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Bioaccumulation and translocation of lead in Lactuca sativa grown on soils from refuse dump contaminated area

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ABSTRACT

The increasing global concern on accumulation of heavy metals (HMs) in African leafy vegetables has prompted the search for new bioremediation approaches that seek to curtail the growing risk of exposure to these carcinogenic agents by consuming crops grown on contaminated soils. An important step in controlling the spread of these soil contaminants is the detection and evaluation of HMs on soils used for the growth of vegetable crops in urban and peri-urban regions. The aim of this study was to quantify the concentration of a widely known toxic metal; lead (Pb) in soils used for growing vegetable in Zaria, and their possible translocation from the soil to different parts of lettuce (*Lactuca sativa*). Analyses of the leaves using Atomic Absorption Spectrometry method based on bioaccumulation factors (BF) revealed little or no accumulation of the HM studied (BF < 1). The BF observed in this study suggest that *L. sativa* may not be an accumulator of lead.

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1. Introduction

Lettuce (*Lactuca sativa*) is an important leafy vegetable consumed for being an excellent source of vitamins and minerals (Aregheore, 2007). It has concentrations of pro-vitamin A. While urban and peri-urban (UPU) agriculture has increasingly impacted food security as urbanization continues in Africa, leafy vegetables remain an important component of human nutrition and health, serving as sources of many vitamins, minerals and dietary fiber (Smith, 1982). However, the presence of heavy metals (HMs) such as lead (Pb), cadmium (Cd), mercury (Hg), and chromium (Cr) in vegetables has become a growing concern because some soils and irrigation waters have been shown to be polluted.

An index for analyzing accumulation of HMs in plants is bioaccumulation factor (BF) (Pachura et al., 2016). Plants with BF of > 1 are said to be hyperaccumulators. Some plants including violet *Viola baoshanensis* is a Cd-hyperaccumulator (Wu et al., 2010). Pb is extremely immobile in soil with a large affinity for organic matter and not easily accumulated by some plants (Bert et al., 2002). Generally, plant species or even populations react differently when exposed to elevated levels of HMs. Some plants accumulate HMs; others exclude them while other plant species are sensitive (Amin et al., 2018).

One of the major sources of water for irrigation in Zaria is Kubanni River, whose tributary passes through Ahmadu Bello University, to Tudun Wada-Zaria, an urban settlement within Zaria metropolis (Yusuf and Shuaib, 2012). The water receives agricultural runoff and municipal wastewater which is utilized for irrigation farming of leafy vegetables such as cabbage, tomatoes, lettuce, and spinach. Though there have been studies on the river (Butu, 2013; Uzairu et al., 2009;

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Yusuf and Shuaib 2012), not much has been said on the soil surrounding it. Human activities such as motor repairing, metal scrapping, and other industrial activities are likely to release HMs into the soils (Butu, 2013).

An important step in controlling the spread of soil contaminants is the detection and evaluation of HMs on soils used for the growing vegetable crops in UPU regions. This study was, therefore, aimed at assessing the concentration of lead and cadmium in soils used for growing vegetable in Zaria, and their possible translocation from the soil to different parts of lettuce.

2. Materials and Methods

2.1. The study area

The study area is located along the basin of Kubanni River in Tudun Wada area of Sabon Gari Local Government, Zaria-Kaduna (Butu, 2013). The source of the river is from Kampagi hills. The river is located on Lat 110 04′59.77″ N – 110 08′ 29.77N and Long 070 34′59.84″ E – 070 41′59.84E (Butu, 2013). The sites were chosen for the work because the river serves as the major source of water for the irrigational farming. Also, some refuse dump was observed at the side of the river which can eventually be taken in by the river itself. The soil type is sandy-clay loam with low infiltration (Iguisi, 1997). The sampling area was split into four different sites and three (3) random points were used from each site. Thus, three samples were taken from each quadrant giving total of 12 samples. The quadrants were labelled A, B, C and D respectively.

2.2. Sample collections

The soil samples were collected using appropriate tools at a depth of 30 cm in each case and further stored in clean labelled collection bags. Three different water samples were collected to give an insight into the levels of the metals within the source.

2.3. Plant sample

Lettuce seeds were planted on 340 g of each soil sample in clean plastic cups and de-ionized water was used as source of water to avoid any additional metal. The plants were kept under greenhouse condition and monitored for growth for 5 weeks before being taken to the next step of the experiment.

