



RESEARCH PAPER

Lead (Pb) Concentrations in Food, Water and Soil of Gold-Ore Mining Communities in Rafi Local Government, North Central Nigeria

Usman, H.B*., Ndatsu, Y., Abubakar, H. and Aliyu, A.O.

Department of Biochemistry, Ibrahim Badamasi Babangida University, Lapai, Nigeria

ABSTRACT

The Federal Ministry of Health of Nigeria notified the World Health Organization (WHO) of a suspected Lead (Pb) poisoning outbreak in Unguwan Magiro and Unguwan Kawu communities in Rafi LGA of Niger State on 15 May 2015, with a total of 48 cases including 14 deaths. This paper aims to estimate the level of Pb in food and ground water in the gold-ore mining communities of Rafi, North central of Nigeria. Samples were collected from 5 different communities in Rafi Local Government Area, which about 12 water samples and 26 food crops samples were analyzed for Pb using Atomic Absorption Spectrophotometer (AAS). The Pb concentrations in the samples were compared with maximum contaminant levels (MCL) values of WHO to ascertain the toxicity levels of Pb in the samples. The average Pb concentration in water ranges from 0.90-1.100 mg/L; food crop range from 1.127-1.791 mg/kg and crop stem range from 1.100-1.567 mg/kg. However, the MCL set by WHO for water, food stuff and crop stem were 0.01mg/L, 0.3 mg/kg and 0.3 mg/kg, respectively. Also, about 80 % of soil (top, sub,) and dust Pb concentrations which ranged as (1.012-1.295, 0.983-1.736 and 154.7-537.3 mg/kg), respectively, were found within the MCL acceptable limit (400 mg/kg) approved by WHO. The findings demonstrated that the concentration of Pb in all analyzed samples exceeded the general MCL values set by WHO. The higher concentrations of Pb observed in all samples could indicate the contamination of samples by gold-ore mining activities. Therefore, all analyzed samples are thus unsafe for domestic uses.

Keywords: Lead, Mining, crop plants, water, soils

INTRODUCTION

Heavy metals (HMs) such as mercury (Hg) and arsenic (As) cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), manganese (Mn), nickel (Ni), lead (Pb), zinc (Zn) continually pose significant risk on human and environmental health. Though, some HMs such as Cu, Fe, Mn, Zn, Cd and Cr are essential for life, others like Hg, Pb, and As, are unfortunately toxic to human and the environment. Pollution due to anthropic activities for example, mining, smelting, exhaust from automobiles, or wastes of different kinds are the main sources of HMs (March *et al.*, 2015). HMs are among the most serious environmental (water and soil) pollutants because of their persistence bioaccumulation and non-degradability (Jonathan, B *et al.*, 2016).

Amongst these toxic HMs, Lead (Pb) is of particular interest, because its poisoning had continuously posed serious danger to human health as well as the environment. Lead is

ubiquitous in nature and one of the earliest metals discovered by the human race (Flora *et al.*, 2012). It is found naturally in the earth's crust. Physically characterized by properties such as ductility, high malleability, softness, low melting point and non-corrosiveness, are the major reasons for its widespread usage (Flora *et al.*, 2012). No thanks to its non-biodegradability, this made it a persistent as well as potent toxin in the environment. Lead toxicity (saturnism) has been recognized as a major public health risk, particularly in developing countries (Bello, Naidu, Mahmudur, Liu, & Dong, 2016). It is a type of metal poisoning and a medical condition in humans and other vertebrates caused by increased levels of the heavy metal lead in the body. Though various occupational and public health measures have been undertaken in order to control lead exposure, cases of lead

Received 24 November, 2018

Accepted 19 December, 2018

Address Correspondence to:

ubhamzat@ibbu.edu.ng

poisoning are still reported (Flora *et al.*, 2012). Exposure to Pb occurs through ingestion or inhalation by humans and other vertebrates (Rosenb *et al.*, 1996). Exposure to Pb can cause autoimmunity: A condition in which a person's immune system attacks its own cells, resulting to joint diseases and ailment of the kidneys, circulatory system and nervous system (Siraj & Kitte, 2013). Therefore, dysfunction or hypertension in adults and delays in children's physical and mental development including decreased intelligence quotient are attributed to prolong exposure to lead (Bello *et al.*, 2016). At higher concentrations, Lead can cause irreversible brain damage. The effect is more pronounced in children, mostly to children under the age of six (Cory-slechts *et al.*, 2003; Nriagu, Oleru, Cudjoe, & Chine, 1997).

