AJ ACADEMIC JOURNALS
expand your knowledge

Journal of Toxicology and Environmental Health Sciences

Full Length Research Paper

Post-epidemic lead exposure to animals following a decontamination exercise in gold mining village of Bagega, Zamfara State, Nigeria

Mohammed Bashir Tijjani[1*], Bello Mohammed Agaie[2], Kenneth Idowu Onifade[2], Abdullahi Sulaiman Mainasara[3], Ibrahim Lamidi Yusuf[1] and Abdulyakeen Olawale Tijjani[4]

[1]Department of Veterinary Pharmacology and Toxicology, Faculty of Veterinary Medicine, University of Maiduguri, Nigeria.
[2]Department of Veterinary Pharmacology and Toxicology, Faculty of Veterinary Medicine, Usmanu Danfodio University, Sokoto, Nigeria.
[3]Department of Chemical Pathology, Faculty of Medical Laboratory Sciences, Usmanu Danfodio University, Sokoto, Nigeria.
[4]Department of Veterinary Public Health and Preventive Medicine, Faculty of Veterinary Medicine, University of Maiduguri, Nigeria

This study focused on the evaluation of environmental lead contamination due to artisanal gold mining at a Nigerian village of Bagega one year after a clean-up exercise was carried out. Water samples were collected from earthen dams, faucets and wells, while plant and soil samples from grazing fields, residential areas and sites within the vicinity of the gold mine. The collected samples were digested and analyzed for lead concentration using the atomic absorption spectrophotometer. The recommended safe level of lead in water is 0.01 ppm and all the sources of water analyzed showed elevated lead concentrations. Water from the earthen dam, tap and well had lead concentrations of 31.49±7.1, 5.98±1.5 and 7.14±1.2 ppm, respectively. In the grazing area, the lead concentration was 4.6±7.5 mg/kg, whereas in the residential area and mining vicinity, the concentrations were 46.84±10 and 1153± 165 mg/kg, respectively. Two plants, *Alysicarpus vaginalis* and *Digitaria debilis* had a uniquely high bioaccumulation ratio, suggesting their potential as hyperaccumulators of lead. Given that international standards accept lead levels of 420 ppm and below, the residential area and the grazing fields may be safe, but the vicinity of the mine which had a toxic concentration could be unsafe. For animal feed, all plant ingredients analyzed accumulated low levels of lead except for *A. vaginalis*. This study suggests that soil remediation may be an effective decontaminating procedure. Additionally, grazing plants in the study area are not important sources of lead exposure to animals. However, water bodies may constitute a probable route of lead exposure to both animals and humans. Therefore, there is a need to prevent water contamination by immobilizing lead from the mining site which could be potentially leached into water bodies.

Key words: Animals, Bagega, mining, environment, decontamination.

INTRODUCTION

A major challenge of metalliferous mining is the mobilization of environmental contaminants, such as

mining leftovers, by agents of dispersion and weathering processes (Hinton et al., 2003). It has been estimatedthat humanity has mined about 1,150 million tons of heavy metals, of which only 2% corresponds to valuable metals. Consequently, the rest is discharged as wastes in the neighbourhood of mine operations (Krishna et al., 2009). Because the efficiency of mining and the extraction process is always below 100%, there is the inherent risk of pollution even when best mining practices are observed. The possibility of pollution is high in unregulated artisanal mining and this could result in widespread poisoning (Bartrem et al., 2014).

Recently, lead poisoning epidemics have been documented in the Nigerian state of Zamfara due to artisanal gold mining from lead-rich ore (Lo et al., 2012). In the Zamfara State village of Bagega, the concentration of lead in the soil reached 23,000 ppm which resulted in the death of many children (Ajumobi et al., 2014) and animals (Tijjani et al., 2016). Albeit decontamination procedures have been instituted in affected areas, mining activities are still on-going. The possibility of recontamination of the environment or, at least, increased background exposure compared to the non-mining areas could exists (Bartrem et al., 2014). This could result in chronic toxicosis due to the gradual accumulation of toxicants over time or subclinical toxicosis in animals that may seem healthy but have derangements that may not be observed by routine physical and clinical examinations (Goyer, 1990; Bischoff et al., 2014).

