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# Investigation of Possible Contamination of Water Used for Gold Mining using Neutron Activation Analysis in MararrabanBirnin Yauri Kebbi State North-West Nigeria

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**ABSTRACT**
The motivation for this research work was the unprecedented death of animals and the appearance of debilitating illnesses in the MararrabanBirnin Yauri community. These deaths and illnesses are suggested to be associated to artisans in the business of gold mining. The artisans use the communities' sources of water in extracting their gold. In the extracting of gold, artisans use chemicals that pollute water bodies used by humans and animals. This work collected water samples from three out four affected Sites and two major community source of drinking water for analysis using Investigated neutron activation analysis method. The choice of this method is informed by the evidence that the method is multi-elemental, non-destructive and safe. Results indicated the presence of fifteen elements: seven are naturally occurring four are alien to the community suggesting they are imported contaminants by the miners. The elements include the following: Al, B, Ca, Ch, Cl, Fe, Hg, K, Mg, N, Na, S, Pb and Zn. Human made contaminants include NaCN and Hg with concentration of 160 ppm and 2.8 ppm respectively. These concentrations are way high above the World Health Organization tolerable limits.

## I. INTRODUCTION

Water is a liquid of ambient condition, but it often co-exists on earth with its solid state, ice and gaseous state, water vapour or steam, water which covers 70% of the earth's surface and is vital for all forms of life. Naturally 53% of the populations rely on groundwater as source of drinking water; in rural areas this figure is even higher. Man uses water for domestic and industrial supply, transportation, irrigation, power generation, fish farming, sports, drainage and waste management (Rice et, al., 1997).

Water pollution is the contamination of water bodies such as lakes, rivers, ocean and underground water by human or natural activities which can be harmful to plants and other organism that live or use the water. Waste product such industrial wastes, mining wastes and agricultural wastes often contain some amount of pollutants as a result of the material used in generating the waste, thereby adding to the level of water pollution (Saiduet al., 1997).

Another form of water pollution is Naturally Occurring Radioactive Materials (NORM) that emits alpha, beta and gamma radiation, these usually have elements in the Uranium and Thorium series whose radioactive gaseous daughters (radon and thorium) in particular cause an appreciable airborne particulate activity and contribute to the radioactivity of rain and groundwater, it also affect drinking water. Furthermore, spring or flowing water passes through rocks that may contain many radioactive materials as a result, the flowing water that leaches affects the soil and plants on its way, and it could also be transported into wells, boreholes and tap water through burst pipes (Saiduet, al., 1997).

The Hungarian Nobel Prize winner Albert Szent-Gyorgyi once said, "Water is life's matter and matrix, mother and medium. There is no life without water." If the water resources are contaminated, so is life. Providing clean drinking

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water for the growing population of the world is one of the most pressing issues we all stand to support in the 21st century (Walker and Sibly, 2001). Both Anthropogenic and natural processes can affect the water quality (Walker and Sibly, 2001).

Gold mine development involves the planning and construction of the mine and associated infrastructure. Mining companies must obtain appropriate permits and licenses before they can begin construction. This will generally take several years, although this varies greatly depending on location. In addition to potential processing capacity, mining companies frequently construct local infrastructure and amenities to support both logistical and operational needs, as well as employee and community welfare. This development provides much long-term support for local communities, and is one of the key ways gold supports economic development(Saiduet al., 1997).

Gold production is associated with contribution to hazardous pollution (Girigisu,et al.,

2012). Environmentalists consider this pollution as major environmental disasters. Heavy metal contamination is an environmental concern because of their toxicity. It can cause damage to practically all organs in the body (Death of a river 2000 and Cyanide spill second only to Chernobyl 2000). Gold ore dumps are the source of many heavy elements such as mercury, copper, Nickel, chromium, manganese, zinc, lead, Iron etc. Water is unsuitable for human consumption if these heavy metals are found in more than 1ppm concentration (Girigisu,et al., 2012).

