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Accumulation of Six Heavy Metal by *Prosopis chilensis* Plant Grown in Contaminated Soil in The Vicinity of Khartoum Tannery

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Abstract

Background: Industrial activities have led to considerable increase in heavy metal levels in all environments especially in soil and water. This situation encouraged scientists all over the world to deal with this problem. Studies of phytoremediation mechanisms are becoming of great importance in enabling growing industries to combat different causes of contamination; especially in the Sudan. Objective: The objective of this study is to evaluate the potential value of Prosopis chilensis plant as phytoremediation for removing six heavy metals namely (Cr, Mn, Fe, Co, Ni, and Cu) from four type of industrial contaminated soils (four type of contaminated soil namely type (1, 2, 3, and 4)) from Khartoum Tannery, watered with unpolluted water in addition to a control experiment. Methods: Plant samples (whole plant, roots, and shoots) were analyzed for detecting heavy metals using - Ray - fluorescence machine (XRF). Heavy metal elements concentration in plant was detecting by using X-ray fluorescence technique. Prosopis chilensis (whole plant, shoot and root) were tested for accumulation of six heavy metals from different types of polluted soil. Results: The result showed that: Chromium: Among all soil type Prosopis chilensis plant, grown in soil type two showed the highest absorption percentage of chromium, obtained by root followed by the whole plant and then stem (79950, 11181 and 6044.4) respectively. Manganese: The highest accumulation percentage of manganese was found in plant grown in soil type four, obtained by the shoot (181.08) followed by whole plant and root with (166.9 and 158.31) concentration respectively. Iron: In all soil types the absorption percentage of iron in both root and whole plant was less than that of the control group, only shoot showed a higher iron ratio than the control, the highest iron percentage obtained by the shoot in soil type one was (170.46) percentage. Cobalt: The plant grown in soil type three obtained highest cobalt concentration by root (497.78), followed by the root in soil type two (377.78). Nickel: The highest absorption percentage was obtained by the shoot in both soil type one and soil type four as (171.70 and 158.49) respectively. Copper: highest absorption was obtained by root in the soil type one with (117.34) percentage, followed by the shoot in soil type four as (114.61) percentage. Conclusion: Since soil contamination with heavy metals is a serious worldwide concern, therefore eco-friendly and solar driven technology which has community acceptance need to be explored. Phytoremediation is one of such approach which needs to be explored further for the removal of contamination. So depend on the results of this study we can use the Prosopis chilensis plant for the above six heavy metals phytoremediation, the most absorbent heavy metal by Prosopis chilensis is chromium, there is a difference in the accumulation of heavy metal depending on the type of metal, soil and explant and the most absorbent heavy metals by Prosopis chilensis plant is chromium.

Keywords: Phytoremediation, Prosopis chilensis, soil type, Accumulation

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INTRODUCTION

Environmental pollution by heavy metals has become a serious problem in the world. The pollution by heavy metals is becoming more and more serious with increasing industrial enterprise and disorder of the natural biochemical cycles. In contrast to organic substances, heavy metals are non-biodegradable and therefore, it is accumulated in the environment. The accumulation of heavy metals in soils and waters create a hazard to environmental and human health. These elements accrue in the body tissues of living organisms (bioaccumulation) and their concentrations mount up as they pass from lower trophic levels to higher trophic levels, a phenomenon known as biomagnification. In soil, heavy metals cause toxicological effects on soil microbes, which may lead to a reduction in their community and their biological activity, Hazrat *et al*., [1]. According to their role in biological systems, heavy metals are classified as an essential and non-essential element. Essential heavy metals are those, which are needed by living organisms in negligible quantities for pivotal physiological and biochemical activity. Non-essential heavy metals are those that are not needed by living organisms for any physiological, and biochemical process, Darbonne *et al*., [2]. Toxicity of Heavy metal has proven to be the main menace, and there are several health hazards accompanying it. The toxic effects of these metals, even though they do not have any biological role, it is harmful to the human body and it reduces the proper functioning of the body. They sometimes act as a dummy element of the body while at certain times, they may even interfere with metabolic processes. Few metals can be removed through removal activities, while some metals get accumulated in the body and food chain, exhibiting a chronic case, Monisha, [3]. High concentrations of heavy metals in surface soil can threaten human health via inhalation, ingestion and dermal contact absorption (Sun *et al*., [4] and Xie *et al*., [5]). Heavy metals in deep soil may result in groundwater contamination. Soil heavy metal pollution characteristics and ecological risks are the foundation of soil environmental quality assessment. Phytoremediation is a set of ecological strategies that utilizes plants, in situ, to promote the breakdown, immobilization, and removal of pollutants from the environment, Murphy and Coats [6].