In July 2013, *ex situ* decontamination procedures were carried out on the soil in the residential areas of Bagega using a technique that isolated and buried contaminated soil. This reduced the incidence of acute lead poisoning among humans but there have been cases among food animals (Kazaure, 2018). However, we presumed that this measure had not reduced the overall risk of lead exposure to animals which, when humans consumed as food, could portend health risks. Therefore, this study aimed at assessing the level of lead in water, soil and plants fed on by bucks in gold mining area of Bagega after the decontamination exercise.

MATERIALS AND METHODS

Study area

Bagega is a typical gold mining village in Anka Local Government Area of Zamfara State. Geographically, Bagega is located at 11° 47' N and 6° 15' E (Figure 1). Growing crops and raising livestock are the primary occupations of the local inhabitants. In recent years, however, mining has become a popular means of livelihood due to its lucrativeness.

Study design

A cross-sectional study was carried out to determine the concentration of heavy metals in soil, water and browse plants. A survey of the environment was carried out to establish the area of mining, grazing areas, water sources and plants consumed by animals.

Sample collection

In May 2014, samples of soil, water and commonly browsed plants were collected. Five soil samples each were collected from the residential area, mining site, gold ore and leftover tailings (Figure 1). The samples were collected in labelled polyethene bags. Five water samples each were collected in sample bottles from an earthen dam located at the outskirts of the village, the public wells and the faucets in the community. Five samples of each of the species of plants commonly consumed by animals in the grazing fields at the outskirts of the community and adjacent topsoil samples were collected for analysis. The leaves of the plants were collected and identified by a plant taxonomist at the Department of Biological Sciences, Usmanu Danfodiyo University, Sokoto. The plant samples were then washed with deionized water to remove traces of soil and surface dust and were dried at room temperatures over a period of two weeks. The samples were then pulverized and sieved using 2 mm stainless steel sift.

Sample analysis

Acid digests of soil and plant samples were prepared using the USEPA 3051A method as recommended by Chen and Ma (1998). Water samples were digested with concentrated nitric acid by adding 10 ml of the acid to 50 ml of water in a 250 ml conical flask. The mixture was then evaporated to half of its volume on a hot plate, which was allowed to cool and then filtered.

A Graphite Furnace Atomic Absorption Spectrometer (GFAAS) was used to measure the total concentration of lead in the digested samples. Biological accumulation coefficient (BAC) for each plant was calculated as a ratio of heavy metal in shoots/leaves to that in its adjacent soil (Cui et al., 2004).

$$\text{BAC} = \frac{\text{Metal in shoot}}{\text{Metal in soil}} \tag{1}$$

Data analyses

Data generated were presented as the mean ± standard deviation of replicate samples, and comparisons were made with internationally acceptable standards. Analysis of variance was used to determine the level of significance within and between groups for each sample groups. The relationship between data generated from the plant and adjacent soil samples was determined by correlation analysis. GraphPad Instat statistical software with the Tukey Krammer post hoc test was used for statistical analysis and values of $p < 0.005$ were considered significant.

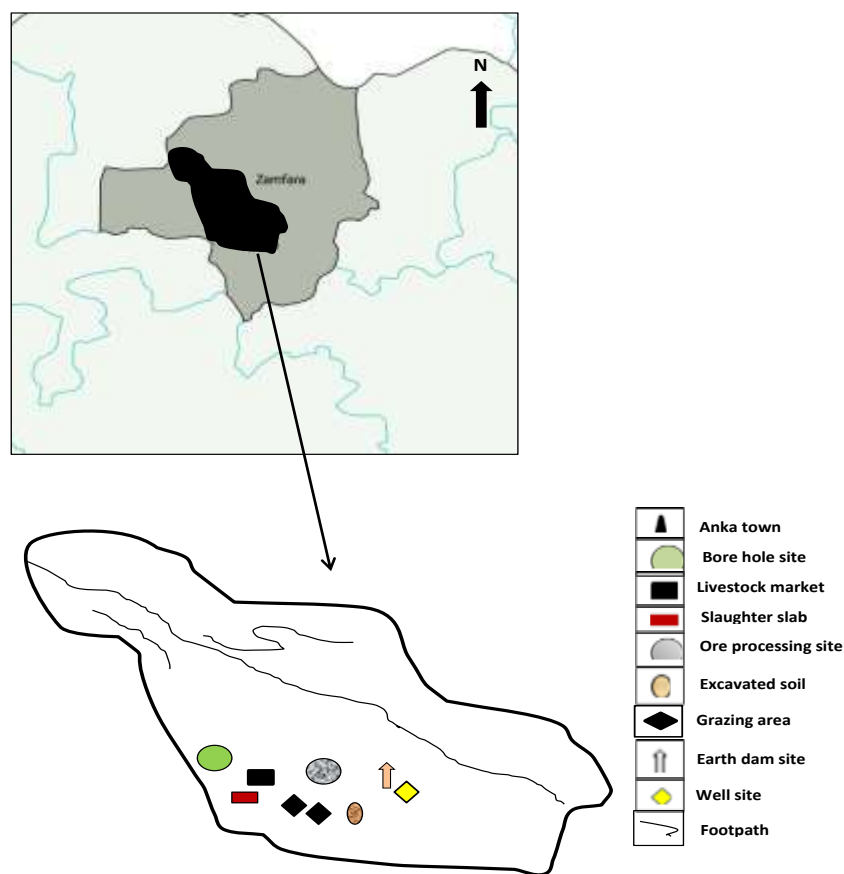*Corresponding author. E-mail: bashvet@yahoo.com. Tel: +2348033187420.

