Risk of toxic metal contamination in gold mining and processing areas of Borgu and Mashegu local government areas of Niger state, Nigeria

Nnaji JC, Omotugba SK

The study reviews artisanal small-scale gold mining (ASGM) in Nigeria and the status of gold (Au) ore extraction and processing in Borgu and Mashegu Local Government Areas (LGAs) of Niger State, Nigeria. The processing methods used and the potential environmental impacts of the practice are analysed. Toxic metals like mercury (Hg) and lead (Pb) are products of Au mining and processing and pose tremendous health risks for miners and other people within the vicinity as evidenced by the Pb poisoning saga that took place in Zamfara State in 2010. Strategies for reducing mercury emissions in ASGM are also discussed and recommendations are made regarding the detailed study and reduction of toxic wastes from ASGM in the LGAs.

Keywords: Small-scale, gold mining, Borgu, Mashegu, mercury, lead

INTRODUCTION

Mining is the extraction of mineral deposits from the surface of the earth or from beneath the surface (Ako et al., 2014). The mining sector in Nigeria consists of the formal large scale subsector, the formal small scale miners and the informal small scale or artisanal small scale miners (Sivotwa and Mtetwa, 1997). The later involves unskilled small scale, informal and usually illegal miners who employ rudimentary methods and processes to extract mineral resources and who most times, have little or no knowledge of environmental issues (Phiri, 2012). There are about 10 to 20 million persons involved in artisanal small-scale gold mining (ASGM) producing about 12 % of the world’s gold (330 tonnes) annually (UNEP, 2008). The uncontrolled mining in developing countries like Nigeria has exposed the environment to serious hazards like the generation and uncontrolled discharge of enormous amounts of toxic wastes which impact adversely on the human health and the ecosystem (Tomov and Kouzmov, 2005). In March 2010, Medecins Sans Frontieres (MSF) discovered an epidemic of lead poisoning in Zamfara state, NorthWestern Nigeria particularly in Anka and Bukkuyum Local Government Areas. This led to the death of hundreds of people (UNEP/OCHA, 2010). The source of the outbreak was associated with artisanal Au ore processing that occurs in the mining communities (Azubike, 2011). The pathways through which people were affected included drinking water, food, inhalation of contaminated dust, oral ingestion of particles especially by children and breast feeding. Pb is a confirmed toxic metal with no known beneficial effect on the human body. It damages the liver, kidneys, brain, central nervous and reproductive systems of man (Lovei and Levy, 2000). Hg occurs in the metallic, inorganic and organic forms in the environment. The most common organic form is methyl mercury which is produced by microscopic organisms in the soil and water. Human exposure to abnormal levels of Hg damages the brain, kidneys and developing foetus leading to irritability, tremors, impaired vision, memory problems, lung damage, nausea, skin rashes etc (UNEP/OCHA, 2010).

*Corresponding author: Jude Chidzie Nnaji, Department of Chemistry, Michael University of Agriculture, Umudike, P. M. B. 7267, Umuahia, Abia State, Nigeria. Tel.: +2348077304555; Email: dozis03@yahoo.com

Co-author:
Omotugba S: +2348031957092, omokay6@yahoo.com
This study reviews artisanal small-scale gold mining (ASGM) and processing in Borgu and Mashegu Local Government Areas (LGAs) of Niger State and the environmental/health implications of the practice as it obtains presently in these areas.

**ARTISANAL GOLD MINING IN NIGERIA**

There are about 500,000 artisanal small scale miners in Nigeria and a significant portion of the minerals find their way to Niamey in Niger Republic, as well as Cotonou in the Republic of Benin (Daily Trust, 2015). Figure 1 shows the major areas of Au mineralization in Nigeria which are associated with the schist belts of Northwest and Southwest Nigeria.

Over 90% of solid mineral production in Nigeria is done by artisanal small scale miners, who are frequently challenged by lack of appropriate mining methods and limited knowledge of mineral processing techniques (Idowu et al., 2013). The extraction and processing of Au ore in ASGM also lead to the generation of mine wastewater containing heavy metals and at low pH. These constitute serious environmental hazards injurious to human health (Azubike, 2011; CDC, 2010). In a study of abandoned primary and secondary Au mines in Ilesa, Osun State, (chromium) Cr concentration of 79.4 mg/kg was found in the soils of the secondary goldmine indicating Cr toxicity, at both 0 to 15 cm and 15 to 30 cm depths (Ekwue et al., 2012). Another study to determine the impact of mining activities on groundwater quality in Dareta village, Zamfara State, found that mean Mg concentration was more than twelve times the World Health Organization (WHO) and the Nigerian Standard for Drinking Water Quality (NSDWQ) permissible limits while Ni and Cr concentrations were about three times the limit (Udiba et al., 2013). The Mineral and Mining Act of 2007 is supposed to guide mining in Nigeria. The Act recognizes both large scale/commercial miners and ASGMs and encourages the later to form mining cooperatives which will serve as vehicle for government intervention (e.g. Extension services, financing and EIA studies) in the sector.

**ARTISANAL GOLD MINING IN BORGU**

Borgu LGA is located in Niger State (Figure 2) and the Au mines of Borgu are located mostly in the communities of Koro, Daban Oli and Daban Fura. Extraction of the Au ore under artisanal mining in Borgu area is an extremely strenuous and hazardous activity. Prospective Au mines are usually located based on intuition and experience (Plates 1 & 2). Mining of Au is
done with little or no attention to safety. Protective gears of any form are not used and several cases of fatal Au mine collapse have been recorded. Explosives are also used by the miners to blast rocks in the process of reaching the Au ore which exposes the miners to environmental hazards. The Au bearing rocks are broken into smaller pieces at the mines before being transported to Nassarawa-Kainji for further processing.

and around mines due to discharge and dispersion of mine wastes into nearby agricultural soils, food crops and stream systems (Jung, 2001). This may eventually, pose a potential health risk to residents in the vicinity of mining areas.

