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Environmental Impact of Artisanal Gold Mining in Luku, Minna, Niger State, North Central Nigeria

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Abstract The evaluation of environmental impact of artisanal gold mining was carried out in Luku, Minna, North Central Nigeria, to evaluate environmental hazards associated with artisanal gold mining through field work and Laboratory analyses. During the field work, observations of the whole mining site were made so as to evaluate the physical impact of mining and representative soil samples were randomly collected from the surface from mined and un-mined areas within the mining sites. The soil samples were analysed at the National Geo-science Research Laboratory (NGRL), of Nigerian Geological Survey Agency (NGSA), Kaduna for trace elements using X-Ray Fluorescence (XRF) method. The average concentration of these elements was compared with the published crustal average concentration of the elements in upper continental crust. Results of field observation reveal that mining activity resulted in lot of physical environmental impact such as land degradation, destruction of vegetation, erosion of soils and degrading water quality. Results from the laboratory analyses show that soils are contaminated with elements such as Pb (85.73 ppm), As (9.27 ppm), Cu (56.46 ppm), Zn (31 ppm), Ni (85.55 ppm), Mn (283.73 ppm), Cd (1.68 ppm), Co (10.91 ppm), Mo (0.91 ppm), Hg (0.27 ppm), Ag (0.73 ppm), and Zr (143.27 ppm). These elements in the soil get accumulated in plants and animals, and are passed on to human through the food chain. Also, these elements can find their way to surface and ground water making the water unsuitable for human consumption. It may cause slow growth rate in plants and respiratory problem, liver and kidney damage in man.

Keywords: *artisanal gold mining, luku, trace elements, land degradation, North Central Nigeria*

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1. Introduction

Mining refers to the process of extraction of mineral deposits from the surface of the earth or from beneath the surface. Mining can only take place where minerals are present and economically viable. Natural resources (metallic, non-metallic minerals and fossil fuels) are important in the development of any country. The general importance of the mining sector has been documented to include foreign exchange, employment and economic development (Obaje and Abba, 1996, Obaje *et al.*, 2005; Nwajiuba, 2000). Artisanal and Small-Scale Mining is a means of livelihood adopted primarily in rural areas (Veiga, 2003). Minerals are extracted in Artisanal and Small-Scale Mining by people working with simple tools and equipment (Bradshaw et al., 1997). This is sometimes called informal sector, which is outside the legal and regulatory framework (Azubike, 2011). When not formalized, organized, planned and controlled, Artisanal and Small-Scale Mining can be viewed negatively by governments and environmentalists, because of its potential for environmental damage, social disruption and conflicts (Opafunso, 2010). Some of these menaces are; depletion of the environment such as land degradation, devegetation, lost of aquatic animals, water pollution and air pollution. Most artisanal miners work in difficult and often very hazardous conditions in the absence of the required safe mining regulations to safeguard the operations (Veiga, 2003). Apart from environmental problems, health issues are not left out because of artisanal and small scale gold mining operations. The use of gravity concentration methods such as panning and sluicing during processing poses health problems.

Toxic materials are released into the environment, posing large health risk to the miners, their families and surrounding communities (Azubike, 2011). Thus, gold mining operations are particularly dangerous, as they often use mercury amalgamation process to extract gold from ores (CDC, 2010). Despite serious dangers posed by this activity, artisanal gold mining operations continue to spread due to; rise in the demand for gold and unattractive nature of other means of livelihoods such as farming in the rural areas where the mineral is substantially available. In March 2010, Medecins Sans Frontieres (MSF) discovered an epidemic of lead poisoning in Zamfara state in North–Western Nigeria particularly in Anka and Bukkuyum Local Government Areas of the state (MSF, 2010). Subsequent investigations by the Centers for Disease Control (CDC), the World Health Organization (WHO) and the Zamfara State Ministry of Health (ZMoH) confirmed that hundreds of children under ages of five were at risk of death or serious acute and chronic health effects due to extremely high levels of lead and mercury (WHO, 2011). At least 10,000 people were estimated to be affected overall (MSF, 2010). The source of the outbreak was associated with artisanal gold ore processing that occurs in the villages (Azubike, 2011). The medium through which the people were affected include drinking water, food, inhalation of contaminated dust, oral ingestion of particles especially by children and through breast feeding.

Mining of gold has being left in the hands of artisanal miners who do not have enough resources and adequate equipment and technology required for the mining activities.

Minna and its environment as a major gold field suffer in the hands of artisanal miners particularly in Luku. This work therefore studies the environmental problems associated with artisanal gold mining in Luku using both physical observations and laboratory analysis of soil samples.