Pollution is the introduction of pollutants such as heavy metal, into the environment leading to detrimental effects which may endanger human health, damage living resources, and environment. One of the most important causes of pollution is the high rates of manufacturing due to the increasing population. Different kinds of pollution are known, but this study deals only with soil pollution. Soil pollution is the degradation of the soil (Onwudike *et al*., [7]).

Phytoremediation, the use of plants to clean out polluted soil and water resources has received much attention in the last few years. Phytoremediation offers owners and managers of metal-contaminated sites are an innovative and cost-effective option to address recalcitrant environmental contaminants. Although not a new concept, phytoremediation is currently being re-examined as an environmentally friendly, cost-effective means of reducing metal contaminated soil (Vasavi *et al*., [8]). Studies prove the ability of native wild plants to take up and transfer heavy metals is useful in screening for potential phytoremediation, and identifying the relationship between heavy metals accumulation and transfer among species will guide the selection of multiple heavy-metal remediation plants (Shuai *et al*., [9]). Industrial activities have led to a considerable increase in heavy metal levels in all environments, especially in soil. This situation encouraged scientists all over the world to deal with this problem. Studies of phytoremediation mechanisms and application of hyperaccumulator plants are becoming of great importance in enabling growing industries to combat different causes of contamination; especially in Sudan. Therefore the objective of this study is to evaluate the potential value of *Prosopis chilensis* plant as phytoremediation for removing six heavy metals namely (Cr, Mn, Fe, Co, Ni, and Cu) from four types of contaminated soil watered with unpolluted water in addition to a control experiment.

MATERIALS AND METHODS

Materials

Prosopis chilensis plant was used to investigate and to evaluate the ability of this plant for Phytoremediation. Through it is a capability to absorb and accumulate different heavy elements from polluted soils under greenhouse conditions.

Prosopis chilensis
Family: Fabaceae
(Eng.) Mesquite
Arabic: Mesquite

The seeds of *Prosopis chilensis* plant were obtained from the local market, Khartoum, Sudan.

Polluted Soil Sample:

A preliminary site investigation was carried out in Khartoum Tannery to select locations of the required samples for investigations (polluted soil samples).

Soil samples:-

Four samples of contaminated soils were collected from four different locations within the premises of Khartoum Tannery. These were:

Soil type one from beam house (soaking).
Soil types two from tanning stage site.
Soil types three from retaining stage site.
Soil types four from the final waste site.
Also, a non-contaminated soil sample (control) as obtained from the University of Khartoum (Green House).

Sand samples

Were collected and washed in running tap water.

X-ray -fluorescence machine (XRF): Instrumental procedures out a line of an energy dispersive XRF spectrometer the system consists of: The source (cadmium) which is also known as the scattering body; Sicli detector; pre-amplifier, multichannel amplifier analyzer, and microprocessor.

Methods

Planting methods:

The *Prosopis chilensis* plant seeds were grown in pots under greenhouse conditions and allowed to reach a suitable size before transplanting.

Experiment I: plants are grown in sand

Prosopis chilensis plants were transplanted in pots (5 plants in each pot).

Experiment 2: Accumulation of heavy metal by *Prosopis chilensis* at different contaminated soils types.

