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Research Article

Phytoextraction of Some Selected Heavy Metals in Contaminated Soil by Arabian Jasmine (*Jasminum sambac*)

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ABSTRACT

Heavy metal contamination in soil is a significant environmental and health concern. This study investigates the potential of Arabian jasmine *(Jasminum sambac)* for phytoremediation of heavy metals in soil. The plants were grown in pots using soil samples collected from contaminated dumpsite soils of Dana Steel Limited in Katsina Metropolis; their ability to accumulate and remove heavy metals was assessed. An atomic absorption spectrophotometer (AAS) was used to measure the concentrations of metals in plants and soil. The statistical analysis of the data obtained was carried out using a t-test. The amounts of the metals under study in the polluted soil before planting were found to be higher than the values from the control soil: Cu (6.49±1.88 mg/kg), Ni (2.67±1.09 mg/kg), Cd (0.20±0.08 mg/kg), Pb (17.57±7.39 mg/kg), Zn (1.63±0.03 mg/kg), and Cr (8.01±2.68 mg/kg). The Bioaccumulation factor for *Jasminum sambac* was less than one (BAF<1) for all the studied heavy metals: Cu (0.10), Ni (0.32), Cd (0.87), Pb (0.30), Zn (0.02) and Cr (0.30), indicating a low bioaccumulation capacity. However, the transfer factor for *Jasminum sambac* was greater than 1 (TF>1) in Cu (3.35), Pb (3.00) and Cr (1.97), suggesting that the transfer rate of these heavy metals from soil into the plant's tissues was higher. These findings suggest that using this plant in phytoremediation can be a viable and sustainable approach to reducing heavy metals contamination in soil, thereby offering a potential solution to a significant environmental problem.

Keywords: Phytoextraction, Heavy Metals, *Jasminum sambac*, Bioaccumulation Factor, Transfer Factor

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INTRODUCTION

The environmental contamination caused by anthropogenic activity is becoming more widespread worldwide. Industrial processes like mining and processing of metalliferous ores, applying an electroplate, gaseous waste, the production of fuel and energy, and the creation of municipal wastes have all contributed to the poisoning (Kabata & Pendias, 1989). Waste materials have consequently accumulated in the environment, with heavy metals being of special concern (Appel & Ma, 2002). According to Ferguson (1990), metallic elements classified as heavy metals (HM) have a comparatively greater density than that of water. The health of people, animals, and plants, as well as the ecosystem as a whole, is seriously endangered by excessive metal concentration in the soil (Nascimento & Xing, 2006). As a result of the effects of industrial expansion in many nations, heavy metal contamination is currently among the significant environmental issues (Israila *et al.,* 2015). Heavy metal residues in contaminated ecosystems can build up in microorganisms, aquatic flora, and fauna. After entering the human food chain, these organisms can result in health problems including lead poisoning, which has killed over 400 children in Zamfara State (Galadima, 2012). Heavy metals are more of a concern than other environmental pollutants because decay cannot eliminate them. Remedial action utilizing various methods is necessary to remove any pollution from heavy metals in soil (Henry, 2000).

The phytoextraction process, a key focus of our research, includes the movement, uptake, and absorption of contaminants by plant roots into the parts of the plant that are above ground (shoots). These above-ground portions can be harvested, burned, and recycled from the ash, making phytoextraction a significant method in environmental science (Resaee *et al*., 2005; Salido *et al*., 2003; Erdei *et al*., 2005; U.S. EPA, 2005). Utilizing plants to eliminate heavy metals from polluted soil is a natural, environmentally friendly method that can be more affordable and long-lasting than traditional remediation procedures, including physical or chemical processes. In the last few years, phytoextraction has garnered significant interest as a potentially effective method for eliminating environmental contaminants such as heavy metals (Shehata *et al*., 2019; Lamine& Saunders, 2019; Asgari *et al*., 2019). Its ability to clean up contaminated and polluted areas has led to its widespread acceptance in developed and developing countries (Sun *et al*., 2011). Not only is it less expensive, but it also does not harm the soil's chemical or physical quality (Israila *et al.,* 2015).

