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Analysis of Heavy Metal in Water used for Irrigation, Soil and Some Vegetables grown around Tin Mine Areas of Heipang District, Barkin-Ladi Local Government of Plateau State

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Abstract

Vegetables growing in mining areas have become a serious food safety concern because of the high levels of heavy metals always associated with mining. In this study, water used for irrigation, soil, cabbage, green pepper and green beans grown in tin mine areas of Heipang District, Barkin-Ladi LGA of Plateau State were analyzed for lead, cadmium and zinc, using Atomic Absorption Spectrophotometer (AAS). The concentrations of the heavy metals in water, soil, vegetables were all in the order Pb, >> Cd > Zn. In the vegetables, the order was: **Pb** → cabbage > green beans > green pepper; **Cd** → green beans > cabbage > green pepper; **Zn** → cabbage > green pepper = green beans. The transfer factors for all the metals (heavy metal in plant / heavy metal in soil) ranged from 0.95 to 1.48. There were high levels of Pb and Cd in all the vegetables, which may be attributed to the metals in the water used for irrigation. Whilst the concentration of Zn in all the samples were lower than recommended limits, the levels of Pb and Cd in the water, soil and vegetables were higher than the WHO/FEPA standard recommended limits reported for vegetables. The Cd concentrations of the vegetables also exceeded the

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tolerance thresholds for animals and human beings and therefore consumption of vegetable from the area would endanger the health of the population.

Introduction

Barkin-Ladi Local Government Area in Plateau State is well known in the State and even beyond the state for its tin mining activities. This has devastated vast portions of the land mass which is evident by the presence of mounds, devastated landscape and exposed fertile lands, abandoned ponds and several mining heaps and tailing dumps which may be a rich source of heavy metals. Mining and ore processing activities in this area are carried out by local illegal miners who have no idea of the pollution problems caused by the open pits and tailings.

Mining exploitation and ore smelting are important sources of heavy metals, since large amounts of tailings and wastewater are produced in the mining process, thereby leading to severe heavy metal contamination in the surrounding environment. Heavy metal pollution problems arising from mining have attracted increasing attention in recent years [1]. In many parts of the State, untreated water from abandoned tin mine ponds is used for irrigation of vegetable gardens and smaller farms around such ponds. When water in smaller streams/ponds dries up, pumps are used to drive water from bigger mined ponds to follow channels or stream, no matter the distance, to the desired destination. This often leads to increase in suspended particles that may have adsorbed heavy metals [2]. The introduction of heavy metals in soil through contamination eventually leads to changes in their chemical forms or phases and distribution, mobility and toxicity [3]. Heavy metals are dangerous for living organisms because of their perseverance, high toxicity and their tendency of accumulation in ecosystems [4, 5]. Their accumulation in the soil threatens human health through various exposure pathways including direct ingestion, dermal contact, and inhalation [6]. Heavy metals rank high amongst the major contaminants of leafy vegetables [7], also, leafy vegetables accumulate higher metal contents than others vegetables [8]. It was discovered that the concentrations of heavy metals in vegetables per unit dry matter generally follow the order: leaves > fresh fruits > seeds [9, 10]. Vegetables, especially leafy ones grown in heavy metal-contaminated soils, accumulate higher amounts of metals than those grown in uncontaminated soils because they absorb these metals through their leaves. The concentrations of total amounts of heavy metals in soil increase with intensity of land use and amount of irrigation in the following sequence: arable fields < occasionally submerged meadows < vegetable gardens < wine gardens and orchards with mixed cropping of vegetables [11].

Food security is a matter of growing concern all over the world. It is therefore important to encourage the consumption of highly nutritious fruit and vegetable crops, rather than distribution of iron and vitamin supplements. Whilst support for increased production and consumption of fresh vegetables is an important goal, there is need to ensure that the vegetables available for consumption are not contaminated beyond acceptable safe limits [12]. Hence, this study is being carried out in order to assess the possible human health impacts arising from heavy metals accumulated in vegetables irrigated with water from ex-tin mines pond.

Study area

Heipang, a District in Barkin-Ladi Local Government Area of Plateau State, Nigeria, has many abandoned mine ponds, around where lots of agricultural activities take place all year round.

