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RESEARCH ARTICLE

Phytoremediation of Heavy Metals: Copper and Arsenic Contaminated Wastewater Using Gladiolus and Chrysanthemum Plants

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ABSTRACT

Plants and human health are negatively impacted by heavy metal toxicity in the soil. They enter the soil through a variety of processes, including smelting, coal combustion, and overuse of herbicides, fertilizers, and sewage sludge. Among various heavy metals Although arsenic and copper are vital, elevated levels of these elements create a number of morphological and biochemical problems in plants. When fruits and vegetables are cultivated on contaminated soil, they enter the food chain and can have a major negative impact on consumers' health. However, in addition to being utilized for aesthetic beauty, ornamental plants may also be investigated for the phytoremediation of heavy metals in soil. A recent study used a completely randomized design to examine the phytoremediation ability of Gladiolus (Gladiolus grandifloras) and chrysanthemum against varying concentrations of arsenic (80 and 100 µg/kg) and copper (80 and 100 µg/kg of soil).After both plants reached the flowering stage, data on the total amount of heavy metals was recorded by splitting the plants into four sections: roots, stem, leaves, and flowers. Significant levels of copper were deposited by the roots, stem, leaves, and flowers of both gladiolus and chrysanthemum. The corresponding accumulations for gladiolus and chrysanthemum were 367, 456, 796, and 1278 ppm Co and 356, 571, 832, and 1478 ppm, respectively. Chrysanthemums readily moved from stem blossoms and absorbed large levels of copper from the stem. Compared to Gladiolus, chrysanthemum has a greater translocation capacity for both metals. Mini Tab Statistics 8.1 was used for the analysis of the data.

Key words: Heavy metals, Waste water, Phytoremediation, Ornamental plants.

INTRODUCTION

Soil is the major component of ecosystem. It is the largest receiving body and is mostly exposed to heavy metals and pesticides which increase soil pollution in agricultural land (Abdulrahman et al., 2022). Heavy metals are elements that have density and are toxic to human beings at very low concentrations (Azad et al., 2020). The most prevalent heavy metals that contaminate the environment are lead (Pb), arsenic (As), copper (Cu), nickel (Ni), chromium (Cr), and mercury (Hg). The primary sources of heavy metals are mining, wastewater, sewage sludge, pesticides, fertilizers, and paints (Alamo-Nole and Su, 2017). Heavy metals required critical concerns in the world due to environmental pollution and human health problems in the ecosystem (Afzal et al., 2018). Since heavy metals are not biodegradable, their buildup has garnered attention recently due to the fact that their elevated concentrations might be harmful to the environment (Álvarez-Mateos et al., 2019). The soil pollution due to heavy metals indicated their entry from natural and anthropogenic sources (Asante-Badu et al., 2020). Parent material, weathering, and soil erosion are the main sources of heavy metals (Ahmad et al., 2019).

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Many common practices for cleaning up polluted soil and water have been proven to be efficient but very expensive and require more labor. The phytoremediation technique is a less expensive and eco-friendly approach that is an alternative to conventional methods (Anumala and Kumar, 2021). Therefore, Phytoremediation is considered the best practice to mitigate health risks regarding contamination of heavy metals (Alsafran et al., 2022) (Diarra et al., 2022). Horticulture occupied 6% of total agricultural land in Pakistan, with the flower sector sharing 0.5%. The total statistical area of flower cultivation is 7,080 hectares in Punjab, with a yearly output of 10,000-12,000 tons of fresh flowers transported to various cities around the country (Fernández-Luqueño et al., 2017). Cut flowers have a significant role in global trade which is up to 60%, followed by potted plants, dry flowers, and other ornamental production. The global floriculture industry is mostly export-oriented and rising at a rate of 15% per year (Ghazaryan et al., 2022). Gladiolus belongs to the herbaceous group and family Iridaceae, they have a bulbous mass. The term "gladiolus" represents "sword" in Latin which came because of its leaf shape (Hillenbrand et al., 2021). *Gladiolus grandiflorus* is one of the most desired and famous crops in the cut flower sector (Harding et al., 2017), due to the great diversity of flower sizes, colors, and patterns (Maddala 2021). The stats show that after rose (1,214 hectares) gladiolus (2,226 hectares) stands as the 2nd most cultivated flower in Pakistan. The chrysanthemum is a Greek word which means that gold and flower. It is herbaceous plant and perennial (Pandey et al., 2019). The recent study was conducted to evaluate the existence of Copper and Arsenic from contaminated waste water through phytoremediation technique using Gladiolus and Chrysanthemum Plants in pots.

