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Lead (Pb) Levels in Soils and Plants Growing Near Heavy Machinery Activities in Bagwai, Kano - Nigeria

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Abstract

The levels of lead (Pb) in soils (S), and eight (8) plants (P) growing naturally in a main agricultural activity, semi-arid zone and where there has been a long-term activity of heavy machineries carrying out construction works in the area were determined using atomic absorption spectrophotometer (AAS). Their concentration factors (CF) were also calculated. Whole plant parts were used, these include: *calotropis procera* (P = 4.6012 µg/g, S = 4.8611µg/g, CF = 0.9465). *Commelina sp* (P = 1.7053 µg/g, S = 1.479 µg/g, CF = 1.153), *Colocynthis bulgaris* (P = 1.4971 µg/g, S = 1.4231 µg/g, CF = 1.052), *cucurbita pepo* (P = 1.754 µg/g, S = 1.342 µg/g, CF = 1.307), *haemanthus sp* (P = 0.1645 µg/g, S = 0.0164 µg/g, CF = 1 0.03), *hibiscus esculenta* (P = 0.5357 µg/g, S=0.1759 µg/g, CF = 3.045), *mitracarpus scaber* (P = 0.3313 µg/g, S=0.85 µg/g, CF = 0.3898) and *lactuca taraxacifolia* (P = 4.1067 µg/g, S = 4.8913 µg/g, CF = 1.63). The study is important considering the harmful effects of Pb in human and animal physiological systems. Results were significant at 0.05 level.

Keywords: Lead, Bagwai, plants, phytoremediation, phytoextraction

1. Introduction

Cucurbita pepo is in the family *cucurbitaceae* cultivated in the Americas and other parts of the world. It includes species grown for their fruit and edible seeds (the squashes, pumpkins and marrows, chilacayote, as well as some species grown only as gourds) [1]. *Mitracarpus scaber* is a perennial, monoecious shrub, native of America and widely distributed in the tropics. It is a member of the *Euphorbiaceae* family and can grow well under any unfavourable agro climatic conditions, because of its low moisture demands, fertility requirements and tolerance to high temperatures [2, 3]. It adapts well to semi-arid marginal sites [4]. *Colocynthis bulgaris* is a dominant and a common desert plant that grows widely in warm and urbanizing regions. The capacity of this specie for taking heavy metals into its tissues due to its abilities to absorb and tolerate heavy metals without serious physiological damage has been reported [5, 6] in Saudi Arabia. The plant is common in sandy places in all the phytogeographical regions of the country. *Colocynth* presents a curious look with patches in the extensive blazing deserts of all the Arab countries. The plants grow stunting in winter and recovering again in summer. They have wonderful adaptation ability to grow up on the hot sandy soil of summer months where scarcely any plant can survive. It grows in sandy habitats of the deserts of Egypt, North African countries, semi-deserts and deserts of North Africa, Southern Europe, and Asia, from the Canary Islands eastwards to India [7]. *Haemanthus specie* belongs to the *Amaryllis* family or *Amaryllidaceae* and are herbaceous, perennials and bulbous flowering plants included in the monocot order *Asparagales*, taking its name from the genus *Amaryllis*. The family consists of about sixty genera, with over eight hundred species with a

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worldwide distribution [8]. Members are widespread in the Neotropics, Mexico, Chile, Central America the West Indies, and Argentina. The greatest generic diversity is found in Peru [9]. *Commelina benghalensis* is a wide-ranging plant, being native to tropical and subtropical Asia and Africa. In China, it is commonly associated with wet locations and it can be found near the sea level. It is found in Taiwan [10]. *Commelina* grown in hydroponic solution was found to contain 66-224 mg/kg Pb [11]. *Lactuca taraxacifolia* belongs to the family *Asteraceae* (*Compositae*), the largest of the dicotyledonous families [12, 13]. *Lactuca* is restricted to the genus *Lactuca* to those species having 7–25 yellow ligular florets and 1–10 longitudinal ribs on each side of the achene, with an acute to filiform beak at its apex [14]. Such a definition limits the genus to the serriola-like species from the sect [15]. *Calotropis procera* is a dominant and a common desert plant that grows widely in warm and urbanizing regions. This specie also have a high capacity for taking heavy metals into its tissues due to their abilities to absorb and tolerate heavy metals without serious physiological damage [5, 6]. The plant is a livestock poisonous plant, belonging to the family *Asclepiadaceae* [16] and spread within different biomes such as “Caatinga” and “Cerrado” [17, 18]. *Hibiscus esculenta* belongs to the sub-kingdom *Tracheobionta* division *magnoliopsida* and family *malvaceae* [19, 20]. The family *malvaceae* is the most important family consisting of 82 genera and 1,500 species with Hibiscus over 200 species, sida 200 species, ablition 190 species and malva 40 species. The family is worldwide in distribution but is represented in the tropical and subtropical regions. *Hibiscus esculentus* accumulates heavy metals.