Though in physiochemical terms, heavy metals are defined as metals with a density at least five times greater than density of water. In medicine it is all toxic metals irrespective of their atomic weight (John, 2002). The relevant route of exposure of the public is internal, via inhalation of dust and aerosols and ingestion of food and water. Mining results in large volumes of mine tailings that may contain enhanced levels of natural radionuclide. Leaching of radionuclides can result in contaminated surface and ground water bodies and thereby exposing the members of the public to danger. Radionuclide, such as $^{226}Ra$ and $^{228}Ra$ are known to have high mobility in the environment due to their high comparative solubility in water. Most of these radionuclides are predominantly alpha emitters and alpha particles tend to cause more internal hazard than beta particles and gamma rays (Faanuet al., 2011).

When sulphide bearing minerals in the ore dumps are exposed to air or water, the sulphide transforms to sulphuric acid which dissolves the heavy metals and facilitate their passage to surface and ground water and this process is called acid mine drainage. Gold ore dumps are considered as long term manmade hazardous waste next only to nuclear waste dumps (Norgate and Nawshad, 2012). Billions of dollars need to be spent to mitigate the heavy metals pollution from worldwide gold ore dumps which are increasing every year (Norgate and Nawshad, 2012).

Most drinking water sources have very low levels of radioactive contaminants (radionuclides), most of which are naturally occurring, although contamination of drinking water sources from human-made nuclear materials can also occur. Some of the radioactive contaminants are at low levels enough to be considered for public health concern. At higher levels, long-term exposure to radionuclides in drinking water may cause cancer (USEPA, 1994). In addition, exposure to uranium in drinking water may have toxic effects to the kidney, (USEPA, 1994).

## II. II RELATED WORK

A study conducted at the Osprey and Fumani gold tailings dams indicated high concentrations of, Zn-96.4, Cu-64.2, and Cr-269.3. High concentrations of these metals have toxicity potential on plants, animals and humans Using Atomic Absorption Spectrometer,(Ogolaet. al., 2010)

Radiological survey and assessment of associated activity concentration of the sNaturally Occurring Radioactive Materials (NORM) in the Migori artisanal gold mining belt of southern Nyanza, Kenya. A study explores the possibility of converting an abandoned dredged mines paddock into a fish pond. The aim of the study is the assessment of the water quality conditions of nine surface water sampling points including paddocks/impoundments created by the operations of defunct dredged gold mine operations more than a decade for conversion into a fish pond. The concentrations of twenty water quality parameters (major ions, physicochemical and trace metals) were determined and compared with threshold values for protection of aquatic life to evaluate the suitability of the paddocks for development into a fish pond Using Neutron Activation Analysis (Aporiet al., 2012).

Elemental Analysis of Soil AroundIkotAbasiAluminum Smelter Plant, Nigeria by Instrumental Neutron Activation Analysis. Concentration of major, minor and trace elements in soil samples around IkotAbasiAluminum Smelter Company of Nigeria (ALSCON)

IkotAbasi, Nigeria were determined by Instrumental Neutron Activation Analysis (INAA) technique using thermal neutron from Nigeria Nuclear Research Reactor (NIRR-1) at Center for Energy Research and Training (CERT), Ahmadu Bello University Zaria. By this analysis, 25 elements were determined in the soil around IkotAbasiAluminum Smelter Plant the element include Cr, Yb, Cs, Sb, Fe, Sm, Dy, Pa, As etc. The results show that INAA of soil samples around the studied area gave maximum values of 9.99 ± 0.41 ppm for As; 9.54 ± 1.06ppm for Sb; 7.725 ± 1.53ppm for Lu; 4.28 ± 0.81ppm for Fe and 3.24 ± 0.18ppm for Cr (Essiettet al., 2011).

Elemental Evaluation of Cereals commonly used in Nigeria Using Neutron Activation Analysis. The concentrations of twenty elements in ten cereals types commonly consumed in Nigeria were determined using Neutron Activation Analysis (NAA). The elements are Al, As, Ba, Br, Ca, Cl, Co, Fe, K, La, Mg, Mn, Na, Rb, Sc, Sm, Sr, Th, V, Zn and the cereals are beans, guinea corn (red and white), maize (white and yellow), millet, rice (basmatic, foreign, and local) and wheat. The results obtained for these elements were compared with World Health Organization (WHO) permissible limits. This showed that the concentrations of all the heavy metals studied (Co, Fe, La, Mn, Sm, Th, V, Zn) and some of the mineral elements (Ca, K, Mg, Na) in the cereal samples were below WHO permissible limits except wheat that showed a higher value in Mg (2.309 %) compared with the WHO permissible limit of 0.139%. The levels of the twenty elements in the cereals did not exceed their permissible levels and are therefore safe for human consumption (Ugoeze, 2019).

