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A Follow-up Study on Lead Poisoning in Soil and Drinking Water Sources in Bagega Village in Zamfara State, Nigeria

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ABSTRACT
Lead poisoning from artisanal small-scale gold mining has occurred in 38 villages in Zamfara State, Nigeria since 2010. Soils from only 8 of the affected villages had been remediated including those from the town used for this study. This study assesses the lead concentration in the soil and water media of the village. Soil samples were collected in the vicinity of the village as well as at the mining/processing site. Water samples were also collected from well, boreholes and the pond near the village. All samples were collected, preserved, and prepared for lead analysis using standard procedures. Atomic Absorption Spectrophotometer was used for lead content analysis. Lead in the mining/processing site (soil) was 9200 to 12500 mg/kg while that of the village soil was between 10.1 and 33.6 mg/kg. Lead content was detectable only in the well water (0.1 to 0.3 mg/kg) and in the pond (0.9 to 1.21 mg/kg). Although the values were below the US Environmental Protection Agency (EPA) guideline for soil lead, the level in water was elevated above the maximum allowable limit for drinking water. Better monitoring of children between 5 and 15 years of age for bioaccumulation was suggested to prevent future reoccurrence of the health impact of the affected children and young adults.

Keywords: lead poisoning, artisanal mining, environmental pollution, soil remediation, Zamfara State

INTRODUCTION
Lead poisoning is one of the most significant and common diseases of environmental origin in the world, accounting for 0.6% of the global burden of disease (WHO, 2013). Lead, a naturally occurring metal, and one of the metals classified as heavy metals, is used in the production of fuels, paints, ceramic products, batteries, solder, and variety of some consumer products (EPA, 2002). Studies have found that lead exposure in children may contribute to increased likelihood of conduct disorders (Braun *et al*., 2006), decreased attention (Chiodo *et al*., 2007), hyperactivity-impulsivity (Nigg *et al*., 2008) and attention-deficit/hyperactivity disorder (Froehlich *et al*., 2009). Children with higher blood lead levels generally have lower scores on IQ test (Surkan *et al*., 2007). Other adverse behavioural patterns associated with childhood lead exposure include increased risks of juvenile delinquency and antisocial behaviours (Needleman *et al*., 2002) leading to higher arrest rates, and arrest rates for violent crimes in early adulthood (Wright *et al*., 2008).

Artisanal small-scale gold mining (ASM) occurs mostly in Africa, Asia and South America, involving 10-15 million miners with about 100 million people living on ASM either directly or indirectly (Spiegel and Veiga, 2006). An outbreak of acute lead poisoning occurred in Zamfara State, Nigeria since March 2010, and resulted in severe neurological morbidity and death in children and domestic animals. According to Dooyema *et al*. (2011), the outbreak was due to artisanal mining processes and was described to be the largest in the world – in scope and magnitude (with respect to residential soil contamination, clinical morbidity and deaths). The same author reported that about 400 children less than five years old were reported dead and over 2000 children became permanently disabled as a result of the outbreak of lead poisoning. However, the containment kept resurfacing as a public health and environmental concern in the state, thereby attracting the attention of governmental and non-governmental agencies, nationally and internationally.

The source of the outbreak was found to be lead-contaminated gold ore, processed with primitive technological methods in remote villages (United Nations Children's Fund (UNICEF), 2011). Noncompliance with environmental or occupational health practices during ore processing operations has caused extensive contamination of villages which lead to inhalation and ingestion of fatal amounts of lead by the people in affected areas, particularly the children (Dooyema *et al*.; 2011, Lo *et al*., 2012).

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Majority of those affected are children, young adolescents and married women particularly pregnant women during the period and those of marriageable age (UNICEF, 2011) are prone to potential effects of adverse reproductive and childhood development outcomes. Further complications of the aftermath of lead exposures in adult males and females are increased risks of miscarriages and spontaneous abortions, depressed sperm counts, and general decreased fertility.