Pb is used in several industries such as the production of batteries, alloys, plastics, varnishes (Clark *et al.*, 2006; Harper, Mathee, Schirmding, Rosa, & Falk, 2003). Therefore, human exposure to lead peculiar to the developing countries occurs through various sources like mining, leaded gasoline, battery recycling, industrial processes such as lead smelting (Bello *et al.*, 2016; Flora *et al.*, 2012).

Illegal/uncontrolled mining and smelting activities in the developing countries like Nigeria have resulted in generation of environmental hazards, enormous amount of wastes and different types of toxicants (Ibrahim *et al.*, 2013). Hence, due to the environmental and health consequences, mining activities can be considered to be more hazardous to economic development than a blessing. Since the aftermath of the first case of lead poisoning in Zamfara, Nigeria in 2010 (Bello *et al.*, 2016; Lo *et al.*, 2012) was reported, many other fatal cases of outbreak were recorded in different part of the country. The presumptive source of the outbreak was associated with semi-industrial scale gold-ore mining and processing that occurs in the affected areas. Key environmental risk factors were contaminated soil, ground water and dust in the environment (Liggans & U, 1998). These mining activities have raised serious concerns on the qualities of crop plants and water sources within and around the mining sites.

The Federal Ministry of Health of Nigeria notified the World Health Organization (WHO) of a suspected Pb poisoning outbreak in Unguwan Magiro and Unguwan Kawu communities in Rafi LGA of Niger State on 15 May 2015, with a total of 48 cases including 14 deaths (CRF 29.2%) reported (WHO, 2015). The outbreak occurs predominantly on children (7 months–11 years) and both sexes (26 male, 22 female) have been affected, with an unusual number of livestock (cows and goats) are also described to be dying (WHO, 2015). Environmental causes were suspected because of a recent increase in gold ore-mining activities in the region. It is discernible that streams and rivers where these toxicants debilitate into, serve the villages and towns along them. Consequently, their drinking water may be contaminated and a possible transmission of Pb may exist from contaminated soil to the plants grown on the polluted soil to the animals that consume such plants. The maximum contaminant levels (MCL) according to WHO, for Lead in food and ground water are 0.3 mg/kg and 0.01 mg/L respectively (Ibrahim *et al.*, 2013).

There are no reports on the Pb concentrations in foods and water of some communities living near the artisanal gold-mining area of Raffi Local Government Area. Therefore, this work aims at analyze Pb levels in food crops and ground water of some communities living around the artisanal gold-mining area of Kagara town of North central, Nigeria.

METHODOLOGY

Analytical grade reagent and distilled water was used throughout the study. All glass ware and plastic container used were washed with detergent solution followed by 20 % nitric acid and then raised with top water and distilled water. Other chemicals and reagents used were of analytical grade and used as received from Sigma Aldrich UK. All working solutions are prepared freshly. Lead Nitrate was used for preparation of Lead standard and Nitric acid, sulfuric acid and perchloric acid mixture was used for sample digestion.

Study Area and Sampling Collection

The current study location were scattered settlement around the artisanal gold-ore mine site in Rafi local government Kawu, Magiro, Kampany, and Madaka communities located in Rafi Local government area, situated in

Niger state of Nigeria. The site lies between a coordinate of latitude $10^{\circ}11'04''N$ and $15^{\circ}12''E$ and longitude $10.18444^{\circ}N$ and $6.25333^{\circ}E$ near a major mining site. The gold-mine site began operation in 2009 and many local people work in it.

The samples collected were significant and apparently convincing. Ground water sample were randomly collected from 12 sampling sites (6 well, 4 borehole and 3 stream) water in 5 different area of the study location. Food samples (Maize, Rice, Millet, Beans, and Corn) were obtained from individuals of the studying area in triplicates. These areas include Madaka, Magiro, Kawo, Magaba, and kampany. The samples were collected during the month June 2017.

Samples Digestion Procedures

Samples were digested to ensure the removal of organic impurities, and thus, to prevent the interference in analysis. The water samples were digested with concentrated Nitric acid. Briefly, 20 mL of nitric acid (50 %) was added to 50 mL of sampling water in a 250 mL conical flask, and then heated on a $100^{\circ}C$ water bath to 10 mL of the mixed solution. After cooling, it was then filtered in a plastic pet bottle and made up to 20 mL with distilled water and then stored in the refrigerator.