2. Materials and Methods

The method adopted for this study consists of fieldwork in which soil samples were collected, field observations to determine the physical environmental impact of mining and the laboratory work in which representative samples collected from the field were analyzed for their trace element contents.

2.1. Field Work

The field work was carried out within the coordinates of the study area. Rocks were described based on their colour, texture and mineralogy. The points where these rocks outcrop the earth surface were plotted on the base map at the appropriate locations. The strike and dip values and directions were measured using a silva compass clinometer. The representative soil samples were randomly collected from the surface using a shovel from mined and un-mined areas within the mining sites. These samples collected were described based on their colour, texture and carefully put in polyethylene bags and labeled.

The points where samples were collected in the field were plotted on the base map at the appropriate locations with the help of a Germin Global positioning system (GPS) and the geographic co-ordinates. A total of fifteen soil samples were collected; two from un-mined area and thirteen from mined area. Out of these, eleven samples were used for geochemical analysis.

2.2. Field Observations

During the field work, observation of the whole mining site was done so as to evaluate the physical impact of mining on the area. Observations were made particularly on the agricultural land use as the study area was main an agricultural land.

2.3. Laboratory Work

2.3.1. Sample Preparation

Sample preparation for chemical analysis was done on eleven out of the fifteen 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 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 50-55 g 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 75 µm. The sample was re-crushed and re-sieved till every bit passes through the sieve. About 30-35 g was weighed on the weighing balance and then packaged in the labeled sample bag with details of the specimen before the analysis.

2.3.2. Chemical Analysis

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 10 g 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

3.1. Lithology and Field Relation

The study area consists of two main rock types. These include the schist and the granites (Figure 1). The schist has been intruded by the granites and form sharp contacts at some places while inferred contacts in other places. The schist is more abundant than granite and covers about 80% of the study area. They are generally low-lying, light coloured with characteristic medium to coarse grained texture. Mineral components of the rock consist of quartz, feldspar and mica. The schist is slightly weathered and foliated. The foliation is manifested by displacement of schisto city (Figure 2). The rock generally trend in NW-SE direction and generally dips between 30° - 40° NW. These rocks are jointed and the joints are filled with quartz vein.

