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Evaluation of Heavy Metal Contents in the Leaves, Stem and Rhizospher Soil of Selected Medicinal Plants Growing in Selected Polluted Sites in Makurdi-Nigeria

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Abstract:
The study assessed the concentration of Lead (Pb), Iron (Fe), Copper (Cu), Manganese (Mn) and Cadmium (Cd) in selected medicinal plants, Azadirachta indica and Phyllanthus niruri; the rhizosphere soil in mechanic and dump sites on which the plants were growing Analysis of selected heavy metals was done using Atomic Absorption Spectrophotometer (AAS) machine. Statistical analysis was done using analysis of variance (ANOVA) at a probability level of 0.05. From the results, it was shown that, Pb, Cd, Fe, Cu and Mn were generally higher in the rhizosphere soil and leaves than in the stems of the medicinal plants (A. indica and P. niruri). P. niruri accumulated more of the heavy metals than A. indica. There were significant differences in heavy, metals concentrations among the leaves, stems of the medicinal plants and rhizosphere soil at P≤0.05. Heavy metals concentrations in sampled plants in the polluted sites were higher than those of the control sites and were statistically significant (P≤0.05). Comparing with WHO standard, the heavy metals investigated where within the acceptable set limits. However, their presence in the investigated plants calls for concern as accumulation over time may increase the level of these metals above set limits. Based on the findings, the study recommended that medicinal plants for therapeutic use should be obtained away from polluted environments and that sorting and recycling of wastes should be intensified to reduce the quantity of these toxic metals in the dumpsites which can subsequently be leached into the soil where they could be taken up by plants.

Keywords: Heavy metals, Medicinal plants, Soil, Stem, Leaves, Polluted sites.

INTRODUCTION

Environmental contamination of pollutants is on increase and the uptake by plants is a problem of significant concern for ecological, evolutionary, nutritional and environmental reasons [1]. Metal contamination issues are becoming increasingly common in Nigeria as reflected in many documented cases of metal toxicity. They are natural part of the environment in soil, rock, air and water with a few metals like Fe, Cu, Mn, among others being essential to plant metabolism in trace amounts but harmful when present in bio available forms at excessive levels [2]. Human beings, animals and plants take up these heavy metals from all possible environments like soil, air, water. These metals have the tendency to accumulate in various plants and as well as in human organs. Since plants and animals contain essential nutrients for man either through dietary sources and various herbal preparations, it is necessary to monitor the levels in biological systems that are explored by man for both dietary and medicinal purposes because deficiencies or excesses of nutrients can be a threat to good health.

The author in [3] defined medicinal plants as any plant which provides health promoting characteristics, temporary relief from symptomatic problems or has curative properties to ailments. Heavy metal is a general term used to classify a group of metals or metalloids with an atomic density greater than 5g/cm^3 [4-5]. They have been reported to play positive and negative roles in human life. Some heavy metals like Cadmium (Cd), Lead (Pb) and Mercury (Hg) even in trace amounts, are considered very harmful to the environment since they do not biodegrade while others like Iron (Fe), Zinc (Zn) and Copper (Cu) are essential for biochemical reactions in the body [6-8].

Moreover, uptake and accumulation of heavy metals in plants is influenced by attributes such as natural occurrences derived from parent material (rock), atmospheric deposition (depending on traffic density), concentration and bioavailability of heavy metals in soil (through addition of pesticides, herbicides, and fertilizers), the nature of soil where herbs are grown (pH and organic matter concentration), individual plant performance (degree of maturity of the plant, time of harvest) [9,10]. These metals accumulate in the living tissue and may affect the central nervous system, kidneys, liver, brain, skin which will in turn impact negatively on memory and reproductive systems [11,12].

Soil is recognized as a repository for pollutants due to the absorption processes which binds inorganic and organic substance to it [13]. Soil to plant transfer of heavy metals is the key process of human exposure to heavy metals through the food chain, top soil and soil near heavy traffic roads in urban areas are indicators of heavy metals contamination from atmospheric deposition [14]. Therefore, the use of herbal medicine derived from medicinal plants in polluted areas raises concern in relation to its safety, as there is a wide misconception that 'natural' means 'safe' [15]. In line with these assertions, this study posits the determination of heavy metal concentrations in the soil, stem and leaves of some medicinal plants growing in selected polluted sites in Makurdi.