Also, about 0.2g of the predigested food samples (Maize, Rice, Millet, Beans, and Corn) were weighed in separate test tubes then, 5ml of digestion mixture (mixture of perchloric acid, nitric acid and sulfuric acid) was added to each test tube. The mixture were then taken into a hot fume chamber and heated over night for digestion. The digests were then mixed with distilled water and filtered, the filtrate were allowed to cool and further diluted with distilled water to 100 mL in volumetric flask. The diluted filtrates were then transferred into a plastic pet bottle. The absorbance was then measured at 530 nm in plastic cuvette using AAS analysis (Spectroscopy Max Plus, Molecular Device Inc. Sunnyvale, CA, USA). The experiments were performed in three replicates and the average absorbance of the replicates was calculated.

Data Analysis

Analyses of metal ions in all the samples were carried out in Atomic AAS. Statistical analysis was done using statistical packages.

RESULTS AND DISCUSSION

The potential pathways of community exposure to Pb other than through soil and dust were investigated. To this end 12 water samples from different sources (stream water, bore-hole water and well water) were involved in the investigation of dietary intake by the communities and 26 food crops samples were analyzed.

Effect of mining on Pb in water

The results of mining on Pb in water sources available to the inhabitants of the artisanal-gold mining communities are shown (Fig 1).

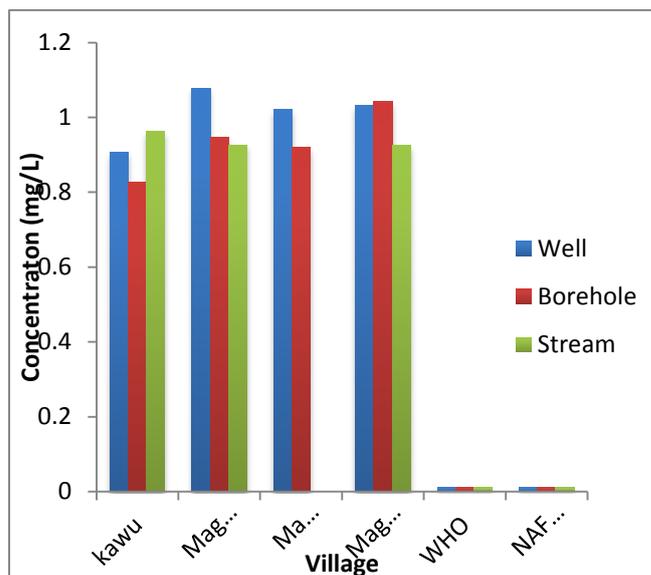


Figure 1. The concentrations of Pb in various water sources

The results of Pb concentrations obtained from different water samples that were randomly obtained around the vicinity of the mining site have demonstrated that the investigated water sources were contaminated with heavy metal; lead (Pb), which could be possibly as a result of the mining activities being carried out at Rafi mining site (Fig. 1). The value of Pb in water samples observed range from 0.90-1.100 mg/L. These values are extremely, higher compared to MCL value for drinking water (0.02 mg/L as recommended by World Health Organization (WHO)). These results are of serious concern as Pb was recognized for since ancient time as a cumulative general metabolic poison (Siraj & Kite, 2013). Exposure to lead produces various deleterious effects on the central nervous, hematopoietic, renal, and reproductive system, mainly through increased oxidative stress. These alterations play a prominent role in disease manifestations. Also,

studies have linked Pb exposures even at low levels with reduced intelligence quotient in children and caused for attention disorders (Cory-slechta *et al.*, 2003; Siraj & Kitte, 2013). In a recent study by (Ibrahim, *et al.*, 2013; Bello *et al.*, 2016) on the effect of Pb contamination of water sources (well, stream and bore-holes) in some Nigerian communities engaging in mining activities, it was reported

that water sources were contaminated with Pb (range: 0.10–0.80 mg/L and 0.09–1.20 mg/L respectively).

Effect of mining on Pb in soils and floor dusts

The result of Pb concentrations in soils and floor dust in the artisanal gold mining communities of Rafi are shown Table 1.