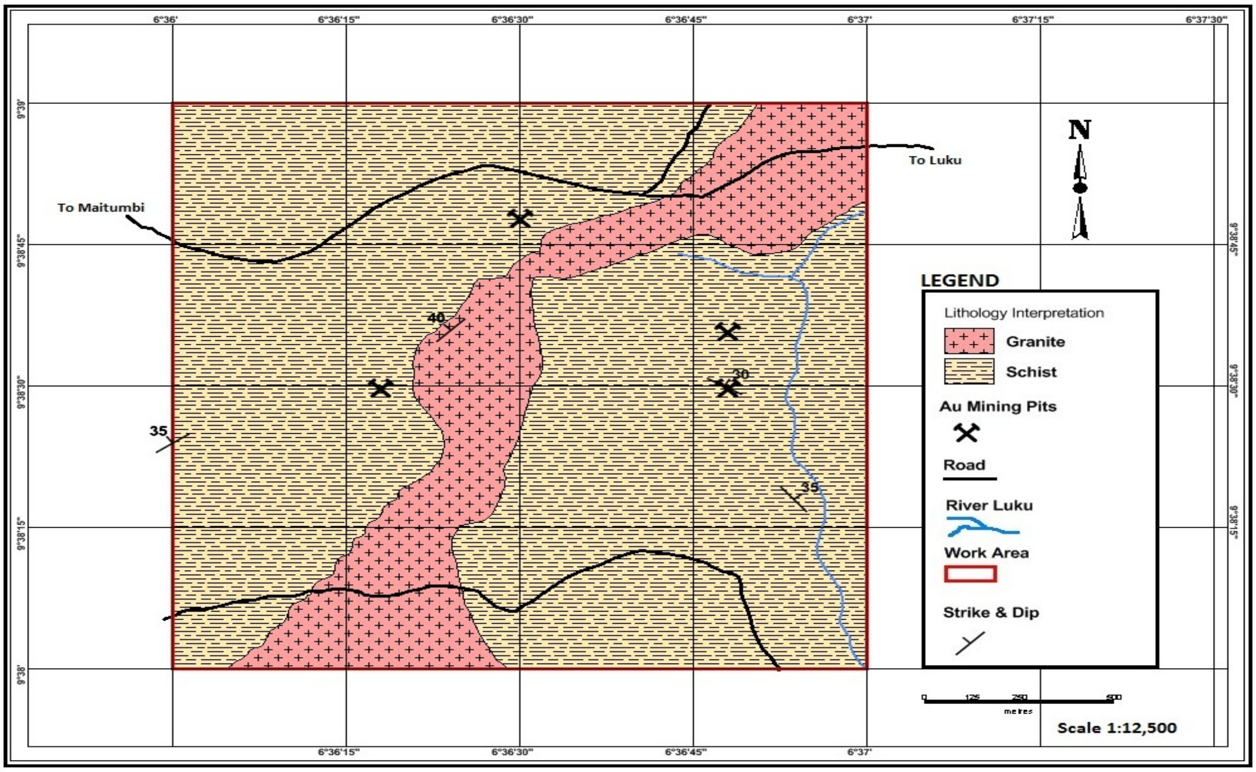

Figure 1. Geological map of Luku area

Figure 2. Schist outcrop in the study area showing schistocity

Figure 3. Photograph showing how natural landscape has been destroyed due to mining in Luku

Figure 4. Heaps of rock wastes and tailings generated as a result of the mining activities

The granites cover about 20% of the study area. They intruded the schist and are light in colour. Texturally, they are coarse grained. Mineral constituent of the rock consist of quartz, feldspar and muscovite. The granites have not been affected by weathering and are highly jointed.

3.2. Field Observations

Field observation revealed that artisanal gold mining in the study area resulted in lot of physical environmental impact on the study area.

3.2.1. Land Degradation

The effect of artisanal gold mining in the study area is the destruction of natural landscape of the area as result of erosion (Figure 3).

The heaps of rock wastes and tailings generated as a result of the mining activity cannot be easily disposed off and this also leads to the destruction of the natural landscape (Figure 4).

Large pits were also created as a result of the mining activity. Some of the pits are not filled with water while other are filled with water (Figure 5 a and b). These pits can be dead traps to both man and animals. It could also become dangerous habitat for reptiles such as snakes which can cause harm to man.

Figure 5. Photograph showing mine pit not filled with water (a) and that not filled with Water (b) in Luku.

Ogezi (2005), reported that on Jos Plateau where tin and columbite mining took place has resulted in the destruction of landscape and left behind over a thousand water ponds, lakes, alluvial heaps and widespread erosion. Humans and animals get drowned in such abandoned mine ponds. Similarly, Salati et al. (2011) reported that devastation of over 1000 hectares of suitable farmlands and flooding of abandoned pits have become death traps due to artisanal mining of Azara barytes deposits in Nasarawa state.

Figure 6. Overburden and rock wastes removed from the mine resulting in different soil texture and structure from the original soil before the beginning of mining.

3.2.2. Loss of Soil Quality

Due to the mining process, the soil in the area has lost its quality. This is due to erosion, sedimentation and contamination of the soil. The removal of overburden and rocks from the mine has exposed the soil and therefore change the original soil texture and structure (Figure 6). The ultimate result of this is the poor crop yield as the soil has been rendered infertile.

Similarly, Ezeaku (2011) reported that soils around the mine site in selected areas of Nasarawa state were coarse textured and acidic due to the influence of open cast mining of solid minerals. These have caused adverse effect on the soil ecosystem hence made the soil not sustainable to plants life. The effects of the pollution loads on the soil equally affected the land uses in the host communities.

3.2.3. Soil erosion and Sedimentation

The major effect of mining activity in the study area is soil erosion and sedimentation. Erosion and sedimentation are caused by land disturbances and removal of vegetation in the process of mining. Erosion from overburden and tailing piles often increase sediment loading in a nearby stream, thereby modifying the stream morphology by disrupting a channel, diverting stream flow and changing the slope or bank stability of the stream (Figure 7). High sediment concentration decreases the depth of stream resulting in greater risk of flooding during times of high stream flow (Figure 8).

Figure 7. Photograph showing a new stream channel being formed as a result disrupting of the old channel by erosion.

Figure 8. Photograph showing high Sedimentation on the stream channel due to erosion. This reduces the depth and with of the stream which may cause serious flooding during the period of heavy rains

Ogezi (2005) also reported that on the Jos Plateau where tin and columbite mining took place, the operations upset the equilibrium in the geological environment, and this triggered off certain geological hazards such as flooding and erosion.