MATERIALS AND METHOD

Analytical reagent grade (Analar) chemicals, deionized and distilled water were used throughout the study. All glasswares and plastic containers were washed with detergent in running tap water, followed by rinsing with Nitric acid (HNO_3) and distilled water [16].

Sample Collection and Preparation

Medicinal plant samples and corresponding soil rhizospheres were randomly collected in triplicates from four locations within Makurdi metropolis. The sampled plants specimens were taken to the Department of Biological Science, Benue State University Makurdi for identification and confirmation. The locations for the sampling were: a mechanic site at Kanshio and an abandoned dump site along university of agriculture road, all within Makurdi, Benue state. Each site had a control 250 m away from it. Soil samples were collected at a depth of 0-15cm using a stainless-steel soil auger (2.5 cm diameter). The samples were pulled together as composite and wrapped in moisture free polythene bags, labelled accordingly and conveyed from the field to the laboratory for pre-treatment and subsequent analysis [17]. Collection of samples was done from July to September. The plant samples were thoroughly washed with tap water and rinsed with distilled water to remove soil debris. The stems were cut into smaller pieces of 1cm. Soil samples were air dried for 3 days and made lump free by crushing.

All plant samples were oven dried using GNLAB Mino economy oven of model MINO/75 at 105 ^{o}C to a constant weight and crushed using wooden mortar and pestle [18]. Porcelain mortar and pestle were also used to crush the soil samples to a homogenized state. The mortar and pestles were rinsed with distilled water and dried after each sample ground to avoid cross contamination [19]. Each sample was passed through a Sachi standard test sieve of 2mm, the fine powder of the samples was stored in air tight plastic containers with lid [20].

ANALYTICAL PROCEDURE

Digestion of samples was done in the Department of Chemistry, University of Benin, Edo state. The method of [18] was adopted in analysing the heavy metals. Each plant sample of 0.5g was weighed into a clean flat bottom flask of 250ml using a scale of model AR2130 Ohaus Corporation China. Clean crucibles were used for soil samples; 5ml of concentrated Nitric per Chloric acid (HNO_3 / $HCLO_4$) in the ratio of 2:1 was added to each sample and shook for proper mixing. Plant samples were allowed to stay for two minutes before been placed on the hotplate of model ES-3615, Everest China in a fume cupboard. This was heated gently until a clear solution was obtained which signified a complete digestion. Soil samples in the crucibles were placed in the fume cupboard and allowed to stay for 24 hours before being filtered.

The crushed plant material was allowed to cool to room temperature (25 ^{o}C), both the plant and soil mixture were filtered using Whatman no.1 Filter Paper. The filtrate was diluted with deionized water to 25ml mark and transferred into clean plastic bottles with lid and labelled for heavy metals analysis. Analysis of selected heavy metals (Cadmium Cd, Lead Pb, Iron Fe, Manganese Mn and Copper Cu) was done using Atomic Absorption Spectrophotometer AAS of Model 210, VGP, Buck scientific USA in the Eco-toxicology laboratory of the Department of Animal and Environmental Science, Faculty of Life Science University of Benin. All samples were analyzed in triplicates.

STATISTICAL ANALYSIS

Data obtained from the laboratory analysis on the selected heavy metals were subjected to inferential statistics using ANOVA at a significance level of $P \leq 0.05$. Figures were used to present the results.

