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Determination of Lead from Tailings of Gold Matrix using Proton Induced X-ray Emission

Buhari Samaila

Federal University Birnin Kebbi P.M.B 1157, Department of Physics with Electronics, Kebbi State, Nigeria

Abstract: ***Proton induced x-ray emission (pixe) was utilized in this research to determine the lead from five geological samples of tailings of gold ores collected from different holes within the same local mining area of maga village under Danko-fasagu zuru emirate, kebbi state Nigeria. The samples was prepared to a scale interrogated by non- destructive technique (PIXE),using 1.7MeV tandem accelerator at the Centre for Energy Research and Development (CERD), Obafemi Awulowo University (OAU) Ile-Ife, Osun state Nigeria. After samples activation with an ion beam of proton, atomic interactions occur that give off electromagnetic radiation of wavelengths in the x-ray part of the electromagnetic spectrums specific to those elements contained in the samples. The spectrum generated from the samples revealed that lead concentration is above the normal. The results of the irradiation of the samples shows that lead (pb) alongside with the other elements were obtained such as Ca, K, Zr, Ba, Ti, Si, Fe, Mn, Cl, Ce, Cu, Sr, S. The work look into the determination of naturally occurring element (lead),whose concentration was found to be above the normal. According to the results obtained from this research indicated that the communities living around the local mining area of maga are at the risk of lead poisoning, due to its high concentration in the area. This is because the tailings (left over) of gold ores at the mining area are spreading through air and water. People inhaled the air into their lungs down to the bloodstream, drink and cook with the water. These increase the potential danger of lead poisoning.***

Keywords: PIXE, Lead, and Tailing of gold matrix

1. Introduction

The PIXE is a powerful, yet non-destructive, technique used in the determination of the elemental constituents of a material or sample. When sample is exposed to an ion beam, atomic interactions occur that give off electromagnetic radiation of wavelengths in the X-ray part of the electromagnetic spectrum specific to that element [1]. Proton Induced X-ray emission (PIXE) is one of the most common and widely used analytical spectrometry techniques at MeV accelerators and the analysis is performed with characteristic X-rays. When charged particles with sufficient energy hit on a sample, a vacancy in the inner shells of an atom may be created. The probability of creating a vacancy is higher when the velocity of the incoming ions matches the velocity of the inner shell electrons. For MeV ions this probability for ejecting inner shell electrons is quite high. Such a vacancy can be filled in a number of ways and one of the processes may emit X-rays with the characteristic energy of that particular atomic number. In the PIXE technique, these characteristic X-rays are detected by detector. Energy dispersive analysis of the detected signals can reveal the identity of different elements present in the sample and more importantly, by measuring the charge, i.e. the number of incoming particles, the concentration of the elements can be accurately quantified [2]. Lead is naturally occurring metals which are widely present in the earth-crust. The highest levels of lead found in the environment come from human activities; include burning fossil fuels, mining and manufacturing. The lead found in rocks and soil, water and air. Human exposure to lead is mainly through food, water, air, soil, and dust [3]. Our concern here is to determine lead from the tailings of gold matrix using PIXE and its concentrations in the study area, weather is normal or above the normal. The tailings of gold matrix are a leftover of gold ores or the residues of gold matrix after it has been processed and the valuable material was removed from it.

2. Theoretical Background of the Research

Proton induced x-ray emission as an analytical method is a relatively recent innovation, being first reported in 1970 by workers at the Lund Institute of Technology. PIXE, like other x-ray spectroscopic techniques used for elemental analysis, utilizes the x rays that are emitted from the atoms in a sample when that sample is exposed to an excitation source. The use of a proton beam as an excitation source offers several advantages over other x-ray techniques. Among these are; a higher rate of data accumulation across the entire periodic table and better overall sensitivities, especially for the lower atomic number elements. Of course, the chief disadvantage of PIXE is that it requires the use of a particle accelerator. The essential element (P, Cl, K, Ca, Mn, Fe, Cu and Zn) concentrations of some local and imported rice commonly consumed in Nigeria were investigated. This is done in order to select the rice with high nutrient to combat malnutrition, especially in children. Proton-induced X-ray emission (PIXE) techniques available at iThemba Labs Someset West, South Africa was used for the analysis. The elemental concentration obtained for Ofada are 8805.5±221, 276.5±32, 3704.5±39, 212±8, 110.5±8, 125.5±7, 14.5±1 and 44.5±4 ppm, while for the imported rice we got 2862.5±150, 399±22, 1433±28, 4.15±2, 8.4±0.8, 4.75±1 and 9.5±2 ppm for P, Cl, K, Ca, Mn, Fe, Cu and Zn respectively. Phosphorus (P) has the highest elemental concentration in all samples. Ofada, one of the local rice was found to have the highest elemental concentration while pure imported rice had the lowest concentrations of the elements. The study suggests that consumption of locally-cultivated (Ofada) rice should be encouraged in order to reduce malnutrition in children in Nigeria [10].