Lead (Pb) has been known to be toxic since ancient times. It is a widespread contaminant in soils and its poisoning is one of the prevalent public health problems in many parts of the world. It was the first metal to be linked with failures in reproduction as it can easily cross the placenta. It affects the brain, causes hyperactivity and deficiency in the fine motor functions, thus resulting in brain damage. The nervous systems of children are especially sensitive to Pb leading to retardation. Pb is cardiotoxic and contributes to cardiomyopathy [21]. Human exposure to Pb can result in a range of biological effects depending on the level and duration of exposure. Various effects occur over a broad range of doses, with the developing foetus and infant being more sensitive than the adult. High levels of exposure may result in toxic biochemical effects in humans which may cause problems in the synthesis of haemoglobin, effects on the kidneys, gastrointestinal tract, joints and reproductive system, and acute or chronic damage to the nervous system [22].

Severe Pb poisoning that can cause evident illness is very rare. At intermediate concentrations, however, there is evidence that Pb can have small, subtle, subclinical effects, particularly on neuropsychological developments in children. Some studies suggested that there may be loss of up to 2 intelligence quotient (IQ) points for a rise in blood Pb levels from 10 to 20 µg/dl in young children [23]. Average daily Pb intake for adults in the United Kingdom is estimated at 1.6 µg from air, 20 µg from drinking water and 28 µg from food [23]. Although most people receive the bulk of their Pb intake from food, in specific populations other sources may be more important, such as water in areas with Pb piping and plumbo-solvent water, air near point of source emissions, soil, dust, paint flakes in old houses or contaminated land. Pb in the air contributes to Pb levels in food through deposition as dust and rain containing the metal. The intense and inadequate use of fertilizers and pesticides in the soil, coupled with the increase in industrial activity and mining are the main reasons for the contamination of soil, waterways and the water table by heavy metals [24]. Among the existing pollutants, Pb is the major contaminant of the soil [25] posing significant environmental problems [26], including the risk of poisoning to human beings and especially the children [27].

Pb absorption is regulated by pH, cation exchange capacity of the soil, as well as by exudation and physicochemical parameters [28, 29]. Absorption by roots from the soil occurs via the plasma membrane, probably involving cationic channels such as calcium channels. Roots are capable of accumulating significant quantities of this heavy metal and simultaneously restrict its translocation to the shoot [30]. The retention of Pb in roots involves binding to the cell wall and extracellular precipitation, mainly in the form of Pb carbonate, which is deposited in the cell wall. At low concentration, Pb can move through root tissue, mainly via the apoplast and radially through the cortex where it accumulates near the endoderm. The endoderm acts as a partial barrier to the translocation of Pb through the root to the shoot. This may be one of the reasons for the much greater accumulation of Pb in roots than in shoots [31]. In a study using three cultivars of lettuce, Michalska [32] showed that 0.5 mM Pb in the nutrient solution resulted in greater Pb accumulation in roots. Ultrastructural studies have revealed the presence of Pb mainly in the intercellular spaces, cell wall, and vacuoles with little deposited in the endoplasmatic reticulum, dictyosomes and vesicles derived from the dictyosomes. The cell wall and the vacuole together account for 96% of the Pb absorbed [33].

Excess Pb causes a variety of toxicity symptoms in plants, such as reduced growth, chlorosis and darkening of the root system. Inhibition of root growth appears to result from Pb-induced inhibition of cell division of the root meristem [34]. Pb inhibits photosynthesis, alters the mineral nutrition and water balance, modifies hormone levels and affects the structure and permeability of the plasma membrane [35]. Plants pump water, solutes and organic matter from the surrounding medium as part of their natural physiological processes. This potential can be explored to stabilize, remove or breakdown contaminants in the soil [36]. In this respect, phytoextraction, a technique that uses hyperaccumulator plants to remove metals from the soil, stands out among other forms of phytoremediation of soils contaminated by heavy metals [37].

The aim of the study is to determine the concentration of Pb in the plants and their soils, and the plants’ hyperaccumulation/phytoremediation potential.

2. Materials and Methods

In the preparation of reagents, chemicals of analytical grade purity (ANALAR grade) and distilled-deionized water obtained from Bayero University, Kano central store were used. All glasswares were washed with detergent solution and were rinsed with water before drying in the oven at 105^0C. Weighing was done on Toledo ABS4 analytical weighing balance.