3.2.4. Destruction of Vegetation

The clearing of the site for mining activities has resulted in deforestation. Large amount of vegetation has been destroyed and this exposes the soil to erosion and renders it unfit for crop production (Figure 9a). The degree of deforestation can be evaluated if compared to the adjacent area which was not affected by the mining activities (Figure 9b).

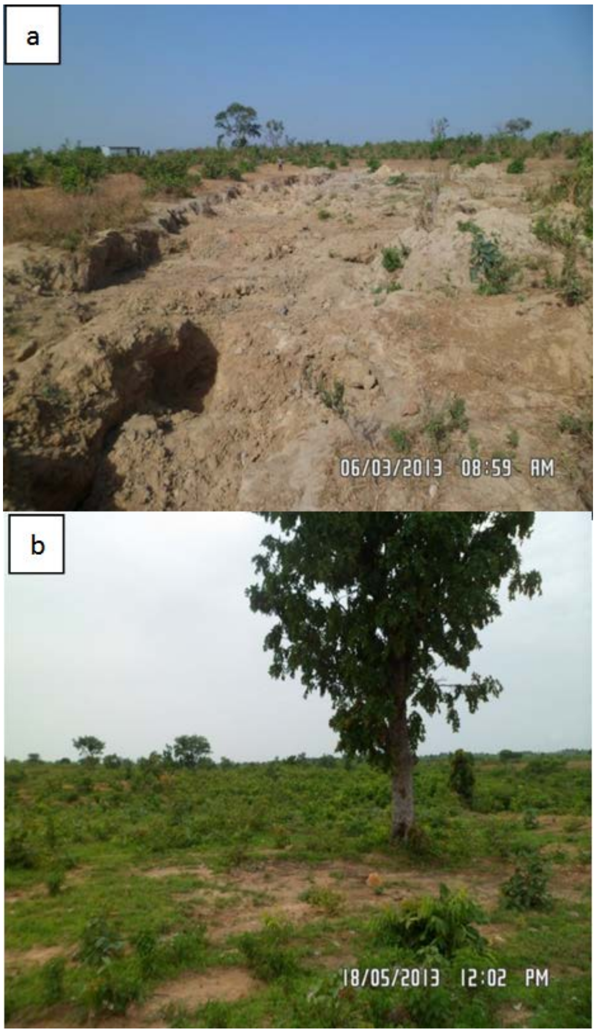

Figure 9. Photograph showing the effect of loss of vegetation on land (a) as compared to an adjacent area that was not affected by the mining activities (b)

Aigbedion and Iyayi (2007), have reported a similar situation in which large amount of vegetation was stripped due to the open cast mining in Jos Plateau. This virtually changed the landscape of the area, which is today vast open grassland. Also, Tolulope (2004) reported a similar case of vegetation loss particularly in the Niger Delta areas where oil spillage has equally affected the growth of vegetation. In the affected areas, the removal of vegetation caused the elimination of some plants and the exodus of some animals that feed on such plants or depend on them for cover.

3.2.5. Degrading of Water Quality

Disturbed areas, mine waste and rock dumps increase the total solid load of water bodies which affect the quality of water in the study area. The water turns brown due to panning of gold which is discharged into nearby streams (Figure 100). Water contaminated as a result of the gold mining may pose human health and environmental risk.

Figure 10. Brown coloured water discharged into nearby stream which renders the water unfit for human consumption

Studies have shown that tailings on the Jos Plateau have high radioactive elements, which could be very harmful to human health (Ogezi, 2005; Aigbedion, 2005). Such tailings are often used for construction of roads, houses or the radioactive waste could be washed into drinking water sources leading to mysterious death of the consumers.

3.3. Geochemistry of the Soil Samples

The results of the concentration of elements in the soils of the study area along with the mean concentrations are presented in Table 1.

Result of geochemical analysis of soil samples show that, Pb has the highest concentration at LSS 1 and lowest concentration at LSS 7 and LSS 14. As and Zn have the highest concentration at LSS 4 and lowest concentration at LSS 6 and LSS 14 respectively. Cu has the highest concentration at LSS 1 and lowest concentration at LSS 6. Ni and Co have the highest concentration at LSS 9 and lowest concentration at LSS 6 and LSS 4 respectively. Mo has the highest concentration at LSS 10 and lowest concentration at LSS 5, LSS 6 and LSS 13. It was not detected at LSS 3, LSS 4, LSS 7, LSS 9 and LSS 11. Hg has the highest concentration at LSS 4 and lowest concentration at LSS 9. It was not detected at LSS 1, LSS 3, LSS 5, LSS 6, LSS 7, LSS 10, LSS 11 and LSS 13. Ag has the highest concentration at LSS 4 and LSS 10 and lowest concentration at LSS 1, LSS 5, LSS 7 and LSS 11. Mn has the highest concentration at LSS 3 and lowest concentration at LSS 9. Zr has the highest concentration at LSS 5 and lowest concentration at LSS 10. Cd has the highest concentration at LSS 14 and lowest concentration at LSS 9.