Proton induced X-ray emission (PIXE) technique was used to characterize fourteen geological samples collected from North-Western Nigeria to determine concentration of zirconium (Zr) and other trace elements. Samples were irradiated and analyzed at Centre for Energy Research and Development, Ile Ife, Nigeria. The result obtained indicated that zirconium is of commercial deposit at some of the regions. Alongside zirconium, Fe, Cu, Rb, Cd, Ba, Ce, W, Bi, and Sn were determined. Also element Fe and Cu concentrations appears to be deposited in commercial quantities [11].

PIXE was employed to investigate elemental properties of colonial and post-colonial Nigerian coins. The weights of the coins varied between1.89 and 1.46 g while their thicknesses ranged from 0.10 to 0.40 mm. The elements; Al, Si, Mn, Fe and Zn were detected along with the major components of Ni and Cu. The elements displayed both positive and negative correlations. The study could aid in solving some scientifically questions of conservators and tourists on "what" material is it especially now that coins have long been demonetized in Nigeria [12].

3. Lead and Its Health Effect

Lead (Pb) is one of the oldest metals known to man. Lead has been used for various purposes in the past, but in modern times it is used mostly in batteries, oil paint pigments and in plumbing. Organic lead used as gasoline additive is the current chief source of environmental lead pollution [4]. Elemental Lead (Pb) is a heavy, soft, bluish metal, and occurs in nature in the form of ores. Once Pb is mined, processed, and introduced into the environment, it is a potential problem forever. There is no technology that will destroy lead or render it permanently harmless. Nearly all of the lead in the environment is due to man's activities. The history of Pb use is quite extensive. Object made of lead have been excavated and dated around 6500 B.C. Pb is present in food, water, air, soil, paint, and other materials with which the general population comes in contact. Each are potential pathways for human Pb exposure via inhalation or ingestion. Today there are three major sources of lead poisoning: lead based paint, drinking water, and urban soil and dust. Exposure to lead mainly occurs through inhalation and ingestion. Essentially, 75% of airborne lead particles are less than 0.7µm in diameter. Because of this small size, a large fraction of inhaled lead may be deposited in the lungs. Studies show that up to 35% of inhaled lead enters the bloodstream to be distributed throughout the body. Lead accumulates in blood, bone, and soft tissue. If lead is ingested, 10 to 15% of it is absorbed into the body. Children and pregnant women absorb even more [5]. Young children absorb 40-50% of lead contained in food and water, while adults absorb approximately 3-10%. Worldwide, more than 80% of the daily intake of lead, in older children and adults, is derived from the ingestion of food, dirt and dust. Drinking water forms relatively small proportion of their total daily intake of lead [5]. Excessive exposure to lead may cause anemia, kidney disease, reproductive disorder, and neurological impairments such as seizures, mental retardation, and/or behavioral disorders. Even at low doses, lead exposure is associated with changes in the processes of the body. Children and fetuses are especially susceptible to low doses of lead, often suffering central nervous system damage or slowed growth. Low-level lead poisoning may have nonspecific symptoms such as headaches, abdominal pain, and irritability. High blood lead levels in children may cause permanent deficiencies in growth and intelligence. In adults, high blood-lead concentrations may cause kidney disorders, infertility, and cancer. Extremely high concentrations (greater than 100µg/dl) usually result in death [5]. The EPA's standard for lead in bare soil in play areas is 400 ppm by weight and 1200 ppm for non-play areas [6].

4. Materials and Methods

4.1 Study area

The study area of this research is Maga village, where local mining area is located. Maga is a village under Danko-wasagu Local Government, Zuru Emirate, Area of kebbi State, Nigeria.

4.2 Materials

The five geological samples were collected from different locations of the same mining area in form of gold ore. Each sample was taken to the grinding machine of its locations for grinding into particle sizes. After grinding and processed into particles- size, the valuable materials removed and left with tailings or leftover. Then this leftover was taken for analysis.