The evergreen shrub *Jasminum sambac* can grow to a height of 0.5–3 m. The plant bears flowers in clusters of three to twelve at the tips of its branches throughout the year. These are white corolla flowers with a powerful aroma—the flowers unfold at night, usually between six and eight o'clock. The distinguishing characteristic of *Jasminum sambac* is its delicious, heavy scent. It is extensively planted as a decorative plant and is renowned for its intensely scented blossoms across the tropical regions of Southeast Asia, the Pacific Islands, and the Arabian Peninsula (Kumari *et al*., 2018; Merlin, 2020). According to Klaus and Joachim (2004), *Jasminum sambac* belongs to the tribe Jasmineae and the genus Jasminum. It is a member of the Oleaceae family of olives. *Jasminum sambac* is commonly called "Arabian jasmine" since it is extensively grown in Yemen, Oman, and the Southwest region of Saudi Arabia (Singh, 2006).

MATERIALS AND METHODS

Description of the Study Area

Dana Steel Limited Company dumpsite is situated in Katsina state, Nigeria, at latitudes 12º 57^{1} 43^{11}N and longitudes 7º 37^{1}11^{11}E. The average annual rainfall is 600 mm, with an average relative humidity of 60% and mean maximum and lowest temperatures of 33.2°C and 18.7°C, respectively (Ladan, 2013).

Figure 1: Location of samples from Katsina L.G showing Dana Steel Limited Company

Sample Collection

Soil samples were collected from Dana Steel Company dumpsite located in Katsina Metropolis and transported to the Central Laboratory, Umaru Musa Yaradua University Katsina. Control soil was collected at least 5km away from the contaminated area from Inwala Janbango behind Al-Qalam University Katsina, where there are no anthropogenic and industrial activities involving the release of heavy metals (Israila *et al*., 2015). A mechanical hand auger was used to collect the soil samples. The seedlings of Arabian jasmine (*Jasminum sambac*) were obtained from uncontaminated farmlands, and transplanted to the pots.

Sample Preparation

After being air-dried and mashed with a mortar and pestle, each soil sample was sieved through a 20 mm mesh screen. Using an electronic scale, 1g of each soil was weighed and added to a sterile, empty beaker. 10mL of HNO_3, 2mL of 60% $HClO_4$, and 5mL of H_2SO_4 were added to each sample, and the mixture was then mixed with a glass rod in the beaker. After cooking for around an hour on a hot plate, the sample was allowed to digest at 100°C until it was completely dry, and then it was allowed to cool at ambient temperature before being filtered into a standard 60mL sample bottle and properly topped off with distilled water. After that, the filtrate was being prepared for analysis (Bello *et al*., 2019). The soil samples were appropriately identified and kept for different kinds of analysis in polythene bags (Zauro, 2017).

Following the crucial testing phase, the plants were meticulously removed from each pot, carefully put inside a plastic bag, and transported to the lab. Equally important, a sample of soil was extracted from each pot, securely sealed inside a plastic bag, and also brought to the lab. The plant samples underwent a thorough cleaning process in distilled water to eliminate any residual dirt. The samples were then methodically divided into sections representing leaves, stems, and roots, and left to air dry in the lab for a few days. With utmost precision, the dried samples were ground into powder using mortar and pestle, a crucial step in preparing them for acid digestion. They were then carefully placed in plastic vials with stoppers for storage. Similarly, the soil samples were sieved using a 2 mm nylon sieve, air-dried, and kept in plastic bags until they were required for acid digestion (Abdulhamid *et al*., 2017).

Determination of Heavy Metal Concentrations

The determination was conducted using an atomic absorption spectrophotometer at the Central Laboratory, Umaru Musa Yaradua University Katsina. Every prepared sample was aspirated into the instrument, and the average concentration value for each metal in each sample was determined. The values obtained in the standard materials in this work were compared with the certified values. All the chemicals used in the experiment were of analytical quality, deionized and purified water were utilized throughout the experiment. The calibration curves for each metal were obtained by running several concentrations of standard solutions, taking into account the corresponding concentration and the measured absorbance. Reading a blank reagent allowed the instrument to be reset to zero (Bello *et al*., 2019).