Table 1. Lead concentration in Soils (top and sub), and floor dusts

Village	Soil(0-15 cm) (mg/kg)	RSD (%)	Soil(15-30 cm) (mg/kg)	RSD (%)	Floor Dust (mg/kg)	RSD (%)
Kawu	1.174	1	1.736	4	537.3	4
Magiro	1.128	1	1.572	3	647.3	1
Madaka	1.103	0	1.215	2	234.3	1
Kampany	1.295	2	1.195	1	181.2	1
Kagara	1.012	1	0.983	3	154.7	4

The result revealed that Pb levels in all the soil samples exceeded the normal recommended concentration range as approved by WHO. This indicates a high risk of lead poisoning through agricultural practices carried out on the soil in the community. The results of soils and dusts showed the average Pb concentrations for top soils (range: 1.012–1.295 mg/kg) while for sub-soils (range: 0.983-1.736 mg/kg). These values were extremely lower than the recommended MCL of 400 mg/Kg by WHO, Standard organization of Nigeria (SON) and 300 mg/kg of Australia's National Environment Protection Measure (NEPM). It appears that most of the top-soils and sub-soils are within the permissible guideline value. The results of the floor dust analysis showed the average Pb concentrations (range: 154.7-647.3 mg/kg). The Pb

concentrations of six (6) samples obtained from Kawu and Magiro Communities exceeded the WHO and SON guideline value (400 mg/kg) and NEPM health investigation level (300 mg/kg). But a general observable trend is that Pb concentrations in floor dusts are generally larger than in sub-soils and top-soils. This finding was in line with result reported previously by (Bello *et al.*, (2016)

that mining activity had a significant impact on surrounding areas.

Effect of mining on Pb in crop Plants

The results of Pb concentration of maize, millet and guinea corn stems cultivated by the local farmers obtained from the four cardinal directions; specifically along the North, the South, the West and the East cardinal directions are shown in Figure 2.

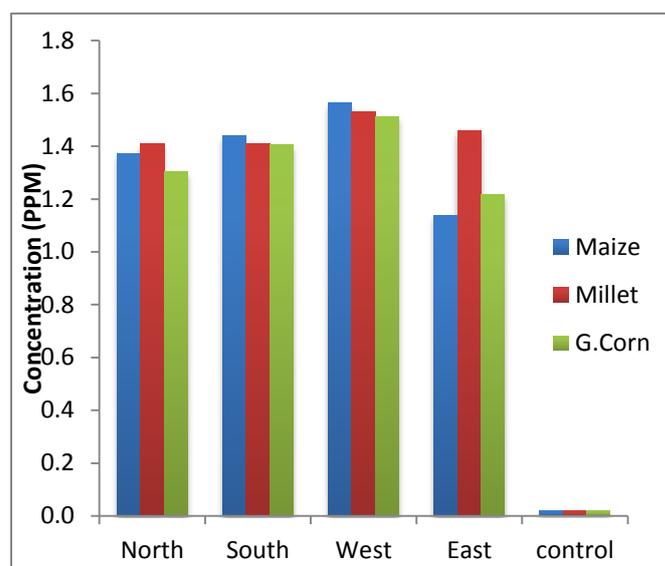


Figure 2. The concentration of Pb in crop plant obtained from the four cardinal direction of the mine site

Lead concentrations were also detected in all crop plants; Maize (1.137, 1.371, 1.44 and 1.563 mg/kg) for east, north, south, and west, respectively, Millet (1.41, 1.41, 1.458 and 1.528 mg/kg) for north, south, east and west, respectively and G. corn (1.215, 1.303, 1.406 and 1.513 mg/kg) for east, north, south and west, respectively. The observed sample values were far above the recommended MCL by WHO (0.3 mg/kg). The variation in Pb concentration may be attributed to variation in the plant crop type's ability to absorb the toxic

element and their accumulation potential over time. This finding indicated that the selected crop plant samples were contaminated with Pb, and this might be possibly through the absorption of water from the contaminated water and soil due to mining activity.

Effect of mining on Pb in food crops

The results of Pb concentration in food crops available to the communities around the vicinities of artisanal-gold mining were shown in Figure 3.