2.1. Study Site

Bagwai-Kano, Nigeria is in the Sudan eco-climatic zone was chosen as the study site. There has been heavy machines activities for the construction works of Bagwai (Watari) dam, the second largest in the state which lasted for several years. It is within the latitude 12.2^0N and longitude of 8.3^0E (Figure 1) and predominantly an agricultural land [38].

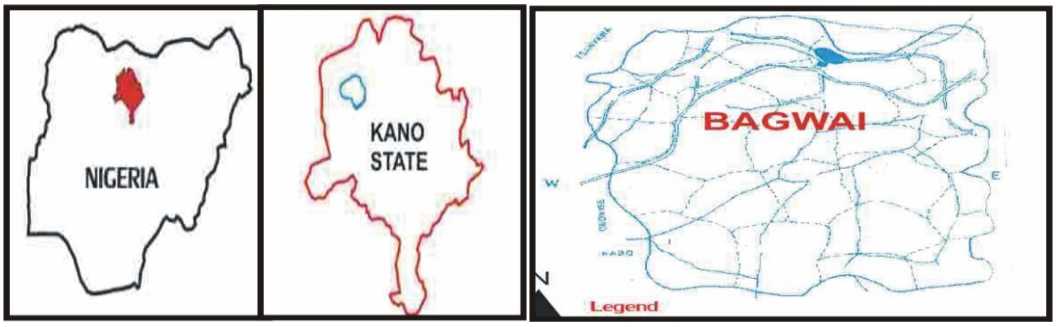

Figure 1. Sample Area Showing the Location of Bagwai (Watari Dam)

The climate of the region is the Sudan savannah type with moderate relative humidity and temperature variation.

2.2. Sample Collection

Five samples each of the fully matured plants were collected and possibly contained the maximum concentration of the trace metals they can absorb [39]. All samples were authenticated by comparison with Herbarium samples of Bayero University Botanical garden in Kano**.**

2.3. Plant Sample Washing

The plant samples were washed thoroughly with tap water and rinsed with deionized water, then dried at 80°C in an oven APHA/AWWA/WPCF [39]. This is to ensure that only those metals absorbed by the plant from the soil will be analysed.

2.4. Treatment of Plant Samples

Plant samples after drying were crushed to fine powder in a steel-bladed electric mill (National Mill Grinder Model MK 308 Tapan) and were sieved through 30 mm mesh sieve [40]. Each sample was oven dried at 105^0C to constant weight. The samples were each packed into double stacked waterproof polyethene bags and stored in screw-capped bottles before use for analysis. A total of five determinations were made for each specimen, with values provided, being the average of 10 determinations for each specie.

2.4.1. Soil Sample Preparation

The soil sample was dried in the oven at 105^oC and was sieved. A 1.0 g soil sample was weighed and digested with 10 mL 50% HNO_3 and was left overnight. This was then heated for an hour at 90^oC [41]. The extract was filtered into a 100 mL volumetric flask and diluted to the mark with 1% HNO_3.

2.5. Elemental Analysis

A 1.0 g of sieved sample was dissolved in 0.1M HNO_3, and diluted to the mark in a 100 mL volumetric flask. Concentrations of the metals were determined using atomic absorption spectrophotometer (AAS) (Alpha 4). The result of each sample was the average of ten sequential readings. Background light absorption and scattering were compensated for by deuterium hollow cathode lamp. Distilled water used as blank was digested using the above procedure.

2.6. Instrumentation

Metal concentrations were determined on a Buck Scientific Mode Alpha 4 AAS equipment with a continue source background correction. Appropriate hollow cathode lamp for each element determined was employed. The machine was switched on and allowed to stabilize for 3 min. The current and wavelength were appropriately selected. The gas control system was adjusted to give a rich fuel flame. A blank and the standard solutions were aspirated and their absorbance readings taken. The unknown samples were aspirated and the absorbance readings recorded. Three separate absorbance readings were taken for each sample aspirated and their average value computed. The distilled water used as blank was digested using the above procedures. A calibration curve of each element under investigation was determined from the calibration curve by extrapolation.

3. Results and Discussions

Based on the results obtained and presented in Table 1 and Figures 2, 3 and 4, Pb levels were found to be highest in *Calotropis procera* (4.6012 µg/g). This is followed by *lactuca taraxacifolia* (4.1067 µg/g) and *Commelina sp* (1.7053 µg/g), and the lowest in *haemanthus sp* (0.1645 µg/g). This is similar to the results for *Helianthus annus* L. [42], *Pinus radiata* [43], spinach [44] and *Prosopis sp*. [45]. The variation arises due to differences in the individual plant's ability to absorb the metal.