Figure 1. Map of Zamfara State showing the location of the study area (black) and the black arrow pointing to north. The enlargement of the study site indicates the sampling sites (Quantum GIS 2.4.0 Chugiak).

RESULTS

The concentration of lead in residential soil

Table 1 shows the concentration of lead in grazing areas and residential soil was 4.60±7.5 and 46.84±10 ppm, respectively. The concentration for soil from the mining vicinity was 1153±165 ppm, while for tailings from direct mining leftovers and gold ore the concentration was 1266±152 and 860±423 ppm, respectively. The concentration of lead in residential soil and the grazing field was significantly ($p <0.005$) lower than the samples obtained from the mining zone and was below the World Health Organization (WHO) permissible levels. The concentration of lead in the mining area, leftovers and gold ore were higher than the recommended safe level (420 ppm) recommended by the WHO.

The concentration of lead in water

Water from the earthen dam, faucets and wells had lead content of 31.49 ± 7.1, 5.98 ± 1.5 and 7.14±1.2 ppm, respectively. These were higher than WHO safe level of 0.01 ppm. The concentration of lead in the earthen dam was significantly ($p<0.005$) higher than that from the faucet and well water and no significant difference ($p>0.005$) between tap and well water (Table 2).

The concentration of lead in leaves of browse plants and adjacent soil in grazing fields

The level of lead concentration in Alysicarpus vaginalis was 68.5 mg/kg which was significantly ($p<0.05$) higher than in other plants sampled. Additionally, A. vaginalis is the only plant with a concentration of above 30 mg/kg. A concentration level of 30 mg/kg is the acceptable level of lead in livestock feed according to European Union Directives 2005/87/EC. Digitaria debilis and A. vaginalis had bioaccumulation coefficients of 4.9 and 2.9, respectively thereby having an excellent ability to absorb lead from soil (Table 3).

Table 1. Soil lead concentration at different locations one year after cleaning up exercise.

Location	Heavy metal concentrations (ppm)	WHO permissible level in soil (ppm)
Residential soil	46.84±10[a]	
Grazing field	4.60±7.5[b]	
Mining site	1153±165[c]	420
Tailing leftovers	1266±152[c]	
Ore	860±423[c]	

Values with different superscript are statistically ($p < 0.005$) different.

Table 2. Concentration of lead in water sources after the clean-up exercise in Bagega mining community.

Water source	Heavy metal concentrations (ppm)	WHO safe level (ppm)
Earthen dam	31.49±7.1[a]	
Faucet (Tap)	5.98±1.5[b]	0.01
Well	7.14±1.2[b]	

Values with different superscript are statistically ($p < 0.005$) different.

Table 3. Concentration of lead in leaves of browse plants and adjacent soils in Bagega village.

Plant name		Lead concentration (mg/kg)		BAC
Botanical	Hausa	Leaves	Adjacent soil	
Ficus synchomorus	Baure	0.12±0.03	0.67±0.14	0.17
Digitaria debilis	Harkeya	4.48±0.23	0.9 ±0.13	4.92
Vitellaria paradoxa	Kade	0.13±0.03	0.62±0.18	0.21
Combretum glutinosum	Taramniya	0.18±0.01	0.32±0.05	0.56
Securinega virosa	Tsah	0.58±0.16	0.94±0.27	0.62
Alysicarpusvaginalis	Gadagi	68.5±30.1[a]	23.94±4.94[a]	2.90
Albizia chevalieri	Katsari	6.18±0.61	6.73±0.06	0.91
Ipomoea muricata	*Yaryadi*	2.83±0.52	5.71 ±0.23	0.50

Value with superscript is significantly ($p < 0.005$) different from other values in the same column.

