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Original Research Article

Evaluation of the phytoremediation performance of *Hammada scoparia* and *Halocnemum Strobilaceum* for Cu, Fe, Zn and Cr accumulation from the industrial area in Benghazi, Libya

Nabil Bader[a] , Mahmoud Faraj[a] , Abdulrahman Mohamed[a], Nessma Al-Shelmani[a,*], Rajab Elkailany[a], Fardous Bobtana[a]

[a]*Chemistry Department, Faculty of science, University of Benghazi, Benghazi, Libya*

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ABSTRACT

The present work aims to evaluate two native plants including, *Hammada scoparia* (*H. scoparia*) and *Halocnemum Strobilaceum* (*H. Strobilaceum)*, which grow in Benghazi-Libya for soil phytoremediation purpose. Plants and soil samples were collected and analyzed for Cu, Zn, Fe and Cr concentrations at different sites in the north coastal region of Benghazi. Performance of *Hammada scoparia* and *Halocnemum Strobilaceum* was evaluated by calculating biological absorption coefficient (BAC), bioconcentration factor (BCF), and translocation factor (TF). Both plants were found to be a moderate extractor. The tendency of the plants toward phytoextraction process and phytostabiliztion process was studied. Both plants tend to phytoextraction process except *Halocnemum Strobilaceum* tends strongly to phytostabiliztion process in case of Cu and Fe.

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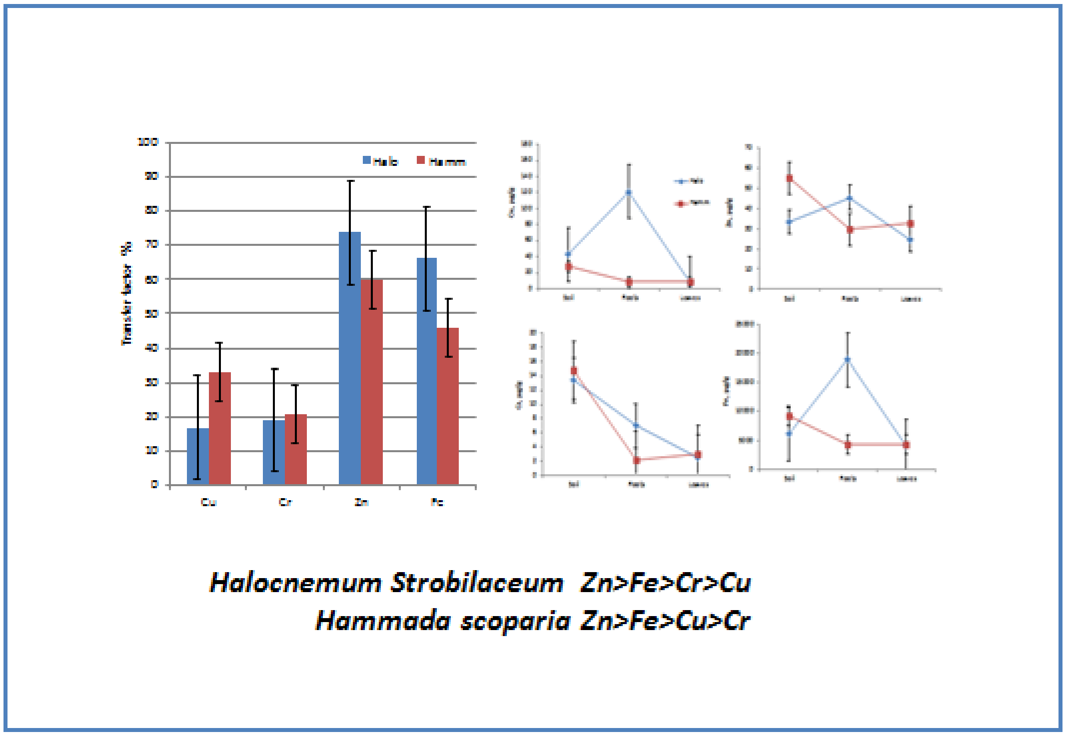
Corresponding author, email: nessma.alshelmani@uob.edu.ly (N. Al-Shelmani).
Tel.: 00218927059305

Graphical Abstract



Introduction

Although heavy metals may present in soil and water, they are generally released from various natural and anthropogenic sources [1]. They can contaminate food chain of the livestock and may accumulate starting from soil or water through the plants, causing health effects. The main target of soil remediation process is to either absorb the contaminant materials or lower their concentration to be less harmful. There are many different soil remediation techniques based on biological, physical, and chemical methods. They are basically efficient but suffer from some limitations including, high costs, time consuming, intensive labor, and environmentally destructive by producing secondary pollutants. Therefore, bioremediation or phytoremediation is a good option to remediate the contaminated soils in environmental friendly and economical way [2, 3]. Phytoremediation includes several processes depending on the plant-soil interaction. For heavy metal contaminated soils the most reliable are phytoextraction and phytostabilization. All the phytoremediation types require many plant characteristics to get optimum results [1].

phytoremediation has some limitations. It is a lengthy process needs several years and applicable to surface soils [4]. Plant selection for phytoremediation purpose is based on the plant characteristics, pollutant nature and concentration, plant-pollutant interaction, root depth, soil structure, soil fertility, and regional climate [5-7]. The selected plants have the ability to grow fast, to absorb and accumulate a wide range of organic and inorganic pollutants without being affectedand many others depend upon the type of pollutants and nature of the contaminated region [8, 7].

According to *Glenn et.al*. [9, 10], a halophyte is a plant that grows in waters of high salinity, coming into contact with saline water through its roots or by salt spray, such as in saline semideserts, mangrove swamps, marshes and sloughs, and seashores. *Hammada scoparia* is commonly used in folk medicine in Libyan countryside with reference to their utilized parts were subjected to extraction [11]. *Halocnemum Strobilaceum* is native to coastal areas of the Mediterranean Sea, the Red Sea, and parts of the Middle East and central Asia, where it grows in coastal and inland salt marshes.