Consequently, given the large scale post curative impacts of lead poisoning in communities, particularly its potential effects on the quality of life of the people and its wider implications on the social structures of the society, a call has been made by the International Consortiums of experts for a periodic monitoring and evaluation of the affected and exposed populations (UNICEF, 2011). So far, a total of 38 villages were confirmed to be contaminated and requiring interventions, with only 8 remediated (soil remediation), according to data available with Zamfara State Ministry of Health. This study was conducted with a view to contributing to the on-going local efforts towards the monitoring of the epidemic in Zamfara State of Nigeria.

MATERIALS AND METHODS

Study Area

Zamfara State is one of the northern states in Nigeria blessed with abundant mineral resources, including gold and lead deposits. The activities involved in such gold ore processing include: digging the ore from the ground; pounding and grinding it into powder; mixing the powder with water to separate out gold particles; treating the slurry with mercury to amalgamate gold particles; then heating the gold to separate out the mercury. The ore in some areas of Zamfara State is heavily contaminated with lead, and the crude processing technique inadvertently frees lead particles, resulting in the contamination of air, soil and communal water resources (wells, streams and ponds) culminating in the deaths of children (Getso, 2013).

Bagega Community is located in Anka Local Government Area of Zamfara State with a population of about 7,323 people (Tirima *et al*., 2016). The village is situated in the humid tropical region of northwest Nigeria and falls within longitudes 5° 40’17’’E to 6° 1’51’’E and latitudes 11° 87’ 30” N to 12° 55’ 53” N. It has distinct wet and dry seasons, and the vegetation is categorized as savanna. Compared to the southern regions of Nigeria, the rainy season is comparatively brief (mid-May to September) and receives moderate amounts of precipitation. Throughout the year, the average temperature stays high, with notable variations between the rainy and dry seasons. It is a regional commercial, education and health center; with people traveling from other villages to the weekly market, to attend primary and secondary school, and to utilize hospital services. In 2010, there was a wide spread case of lead poisoning in about 38 villages including Bagega, affecting about 17,000 villagers. Remediation exercise commenced in the Bagega village between February and July, 2013. The remediation exercise involved characterization, excavation of contaminated topsoil, replacement with clean soils and landfilling of the contaminated soil.

Collection of Samples

Water samples were collected in 1L plastic bottles from surface water from the mining site, boreholes and well water from the village (Figure 1). The water samples collected were then transported to the laboratory for lead analysis. Soil samples were also collected randomly from the mining site and the village at a depth of 0 to15 cm using a soil auger. The field work lasted for three months (September to November 2015) to avoid the rainy season which could adversely affect site visits and data collection. Lead content in the water and soil samples were determined using an atomic absorption spectrometer (Perkin Elmer 5100).

RESULTS AND DISCUSSION

The soil at the mining/processing sites contained high concentrations of lead in the range of 9200 to 13400 mg/kg in the three soil samples (Table 1), which could be connected to the mining and processing activities on the sites. These values were above some of those reported by Fagbote and Olanipekun, 2010 in the soil of Agbabu bitumen deposit, and those reported by Ezeh and Chuckwu, 2011 in the soils of Ishiagu Mining district in Nigeria. However, this result collaborated the conclusion of Dooyema *et al*. (2011) that the magnitude lead soil contamination in the affected communities was high. The joint team of United Nations Environment Programme/Office for the Coordination of Humanitarian Affairs (UNEP/OCHA, 2010) and Aliero *et al*. (2023) reported similar values found for the soils close to the mining/processing site which remain elevated. The soil lead levels in the village were much lower than those found by the UNEP/OCHA team, and were below the US EPA guideline for soil lead (400 mg/kg). However, the toxic effects of lead are the same, irrespective of whether it is ingested or inhaled, more so that there is no blood level that does not produce adverse effect, particularly in the developing central nervous system for children less than 5 years old. Children with lead poisoning can suffer from headaches, high fever, convulsions, hearing problems, slowed growth, and hyperactivity. For adults, bioaccumulation of lead in human body interferes with the functioning of mitochondria, thereby impairing respiration, and also causes