Mining of solid minerals has been identified as an entry point of heavy metals into the environment, consequently polluting various components of the environment such as water and air. Five water samples and a kilogram each of selected solid minerals (Gold, tantalite and columbite) from one of the gold mines of Zamfara state were analysed for mineral and heavy metals (Mn, Zn, Pb, Mg, Al, Cd, Cr, Ni, Co and Cu) using Neutron Activation Analysis. The results revealed high concentration of Heavy metals in water which indicate significant contamination. The study concluded that there was pollution of water body especially for toxic metals like Pb and Cd (Tsafeet al., 2012).

A study was carried out on the concentrations of constituent (major, minor and trace) elements present in soil samples collected from different parts of Abuja Metropolis and their effect on the surrounding. In carrying out the analysis, the best and most convenient method being the Instrumental Neutron Activation Analysis (INAA) otherwise known as Non-Destructive Neutron Activation Analysis (NDNAA) was adopted. Soil/ Rock Samples were obtained, crushed to powdery form and samples prepared for INAA. 250mg of the samples were fed in to the nuclear reactor by means of pneumatic transfer with the aid of rabbit capsules. The irradiated samples were analyzed and the following elements identified: Al, Ti, Ca, Mg, K, Na, V, Mn, Dy, Sc, Zn, La, Sm, Co, Th, Rb, Ce, Hf, Fe, Yb, As, Eu, Lu and U. There have been higher concentrations found in the Airport Road soil than in the other soils as seen in Fe from the following results: Airport Soil (0.4212±0.014), Airport Road Soil (1.31±0.20), Aso Radio Soil (0.6641±0.017) and Karu soil (0.528±0.013); indicating that soil in that region might favour the growth of particular plants compared with soils from other region; however there was relative distribution in the overall outcome of trace and major elements. The results and technique compared with that of Oladipos who had a total of 22 elements from 7 different clay samples indeed showed that NAA is effective method of elemental analysis (Innocent et al., 2013).

## III. III MATERIALS AND METHOD

### 3.1 Materials and Method

1. The main material is water sample that was collected from the three out of four mining sites and two community drinking water source, other materials are:
2. Neutron Activation Analysis Machine which contain the following properties

i. High voltage power supply refers to voltage above certain threshold that is why special safety requirement and procedures are employed.

ii. Scintillation counter is a radiation detector that is triggered by a flash of light produce when ionizing radiation transverses certain solid or liquid substances. The light flashes are converted into electric pulses by photoelectric alloy of caesium and antimony amplified about million times by photomultiplier tube and finally counted.

iii. Lead shield refers to the use of lead as a form of radiation protection to shield people or objects from radiation so as to reduce the effective dose. Lead can effectively attenuate certain kinds of radiation because of its high density and high atomic number. It is effective at stopping gamma rays and x-rays.

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iv. Multi-Channel Analyser (MCA) for γ-spectroscopy can be used for different applications. We have mainly focused on the quality control aspects and the determination of radio nuclide purity.
v. Desktop computer running CASSY software is popular software for recording and analysing measurement data.

### 3.2 Sample Collection

Water sample was collected from MararrabanBirnin Yauri Mining area from the three out of the four main mining sites and the two main community source of drinking water. In order to ensure representation, 1000cl of water sample was collected from each of the following camp in the mining area, sample from indigenous camp, foreign camp, samples from the mix-up camp and community source of drinking water for the analysis. Initial survey was carried out in the area to determine the sampling points. The selection of the sampling locations was based on the accessibility to the public and proximity to the mine. All the samples were taken to Centre for Energy Research & Training Sections (CERT) of Ahmadu Bello University (ABU) Zaria for analysis.