DISCUSSION

The process of removing all the contaminated topsoil and isolating it in a controlled disposal site is called soil destruction and is carried out when other remediation methods cannot guarantee containment of toxicants (Blacksmith Institute, 2011). In Bagega, the contaminated soil was removed but not replaced with good, unaffected soil. However, remediation exercise was not carried out on water and plants. After one year of soil decontamination, lead concentration levels have significantly declined from their initial value of 5000 ppm, as earlier reported (Blacksmith Institute 2012). This could be attributed to the adoption of new methods for safer mining activities than previously used, as well as increased education and awareness on lead poisoning.

The lead content of grazing fields and residential soil in Bagega was found to be low compared to the international standard of 420 ppm. As the distance from the mining vicinity decreased, higher levels were obtained which exceeded safety limits, as seen in the soil from the mining area, tailing and gold ore. The primary focus of the cleaning exercise was the residential area and could be the reason for the low concentration of lead found in Bagega residential soil. Since the concentration of lead was within international safety levels for all the residential and grazing fields, this study found that soil remediation may have been successful.

In water samples, the highest concentration of lead was recorded in earthen dams, followed by faucets and

wells. However, all sources of water had elevated lead content compared to acceptable international standards of 0.01 ppm (WHO, 2008). This may be worsened by the lack of potable water supply for human and animal consumption in rural villages. As such, animals often drink from surface waters which are polluted with environmental contaminants. Heavy metals accumulate in surface waters due to leaching (Sophocleous, 2002). Guidelines on acceptable lead levels in drinking water by WHO and National Agency for Food and Control (NAFDAC) in Nigeria are stringent because heavy metals are slowly excreted from human and animal bodies resulting in build-up of lead-levels (Lanphear, 1998; Standard Organization of Nigeria, 2007; WHO, 2008). The higher concentration of lead in the earthen dam when compared with other sources may be attributed to the fact that surface water is more easily subjected to environmental contamination than underground water. Because surface water remains the primary source of water in Bagega, animals are still at risk of being affected by lead poisoning.

Among plants species used for animal feed, *A. vaginalis* leaf was found to have remarkably elevated values. Plants with bioaccumulation coefficients above 1 indicate good ability for absorbing lead in their leaves (Kazaure, 2018). Therefore, *A. vaginalis* and *D. debilis* pose a hazard to grazing animals.

The ecological zone of Zamfara State falls within Northern Guinea Savannah that is characterized by abundant grasses and shrubs; hence, grazing animals thrive well because of abundant feed (Garba et al., 2015). Some plants accumulate heavy metals in their leaves from their surroundings. Among all the plants sampled, the present study discovered that leaves of *A. vaginalis* have the highest concentration of lead, with its concentration exceeding acceptable standards. A proportionately high concentration of lead in adjacent soil observed in *A. vaginalis* could be due to inherent biological differences that affect its uptake capacity. *D. debilis* had a four-fold higher concentration of lead in its leaves compared to its soil while *A. vaginalis* has 2.3 times higher. Since this study confirms that there is a positive correlation between soil and plant leaves, *D. debilis* could be more dangerous in accumulating lead in its leaves and *A. vaginalis* should be investigated for possible phytoremediation of the environment.

Conclusion

Grazing plants as a source of exposure to lead in Bagega after the cleaning up exercise, have been remarkably insignificant as all the plants accumulated safe levels of lead except for *A. vaginalis*. Water sources from the area have been shown to have high concentrations of lead when compared with internationally acceptable standards.

Plants used in this research could also be used as indicators of environmental lead pollution because of the positive correlation with the soil concentration.

There is a need to assess the buffering capacity of soil in Bagega to further investigate the safety of the low lead concentrations observed after the clean-up exercise. Also, since many ores are polymetallic, further studies should be carried out to assess concentrations of other heavy metals in the environment. Water is the most important source of exposure and better design of mine waste storage is necessary to prevent weathering, leaching and mobilization of contaminants. Also, provision of potable water for both human and animals will greatly reduce the risk of exposure to lead poisoning.