The mean concentration of twelve elements in the samples was compared with Wedepohl, (1995) and Taylor and McLennan, (1985) average concentration of elements in upper continental crust.

Table 1. Geochemical data of the concentration of elements (ppm) in soils from Luku

Element (ppm)	LSS1	LSS3	LSS4	LSS5	LSS6	LSS7	LSS9	LSS10	LSS11	LSS13	LSS14	Mean Concentration (ppm)
Pb	330	80	313	53	30	10	20	34	27	36	10	85.73
As	21	9	22	4	1	20	8	5	7	3	2	9.27
Cu	73	55	60	63	40	56	62	62	44	56	50	56.45
Zn	23	20	72	41	21	24	26	47	20	29	18	31.00
Ni	34	35	21	67	77	86	94	86	47	73	24	58.55
V	87	98	77	106	100	65	92	71	63	54	93	82.36
Cr	2	30	4	10	1	33	35	25	2	1	10	13.91
Ba	200	920	214	600	220	400	900	600	66	600	780	500.00
Sr	971	643	470	310	90	230	124	120	200	200	95	313.91
Mn	590	690	520	250	143	180	42	280	56	190	180	283.73
Cd	2	1	4	-	-	-	<1	-	1	1	9	1.68
Sb	-	2	1	-	-	-	-	3	1	-	-	0.64
Co	11	18	13	12	18	-	26	3	14	-	5	10.91
Th	121	-	1	9	-	4	-	12	3	9	-	14.45
Mo	2	-	-	1	1	-	-	3	-	1	2	0.91
Hg	-	-	2	-	-	-	1	-	-	-	-	0.27
Ag	1	-	2	1	-	1	-	2	1	-	-	0.73
Au	-	-	1	1.2	-	-	0.4	-	2	0.3	-	0.45
Yb	8	1	-	-	-	6	-	-	5	1	2	2.09
Re	15	15	14	5	7	-	16	2	-	-	10	7.64
Ta	4	-	1	-	-	-	2	-	1	-	-	0.73
Eu	21	20	20	18	-	11	21	20	4	10	22	15.18
Y	17	12	6	16	37	22	30	28	32	4	31	21.36
Rb	16	54	3	-	5	7	-	8	86	-	2	16.45
Zr	130	46	187	360	197	75	160	34	50	221	116	143.72
Nb	24	2	61	-	3	-	-	4	9	-	1	9.45

Table 2. Summary of the mean concentration of elements in soils in the study area compared with average concentrations of the elements in crustal rocks

Element	Average concentration (ppm)	Guide for Maximum Allowable Concentration in Upper Continental crust			
		Wedepohl, (1995) Average Concentration	Status	Taylor and McLennan, (1985) Average Concentration	Status
Pb	85.73	17 ppm	High	20 ppm	High
As	9.27	2.0 ppm	High	1.5 ppm	High
Cu	56.45	14.3 ppm	High	25 ppm	High
Zn	31.00	52 ppm	Low	71 ppm	Low
Ni	58.55	18.6 ppm	High	20 ppm	High
Mn	283.73	527 ppm	Low	600 ppm	Low
Cd	1.68	0.102 ppm	High	98 ppb	High
Co	10.91	11.6 ppm	Low	10 ppm	Low
Mo	0.91	1.4 ppm	Low	1.5 ppm	Low
Hg	0.27	0.056 ppm	High	40 ppb	High
Ag	0.73	0.055 ppm	High	50 ppb	High
Zr	143.27	237 ppm	Low	190 ppm	Low

Pb, As, Cu and Ni range from 10 ppm-330 ppm, 1 ppm-22 ppm, 44 ppm-73 ppm and 21 ppm-94 ppm with mean concentrations of 85.73 ppm, 9.27 ppm, 56.45 ppm and 58.55 ppm respectively (Table 1). The results further show that the mean concentrations of Pb, As, Cu and Ni are higher compared to the published crustal averages (Table 2).