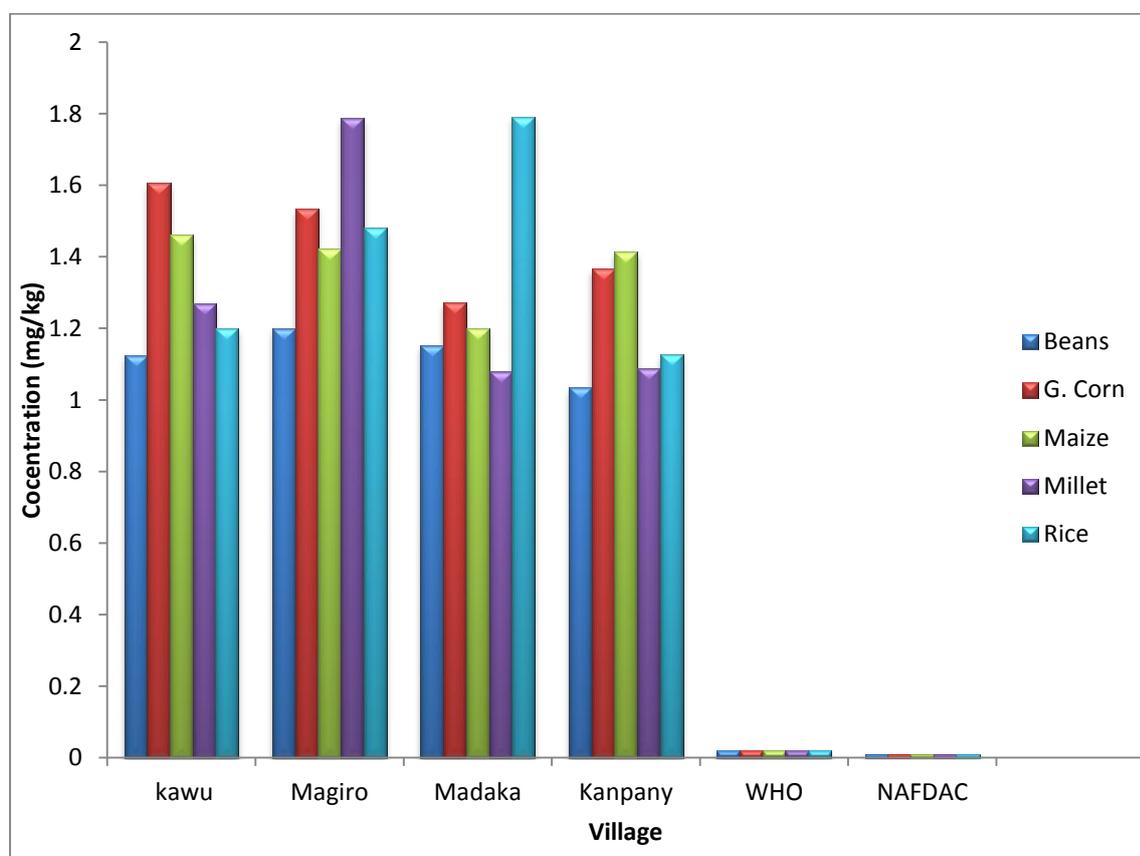


Figure 3. The concentration of Pb crop grains obtained from the communities around the mine site

Elevated Pb concentrations were also observed in crop grains obtained from various communities in the vicinity of artisanal-gold mine site. Although varying average concentrations of Pb were detected in all grains obtained from various communities. The average Pb concentrations in all grains range as; Beans (1.035-1.199 mg/kg), G. corn (1.272-1.605 mg/kg), Maize (1.199-1.462 mg/kg), Millet (1.079-1.786 mg/kg), and Rice (1.127-1.791 mg/kg). The trend of results is

worrisome when it was compared with standard MCL (0.3 mg/kg) set by WHO and NAFDAC. The increased artisanal-gold mining activities might have contaminated their drinking water and a possible transmission of Pb may exist from contaminated soil to the plants grown on the polluted soil to the animals that consumed such plants. These findings had corroborated with the report of WHO, (2015) that a suspected Pb poisoning outbreak occur in

Magiro and Kawu communities, that resulted to a total of 48 cases including 14 deaths (CRF 29.2%). The result has lent more credence to reports by many studies (Ibrahim *et al.*, 2013; Bello *et al.*, 2016) that mining activity increased the incidence of Pb exposure in the mining communities.