RESULTS AND DISCUSSION

In Figure 1, data showed that Pb, Cd, Cu, Mn and Fe concentrations were higher in the rhizosphere soil of *A.indica* in the mechanic site than in the leaves and stem. The mean values of the heavy metals were from Fe 0.756±0.006 – 7.219±0.002 mg/kg, Pb 0.169±0.013 - 5.659±0.003 mg/kg, Cd 0.151±0.007 – 5.882±0.012 mg/k, Cu 0.682±0.006 – 3.649± 0.050 mg/kg and Mn 0.230±0.008 – 1.072±0.051 mg/kg. Fe and Cu were higher in concentrations in the rhizosphere soil and leaves while Pb and Cd were lowest in the stem and leaves of the sampled plant. Similarly, the accumulation of Pb, Cd, Cu, Mn and Fe were higher in the rhizosphere soil followed by the leaves with the least concentrations of the metals in the stem of *P.niruri* at the mechanic site (Figure 2). The mean values of the investigated heavy metal ranged from 0.119±0.002 – 5.228± 0.002 mg/kg for Pb, 0.114±0.002 – 5.872± 0.004 mg/kg for Cd while Fe, Cu and Mn had a mean range of 1.995±0.003 – 7.221±0.001 mg/kg, 0.886±0.002 – 3.768±0.004 mg/kg and 0.056±0.002 – 1.115±0.002 respectively.

Result of this study showed that, at the abandoned dump site, the rhizosphere soil accumulated higher amounts of Fe, Mn, Cu, Cd, and Pb, followed by the leaves while the stem had the least concentrations of the investigated heavy metals. The mean values of the heavy metals were from 0.080±0.006 – 2.546±0.021 mg/kg, 0.043±0.003 – 1.369± 0.002 mg/kg, 0.513± 0.003 – 3.161± 0.104

mg/kg, 0.840±0.004 – 3.124± 0.002 mg/kg and 0.220± 0.001 – 0.770± 0.002 respectively for Pb, Cd, Fe, Cu and Mn (Figure 3)

Results in Figure 4 showed higher concentrations of Pb, Cd, Cu, Mn and Fe in the rhizosphere soil than in the leaves and stems of *P.niruri*. Fe and Cu had higher concentrations in the leaves than in the stem. The mean values of the heavy metals ranged from 0.205± 0.012 – 2.293±0.084 mg/kg for Pb, 0.031±0.002 – 1.378± 0.020 mg/kg for Cd, 0.713± 0.002 – 5.612± 0.008 mg/kg for Fe, 0.864± 0.002 – 3.402± 0.004 mg/kg for Cu and 0.271± 0.003 – 0.815 ± 0.005 for Mn respectively.