### 3.3 Method

The method that was used is Neutron Activation Analysis (NAA) the process of analysing samples by NAA involves irradiating them with a neutron source. Neutrons are captured by elements in the sample to produce unstable radioactive isotopes (radionuclides). Beta particles and in most cases gamma rays, are emitted from the radionuclides as they decay. The energies of these gamma rays are in general distinct for a specific nuclide and the rate at which these photons are emitted with a particular energy can be measured using high resolution semiconductor detectors. Because the production and decay rate of gamma radiation are dependent on the half-life of the nuclide, elemental measurements can be optimised by varying the irradiation and decay times (ie. how long the sample is near a neutron source and when the sample is analysed).

## IV. IVRESULTS AND DISCUSSION

To identify the natural and artificial contaminant five water samples was collected out of the six sample points for analysis and the following result was obtained:-

The table1, shows concentrations of elements (ppm) present in samples

| Sample | Al | B | C | Ca | Ch | Cl | Fe | Hg | K | Mg | N | Na | S | Pb | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. HAND P. | 0.006 | 0.007 | 0.00 | 1000 | 10 | 0.00 | 2.0 | 0.00 | 0.0 | 1500 | 0.00 | 0.00 | 0.00 | 0.00 | 0.45 |
| 2. RIVER W. | 0.015 | 0.007 | 4.0 | 6.15 | 0.0 | 3.2 | 0.0 | 0.0 | 0.0 | 4.20 | 0.00 | 12.0 | 6.0 | 0.00 | 0.2 |
| 3. JIRGI | 0.02 | 0.007 | 9.3 | 10.4 | 4.3 | 0.00 | 11.2 | 2.8 | 4.2 | 10.0 | 0.00 | 12.3 | 23.4 | 0.03 | 2,52 |
| 4. RUWA-R. | 0.04 | 0.007 | 9.3 | 10.4 | 4.3 | 0.00 | 11.2 | 2.4 | 3.2 | 10.0 | 0.00 | 13 | 23.4 | 0.03 | 2,52 |
| 5. BARKINE | 0.015 | 0.007 | 165 | 10.4 | 4.3 | 0.00 | 11.2 | 0.00 | 4.2 | 10.0 | 160 | 165.2 | 6.4 | 0.05 | 0.00 |
| 5. PAGMI | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

### 4.2 Graphical Representation of the Results

The result of all the mining site and community source of drinking water was represented graphically below

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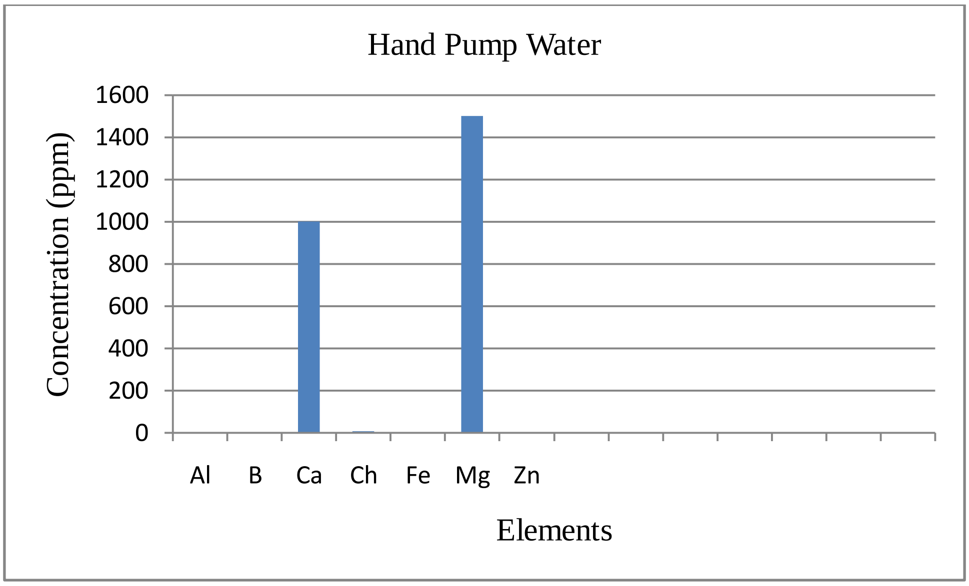


Fig. 6 shows concentration of elements present in the water from the hand pump, the main community source of drinking water.