Conclusion

As much as mining activity is acknowledge in Nigeria, there is also an important need to recognize its environmental and health hazard/effect and also to find a means of resolving it. The study reveals that Pb levels in water sources, food crops available to the inhabitants around Rafi mine-site far exceeded the WHO's recommended levels (0.02 mg/L and 0.03 mg/kg respectively) of Pb. The observed Pb concentrations in soils fall within the acceptable MCL values as approved by the regulatory agencies. Also, the Pb concentrations observed in six (6) samples obtained from Kawu and Magiro communities exceeded that of WHO and SON guideline value (400 mg/kg) and NEPM health investigation level (300 mg/kg). Therefore, this work had substantiated the hypothesis by WHO that a "suspected Pb poisoning outbreak in Magiro and Kawu communities in Rafi LGA of Niger State on 15 May 2015, with a total of 48 cases including 14 deaths", this is due to proximity of the communities to the gold-ore mine site. Therefore, it could be observed that the exposure pathway to Pb contaminations in this communities is not only limited to dusts, but also well water and food crops. Hence, there is a need for urgent and serious measures by Government to regulate the mining activities at the site, so as to minimize the environmental and health hazard of Pb.

REFERENCES

- Bello, O., Naidu, R., Mahmudur, M., Liu, Y., & Dong, Z. (2016). Lead concentration in the blood of the general population living near a lead – zinc mine site , Nigeria : Exposure pathways. *Science of the Total Environment*, *The*, 542, 908–914. <https://doi.org/10.1016/j.scitotenv.2015.10.143>
- Clark, C. S., Rampal, K. G., Thuppil, V., Chen, C. K., Clark, R., & Roda, S. (2006). The lead content of currently available new residential paint in several Asian countries \$, 102, 9–12. <https://doi.org/10.1016/j.envres.2005.11.002>
- Cory-slechta, D. A., Ph, D., Cox, C., Ph, D., Jusko, T. A., & Lanphear, B. P. (2003). Intellectual Impairment in Children with Blood Lead Concentrations below 10 µg per Deciliter. *The New England Journal of Medicine*, 348(16), 1517–1526.
- Flora, G., Gupta, D., & Tiwari, A. (2012). Toxicity of lead: a review with recent updates. *Interdisciplinary Toxicology*, 5(2), 47–58. <https://doi.org/10.2478/v10102-012-0009-2>
- Harper, C. C., Mathee, A., Schirnding, Y. Von, Rosa, C. T. De, & Falk, H. (2003). The health impact of environmental pollutants: a special focus on lead exposure in South Africa, 322, 315–322.
- Ibrahim, A. Abdulfatai, J. Okafor, J. Abdulkareem, A. Abdulwahab, G. (2013). Effect of Lead Mining Activities on Crop Plants and Water: A Case Study of Tunga Tsauni, Gurara, Niger State, Nigeria. *International Journal of Engineering and Technical Research*, 2(12), 755–765.
- Jonathan, B. Maina, H. & Maitera, O. (2016). Heavy metal pollution assessment in the sediments of lake chad, Nigerian sector. *Bayero Journal of Applied Sciences (Bajopas)*, 9(1), 213–216.
- Liggans, G. L., & U, J. O. N. (1998). Lead poisoning of children in Africa , IV : Exposure to dust lead in primary schools in south-central Durban , South Africa.
- Lo, Y., Dooyema, C. A., Neri, A., Durant, J., Jefferies, T., Medina-marino, A., ... Samson, M. Y. (2012). Childhood Lead Poisoning Associated with Gold Ore Processing :a Village-Level Investigation—Zamfara State, Nigeria. *Research | Children ' S Health*, 1450(10), 1450–1455.

- March, G., Nguyen, T., & Piro, B. (2015). Modified Electrodes Used for Electrochemical Detection of Metal Ions in Environmental Analysis. *Biosensors*, 5(2), 241–275. <https://doi.org/10.3390/bios5020241>
- Nriagu, J., Oleru, N. T., Cudjoe, C., & Chine, A. (1997). Lead poisoning of children in Africa , I I I. Kaduna, Nigeria, 197, 13–19.
- Rosenb, J. F., Guoa, D., & Wua, S. (1996). Childhood lead poisoning in China, 181, 101–109.
- Siraj, K., & Kitte, S. A. (2013). Analysis of Copper , Zinc and Lead using Atomic Absorption Spectrophotometer in ground water of Jimma town of Southwestern Ethiopia. *International Journal of Chemical and Analytical Science*, 4(4), 201–204. <https://doi.org/10.1016/j.ijcas.2013.07.006>
- WHO. (2015). *Nigeria: Lead poisoning in Nigeria*. Retrieved from <http://reliefweb.int/report/nigeria/lead-poisoning-nigeria-15-may-2015> Nigeria