Procedure

On a heated plate in a fume cabinet, each gram of soil and plant sample was separately digested using 10 cm^3 of aqua regia. Periodically, water was introduced to prevent the digest from drying out. After adding 30 cm^3 of water to the heated solution, it was filtered through filter paper and moved into a 50 cm^3 standard volumetric flask, where it was further diluted to the required amount. An atomic absorption spectrophotometer was used to analyze the levels of metals in the soil and plant samples (Kisku *et al*., 2000),

Determination of Bioaccumulation and Transfer Factors

Using the heavy metal-contaminated soil from the study area, the bioaccumulation factor (BF) and the transfer factor (TF) were computed to assess the level of metal accumulation in the plants grown.

$$BF = \frac{Concentaration\ of\ metals\ in\ plants}{Concentation\ of\ metals\ in\ soil}$$

$$TF = \frac{Concentration\ of\ metals\ in\ plant\ shoots}{Concentration\ of\ metals\ in\ plant\ root}$$

Data Analysis

The mean and standard deviations (SD) were calculated using Microsoft Office Excel 2016.The t-test was used to calculate the amounts of heavy metals in soil samples both before and after planting. When the statistical differences were $p<0.05$, they were deemed significant. To find any notable variations in the metal concentrations between plants from contaminated soil and control soil, a t-test comparison was also employed.

RESULTS AND DISCUSSIONS

The outcomes of the amount of heavy metals in contaminated and controlled soils before planting, a crucial aspect of our research, are presented in Table 1. In contrast, the results after harvest, which further contribute to our understanding, are shown in Table 2 as the Mean ± Standard deviation. The values found in the target soil were subjected to an analysis using Microsoft Excel 2016 T-test at $p<0.05$ to determine the degree of variation in the heavy metal concentrations in contaminated soil before planting and following harvest.

The amounts of the studied heavy metals were higher than the control. The studied soil has the lowest values in Cd but is highest in Pb. Abdulhamid *et al*., (2017) reported a relatively high value of Pb. The total amounts of heavy metals present in soil before planting varied and reduced in the following order: Pb> Cr > Cu > Ni > Zn > Cd. Therefore, compared to the findings of (Inbome *et al*., 2014; Rahib *et al*., 2015; Audu *et al*., 2016 and Abdulhamid *et al*., 2017), the amounts of heavy metals reported in this study were low. The maximum lead content in the contaminated soil and control also deviate from the heavy metals in the soil study (Zauro *et al*., 2017). However, as it concurs with the report of Bello *et al*. (2015). The high amount of lead may be related to the main highway that is close to the dumpsites, where cars are driven (Abdulhamid *et al*., 2017). The level of metals after harvest indicated lowest values in Cd and highest values in Cr. The total amounts of heavy metals present in soil after harvest changed dramatically and dropped in the following order: Cr >Ni > Cu >Pb> Zn > Cd. After harvest, the amount of heavy metals in the contaminated soil decreased, demonstrating the potential of phytoremediation in soil pollution control.

Figure 2 meticulously details the levels of the heavy metals under study in various sections of the *Jasminum sambac* plant. These plants were carefully selected from both contaminated soil and the control. The metal concentrations (mg/kg) in the leaves, stem, and roots were measured with utmost precision, ensuring the reliability of our findings. The values for copper, nickel, cadmium, lead, zinc, and chromium in the leaves were found to be 0.87±0.41, 0.58±0.08, 0.13±0.002, 8.16±0.98, 0.03±0.02 and 2.62±0.18, respectively. In the stem, the concentrations were 0.77±0.15, 0.70±0.12, 0.19±0.02, 6.47±5.83, 0.04±0.04 and 3.18±018. The roots showed Cu – 0.2±0.09, Ni - 1.31±0.53, Cd - 0.19±0.01, Pb - 1.18±0.02, Zn - 0.04±0.01, and Cr - 1.47±0.07.