MATERIALS AND METHODS

Study Site

The study was carried at the field area of the department of the Horticulture MNS University of Agriculture, Multan to evaluate the phytoremediation potential of Copper and arsenic by two different ornamental plants named Gladiolus and Chrysanthemum. A pot experiment was performed on seedlings purchased from the local nursery of Multan in December 2024.

Plant Type

The experiment was conducted on Gladiolus and chrysanthemum plants. Gladiolus and chrysanthemum were purchased from a certified nursery of Multan. All the selected plants are disease-free and healthy. A total of 12 pots were used for the experiment. The wide range of size of pots were used to ease the germination of plants. The design of the pots was so good that ease the drainage system and walls of pots surrounded by potting soil.

Soil Preparations

The soil was taken from the Research site area of the Horticulture Department at MNS University of Agriculture Multan. The collected soil was air dried and sieved on a sieve having 4 mesh sizes. After sieving soil was thoroughly mixed with contaminant before plantation. The soil was mixed with peat and peat was purchased from Sky Vegetable and Flowers Seed, *Company Lahore.*

Copper and Arsenic Contaminants

To make sure that the contaminants were evenly distributed throughout the soil matrix table 1, copper and arsenic were combined with the prepared soil, allowed to air dry, and then sieved through sieve #4 mesh size.

Table 1: Quantity of Heavy Metal used against Gladiolus and Chrysanthemum

Heavy Metal	Gladiolus µg/kg of soil	Chrysanthemum µg/kg of soil
Copper	100	100
Arsenic	100	100

Up-keeping of Plants

Throughout the trial, constant maintenance was carried out. Plants were irrigated once a time in a week. Trace elements were sprayed two times a week on the plants using spring. The soil surface was plowed up with a tiny shovel. In five months, the trial was finished. After two months of being grown in a greenhouse, the plants were removed to spend three more months growing at the nursery area (Soylak et al., 2013).

Measuring Contaminant Concentration

After the flowering stage, the plants were pulled off from pots and the plant parts were separated for analysis. The top, Centre, and bottom of the pots were all used to sample the laced soil. Measurements were made of extraction and pollutant concentrations in the soil as well as the various plant sections employed. The 1M HNO_3 solution approach was used to remove the pollutant from the soil as well as from every component of the plant (Salam et al., 2021).

Extraction of Heavy Metals from Plant Parts

The collected plant parts were crushed with the help of mortar and subjected to separate beakers. After extraction, the plant parts were subjected to the centrifuge tube with reagents of various concentrations for completeness of extraction from every part. The adsorbed Cu and as were extracted using ammonium acetate solutions of various pH levels. The metals connected to the amorphous substance were dissolved using NH_4 and NH_2OH.This approach was used for extractions of Cu and as in the extracted solutions. After being weighed, one gram of each sample was put into a unique 50 mL centrifuge tube, and reagents were then added. Samples were centrifuged after each extraction at 12000rpm for 25 minutes at 20°C (Sungur et al., 2013).

Experimental Design and Statistical Analysis

The research was design under CRD, each treatment consisted of three replications (two plants per replication). Microsoft Office Excel 2010 was mostly used to process the trial data. SPSS 10.0 was used to do a one-way analysis of variance. The statistical difference was verified using the Duncan test, with the significance level set to P= 0.05, and the results were frequently expressed as the mean standard deviation (SD).

RESULTS

The extracted solution of Cu and as was measured in ppm from roots, stems, leaves and flowers. The various quantity of copper and arsenic were observed from plant parts of Gladiolus and chrysanthemum as shown in the graph below.

Phytoremediation is an economical way to eliminate toxins from soil, plant do this process by different methods. The capacity of a plant to extract and relocate the metals in their components is called phytoextraction. A recent study showed that the flower of gladiolus absorbed 30% copper and 42% arsenic from the soil through translocation. The remaining parts leaves of plants translocated more heavy metals than roots and stems. Leaves of gladiolus absorbed 25% and 16% copper and arsenic respectively followed by other parts of plants. Minimum absorption was recorded in stem flowed by roots (Sinha et al., 2015) (Fig. 1,2).