The result of the borehole water, which is the main source of community drinking water, shows high concentration of calcium and magnesium which proving that the water is moderately hard.

The formation of lather with soap in water determines the hardness property of such water which also increases the boiling point of water. Hardness of water depends mainly on the amount of calcium or magnesium salt or both present in the water sample (Singh, et al., 2003 and Werner, et al., 2006). Hardness has been classified as follows: soft 0 to 60 mg/l, (0 to 600 ppm) moderately hard, 61 to120 mg/l, (610 to 1200 ppm) hard 121 to 180 mg/l, (1210 to 1800 ppm) and above 180 mg/l (1800 ppm) as very hard (Durfor and Becker, 1964). This is a major characteristic for determining the usability of water for domestic, drinking and many industrial purposes (Lee, 2005). This hardness is natural considering the depth of the borehole and it has been long with this test according to the inhabitants who have no any other drinking water source except that borehole water. The concentration of magnesium and calcium (main causes of water hardness) ranges between 1000 ppm to 1500 ppm see figure 6, (1 g/l to 1.5 g/l) which is within the limit of hard water, (Durfor and Becker, 1964).

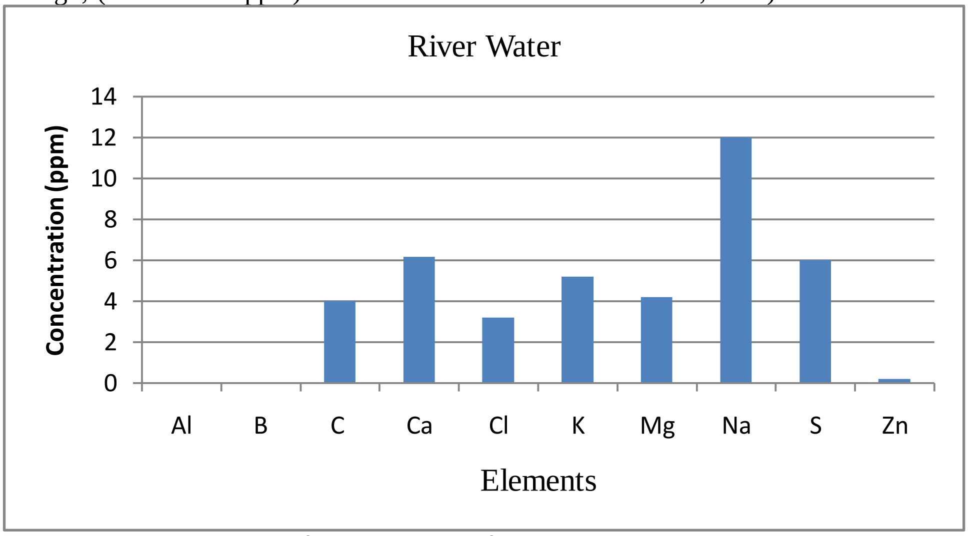


Fig. 7 shows the concentration of elements in the flowing water (stream) another community drinking water source.

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Spring or flowing water is the second largest source of drinking water for the community, although majority of these water users are gold miners, famers and nomad. According to figure 7, the concentration of elements present in the water is at low level enough to be considered for public health concern. The contaminants here may be natural or artificial since part of ruwa-ruwa activities are taking place inside the river directly.