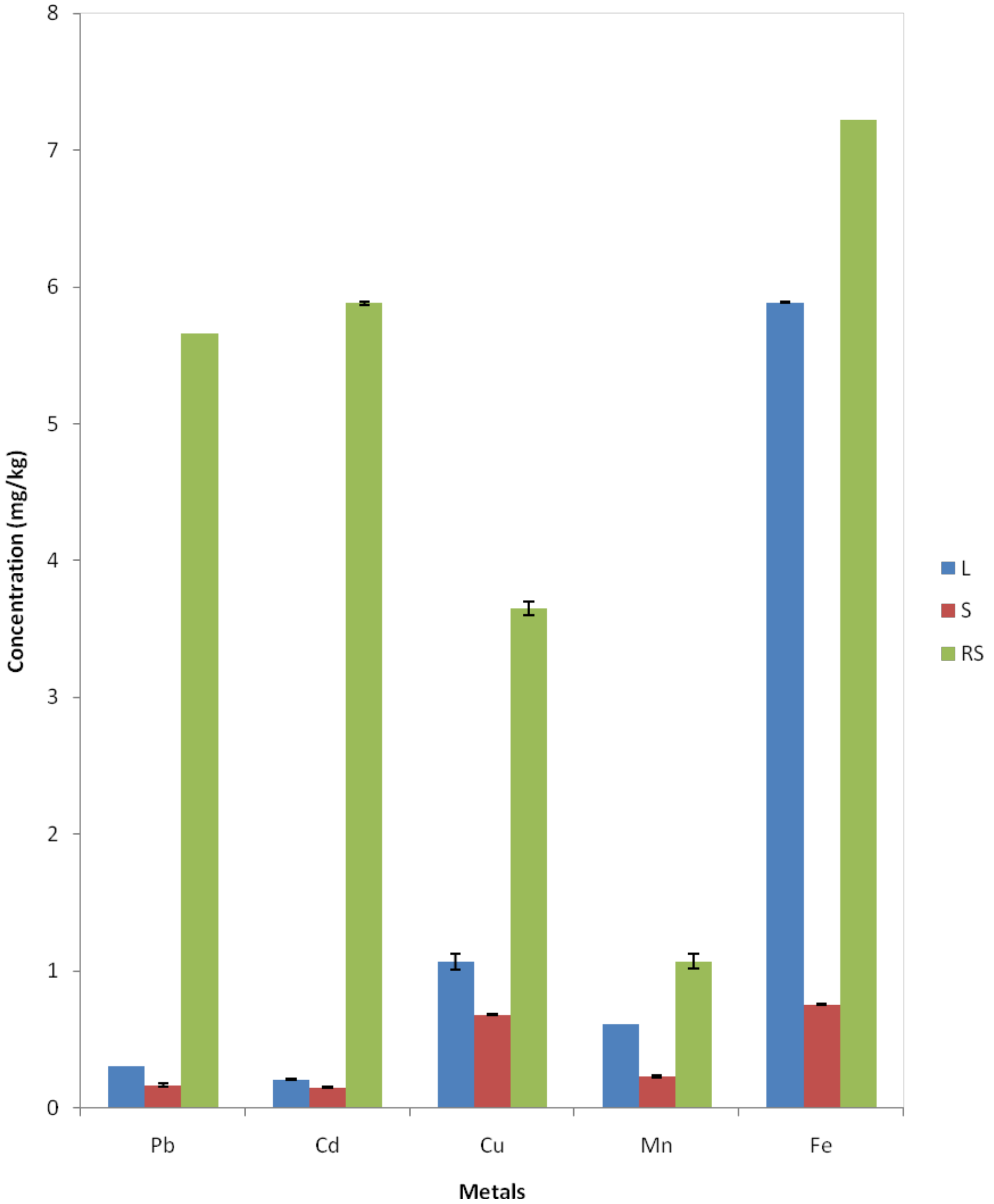

Figure 1: Concentration of Heavy Metals in the Leaves, Stem and Rhizsphere soil of *Azadirachta indica* in the Mechanic Site. Key: L- Leaves, S-Stem, RS- Rhizosphere Soil.