Plant samples were analyzed the total of heavy metals - Ray -fluorescence machine (XRF), to evaluate Cr, Mn, Fe, Co, Ni, and Cu in the whole plant, roots, and shoots

Plant Samples preparation for analysis

The plant samples were transferred to the laboratory, washed with distilled water, and then dried at room temperature in a clean area to a constant weight. Dry weight was taken using an analytical balance. Dried plant samples were ground using a grinder and sieved by using 1 mm mesh sieve. Plant samples were analyzed using X-Ray -fluorescence machine (XRF), samples were ground into a fine powder with uniform size, which is important for obtaining reproducible results. One gram from each sample was pressed into a disc shape pellet as particle size is wave length dependent. Pellets should be thick enough to maximize the count rate for the shortest wave length line. If a sample does not easily bind into a tablet disc, it is advisable that cellulose or acrylic powder must be added as a binder. This can become by either baking or mixing the sample with the binder before compression.

RESULTS AND DISCUSSION

Table 1, Fig 1 and 2 showed the potential value of *Prosopis chilensis* plant, for phytoremediation of six heavy metal elements (Cr, (Mn, Fe, Co, Ni, and Cu). The plant was grown in four different contaminated soils and an uncontaminated soil as control.

Chrome: In this experiment an increase of Chromium over the control was observed ,among type of soil *Prosopis chilensis* plant grown in soil type two showed the highest absorption percentage of chromium, The higher absorption percentage of chromium was obtained in the root followed by the whole plant and then stem as (79950, 11181 and 6044.4) respectively. The highest value was obtained by root in type two 79950 % over the control followed by root in type four 18150%over control. The lowest value was obtained by a shoot in type one 525.93% over the control. The increase in uptake of chromium at high concentrations is in agreement with the work of Barocsi *et al.*, [10], Garcia *et al.*, [11], and Weis and Weis [12], who noticed an increase in Cr uptake with the increase of concentration in the growth media.

Manganese: According to Last [13], few reports are available about Manganese accumulation by different plant species. The highest accumulation percentage of manganese was obtained by *Prosopis chilensis* plant grown in soil type four. The highest percentage of manganese accumulation obtained by the shoot followed by whole plant and root with (181.08, 166.9 and 158.31) respectively. The whole plant recorded an increase only in soil type one and soil type four, with a maximum in soil type four (143.35 ppm, 166.9 %). The shoots resulted in an increase over the control except in soil type two with a maximum in soil type four (61 ppm, 181 %). The roots also gave an increase only in soil type one and soil type four, with a maximum in soil type four (82 ppm, 158%).

Iron: In all soil types the absorption percentage of iron in both root and the whole plant was less than that of the control group, only shoot showed a higher iron ratio than the control, the highest iron percentage obtained by the shoot in soil type one. Whole plant and root showed decrease below the control for all types of soil. The shoots showed the highest Fe uptake in soil type one as (170.46). Soils are generally not deficient in Fe but may be deficient in its exchangeable and soluble forms. The result in agreement with Banerjee *et al.*, [14] who reported that *Thus vetiver* grass could be effectively used for rehabilitation and soil stabilization of sites contaminated with high levels of heavy metals, particularly Fe, Mn, Zn and Cr. However, in this study, Fe values exceeded a normal concentration in some tests. Fe contents in general recorded a decreasing trend interrupted by occasional increase, which might be explained by the observations of Jyoti *et al.*, [15] , who reported that, the level of heavy metal was higher in soil than in plant parts studied. Accumulation of heavy metals varied from plant to plant as reported by Li *et al.*, [16]. This was in agreement with Shuai *et al.*, [9], who recorded that the Knowledge of the ability of native wild plants to take up and transfer heavy metals is useful in screening for potential phytoremediation, and identifying the relationship between heavy metals accumulation and transfer among species will guide the selection of multiple heavy-metal remediation plants. Moreover, differences between the populations of some species were reported by Brunetti., *et al.*, [17] who study the tolerance and accumulation of heavy metals by wild plant species grown in contaminated soils and reported that, studied wild species plant can be considered as metal excluder or tolerant plants with the ability of growing in soils with a wide range of heavy metal concentrations and Kumar *et al.*, [18] who reported the occurrence of variation in accumulation of $Cu2+$, $Fe3+$ and Hg2 from their aqueous solution amended at different concentration (5, 10 and 15 mg $L{-}1$) by lettuce (*Pistia stratiotes* L.) plant.