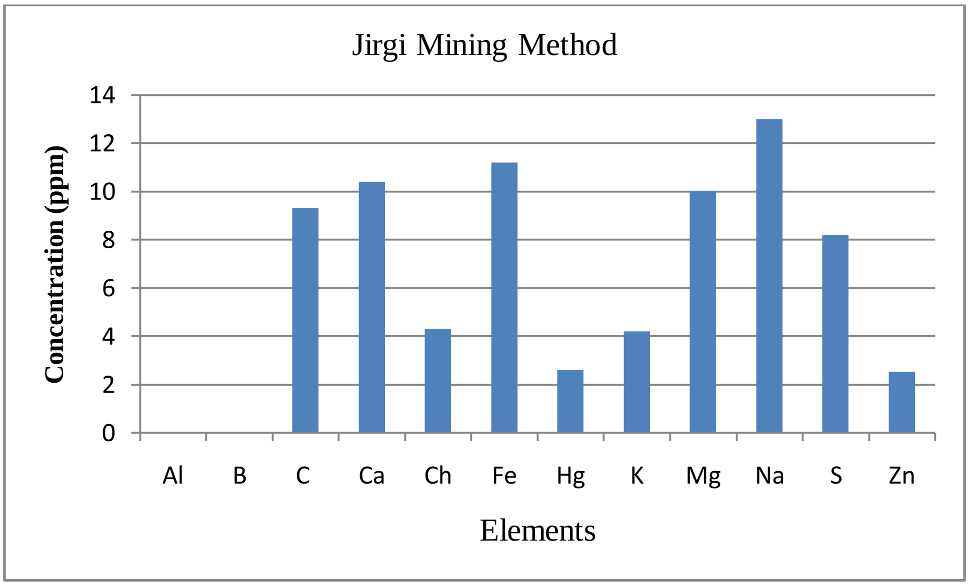


Fig. 8 Shows Concentration of elements in Jirgi mining operation (indigenous mining site)

Jirgi mining method is mostly done by indigenous miners (mostly inhabitants and other Nigerians from the neighbouring state,), it is similar to Ruwa-ruwa mining activities but the main differences between the two is that Ruwa-ruwa is been carryout by indigenous and foreign miners and in Ruwa-ruwa machine is required while Jirgi all it activities is done by human beingsbut the mode of operation of the two is the same. Apart from the contaminant found in raw 1 and 2 (i.e drinking water source), raw 3 and 4 from the table 1 above, shows additional elements (i.e. Jirgi and Ruwa-ruwa mining method) which is mercury although our research did not find any recommended dose limit from the international bodies for the mercury and it appears in this area to be non-natural contaminant (i.e anthropogenic), since its absent in raw 1 and 2, (all the drinking water source).

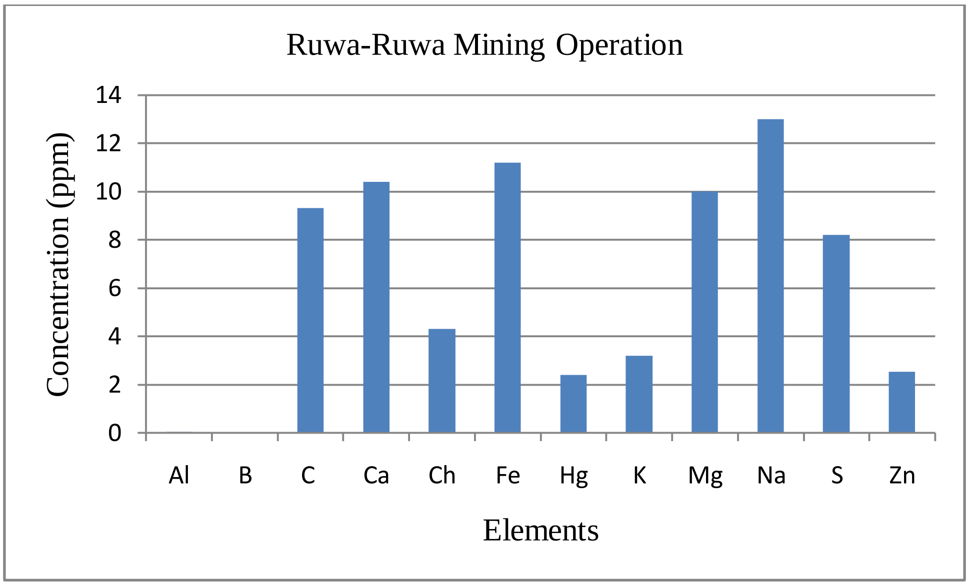


Fig. 9 Shows Concentration of elements in Ruwa-Ruwa mining site, the operation that involves both foreign and indigenous miners, it has the same mode of operation with Jirgi method.