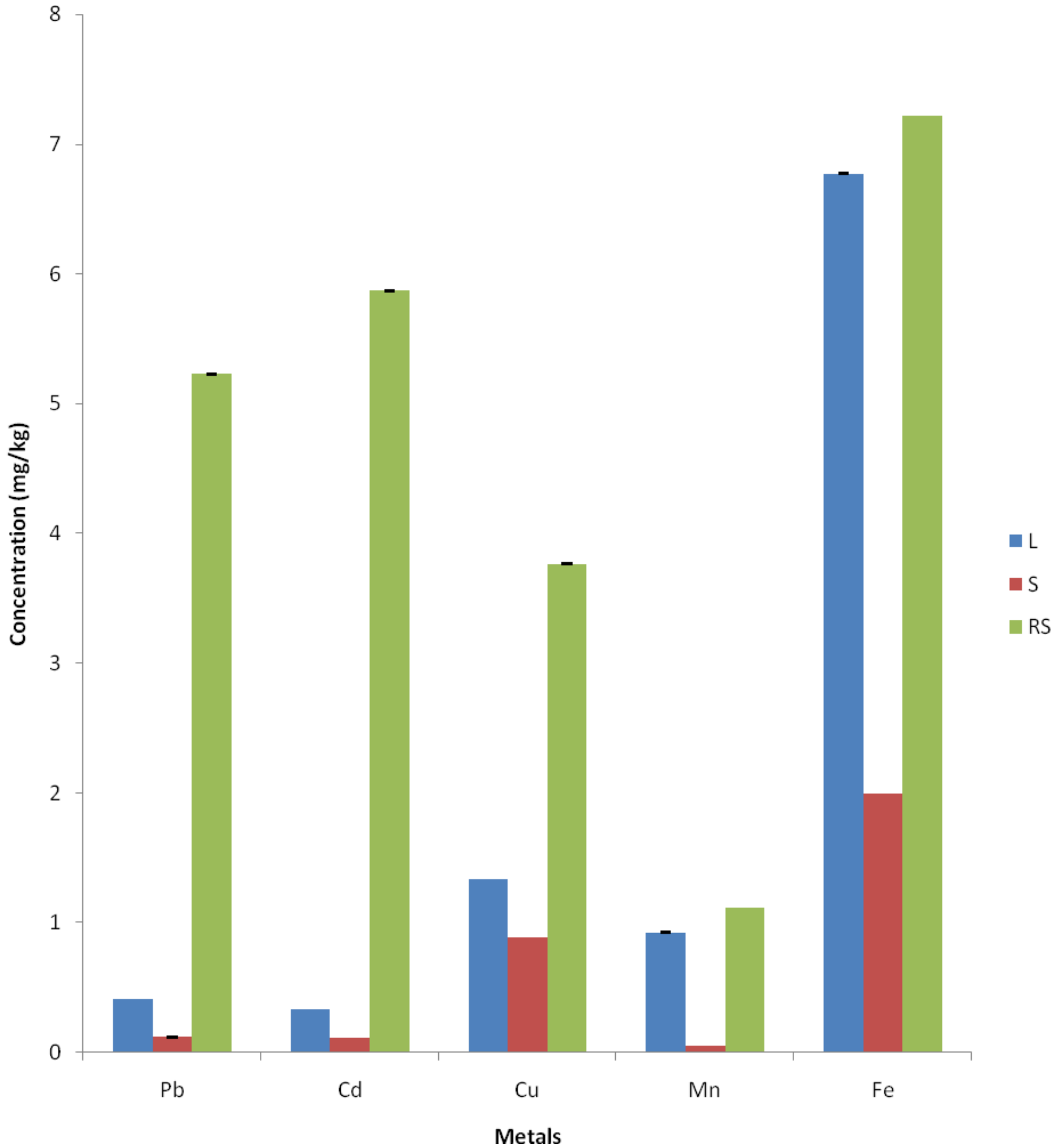

Figure 2: Concentration of Heavy Metals in the Leaves, Stem and Rhizsphere Soil of *P.niruri* at the Mechanic Site. Key: L- Leaves, S-Stem, RS- Rhizosphere Soil.