Food animals in Bagega are managed semi-intensively and, as such, are at high risk of lead exposure by grazing on plants and drinking from surface water. For one health benefits, there is a need to assess the incremental health risk associated with lead exposure in animal populations in Bagega.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

REFERENCES

Ajumobi OO, Tsofo A, Yango M, Aworh MK, Anagbogu IN, Mohammed A, Umar-Tsafe N, Mohammed S, Abdullahi M, Davis L (2014). High concentration of blood lead levels among young children in Bagega community, Zamfara–Nigeria and the potential risk factor. The Pan African Medical Journal 18(Supp 1):14

Bartrem C, Tirima S, von Lindern I, von Braun M, Worrell MC, Mohammad Anka S, Abdullahi A, Moller G (2014). Unknown risk: co-exposure to lead and other heavy metals among children living in small-scale mining communities in Zamfara State, Nigeria. International Journal of Environmental Health Research 24:304-319.

Bischoff K, Thompson B, Erb HN, Higgins WP, Ebel JG, Hillebrandt JR (2014). Declines in blood lead concentrations in clinically affected and unaffected cattle accidentally exposed to lead. Journal of Veterinary Diagnostic Investigation 24(1):182-187.

Blacksmith Institute (2012). Project completion report: Nigeria lead poisoning   crisis.   Available   at http://www.blacksmithinstitute.org/nigerian-lead-poisoning-crisisblacksmith-report.html [accessed 26 June 2012]

Blacksmith Institute (2011). UNICEF program cooperation agreement.

Environmental remediation - Lead poisoning in Zamfara State. Final Report (2011):57.

Chen M, Ma LQ (1998). Comparison of four USEPA digestion methods for trace metal analysis using certified and Florida soils. Journal of Environmental Quality 27(6):1294-1300.

Cui YJ, Zhu YG, Zhai RH, Chen DY, Huang YZ, Qiu Y, Liang JZ (2004). Transfer of metals from soil to vegetables in an area near a smelter in Nanning, China. Environment International 30(6):785-791.

Garba J, Rabiu T, Yusuf A, Aliyu M, Musa N, Muhammad H (2015). A survey on preservation methods of leftover vegetables among retailers of Bungudu Local Government Area Zamfara State-Nigeria. Journal of Agricultural Extension and Rural Development 7(2):28-*32*.

Goyer RA (1990). Lead toxicity: From overt to subclinical to subtle health effects. Environmental Health Perspectives 86:177.

Hinton JJ, Veiga MM, Veiga ATC (2003). Clean artisanal gold mining: a utopian approach? Journal of Cleaner Production 11(2):99-115.

Kazaure MB (2018). Distribution of bacteria in lead contaminated soil in Anka local Government Area, Zamfara State, Nigeria. Acta Scientific Microbiology 1(7):53-60.

Krishna AK, Satyanarayanan M, Govil PK (2009). Assessment of heavy metal pollution in water using multivariate statistical techniques in an industrial area: A case study from Patancheru, Medak District, Andhra Pradesh, India. Journal of Hazardous Materials 167(1-3):366-373.

Lanphear BP (1998). The paradox of lead poisoning prevention. Science 281:1617-1618.

Lo YC, Dooyema CA, Neri A, Durant J, Jefferies T, Medina-Marino A, de Ravello L, Thoroughman D, Davis L, Dankoli RS (2012). Childhood lead poisoning associated with gold ore processing: A village-level investigation-Zamfara State, Nigeria, Environmental Health Perspectives 120(10):1450-1455.

Sophocleous M (2002). Interactions between groundwater and surface water: the state of the science. Hydrogeology Journal 10(1):52-67.

Standard Organisation of Nigeria (2007). Nigeria standard for drinking water quality. Available at https://www.unicef.org/nigeria/ng_publications_Nigerian_Standard_for_Drinking_Water_Quality.pdf

Tijjani MB, Agaie BM, Onifade KI, Mainasara AS, Tijjani AO (2016). Retrospective survey of suspected lead poisoning cases in bagega village, Zamfara State, Nigeria. Sahel Journal of Veterinary Science 15(1):91-94.

World Health Organization (WHO) (2008). Guidelines for drinking-water quality, (3rd edition, Volume 1) –Recommendations, P 193. Available at http://apps.who.int/iris/bitstream/handle/10665/204411/9789241547611_eng.pdf;jsessionid=980E17632EA97B6D61E8B37430DB44E4?sequence=1