4.3 Preparation of Samples

The analysis of geological materials by PIXE demanded that sample must to be rendered homogeneous on a scale that is interrogated by this technique. The tailings of gold matrix provide good examples of such materials that should be ground to a small particles size. After thorough mixing of the gold tailings with some binding agent such as chemflex TM or polyvinylpyrrolidone, pellets are prepared with hydraulic press. Five pellets are made and thereafter fastened to the specimen holder (special ladder akin to a slide projector, which enables the analysis of many hundred in sequence).The aluminum foil paper is placed behind the pellets before it is fastened to the special ladder to avoid the masking tape sticking to the pellets. It is then meticulously lowered into the specimen chamber. Once the specimen is securely placed in the specimen chamber, the chamber is made vacuous by a special vacuum pump affixed to the chamber. The specimen is now ready for irradiation**.**

4.4 Irradiation and Analysis

Irradiation has to do with the bombardment of samples with energetic protons ion beam. With PIXE, Irradiation and spectrum generated are sequential. Each sample is irradiated and counted for ten minute (10 min).The projectile (proton) accelerated with 1.7 MeV Tandem accelerator at the Centre for Energy Research and Development (CERD), Obafemi Awulowo University (OAU) Ile-Ife, Osun state Nigeria, in

the energies ranged from 2-3 MeV. The proton hit the target atoms in the sample which led to the atomic interactions that give off electromagnetic radiation of wavelengths in the X-ray part of the electromagnetic spectrum specific to the element contained in the sample [1]. The number of emitted X-rays with characteristic energy peak is a measure of elemental concentration for specific element. The X-ray spectrums emitted are passed through a window detected by silicon detector. Subsequently, the spectrum obtained is stored for qualitative and quantitative calculation at a later date. Irradiation is done together with Standard Reference Material (SRM) for relative quantitative calculation and quality control. The precision and trueness of the method were checked by analyzing the single SRMs under the same condition as the sample.

4.5 Data Analysis

Data were analyzed using GUPIX software that can simply, automatically and quickly fit the PIXE spectra to obtain the elemental concentrations. Elemental concentration calculation of each element C_Z is based on the following equation

$$C_z = \frac{Y}{Y_t Q \varepsilon T H}$$

Where Yt is the X-ray theoretical intensity (i.e. the yield per micro-Coulomb of charge per unit concentration), Y is the x-ray experimental intensity or yield, Q is the measured proton beam charge, ε is the efficiency of the detector and T is the transmission through any filter or absorbers between the target and the detector. H is an instrumental constant equivalent to the product of the geometrical solid angle of the x-ray detector and any systematic normalization factor present in the charge integration system [7]. GUPIX is developed in the Guelph University, Canada. It is capable to analyze PIXE spectra from thin, thick and layered targets. The choice of GUPIX was based on the fact that it uses all updated best available databases i.e. cross-sections, Fluorescence and Coster-Kronig probabilities, stopping powers, and attenuation coefficients [8].

5. Results and Discussion

PIXE analyses have been carried out [8] using a 2-3 MeV proton beam generated with the aid of the 1.7 MV tandem accelerator of the CERD Ile-Ife, osun state. Among five geological samples of tailings of gold matrix collected and analyzed, the concentration of Lead (Pb) varies between 791.3±53.2 ppm and 3826.3±99.1 ppm. While in one of the samples the lead is below detection level of PIXE. The lead concentration in most of the tailings of gold ores in this research was observed to be above the normal. The mean lead concentration of the samples is equal to 1628.025 ppm. The result obtained is above the normal concentration of lead in a bare soil which is 1200 ppm stated by EPA [6].

6. Conclusion

The present study reveals that tailings of gold ore samples of maga mining area contain significantly high level of lead concentrations. From the foregoing of this research could be concluded that the peoples living in the area of maga near the mining area, can be affected by lead poisoning since the concentration of lead is beyond World Health Organization (WHO) permissible level. Its concentration was found to be 1628.025 ppm, above the normal concentration of lead in the bare soil which is 1200 ppm stated by EPA (2017).

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Author Profile

Buhari Samaila received B.Sc in Physics from Kebbi State University of Science and Technology Aliero (KSUSTA) in 2013. During 2013-2016, I taught various aspects of physics together with practicals at different Secondary Schools in Kebbi State. From 2016 to date, I'm a graduate Assistant at Federal University Birnin Kebbi, Nigeria, department of physic with electronics taught various courses of physics at UG 1 & UG 2. Currently pursuing my M.Sc physics at KSUSTA.