2.4. HM analysis

Samples were prepared by weighing 0.5 g of each soil sample, which was air dried (for 2 days) and then sieved before they were transferred into a sterile beaker. The soil was prepared according to the method of digestion (EPA-ROC, 1994) mixture of concentrated HNO_3 and $HClO_4$ at a ratio of 2:1 were added. The beaker was placed on a hot plate and heated to near dryness. The white residue was left to cool before being dissolved with 20% nitric acid. Mixture was then filtered and a digestion volume of 30 cm^3 was made with de-ionised water. Each of the digested mixtures was then subjected to metal analysis using the SHIVZUM Atomic Absorption Spectrophotometer (model 2500). The same procedure was applied for both the plant's leaves and roots.

3. Results

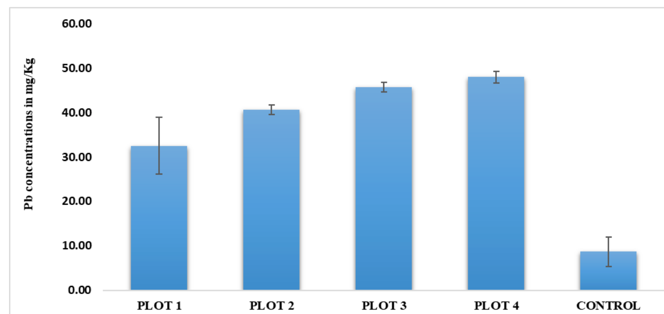

Figure 1. Lead (Pb) concentration (mg/kg) analyzed within soil samples collected from Kubanni farm, Zaria.

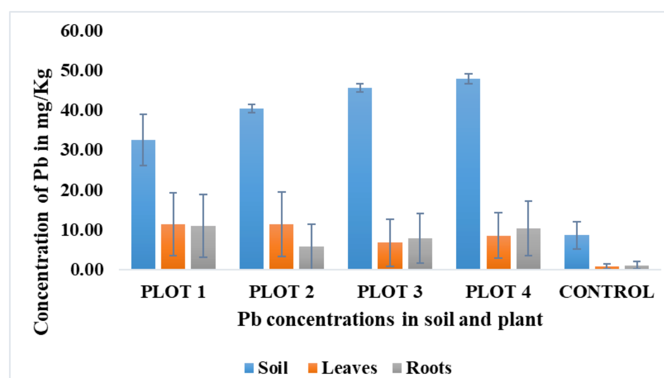

Figure 2. Levels of Pb in *L. sativa* plant that were grown on the soil samples collected from farms along Kubanni river.

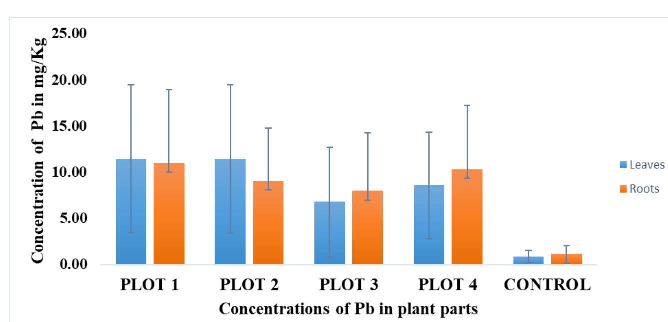

Figure 3. Levels of Pb in the soil samples collected along with the concentrations found in the *L. sativa* plant.

Groups	Bioconcentration factor
PLOT 1	0.61
PLOT 2	0.43
PLOT 3	0.24
PLOT 4	0.39
CONTROL	0.32

Figure 4. Bioconcentration factor levels of lead in *L. sativa.* BCF < 1 or = 1 means no influence and the plant absorbs only; BCF > 1 means the plant is an accumulator.

Group	Translocation factor (TF)
PLOT 1	2.07
PLOT 2	1.04
PLOT 3	0.55
PLOT 4	0.76
CONTROL	1.09

Figure 5. TF levels of lead in *L. sativa.*

4. Discussion

The purpose of this study was to assess the lead level in farms surrounding Kubanni river basin, which was not documented in an earlier research conducted by Butu (2013) and also to check its translocation into lettuce plant (*L. sativa*), which is one of the major vegetables cultivated on the farm.

Butu (2013) established the presence of 29 different HMs contaminants in the sediments of Kubanni river (for points representing it from the Kampagi hills down into River Galma. He used the Nigerian Research reactor (NIRR-1), which is reported to be the most accurate in analyzing sediments to carry out the analysis (Jonah et al., 2006). The recorded metals are Mg, Al, Ca, Ti, V, Mn, Dy, Na, K, As, Br, La, Sm, Yb, U, Sc, Cr, Fe, Co, Zn, Rb, Cs, Ba, Eu, Lu, Hg, Ta, Sb, and Th.