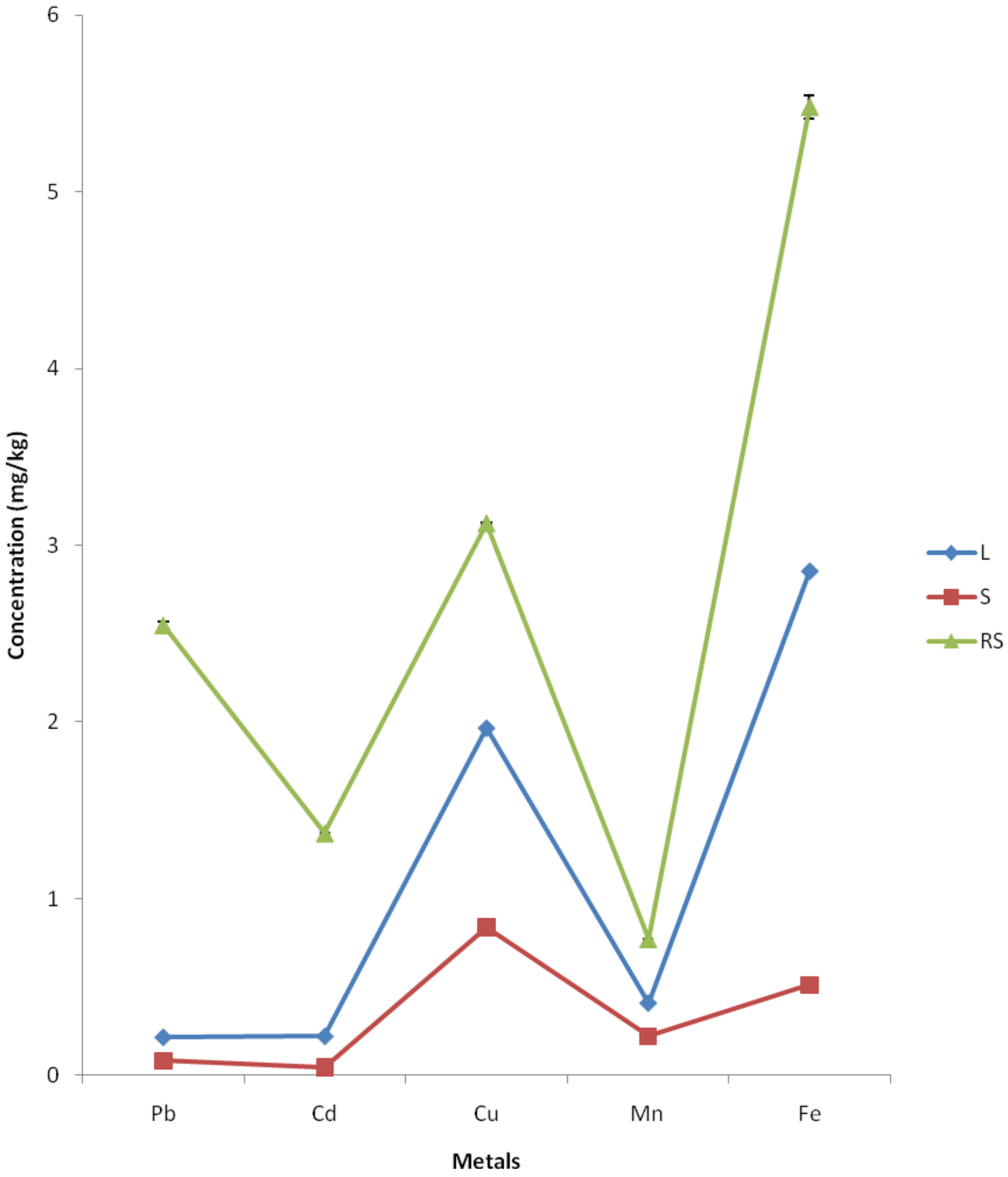

Figure 3: Concentration of Heavy Metals in the Leaves, Stem and Rhizosphere soil of *Azadirachta indica* in the Abandoned Dump Site. Key: L- Leaves, S-Stem, RS- Rhizosphere Soil.