Zn, Mn and Co concentrations range from 18 ppm-72 ppm, 42 ppm-690 ppm and 3 ppm-26 ppm with mean concentrations of 31.00 ppm, 283.73 ppm and 10.91 ppm respectively. The results show that the mean concentrations of Zn, Mn and Co are lower compared to the Wedepohl, (1995) and Taylor and McLennan, (1985) values.

Mo and Zr concentrations range from 1 ppm-3 ppm and 34 ppm-360 ppm with mean concentrations of 0.91 ppm and 143.27 ppm respectively. The results show that the mean concentrations of Mo and Zr are lower compared to the Wedepohl, (1995) and Taylor and McLennan, (1985) values.

Cd, Hg, Ag, concentrations range from< 1 ppm-9 ppm, 1 ppm-2 ppm and 1 ppm-2 ppm with mean concentrations of 1.68 ppm, 0.27 ppm and 0.73 ppm respectively. The mean concentrations of Cd, Sb, Th, Hg, Ag, Au, Re and Eu exceeded the published crustal averages (Table 2).

The average concentrations of elements in the soils of the study area are presented on a bar chart (Figure 11).

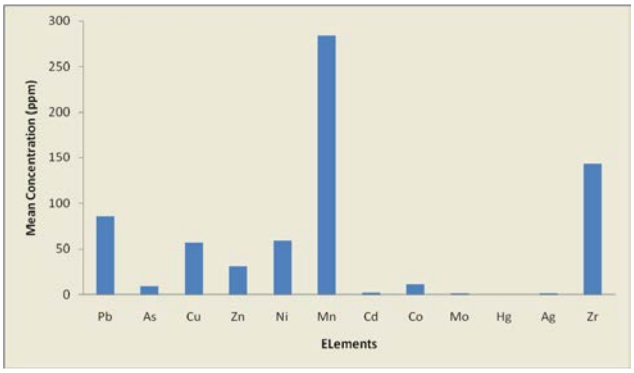

Figure 11. Bar chart showing the mean concentrations of elements in the soils in Luku

From the graph it is seen that Lead (Pb) has a mean concentration of 85.73 ppm (Figure 11). The mean concentration of Pb is higher compared to the published crustal averages (Table 2). Hongyu et al. (2005); Osher et al. (2006) reported that elements such as Pb is transported in water, food and soil. It gets accumulated in plants and animals and passed across the food chain to human. Pb content in food is due to air pollution. It gets into human through food and drinking water (WHO, 1996) and animals through water, feeds and soil (Dwivedi et al., 2001). Ling et al., 2006, reported that it causes brain and kidney problem in human. High content of Pb in plant is detrimental to its morphology, growth and photosynthetic processes (Nagajyoti et al., 2010). It is exceptionally high at LSS 1 and other mine out area and low at LSS 7 and LSS 14. This is possibly due to local geology and mining activity in the study area.

The mean concentration of As exceeded the Wedepohl, (1995) value and the Taylor and McLennan, (1985) value. Arsenic may be inhaled from dust in the mine. Fairfax (1993), reported that As get into the body by intake of water from wells or in mine drainage areas. Parga et al. (2006) stated that the high Arsenic concentration in ground water is as a result of natural weathering of rocks. Arsenic may occur in high concentration areas where Au, Cu, Ni and Ag ores are found. It is also ingested by human through food especially sea food in diet. Plants take up As through root from contaminated soil and dust that settle on leave (Data et al., 2000). Arsenic gets into the food chain through their accumulation in plants. It causes cancer and death from respiratory and cardiovascular failure in human. It also results in change of skin colouration. Arsenic concentration is highest at LSS 4 and lowest at LSS 6 which are both mined areas. As content is also high at LSS 7 which is an un-mined area. The high concentration of As in the study areas is probably related local geology and the mining activity.

Copper (Cu) has mean concentration of 56.45 ppm. It ranges from 40 – 73 ppm. The mean concentration of Cu is higher compared to the published crustal averages (Table 2). Cu is an important micronutrient for plant (Thomas et al., 1998). It is essential at low concentration and hazardous in plants, animals and human at excessive level. According to Zarie et al. (2011), high ingestion of Cu leads to liver and kidney damage. It slows down the growth of plants and causes leaf chlorosis (Lewis *et al.*, 2001). Cu content is generally high with highest concentration at LSS1 in the study area. This is probably due to combination of local geology and mining activity.

Zinc (Zn) has mean concentration of 31 ppm. It ranges from 18 – 72 ppm. The mean concentration of Zn is lower compared to the published crustal averages. Cakmak and Marshner (1993) reported that Zn is a vital micronutrient that affects several metabolic processes in plant. It is required in very small quantity. High Zn concentration leads to chlorosis in leaves and stunted plant growth and kidney failure in human. The Zn content is generally low in the study area. The highest Zn concentration at LSS4 is possibly due to mining activity.

