb has a significant effect on mice and man as a result of allergic asthma.

Arsenic (As) has a highest concentration in LSS 4 (22ppm) and a lowest concentration in LSS 6 (1ppm) and a range from 1 to 22ppm. Its average concentration in the sample is 9.273 ppm. The concentration of As in the samples is higher than the comparable standards. Its health related diseases include decrease in the production of red and white blood cells, skin changes, irritation of stomach and intestines. According to kapaj *et al*., (2006) accumulation of As in the body can increase skin and internal organ risk, lung cancer, verbal IQ(intelligent quotient) and long term memory can also be lost. It can also increase foetal loss and premature delivery, decrease birth weight in infants (even at lower (<10 micro g/l) exposure levels) and cardiovascular diseases. Elewa, (2009) has reported ulcers, carcinogenic effects, emphysema and fibrosis as effects of excess as in the body. It has also been reported by WHO,(2012) that As is naturally present at high levels in ground water in numerous countries and when consumed by man has both acute and chronic effects which include, vomiting, abdominal pain, diarrhea, skin cancer, skin lesion, hard patches on palms and soles of the feet. Smedly and Kinniburgh,(2002 reported that areas which contain high levels of As in the groundwater are found all over the world. However, the Bengal Basin in India represents one of the largest problems, with an estimated 40 million individuals drinking water with elevated and potentially dangerous levels of As. The affected aquifers are situated in highly reducing environments which favour the mobilization of As. In general, the aquifers are shallow and consist of micaceous sand, silt and clay of Holocene age, capped by a layer of clay or silt and recent solid organic matter. Health problems were first identified in the 1980's; however, the first official diagnosis was not made until 1993. The dominant resulting health problems in the region are skin disorders (e.g., changes in skin pigmentation and keratosis).

Copper (Cu) has a highest concentration in LSS 1(73 ppm) and the lowest concentration in LSS 6 (40 ppm), a range of 40 to 73ppm and an average of 56.455 ppm. The average concentration of Cu is also higher than the compared standards. It is usually associated with diseases such as stomach aches, dizziness, nose, mouth and eye irritations, headaches, liver damage, kidney damage and death. Turnlund *et al*., 2004 show that the result from present and previous human studies support claims based on animal models that both Cu deficiency and excessive intake modulate the immune response. Diabetes, coronary and cardiovascular diseases occur as a result of high intake of copper in human study and consistent with those of Cu deficiency or marginal intake.

Nickel (Ni) has a highest concentration in LSS 9 (94 ppm) and a lowest concentration in LSS 4 (24ppm), a range of 21 to 94ppm and an average of 58.545 ppm. The average concentration of Ni in the sample is higher than the comparable standards and its health related diseases include, high chances of development of lung cancer, birth defects, allergic reaction such as rashes, asthma and chronic bronchitis. According to Das *et al*., (2008), the adverse health effects of Ni depend on the route of exposure such as inhalation, oral, dermal and cause diseases as headache, nausea, vomiting, cough, irritability, chest pain, birth defects, asthma and bronchitis. It was also reported by Duda-Chodak and Blaszczyk, (2008) that contact with Ni can lead to various adverse effects in man. The most important and frequent are Ni allergy in the form of contact dermaties, lungs fibrosis, cardiovascular and kidney diseases, lung and nasal cancers. There is evidence that some Ni have carcinogens effects on humans.

Cadmium (Cd) has a highest concentration in LSS 14 (9 ppm) and a lowest concentration in LSS 9 (1ppm), a range 1 to 9ppm and an average of 1.727 ppm. This average concentration of Cd is higher than the compared standards and it is usually associated with diseases such as bone fracture, damage to immune system, stomach pains and kidney damage. It was reported by Bernard,(2008) that accumulation of Cd is usually associated with kidney poisoning, bone effect, cancer, anaemia, cardiovascular diseases, cancer of the lung and prostate gland and degeneration of kidney and bones.

Colbalt (Co) has a highest concentration in LSS 9 (26 ppm) and a lowest concentration in LSS 10 (3ppm), a range of 3 to 26ppm and an average of 10.909 ppm. This value is slightly higher than the average concentrations in the upper continental crust. If such concentrations enter the tissues of man, it can cause diseases like lung irritation and low blood pressure. It was reported by Rokade, (2012) that the typical effects associated with chronic exposures include nausea, vomiting, heart failure and goiter.

The average concentration of molybdenum (Mo) in the samples is 0.909 ppm. This concentration was observed to be slightly lower than the comparable standards of Taylor and McLenna (1985) and Wedepohl (1995) of 1.5 and 1.4 ppm respectively. Thus, the concentration of this element may take a very long time to reach values that may have very negative effects on man. However, High concentration of Mo in man is usually associated with liver diseases. According to Anke *et al.*, (2007), the amount of Mo accumulation in wild and domestic mammals is higher in the liver, kidney and low in the muscles, tissue and hair. Mo deficiency and intoxication causes diseases such as liver, kidney and blood diseases.

Average concentration of silver (Ag) in the soil samples is 0.727 ppm which is higher than the 0.05 and 0.55 ppm of the Taylor and McLenna (1985) and Wedepohl (1995). High concentration of Ag in the body is usually associated with diseases such as skin colouration. Drake and Hazelwood, (2005), reported that the adverse effects of chronic exposure to Ag are permanent bluish-gray discolouration of skin (argyria) or eye (argyrosis), toxic effects include liver damage, kidney damage, changes in blood vessels, irritation of the eye, respiratory and intestinal tract.

4. Conclusion

Trace elements such as iron, manganese, zinc, copper, silver, cobalt, molybdenum, lead and arsenic are required by organisms in small amounts to ensure normal metabolism and physiological functions in living organisms. While these trace elements in very small amounts are necessary to support life, in larger amounts they become a significant health risk. Trace elements such as cadmium, lead and mercury are capable of disrupting essential physiological processes in living organisms. Some of these elements form stable and long-lasting complexes with sulfur in biological molecules, which can disrupt their biological function, allowing the metals to become concentrated at higher levels of the food chain The elements may contaminate surface and ground water which is harmful to the soil, man and environment; the soil contaminates plants which are cultivated on it and when consumed by man can lead to various diseases. Aquatic animals which take the contaminated water will be harmful to man when consumed. It is, therefore, recommended that before any mining activity is carried out either in small or large scale, an Environmental Impact Assessment (EIA) of the area should be carried out. Also, the government should set up regulating and monitoring teams to help minimize the impact of mining on the environment and finally, public awareness should be created among mining communities on both the good and harmful effects of mining on the environment.

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