Our findings on the amounts of heavy metals in different parts of *Jasminum sambac* in the contaminated soil and the control, along with their respective bioaccumulation and transfer factors, are significant. We observed a variation in the metal levels in the leaves, stems and roots of the plant except for Cd and Zn. The bioaccumulation factor (BF) for all the studied heavy metals (copper, nickel, cadmium, lead, zinc, and chromium) was less than one, indicating that the concentration of the heavy metals in the *Jasminum sambac* plant is lower than in the soil as shown in figure 3. This suggests that *Jasminum sambac* has low bioaccumulation capacity and can be called a non-hyperaccumulator plant for the six studied heavy metals. The transfer factor (TF) for Cu, Cd, Pb, and Cr were more significant than one, indicating that *Jasminum sambac* can transfer these metals from soil to its tissue at a higher rate. However, those of Ni and Zn were less than 1, suggesting that *Jasminum sambac* absorbs Ni and Zn at a lower rate than is transferred from the soil. Importantly, the leaves of the *Jasminum sambac* accumulated a high amount of lead (Pb), which is similar with the report of Parveen *et al*. (2011).

Table 1: Heavy Metal Concentrations in Contaminated and Control Soils before planting

Sample	Heavy Metal concentrations (mg/kg)					
	Cu	**Ni**	**Cd**	**Pb**	**Zn**	**Cr**
Test soil	6.49±1.88	2.67±1.09	0.20±0.08	17.57±7.39	1.63±0.03	8.01±2.68
Control soil	0.20±0.09	1.08±0.09	0.10±0.03	15.32±14.18	0.86±0.10	2.03±0.24

Mean ± SD

Table 2: Heavy Metal Concentrations in Contaminated and Control Soils after harvest

Sample	Heavy Metal concentrations (mg/kg)					
	Cu	Ni	Cd	Pb	Zn	Cr
Test soil	1.58±0.79	2.37±1.40	0.04±0.02	1.39±0.73	0.30±0.16	4.51±1.74
Control soil	0.34±0.07	0.51±0.02	0.06±0.07	0.43±0.15	0.01±0.00	4.283±4.18