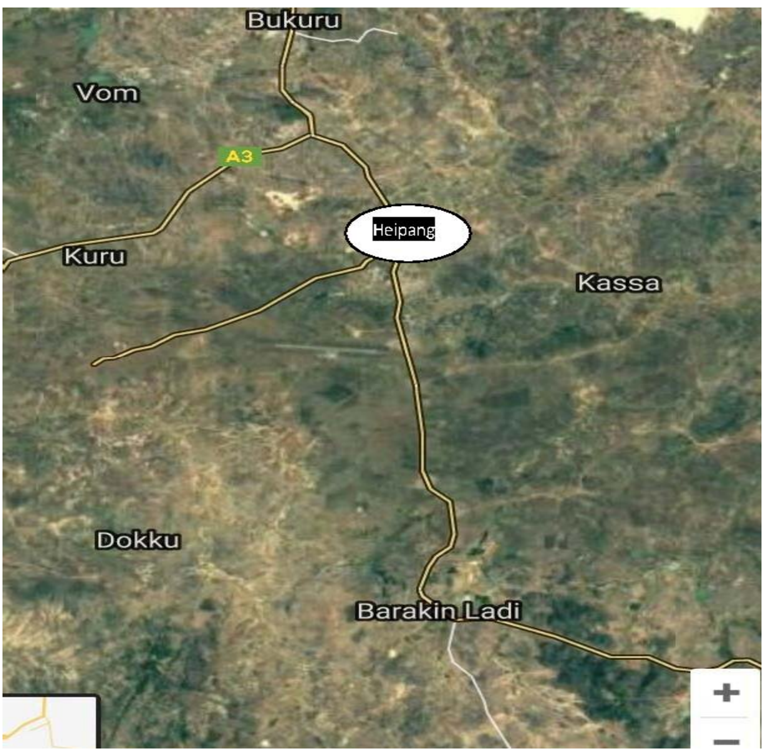

Figure 1. Map of the Study Area (Astrium, Digital Globe Maps, 2015).

Soil sampling

Soil samples were collected at the Heipang tin mine irrigation sites during irrigation, using hand shovel. The soil samples collected at different points at the irrigation sites were then mixed, to obtain a homogeneous mixture and stored in a clean polyethylene bag which was taken to the laboratory for further analysis.

Plant sampling

Vegetables (cabbage, green pepper and green beans) were collected from the farms where the soil was collected and stored separately in labelled polyethylene bags and were transported to the laboratory for further analysis.

Water sampling

20ml of water samples were collected from different mine ponds, using plastic cup. The samples were mixed together and taken to the laboratory for further analysis.

Preparation of soil and vegetable sample

The soil and vegetables sample were oven dried at a temperature of about 106°C, pounded and sieved into fine particles using a 25mm sieve. The samples were then ashed with Laboratory Thermo furnace (TYP: OH-85TR) at a temperature of 400°C in a crucible and was stored for further analysis.

Digestion and analysis samples

0.1g of each dried, ground and sieved/ashed sample of soil and vegetables (cabbage, green pepper and green beans) respectively were accurately and separately weighed into a 250ml Erlenmeyer flask, 20ml of aqua regia was added to each sample and swirled gently to mix with the sample properly. Each of the flask was placed on a hot plate and heated until a clear solution was obtained without the white fumes of HCl and the volume was reduced to one third (1/3) the original volume in the flask with the flask shaken intermittently in every 2 minutes. The mixture was then cooled and was filtered into a 100ml volumetric flask using filter paper rinsing the residue severally. The filtrate was then made up to the mark with distilled water and analyzed for Pb, Cd, Zn at their respective wavelengths using AAS (VGP 210, Bulk Scientific).

Results and Discussion

Table 1. Results of the total concentrations of heavy metals in water, soil and vegetables.

Samples	Concentration of Heavy Metals		
	Pb	**Cd**	**Zn**
Water (mg/l)	16.86±0.82	5.33±0.04	2.26±0.05
Soil (mg/kg)	15.93±0.05	5.59±0.31	2.13±0.04
Cabbage (mg/kg)	23.53±0.45	6.58±0.01	2.59±0.18
Green Pepper (mg/kg)	15.93±5.52	5.32±0.07	2.50±0.30
Green Beans (mg/kg)	17.90±0.41	6.77±0.01	2.50±0.33

Table 2. Transfer factor of the vegetables.