constipation, swelling of the brain, paralysis, high blood pressure, memory and concentration problems, nerve disorders and reproductive problems in men and women (UNEP/OCHA, 2010). The water samples from the wells and the pond (Table 2) contained elevated levels of lead which were higher than maximum permissible limit of lead in domestic water (0.01 mg/L) as specified by World Health Organization. Hassan *et al*. (2015) had also earlier reported 0.735 mg/L Elead in the surface water (dam) in the same community as this study. Again, these results corroborated the report of the UNEP/OCHA, 2010 team that while most of the boreholes were not poisoned, the well and surface waters had been contaminated and were due for remediation. Children are particularly more vulnerable to lead poisoning than adults because they absorb lead from their environments – soil, food, water and air. Again, blood level lead (BLL) as low as ≥10 µg/dl in children have been associated with a wide range of adverse effects including lowering of IQ scores and academic skills, hyperactivity, disorders in bone metabolism and death (Schnaas *et al*., 2006). With the elevated level of lead in the media studied both at the mining/processing site and from the village, it is very dangerous for children under fifteen years of age (especially those below the age of 5 years) that are known to be playing with soil because one of their peculiar characters is the habit of building houses with muds and invariably consume such soil either accidentally or deliberately. Their inability to wash their hands before eating and through inhalation of lead laden dust could also increase the level of lead-poisoning (Adeolu, 2014). Also, lead in the soil, well water and surface water of the village could also cause bioaccumulation of lead in the food chain (Owoade *et al*., 2014) of the community (involving domestic animals such as fowls, goats, cattle as well as crops and vegetables.



Figure 1: Activities around sampling locations in the village.

Table 1: Lead concentration in the soil at the mining site, processing site and Bagega village

Location	Sampling point	Coordinates	Pb (mg/kg)
Soil from Mining/Processing site	1	N11° 51.295′ E005° 59.846′	12500
	2	N11° 51.271′ E005° 59.834′	9200
	3	N11° 51.249′ E005° 59.823′	13400
Soil from Bagega Village vicinity	1	N11° 51.822′ E006° 00.822′	33.60
	2	N11° 51.855′ E006° 00.196′	10.10
	3	N11° 51.877′ E006° 00.163′	16.10

Table 2: Results of the lead analysis of the water samples

Source Description	Sampling point	Coordinates	Pb (mg/g)
Water from Boreholes	1	N11° 52.027′ E006° 068′	ND
	2	N11° 51.847′ E006° 203′	ND
Water from Wells	1	N11° 52.048′ E006° 117′	0.21
	2	N11° 52.029′ E006° 034′	0.10
	3	N11° 51.853′ E006° 192′	0.30
Surface Water (Pond)	1	N11° 51.667′ E006° 324′	1.21
	2	N11° 51.676′ E006° 312′	0.90

ND – Not Detected

CONCLUSION AND RECOMMENDATIONS

The results from this study have shown that the level of lead in the soil from the processing sites and well water of communities affected by lead poisoning since 2010 are still rather elevated and if not promptly attended to could lead to a re-occurrence of lead poisoning in the village. The need for proper remediation and amelioration for the affected communities in the entire state cannot be overemphasized. The following are hereby recommended: that adequate treatment and periodic monitoring of lead in the blood of children in all the villages concerned be carried out; that members of the village be properly educated on the need to protect their children and environment; that government train and further empower the people in the community on environmentally friendly and healthy mining technologies; that an enforcement of relevant environmental laws by the government agencies such as NESREA to secure the health of people and the environment from future occurrence in the state and in other locations where such activities is practiced; and that full remediation of soil and water media for all the affected villages be carried out as soon as possible.

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