The same chemicals were repeated against the chrysanthemum flower plant. The recorded data showed that the flower of chrysanthemum plants uptake more copper and arsenic than other parts of plants like stem, leaves, and roots due to the high metabolic efficiency of the chrysanthemum plant. The flower of chrysanthemum absorbs 50% copper from soil followed by leaves and stem. Arsenic absorb by chrysanthemum flowers was significantly more (46%) than other plant parts. The uptake of these two heavy metals helps the phytoremediation of soil. The depth of the contaminated soil, the metal's bioavailability, the plant's ability to absorb and store the metal in its biomass, and the physical and chemical properties of the soil are some of the factors that influence how well phytoremediation using plants works. The buildup of metals in plant tissues is particularly significant. The data indicated that the faster rate of transpiration and higher transfer of plant sap and metals to the plant's leaves and flowers may be connected to the enhanced accumulation of Cr and As in chrysanthemum flowers and leaves (Teixeira et al., 2013). The required amount of heavy metals participates in cellular functions via metabolism; however, an overload of heavy metals may affect cellular organelles and components (Subpiramaniyam et al., 2021). Therefore, horticultural ornamental plants are the best source for phytoremediation as they break down the food chain and risk related to human beings (Wahocho et al., 2016) (fig. 3,4).

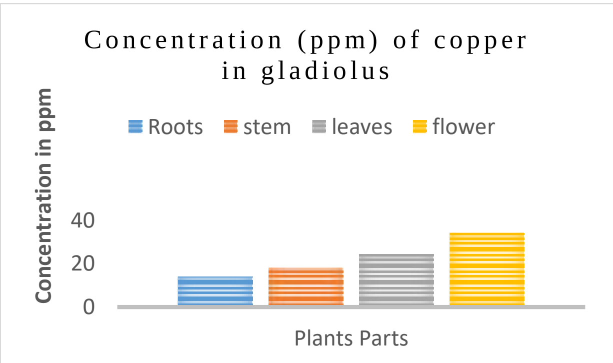

Fig. 1: Copper concentration (ppm) at various parts of Gladiolus (Roots, stem, leaves, flowers).

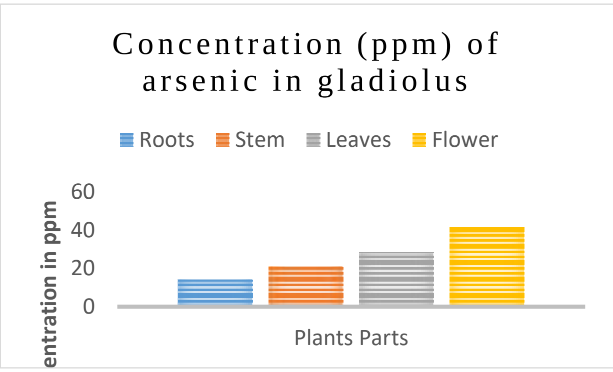

Fig. 2 Arsenic concentration (ppm) at various parts of Gladiolus (Roots, stem, leaves, flowers).

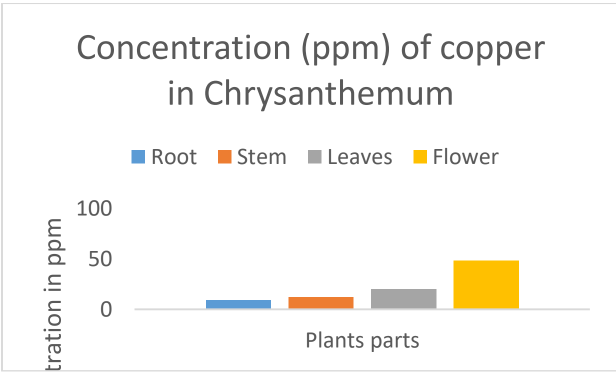

Fig. 3: Copper concentration (ppm) at various parts of Chrysanthemum (Roots, stem, leaves, flowers).

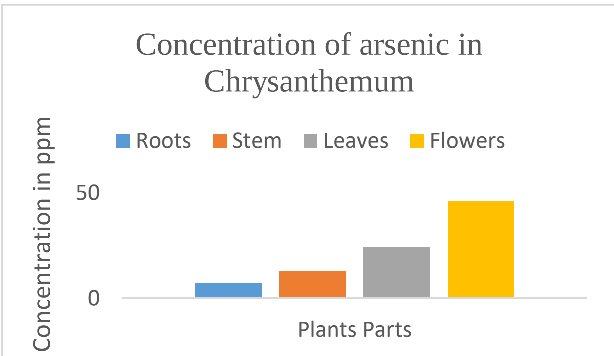

Fig. 4: Arsenic concentration (ppm) at various parts of Chrysanthemum (Roots, stem, leaves, flowers).