This study established the presence of lead (Pb) in the soil with a maximum of 47.95 mg/kg and minimum of 32.45 mg/kg (Fig. 1) just 4 years after what Butu reported. These levels however, are lower than the limits provided by the Dutch codex, which is 85 mg/kg for justification purpose, a pilot study was carried out on the flowing water along the farms, Pb level of 0.79 mg/kg was recorded.

Figure 2 has also shown the presence of this metal in Lactuca sativa although it was not as high as it was in the soil sample collected as presented in Figure 3. This could be attributed to the presence of some transporter genes than regulate the transfer of heavy metals from one region to another.

Based on the data provided by Butu (2013), the presence of Pb in the soil is a reflection of the ugly practices happening in the surrounding and probably due to anthropogenic activities too. Refuse dumping, application of chemical fertilizers, discharge of oils, grease, and other effluents among other practices could have contributed to this discovery. Further usage of chemicals close will increase the accumulation of these HMs, thereby affecting soil fertility and biomass yield of plants; hence, plants are highly exposed to HM accumulation in soils (Bhargava et al., 2012).

Plants can be accumulators, hyperaccumulators, and non-hyperaccumulators of HM, hence their use in phyto-extractions, stabilizations, and remediations. Among the indices used for this classification, the bioconcentration factor (BF) shown in Figure 4 and the TF shown in Figure 5 are the two proper ratios widely used.

The lettuce plant grown on both the samples and the control (Fig. 4) had a BF less than one (BF < 1), which according to Ahmadpour et al. (2014) disregards the sample plant (lettuce) as a hyperaccumulator. The TF were observed to be greater than 1 (TF > 1) in lettuce vegetables (Fig. 5) from PLOT 1, PLOT 2 and the control. PLOT 3 and PLOT 4 plants had their TF to be < 1. From a previous research, Tangahu et al. (2011) reported that for a plant to be a hyperaccumulator, it is necessary to have a TF > 1.

Plants with BF and TF values > 1 are considered to be promising phytoextractors while those that have both to be < 1 are not (Ahmadpour et al., 2014). Also plants BF > 1 and TF < 1 as potential phytostabilizers (Ahmadpour et al., 2014). Between the tested lettuce plants, none of the plant groups are either phytoextractors nor phytostabilizers.

This further indicates that *L. sativa* may not be regarded as a plant with high efficiency for Pb translocation, thus, lettuce from this study could not be identified as a hyperaccumulator. Since HMs are non-biodegradable, the increase in their concentrations can be potentially toxic to the life on earth. As a result, they can increase toxicity by generating reactive oxygen species, which can lead to cell damage such as macromolecule degradation, ion uptake and usage, and DNA damages (Ahmad et al., 2015). In plants, HMs in particular can affect the process of photosynthesis by interfering with electron transport chain (Rascio and Navari-Izzo, 2011), water relations, and biochemical and enzymatic activities (Ahmad et al., 2015).

Humans, plants, and animals are all equally affected by enhanced levels of HMs. Even the microorganisms in the soils are threatened by their toxicity because

HMs hinder their biological activities by accumulating in their cells and tissues. This increase in the concentration of HMs is a consequence of both natural activities like volcanic eruptions and soil erosion and weathering as well as anthropogenic activities like ore mining, burning of fossil fuels, smelting, transport and industrial wastes, and use of fertilizers and other agricultural activities (Kanakaraju et al., 2008; Lias et al., 2013).

In summary, the BF for Pb was found to be less than 1 in all sites, nevertheless sites A, B, and the control had TF values greater than 1. The BCF and TF are indices that assess the suitability of a plant considered for use in phytoremediation either in the form of phytostabilisation or phytoextraction.

The above observation indicated that *L. sativa* plant grown on the soil samples is more of an excluder than an accumulator. Further works should be carried out to confirm this in *L. sativa* from Kubanni farm.

5. Conclusion

Although the present study has established the presence of lead in the farms along river Kubanni, nevertheless, they are not above the permissible limits given by the Dutch codex (85 m/kg). HM levels from the different locations did not vary significantly in the soil samples but as time goes on, such may occur and thereby consumption of food items farmed on the soil may have to be regulated if not discouraged to prevent excessive buildup of HMs. If above 50% of the acceptable limit (85 mg/kg) is recorded in 4 years, what will it be in the next few years if such uncalled practices should continue?

Thus, continued intake of these vegetables can result in accumulation of the metals in the tissues of the consumers with untold consequences.

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