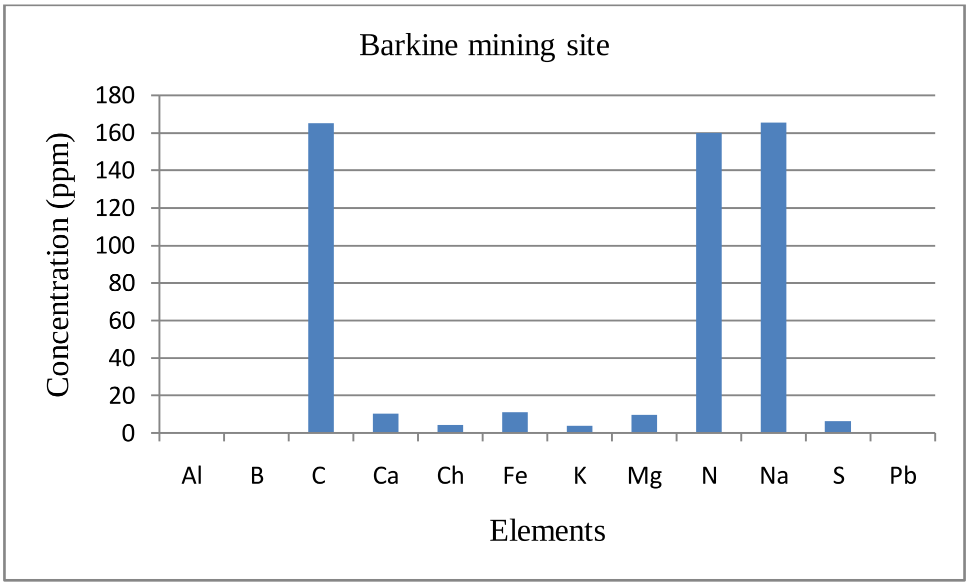


Fig. 10 Shows Concentration of elements in Barkine mining site.

The fifth site is the Barkine mining site where the operators are 100% foreigners, they do mostly isolate themselves without inclusion of any indigene (or inhabitant from the community), and sample from their site shows high concentration of elements such as carbon, Nitrogen and sodium in a similar proportion 160 ppm and above. There is also other element like Aluminium, Boron, Calcium, Chromium, Iron, Potassium, Magnesium, Sulphur and Lead but they are also found in virtually all the mining site which proved to us they are naturally there and their concentration is insignificant to cause any health hazard.

The concentration of carbon, nitrogen and sodium confirm to us the presence of Sodium cyanide NaCN, according to chemical equation below

$$HCN + NaOH \rightarrow NaCN + H_2O \qquad (4.1)$$

The miners in that site (Barkine) are using leaching method in their effort to separate gold from it ore, therefore, NaCN solution is important in dissolving gold and facilitate it passage to the next stage of the extraction, according to equation 4.2

$$4\ Au_{(s)} + 8\ NaCN_{(aq)} + O_2(g) + 2H_2O_{(l)} \rightarrow 4\ Na[Au(CN)_2]_{(aq)} + 4\ NaOH_{(aq)} \quad (4.2)$$

Wilson (2018), cyanide is highly toxic, and can result in substantial environmental impacts and public health risks if released into the environment. Cyanide spills have resulted in major fish kills, contaminated drinking water supplies and harmed agricultural lands. For example:

- **Mexico, 2014:** 500,000 gallons of cyanide solution spilled from a retaining pond at the ProyectoMagistral mine, after heavy rains.
- **Kyrgyzstan, Kumtor Gold Mine,** 1998: A truck carrying 2 tons of sodium cyanide crashed into the Barskoonriver, resulting in more than 2,000 people seeking medical care.
- **Romania,** Aural Gold**, 2000:** A tailings dam ruptured, spilling 3.5 million cubic feet of cyanide-contaminated waste into the Tisza and Danube Rivers, killing fish and poisoning water supplies as far as 250 miles downriver in Hungary and Yugoslavia.
- **United States,** Zortman-Landusky Mine, Montana**, 1982:** 52,000 gallons of cyanide solution poisoned the aquifer that supplies fresh drinking water for the town of Zortman. The accident was discovered when an employee of the mine noticed the smell of cyanide in his tap water at home.

## V. CONCLUSION

In conclusion it's therefore, certain that both indigenous and foreign miners used artificial contaminants although there are natural contaminants which are at low level enough to cause any public health concern. Human contaminants are at high level enough to cause any public health concern. Presence of mercury (Hg) and sodium cyanide (NaCN), possess a great threat to survival of both community there Animals and environment in general.

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