DISCUSSION

The present study evaluated the phytoextraction potential of *Gladiolus grandifloras* and *Chrysanthemum morifolium* for copper (Cu) and arsenic (As) accumulation in different plant parts, namely roots, stems, leaves, and flowers. Results clearly demonstrated that both ornamental plants translocated significant amounts of heavy metals from the soil to their above-ground biomass, with maximum accumulation observed in flowers, followed by leaves, stems, and roots. This trend suggests strong translocation efficiency and makes these ornamentals promising candidates for phytoremediation of Cu and As-contaminated soils.

Our findings on gladiolus revealed that flowers accumulated up to 30% Cu and 42% As, whereas leaves accumulated 25% Cu and 16% As. Roots and stems showed relatively lower uptake. These results are in agreement with Sinha et al. (2015), who reported that gladiolus is capable of absorbing and translocating significant quantities of heavy metals, particularly into reproductive structures. This can be attributed to the high metabolic activity in flowers and their role as strong sinks for nutrients and metals transported via xylem sap.

Similarly, chrysanthemum demonstrated even higher phytoextraction capacity, with flowers accumulating nearly 50% Cu and 46% As. Leaves and stems also showed appreciable accumulation, while roots had the least. The higher accumulation of metals in chrysanthemum flowers compared to gladiolus flowers could be linked to the greater transpiration rate and stronger sap flow in chrysanthemum, which facilitates metal transport from root to shoot (Teixeira et al., 2013). The enhanced efficiency of chrysanthemum also highlights its potential as a bioindicator plant, reflecting the level of soil contamination.

The observed variation in Cu and As uptake among plant organs can be explained by physiological processes. Flowers and leaves are metabolically active, demanding higher transport of water and nutrients, which inadvertently carry heavy metals. Metals such as Cu are essential micronutrients required in redox reactions, chlorophyll formation, and enzymatic activity; however, excess Cu can lead to oxidative stress and damage to cellular structures (Subpiramaniyam et al., 2021). Arsenic, on the other hand, has no known biological function and is toxic even at low concentrations. Its presence in plant tissues may interfere with phosphate uptake, photosynthesis, and ATP synthesis, ultimately affecting plant growth and productivity. Nevertheless, both gladiolus and chrysanthemum tolerated As accumulation in their tissues, which is indicative of their adaptation to contaminated soils.

The efficiency of phytoremediation is influenced by multiple factors, including soil physicochemical properties, bioavailability of metals, and depth of contamination (Wahocho et al., 2016). In our study, both ornamentals showed clear potential as phytoremediators due to their ability to uptake and sequester heavy metals in harvestable biomass. Importantly, the use of ornamental plants for phytoremediation offers an advantage over food crops, as they do not enter the food chain and thus minimize risks to human health. This aligns with the findings of previous studies, which emphasized the suitability of ornamentals in reducing ecological and health risks associated with metal contamination (Teixeira et al., 2013; Wahocho et al., 2016).

Furthermore, the accumulation of Cu and As in flowers suggests a practical strategy for remediation: periodic harvesting of floral biomass could remove substantial quantities of heavy metals from the soil. Since both gladiolus and chrysanthemum are commercially valuable cut-flowers, their cultivation on contaminated lands may provide dual benefits remediation of polluted soils and economic returns from the floral industry. This approach supports the concept of "phytoremediation with value addition," where plants serve both environmental and economic functions.

Overall, the study highlights that both gladiolus and chrysanthemum possess high phytoextraction potential, particularly for Cu and As. While gladiolus exhibited moderate efficiency, chrysanthemum proved to be more effective, especially in translocating metals to flowers and leaves. However, long-term field trials are necessary to validate these findings under natural conditions, as greenhouse and incubation studies may not fully capture environmental variability. Future research should also focus on the biochemical mechanisms of tolerance, particularly antioxidant enzyme activity, chelation, and compartmentalization, which enable these ornamentals to withstand high levels of toxic metals. In conclusion, the ability of gladiolus and chrysanthemum to accumulate Cu and As in significant amounts, especially in flowers and leaves, makes them ideal candidates for ornamental phytoremediation. Their cultivation in contaminated soils could provide an eco-friendly, cost-effective, and socially acceptable approach to managing heavy metal pollution while simultaneously generating economic value.

Conclusion

The basis for plant and animal productivity is soil, which also supports human existence and development. These days, soil pollution with the heavy metals Cu and As has developed into a severe environmental problem that calls for technological solutions that are both efficient and practical. Overuse of heavy metals in the environment poses a grave threat to human health and animals. The current study recommended that phytoremediation is the best and most eco-friendly approach for the eradication of heavy metals present in the soil.

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