Cobalt: In biological systems, cobalt works as a cofactor for different enzymes. However, at higher concentration, it is hazardous for human health (Leyssens *et al.*, [19]. The *Prosopis chilensis* plant grown in soil type three obtained highest cobalt concentration by root (497.78), followed by the root in soil type two (377.78). The results obtained have shown variations in the quantities of cobalt accumulation between whole plant, shoots and roots., the lower value 38% in the soil type four obtained by the whole plant . The results obtained in this investigation are in agreement with Shrestha *et al.*, [20] who reported that the soil type effect on plant accumulation of heavy metal and Prieto *et al.*, [21] , who reported that Phytoremediation includes complex interactions, where they are involved the plant, soil and contaminants.

Nickel: The highest absorption percentage of nickel was obtained by the shoot in both soil type one and soil type four as (171.70 and 158.49) respectively. The highest value 171.70% recorded in the soil type one by the shoot followed by shoot soil type four (158%), while the lowest value was recorded by root in soil type three as (30.87%). These results are in agreement with what was reported by Eskandari and Alizadeh [22], who reported the possibility of use phytoremediation as a suitable means for eliminating the excess concentration of zinc (Zn) and nickel (Ni) accumulators by (wheat, clover and Rapeseed plants).

Copper: the highest absorption of copper obtained by root in the soil type one as (117.34) percentage, followed by the shoot in soil type four as (114.61) percentage, the result showed that Copper was accumulated principally in roots, this result in agreement with Melignani *et al.*, [23] and Bader *et al.*, [24]. So depending on the results of this study, there are differences in absorption percentage, due to element variation in plant part and type of polluted soil.

Table 1: Accumulation Percentages of Cr, Mn, Fe, Co, Ni, and Cu by *Prosopis chilensis* plant (whole plants, shoot and root) at different contaminated soils types

Element Accumulation	*Whole Plant*	*Shoot*	*Root*
Control Cr	100	100	100
Type One Cr	1003.2	525.93	7300
Type Two Cr	11181	6044.4	79950
Type Three Cr	1840.7	859.26	16250
Type Four Cr	3151.3	2355.5	18150
Control Mn	100	100	100
Type One Mn	137.5	157.27	124.71
Type Two Mn	*53.6*	88.43	30.89
Type Three Mn	97.0	135.90	54.05
Type Four Mn	166.9	181.08	158.31
Control Fe	100	100	100
Type One Fe	85.3	170.46	55.46
Type Two Fe	35.9	73.22	22.94
Type Three Fe	60.2	130.00	35.80
Type Four	34.6	69.40	22.43
Control Co	*100*	100	100
Type One Co	91.2	134.29	57.78
Type Two Co	226.25	34.29	377.78
Type Three Co	326	77.14	497.78
Type Four Co	36	48.57	26.67
Control Ni	100	100	100
Type One Ni	104.4	171.70	36.34
Type Two Ni	102.8	113.20	92.35
Type Three Ni	38.1	45.28	30.87
Type Four Ni	132.2	158.49	105.74
Mean Ni	6.96	122.10	66.12
Control Cu	100	100	100
Type One Cu	101.3	86.01	117.34
Type Two Cu	96.2	92.95	99.78
Type Three Cu	99.5	90.85	108.67
Type Four Cu	107.4	114.61	99.56