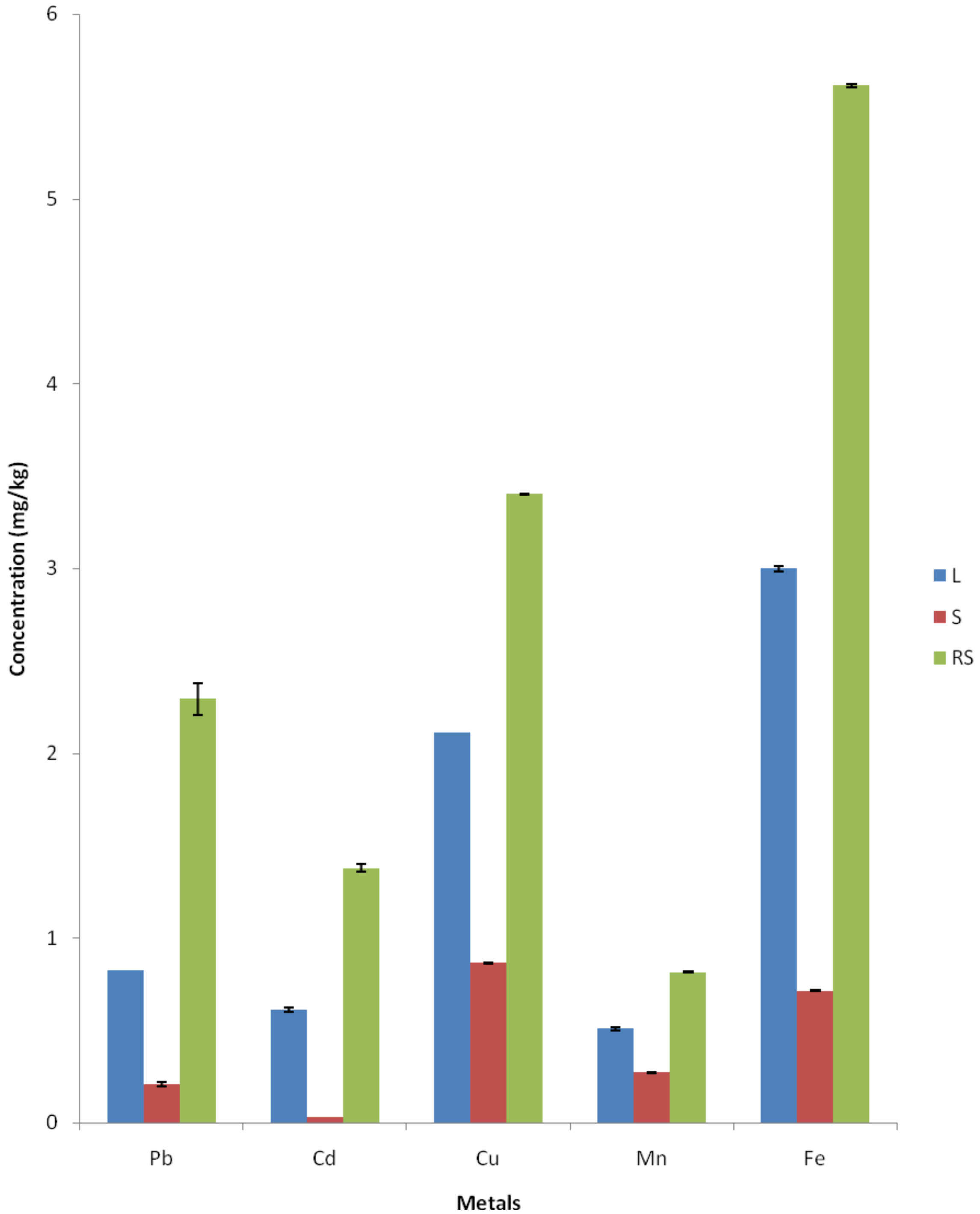

Figure 4: Concentration of Heavy Metals in the Leaves, Stem and Rhizosphere Soil of *P.niruri* in the Abandoned Dumpsite. Key: L- Leaves, S-Stem, RS- Rhizosphere Soil.

From the results in Figures 1-4, it is shown that, Pb, Cd, Fe, Cu and Mn were generally higher in the rhizosphere soil and leaves than in the stems of the medicinal plants (*A.indica and P.niruri*). The leaves of *P.niruri* accumulated metals more than *A.indica* in the leaves. This could probably be that, *P.niruri* had higher capacity to take up more of these metals than *A.indica*. It is also possible that the indiscriminate disposal of acid batteries, waste motor oil, grease and paints, disposal and burning of wastes was more on the soil on which *P.niruri* plant grew. The ability of different plant species to store or accumulate various metals in different parts could also contribute to the variations in the heavy metal's accumulation in the plant parts and between plant species. This agrees with the findings of [20] who reported that heavy metals accumulation in plants varied with plant species and tissues.

In *P.niruri*, similar trend of accumulation was observed with high mean value in the leaves than stems of the medicinal plants but *P.niruri* accumulated higher Pb than *A.indica* in the leaves. This variation in accumulation of Pb in the leaves of *P. niruri* and *A.indica* could be as a result of variation in plant species as some plant species accumulate more metals than others. The high metal concentrations in the rhizosphere soil could be attributed to indiscriminate disposal of lubricants and vehicle batteries, wearing of paint on the body of vehicles, corrosion of vehicle parts which leached into the soil. The low concentration in the stem could be attributed to low metal mobility in the plant tissues as some of the elements like Pb and Cd have been reported to have low translocation from soil to leaves. The high concentration of Pb in the rhizosphere soil than in the leaves and stem buttress the fact that soil on which a particular plant grows or is cultivated may have a high concentration of heavy metals but same may not be the case in the plants tissues and could be at a minimal concentration (22).