GOLD ORE PROCESSING

There are two types of Au ores; non refractory and refractory ores. Non refractory Au ores require a straightforward recovery with a relatively simple conventional technology while refractory Au ores are those that do not allow the Au recovery by gravity concentration or direct cyanide leaching since Au is contained within the crystalline structure of sulfide minerals such as pyrite (FeS\textsubscript{2}) and arsenopyrite (FeAsS). They require sophisticated recovery techniques. The most common methods for processing Au ore include gravity concentration, cyanidation and amalgamation (Adebayo et al., 2012).
Gravity Concentration – This separates minerals based on differences in densities. It relies on the principle that Au contained within an ore has higher density than the rock matrix. Elemental Au has a density of 19.3, and a typical ore matrix has a density of about 2.6. All gravity concentration devices create movement between the Au and host rock particles in a manner to separate the heavy pieces from the lighter pieces of material (John, 1989). The limits of gravity concentration are mainly determined by the size and shape of gold particles; Particles of size <30 µ can hardly be recovered by gravity and tiny flakes do not settle as fast as rounded grains (Lehne, 2006).

Cyanidation – Globally, cyanide leaching is the most popular method for recovering Au throughout the world today. The standard process consists of grinding the ore to about 80 - 200 mesh, mixing with water and adding about 2 lbs/ ton of NaCN to the slurry. Enough CaO is also added to keep the pH of the solution at about 11.0.

4Au + 8NaCN + O2 + 2H2O → 4Na[Au(CN)2] + 4NaOH
Au is then recovered from the pregnant solution by Zn precipitation (Merrill-Crowe process) and the solution is recycled for reuse in leaching and grinding (Veiga et al., 2006).

2[Au(CN)2] - + Zn → 2Au + [Zn(CN)4]2-

Amalgamation – Hg forms amalgams with all metals except Fe and Pt. Au combines with Hg forming a wide range of compounds. The three main amalgams are: AuHg2, Au2Hg and Au3Hg. The amalgamation process is based on the low surface tension between Au and Hg, which allows Au particles to be wetted and enclosed by the liquid metal forming an amalgam.

In Nassarawa-Kainji, the ground Au ore tailing is subjected to washing and panning. The heavier Au laden silt is recovered from the base of the pan and is combined with mercury to form a hardened amalgam which picks up most of the gold from the silt. Heating of the amalgam with blow torches or over an open flame evaporates Hg leaving Au pieces. Gaseous Hg is inhaled by the processors and others in the vicinity while un-inhaled Hg settles into the surrounding environment or is transported and deposited faraway. Elemental Hg gives rise to a vapour that is only slightly soluble in water, but is problematic because of easy transport in the atmosphere (Boening, 2000). Estimates of annual global releases of Hg into the environment from ASGM range from 400 to 1,102 metric tons/year (Pirrone et al., 2010; Telmer and Veiga, 2009). Microorganisms transform elemental Hg into methyl mercury, one of the most dangerous neurotoxins which contaminates the food chain through bioaccumulation. Amalgamation is regarded as an inefficient process (UNIDO, 2007).

- Detailed study of toxic metal pollution of the environment in the LGAs
- Establishment and enforcement of adequate environmental quality standards for ASGM.
- Remediation of polluted environmental media in the study areas.

POTENTIAL ENVIRONMENTAL EFFECTS OF ARTISINAL MINING IN BORGU AND MASHEGU

- Inhalation of metal laden dust and risk of developing diseases
- Toxic metal pollution of agricultural soil, surface and groundwater.
- Continuous leaching of toxic chemicals from waste rock piles after closure of mines
- Landscape degradation through the production pits on the surface
- Destruction of habitats
- Loss of organic soil for farming, erosion of soil and sedimentation of surface waters
- Deforestation as a result of logging for Au prospecting
- Increase in child labour involving underage boys and girls. It is estimated that one to two million children may be involved in ASGM worldwide (UNEP, 2010).

STRATEGIES FOR REDUCING TOXIC METAL EMISSION AND CONTAMINATION

(i) Re-activation and re-use of Hg – Used or dirty Hg recovered after processing is usually discarded since it does not amalgamate Au as well as new Hg. Dirty Hg can be reactivated inexpensively in the field using salt water and a 12-volt battery and in this way dirty Hg can be used for a long time thereby reducing the amount of Hg emitted into the environment.

(ii) Using retorts or other mercury vapour capture systems, which can reduce mercury losses by as much as 95 percent (UNEP, 2010).

(iii) Use of non-mercury processing methods – Au from certain types of ores can be extracted effectively by non-mercury methods alone. However, such methods require special knowledge, equipment and skilled operators which may be out of the reach of the artisanal miner.

(iv) Use of protective gears by miners and processors

(v) Awareness creation among miners on the health and environmental implications of the practice, protective measures and government policies on mining. The Emirate councils, Local Government Councils and Miners Associations have crucial roles to play in this regard.

CONCLUSIONS AND RECOMMENDATIONS

Mine wastes generated by the mining industry contain high concentrations of metals and metalloids which can contaminate groundwater, surface water and the soil. Some of these metals are toxic and non-biodegradable. The following recommendations are pertinent:

REFERENCES

Jung MC (2001). Heavy metal contamination of soils and waters in and around the Imcheon Au–Ag mine, Korea. Applied Geochemistry 16: 1369–1375

Accepted 20 April, 2016.


Copyright: © 2016 Nnaji and Omotugba. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are cited.