Nickel (Ni) has mean concentration of 58.55 ppm. It ranges from 21 – 94 ppm. The mean concentration of Ni exceeded the Wedepohl, (1995) value and the Taylor and McLennan, (1985) value. According to Gimemo-Garcia et al. (1996), human activities such as mining increase Ni concentration in certain areas. Acid rain increases the transportation and accumulation of Ni in soil and ground water. High concentration of Ni causes chlorosis in different plants (Zomoza *et al.,* 1999; Pandey and Sharma, 2002; Rahman *et al.,* 2005). In human, high Ni content leads to respiratory system cancer and skin disorder. In the study area, Ni concentration is generally high with highest at LSS 9 in the un-mined area. This is possibly related to combination of local geology and mining activity.

Manganese (Mn) has the highest mean concentration of 283.73 ppm. It ranges from 42 - 690 ppm. The mean concentration is lower compared to the Wedepohl, (1995) and Taylor and McLennan, (1985) values. Mn is an essential micronutrients (Reeves and Baker, 2000), whose excessive concentration becomes toxic to plant and animals (Monni et al., 2000; Blaylock and Huang, 2000). Wu (1994) reported that leaves turn brown and also results in reduction of photosynthesis. Mn gets into human body through breathing, eating, drinking and skin absorption. This causes health problem. Mn content is low in the soil; the highest Mn concentration at LSS3 is probably related to mining activity in the study area.

Cadmium (Cd) has mean concentration of 1.68 ppm and it ranges from 1 – 9 ppm. The mean concentration of Cd is higher compared to the published crustal averages. Crops grown in soils with high Cd concentration lead to chlorosis, browning of roots and death of plants (Sanita di Toppi and Gabbrielli, 1999; Wojcik and Tukiendorf, 2004; Guo et al., 2008). In human, source of exposure is through ingestion of food and water and inhalation of dust. High Cd concentration may cause kidney damage. The highest Cd concentration at LSS 14 is due to mining activity in the study area.

Cobalt (Co) has mean concentration of 10.91 ppm. It ranges from 3 – 26 ppm. The mean concentration of Co is lower compared to the published crustal averages. High Co concentration leads to chlorosis and death of plants. Co gets into human through inhalation of air or dust and ingestion of food and water. Co content is low in soil, the high concentration at LSS 3, LSS 6 and LSS 9 may be due to the geology and mining activity in the study area.

Molybdenum (Mo) has mean concentration of 0.91 ppm and it ranges from 1 – 3 ppm. The mean concentration of Mo is lower compared to the published crustal averages. Mo is required in trace amount by plants and human. The high Mo concentration at LSS 10 may be related to mining activity.

Mercury (Hg) has mean concentration of 0.27 ppm and it ranges from 1- 2 ppm. The mean concentration of Hg exceeded the Wedepohl, (1995) value and the Taylor and McLennan, (1985) value. Hg occurs naturally in trace quantity in the earth crust (Cava *et al.,* 2004). Berzas *et al.,* (2003) reported that mining of ore expose human to mercury. Hg may be released into water bodies, deposited in sediment or emitted into the atmosphere. Mercury contamination is passed through food chain to human. It is toxic to the reproductive and nervous system (Frumkin *et al.,* 2001). High Hg content interrupt metabolism in plants (Messer *et al.,* 2005). The high Hg concentration in the study area is probably related to mining activity.

Silver (Ag) has mean concentration of 0.73 ppm and it ranges from 1-2 ppm. The mean concentration of Ag is higher compared to the published crustal averages. Ag gets into human through ingestion and inhalation.

Exposure to high level of Ag leads to discolouration of skin and breathing problem. The high concentration of Ag in the study area is possibly due to the local geology and mining activities

Zirconium (Zr) has mean concentration of 143.27 ppm. It ranges from 34 -360 ppm. The mean concentration of Zr is lower compared to the published crustal averages. Zr gets into the plants through the soil; this is an important link for the metal to enter into the food chain (Wang *et al.*, 2000; Shi *et al.* (2002). Excessive concentration of Zr causes reduced plant growth. Zr concentration is generally low. The high content at LSS 5 and LSS 13 is possibly related to mining activity.