Samples	Transfer Factor		
	Pb	**Cd**	**Zn**
Cabbage	1.48	1.18	1.22
Green Pepper	1.00	0.95	1.17
Green Beans	1.12	1.21	1.17

Discussion

The concentrations of the heavy metals in water, soil, vegetables were all in the order Pb, >> Cd > Zn. The results for the different heavy metals in vegetables were in the order: **Pb** → cabbage > green beans > green pepper; **Cd** → green beans > cabbage > green pepper; **Zn** → cabbage > green pepper = green beans as represented in Table 1. The transfer factors (heavy metal in plant / heavy metal in soil) are all around 1, represented in Table 2.

The result indicated that cabbage accumulated more of the heavy metals on the average than green pepper, but Cd in green beans is slightly higher than in cabbage.

Lead (Pb) has been reported to be a serious cumulative body poison which penetrates into the body system via food air and water respectively and cannot be detached by washing the vegetables. The high levels of Pb in some of these leafy vegetables may be attributed to pollutants in irrigation water. The level of Pb reported for the leafy vegetable in this study is higher (ranging from 15.93-23.53mg/kg) than those reported [13, 14] and higher than the WHO/ FAO standard recommended limits of 5.0µg/g reported for some leafy vegetables [15]. This is indicates that there is high pollution load of Pb in the vegetable from the studied area. Pb is known for its toxicity and negative impacts on human health. Its toxicity results in decrease in haemoglobin production, disorder in the working of kidney, reproductive system, joints and cardiovascular systems and causes long-lasting injury to the central and peripheral nervous systems [16]. These effects are more pronounced in children and in severe cases, death may even occur. The metabolism of both Pb and Ca are similar in both their storage and movement in the bones [17]. Under usual circumstances, more than 90 % of the Pb reserved in the body exists in the skeleton. Moreover, during lactation and pregnancy, lead moves from mother's bones to breastfed infants and fetuses [18].

Cadmium (Cd) showed concentrations in the vegetables ranging from 5.32-6.77mg/kg, which exceeded the WHO limit (3mg/kg) and the tolerance thresholds for animals and human beings (0.5-1.0mg/kg) and therefore present high risk to health of the population. Cd is the most mobile heavy metal, thus, an increasing uptake by plants will occur under slightly acid conditions below pH 6.5 especially in arable soils. Due to the fact that agriculture and irrigation favors decalcification and acidification, an increase of the Cd mobility must be taken into account [11]. Continuous consumption of Cd in edibles and water leads to the accumulation of this metal in kidneys, causing kidney diseases [19]. High exposures to Cd may result in lung disorders like bronchiolitis, emphysema and alveolitis; renal effects may also occur due to sub chronic breathing of Cadmium [16, 17]. One important source for the heavy metals uptake into the food chain is the adhesion of fines to leaves and stems of herbs, which have direct contact with the irrigation water. Therefore washing of the crops in clean water diminishes the heavy metals concentrations.

Zinc (Zn) is one of the important trace elements that play an important role in the physiological and metabolic process of many organisms. However, high concentrations of zinc can be toxic to the organism. It plays a vital role in protein synthesis and also shows fairly low concentration in surface water due to its restricted mobility from the place of rock weathering or from the natural sources [13]. This could be the reason why the concentrations of zinc in this study are very low (ranged from 2.13-2.59mg/kg).

Conclusion and Recommendations

Conclusion

The result of this study indicates a substantial build-up of Pb and Cd in vegetables irrigated with the water from abandoned mine ponds and thus would justify the restrictions of the use of such waters for irrigation, due to a presumable transfer of this highly toxic element into the food chain. The study highlighted that both adults and children consuming vegetables grown in this area, ingest significant amount of these metals into the body.

Recommendations

Government should integrate reclamation into mining activities to ensure that mining operations are conducted in manners that are compatible with the environment, social and economic needs of the people, such as back filling, grading, top soil replacement, stabilization and vegetation of disturbed areas to avoid loss of productive soil and provide a pollution free environment. The build-up of these toxic metals in the environment should also be monitored.

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