There was significantly high difference in the concentrations of Cd in the rhizosphere soil and tissues of the selected medicinal plants and heavy metals investigated at $p \leq 0.05$. The concentration of Cd was high in the leaves of *P.niruri* and *A.indica* than the stems both at MS and ADS. The high Cd concentration in the rhizosphere soil of sampled sites than the leaves and stems of selected medicinal plants may be attributed to dumping of PVC plastics, burning of waste, disposed batteries, motor oil/lubricant disposed on the soil, tear and wearing of tyres and wearing of paint on the body of vehicles. The uptake and translocation of Cd from the soil through the xylem to the leaves might have attributed to high Cd concentration in the leaves than the stem. Also, the differences in ability of plant to control the movement of trace metals from xylem to phloem and via the phloem to other parts of the plant might have contributed to variation of Cd concentration in the investigated samples. Findings of this study agrees with the report of (23)

High concentration of Fe was found in the rhizosphere soil than in the leaves of sampled plants with the stems accumulating the least amount of the metal. *P.niruri* accumulated more Fe in its leaves than *A.indica.* The high Fe concentration in the rhizosphere soil could be attributed to metal scraps, warn out parts of automobile and high Fe content in the soil. High Fe concentration in the leaves could be attributed to the fact that Fe is very important in plant photosynthesis and its deficiency could produce symptoms such as chlorosis, thus Fe may be transported and stored in the leaves mostly. These findings uphold the submission of (24, 25) who opined that, the uptake and accumulation of heavy metals in plants is through the root system of the plant or the foliar surface by dry or wet deposition of metal particles.

Cu concentration was higher in the rhizosphere soil and the leaves than the stems of *P.niruri* and *A.indica. P.niruri* accumulated more Cu than *A.indica*. High accumulation of Cu in the rhizosphere soil may be attributed to waste metals containing at the dump site which could eventually leached into the underlying soil, used motor oil, break lining of modern automobiles which wears away over time, fertilizer, pesticide and fungicide application as agricultural activities are being carried out around the Mechanic site and the Abandoned dump site. The variation in heavy metals concentration in the plants species may be as a result of the difference in metal accumulation in plant parts and species as plants ability to accumulate heavy metals varies. This result is consistent with report of (25) who found high concentration of Cu in the leaves than the stem of *Datura stramonium and Amaranthus spinosus.*

Manganese (Mn) concentration was significantly lower at p≤0.05 between plant parts (Stem and Leaves) and heavy metals investigated. Its accumulation was in the increasing order of magnitude: rhizosphere soil, leaf and stem. The accumulation of Mn in the rhizosphere soil could be attributed to the fact that Manganese is one of the most abundant metals in soils, also, fertilizer from agricultural activities and fossil fuel in automobiles could contributes to its concentrations. *P.niruri* accumulated more Mn than *A.indica* with high concentration observed in the leaves both at ADS and MS. This could be attributed to fossil fuel combustion around the mechanic site and the closeness of the abandoned dump site to the road. This result agrees with the report of (26) who found higher accumulation of Mn in the leaves of *Talfairia occidentalis* cultivated on the South Bank of river Benue.

CONCLUSION

This study has established the presence of heavy metals in the sampled medicinal plants and in the rhizosphere soil upon which the plants grew. From the results, Fe and Cu accumulated more than Mn and Pb while Cd was least. The accumulation of the metals was more in the rhizosphere soil and leaves than in the stems of sampled medicinal plants.

This study has clearly shown that the level of absorption and accumulation of these metals varied in the two plant species (*A.indica and P.niruri*). The accumulation also varied among the different plant tissues and organs for each of the plant studied. This is an indication that some metals though present in the soil, have low translocation from soil to plant parts (22). Also, the high presence of metals in the soil does not necessarily mean that it would be taken up by plants in the same high concentrations. Heavy metals concentration of *A.indica and P.niruri* in the polluted sites were higher than those of the control. This implies that, plants collected for medicinal use should not be taken from polluted areas because there is the risk of having these metals in the concentration that can affect health adversely over time. In comparing with the set standard by [9], the heavy metals investigated where within the acceptable set limits. However, their presence in the investigated plants calls for concern as accumulation over time may increase the level of these metals above set limits. Additionally, findings of this study revealed that, anthropogenic activities play a major role in metal accumulation in the environment which in turn, pose a serious environmental and health challenges to man. Based on these findings, the study recommends that medicinal plants for therapeutic use should be obtained away from polluted environments. Also, Sorting and recycling of wastes should be intensified to reduce the quantity of these toxic metals in the dumpsites which can subsequently be leached into the soil where they could be taken up by plants.

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