3.4. Element Enrichment Ratios

Element Enrichment Ratios were calculated in order to know the extent of enrichment or depletion of elements in the soils of the area relative to their crustal concentrations. The Upper Continental Crust concentrations of the elements by Taylor and McLennan, (1985) were used as background values. Enrichment ratio (ER) was calculated using the equations:

$$ER = \frac{Cn}{Bn}$$

Where Cn is the concentration of an element measured in a sample and Bn is the background concentration, that is, the upper crustal concentration of the element by Taylor and McLennan, (1985). The enrichment ratios are summarized in Table 3.

Sutherland (2000) interpreted enrichment ratio, ER as follows:

ER < 2 – Depletion to minimal enrichment
ER 2 < 5 – Moderate enrichment
ER 5 < 20 – Significantly enrichment
ER 20 < 40 – Very high enrichment
ER> 40 – Extremely high enrichment

Table 3. Summary of enrichment ratios (ER) for the samples from the study area

Elements	Mean Concentration (ppm)	Taylor and McLennan, (1985) Average Concentration	Enrichment ratio(ER= Cn/Bn)	Status
Pb	85.73	20 ppm	4.3	Moderately Enriched
As	9.27	1.5 ppm	6.2	Significantly Enriched
Cu	56.45	25 ppm	2.3	Moderately Enriched
Zn	31.00	71 ppm	0.4	Depleted
Ni	58.55	20 ppm	2.9	Moderately Enriched
Mn	283.73	600 ppm	0.5	Depleted
Cd	1.68	98 ppb	17.1	Significantly Enriched
Co	10.91	10 ppm	1.1	Depleted
Mo	0.91	1.5 ppm	0.6	Depleted
Hg	0.27	40 ppb	6.8	Significantly Enriched
Ag	0.73	50 ppb	14.6	Significantly Enriched
Zr	143.27	190 ppm	0.8	Depleted

The results show that Zn, Mn, Co, Mo and Zr are generally depleted element relative to their background value, with enrichment ratios less than 2 (Table 3). Pb, Cu, and Ni are moderately enriched element relative to the background value, with enrichment ratios between 2 and 5 (Table 3). As, Cd, Hg and Ag are significantly enriched element relative to the background value, with enrichment ratios between 5 and 20. This indicates that artisanal mining activities have contaminated the environment with these elements.

Pb is an enriched element relative to the background value, with an ER of about 4.3. It is not essential to either plant or Human. If present in large quantity, in certain mineral or chemical form, it may be toxic. Lin-chu (2006) reported that high concentration of Pb causes brain and kidney problem in human and is detrimental to its plants morphology, growth and photosynthetic processes. Jason et al. (2002) reported that the concentration of Pb was high in soils of the Migori gold belt, Kenya. The study revealed that the concentration of Pb, As and Hg was above acceptable levels in the tailings at panning sites and stream sediments. The high concentration of Pb is possibly due to mining activity in the study area. Hg and As are enriched elements relative to the background value, with an ER of about 6.8 and 6.2 respectively (Table 3). The high concentration of As in the study areas is probably related local geology and not controlled by the mining activity. Hg emissions from artisanal mining pose a threat to human health. Widespread pollution of soils and sediments occur as a result of careless handling of Hg during gold panning and Au/Hg amalgam processing contaminates soils. According to Waziri (2014), the concentrations of Pb and As was high in soils and stream sediments from the Birnin-Gwari artisanal gold mining area, North-western Nigeria.

Cu and Cd are enriched elements relative to the background value, with an ER of about 2.3 and 17.1 respectively. Ezeaku (2011) reported that the concentration of Pb, Cu and Cd are high in soils from the open cast mining of solid mineral in Nasarawa state, North-central Nigeria. The study revealed high contents of Pb, Cu and Cd may have caused adverse effect on the soil hence unsustainability of plants life.

4. Conclusion

Artisanal gold mining is a means of livelihood adopted in Luku area. Yet, it operations are dangerous and have resulted in environmental problems such as land degradation, deforestation, erosion and loss of soil quality.

The result of chemical analysis shows that the soils from Luku are enriched moderately with Pb, Cu, and Ni and significantly with As, Cd, Hg and Ag. The artisanal mining activities have contaminated the environment with these elements. These elements can easily be absorbed by plants and if such plants are eaten by man, they accumulate in the tissues. This may lead to different health problems such as slow growth rate, difficulty in breathing, liver and kidney problem. The dispersion of these elements into ground and surface water may also render them unsuitable for human and animal consumption. High concentration of these elements in plant tissues may causes different problems such as retarded growth, yellowing of leaves, poor crop yield and shedding of leaves.

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