Mean ± SD

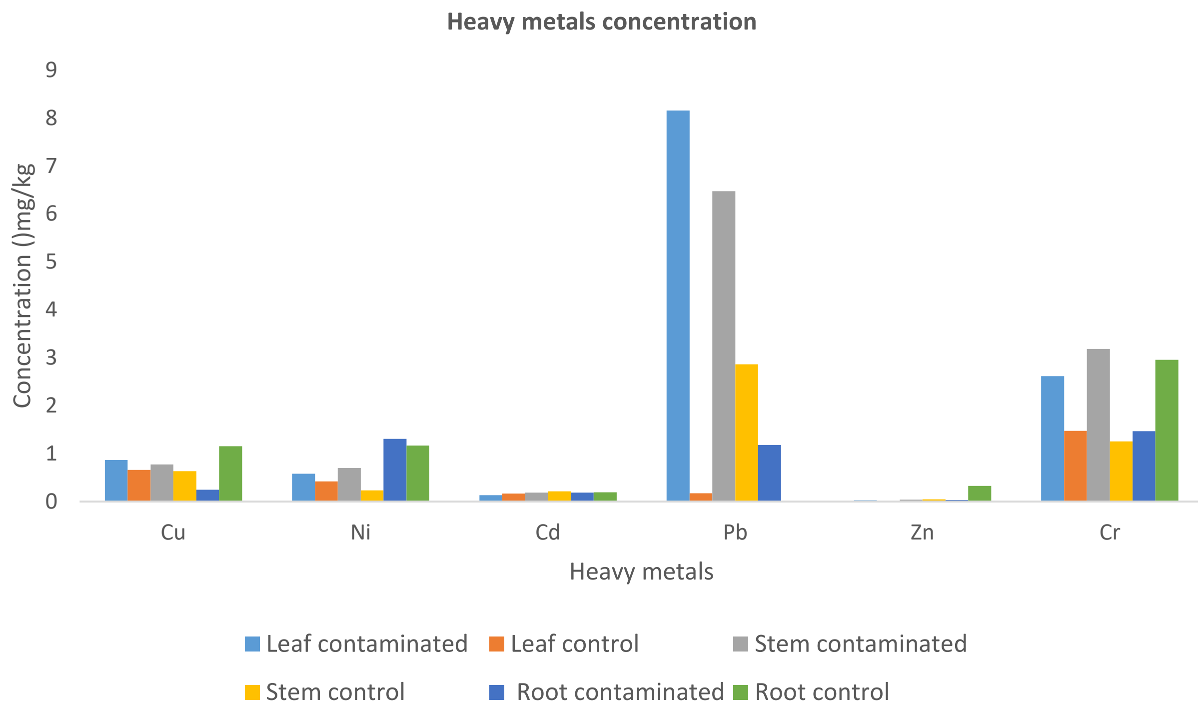

Figure 2: Concentration of the studied Heavy Metals in different parts of Arabian jasmine *(Jasminum sambac)*

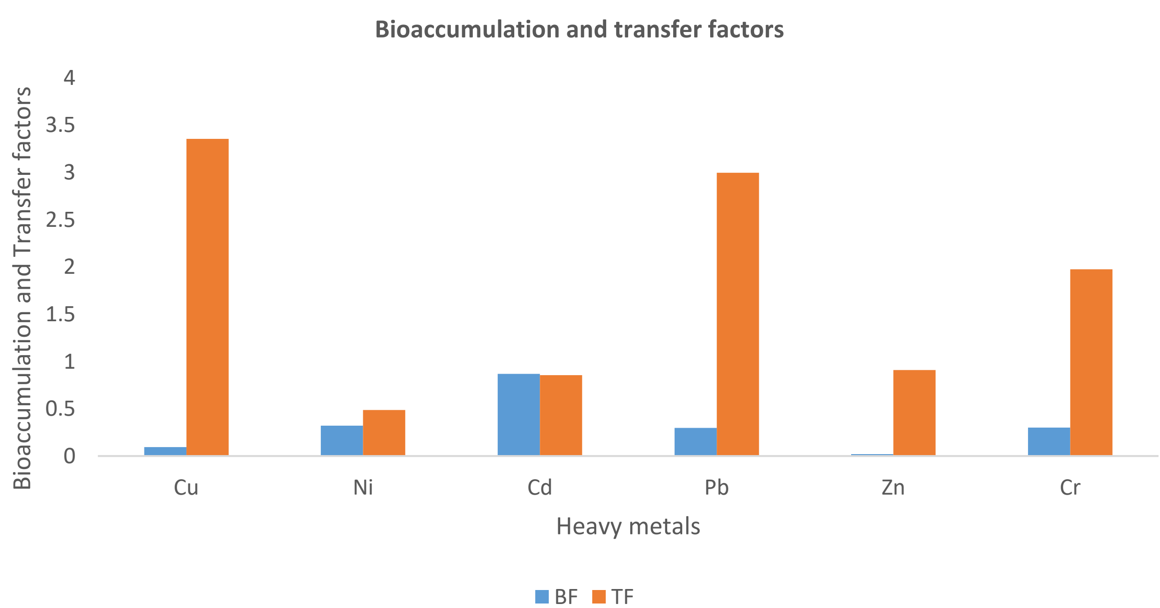

Figure 3: Bioaccumulation and transfer factors of Arabian jasmine *(Jasminum sambac)*

CONCLUSION

The research findings showed that the contaminated soil contained higher quantities of Cu, Ni, Cd, Pb, Zn, and Cr than the control soil, indicating significant contamination due to the dumping of scrap metals, which poses potential health risks as crops are planted on nearby farmlands. Arabian jasmine *(Jasminum sambac)*, used in this study, demonstrated a significant ability to absorb Ni, Pb, and Cr, reducing the amounts of these pollutants in the contaminated soils. The results underscored the importance of monitoring the amount of heavy metals in soil before and after planting. Despite its low bioaccumulation capacity for the studied heavy metals, *Jasminum sambac* exhibited a higher in Cu, Cd, Pb, and Cr transfer factor. The findings highlight the plant's potential phytoremediation, offering a hopeful solution by effectively reducing heavy metal levels in contaminated soils and mitigating environmental impact.

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