Table 1. Pb Levels in Plants, Soils and Concentration Factors

	Concentration (µg/g)		**Concentration factor (CF)**
	Plant (P)	Soil (S)	
Calotropis procera	4.6012	4.8611	0.9465
Commelina sp	1.7053	1.479	1.153
Colocynthis bulgaris	1.4971	1.4231	1.052
Cucurbita pepo	1.7540	1.3420	1.307
Haemanthus sp	0.1645	0.0164	10.03
Hibiscus esculenta	0.5357	0.1759	3.045
Mitracarpus scaber	0.3313	0.8500	0.3898
Lactuca taraxacifolia	4.1067	4.8913	1.6300

Moreover, according to Raskin *et al.* [46], Pb hyper-accumulator plants are those capable of extracting and accumulating over 1.0 g/kg in their tissues. Castor bean was found to have larger values in the range 10.54 to 24.61 g/kg and was an hyperaccumulator and phytoextractor for Pb.

The concentration of the metal in different soils resembles that of the plants though the highest value obtained is for *Lactuca taraxacifolia* grown soil (4.8913 µg/g), followed by *Calotropis procera* grown soil (4.8611 µg/g), *Commelina sp* grown soil (1.497 µg/g) and the least in the *Haemanthus sp* grown soil (0.0164 µg/g).

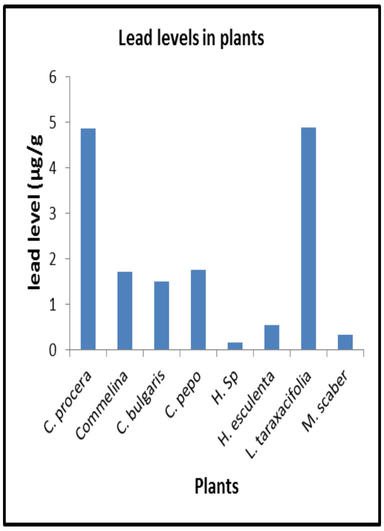

Figure 2. Pb Levels in Plants

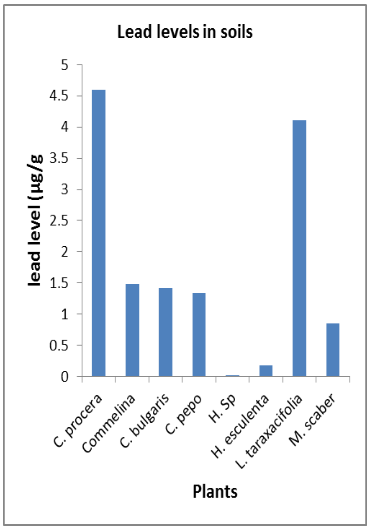

Figure 3. Pb Levels in Soils

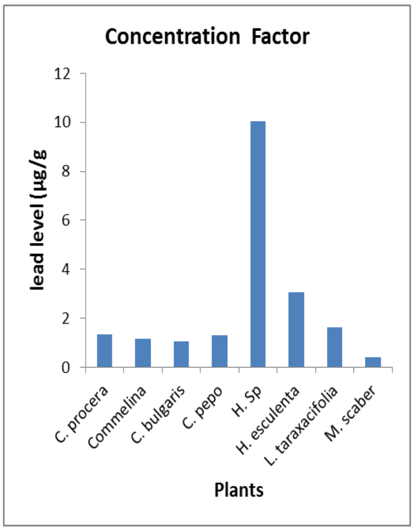

Figure 4. Concentration Factors

The concentration factors (CF) of the plants are: 0.9465, 1.153, 1.052, 1.307, 10.03, 3.045, 0.3898 and 1.63 for *calotropis procera*, *Commelina sp*, *Colocynthis bulgaris, Cucurbita pepo, Haemanthus sp, Hibiscus esculenta*, *Mitracarpus scaber* and *lactuca taraxacifolia*, respectively. Stoltz and Greger [47] also reported a similar result that castor bean plants were able to accumulate large quantities of Pb, especially in roots, demonstrating the high capacity for Pb absorption and accumulation of that organ. Similar results were obtained for *Carex rostrata, Eriophorum angustifolium* and *Phragmites austra-*

lis grown in hydroponics.

4. Conclusions

From the results obtained it could be inferred that *Calotropis procera* contains the highest value of Pb in its tissue and a high value in its soil. But it has a comparatively low concentration factor (0.9465) and is considered a low bioaccumulator. The Pb levels in *Haemanthus sp* plant tissue, soil and its highest CF of 10.03, shows that *Haemanthus sp* could be used as phytoremediator or phytoextractor to clean up Pb-polluted soils. This is followed by *Hibiscus esculenta* whose CF was 3.045.

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