*Figures are the means expressed as a percentage over the control

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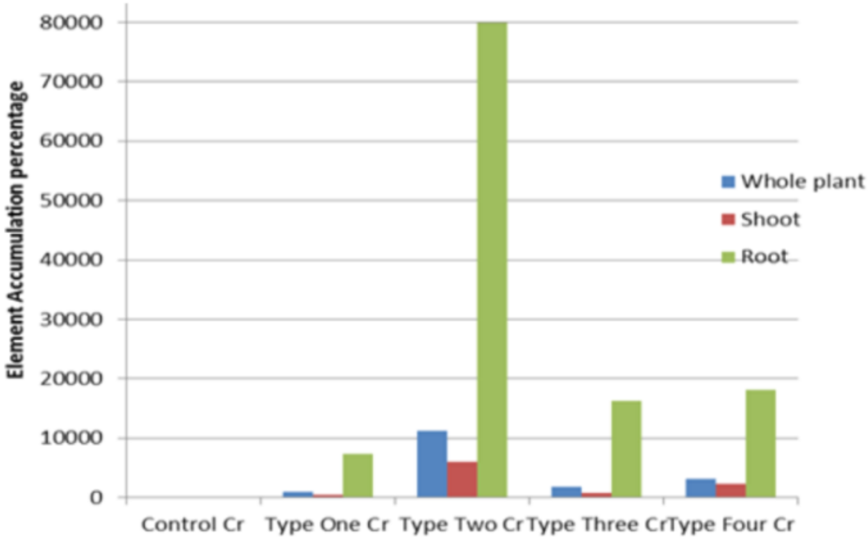

Fig.1: Accumulation Percentages of Cromium by *Prosopis chilensis* plant (whole plants, shoot and root) at different contaminated soils types

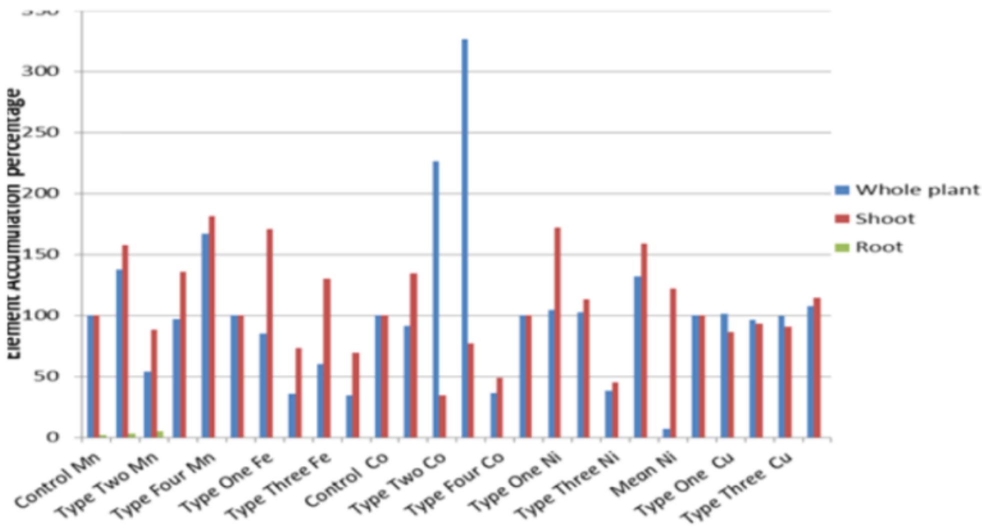

Fig.2: Accumulation Percentages of Mn, Fe, Co, Ni, and Cu by *Prosopis chilensis* plant (whole plants, shoot and root) at different contaminated soils types

CONCLUSION

This study aimed to establish phytoremediation of metals at a low - cost, low impact and environmentally sound technology, these research have shown the ability of *Prosopis chilensis* plant for Phytoremediation of six heavy metals. Also, Phytoremediation includes complex interactions, where they have involved the plant, soil and contaminants. The interactions are multiple and are not clear, it is possible to identify the positive effects of the use of plants in the remediation of contaminated soils, but not the mechanisms of phytoremediation, or performance stages where pollutants are absorbed and transformed to its final destination, and the following conclusions can be obtained from the results of this investigation:

- The most absorbent heavy metal by *Prosopis chilensis* is chromium
- There is a difference in the accumulation of metal depending on the type of metal, soil and explant
- We can use the Prosopis chilensis plant for heavy metals phytoremediation
- We noticed that most metals are accumulated in the nontoxic form in the upper parts at both low and high concentrations

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