Experimental

pH was measured in 1:1 (soil: water) suspension as described by *Mckeague* [12]. The electrical conductivity and total dissolved solids in 1:1 (soil: water) suspension were measured using the electrical conductivity method [13]. *Halocnemum Strobilaceum* and *Hammada Scoparia* and its soil samples were collected from the industrial area near Benghazi asphalt factory, steel factory and Benghazi power station at the north coastal area of Benghazi city. The plants samples were collected with the soil surrounding the roots, then transferred to the laboratory, washed by distilled water, then dried at room temperature in a clean area, ground and sieved through 1mm mesh sieve. The soil samples were collected in plastic bags and then dried at room temperature to a constant weight, ground, and sieved using a 1 mm mesh sieve.

Determination of heavy metals

All chemicals used in this reasrach study were in analytical grade. A 1.00-2.00 g homogenous representative plant or soil sample was obtained and placed in conical flasks. sample slurries were prepared by adding 10 mL of 1:1 nitric acid (HNO3), then covered heated to near boiling, and refluxed for 15 min. After refluxing, the slurries were cooled and then 5 mL of concentrated HNO3 were added and the solution was again allowed to reflux for an additional 30 min. The last step was repeated to ensure the complete oxidation of the metals. After the third refluxing period, the sample was cooled to room temperature and 2 mL of deionized water and up to 10 mL of 30% hydrogen peroxide were added. The samples were then filtered to remove any particulates which might interfere with FAA analysis. The filtrates were collected in a 100 mL volumetric flask and were diluted with deionized water to the final volume [14, 6, 15]. The metals concentration was determined using Shimadzu 6800 flame atomic absorption spectrometer in Ras Lanuf company laboratories. Total heavy metals content were extracted with concentrated. Soil samples were analyzed the total of heavy metals. To evaluate Cu, Cr, Zn and Fe total concentration [16, 17].

Results and discussion

The pH values were 8.51 and 9.15 for Halo and Hamm, respectively, and the conductivity values were 1.63 and 0.74 ms/cm for Halo and Hamm, respectively. The results obtained from FAAS analysis for Cu, Cr, Zn and Fe in soil, roots, and shoots are demonstrated in Figure 1. The metal content was in the following order Fe> Cu> Zn> Cr [18].

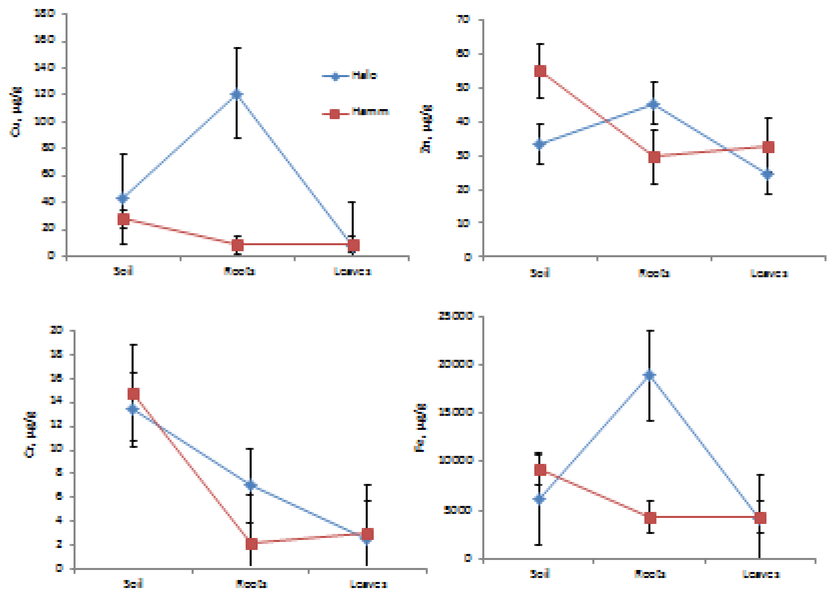


Figure 1. Metal concentration (µg/g) in soil, roots, and leaves

The main factors affecting the mobility of the metal ion and therefore the plant uptake are pH and the presence of chelating agents, in addition to other factors such as metal concentration, metal solubility in water, root size, plant age, and soil salinity.

Biological absorption coefficient (BAC)

Biological Absorption Coefficient (BAC) is the ratio of heavy metals content in the plant and soils [19, 20] it can be calculated by using the following formula:

BAC = CPlant / CSoil

C = Metal concentration

It is used to classify the plants according to its accumulation of the metal ions into four levels, high accumulator (1.0-10), moderate accumulator (0.1-1.0), low accumulator (0.01-0.1), or non accumulator plant (BAC < 0.01) [21]. It is useful factor to chose the proper plant for the purpose of phytoremediation of the contaminated soils.

Table 1. *Bio Accumulation Factor(* BAC).

Metal	***Halo***	***Hamm***
Cu	0.17	0.33
Cr	0.19	0.21
Zn	0.74	0.60
Fe	0.66	0.46

Halo and Hamm are moderate accumulator plants for the metals in following order Zn>Fe>Cr>Cu for Halo and Zn>Fe> Cu > Cr for Hamm. Based on bioavailability categories, Zn and Cu are readily bioavailable, Fe is moderately bioavailable, and Cr is least bioavailable [22, 23]. Among the heavy metal ions, Zn is more mobile and available for plant uptake [24], and based on their physiological activities, Fe, Cu, and Zn are essential heavy metals which are micronutrients necessary for physiological and biochemical functions of plant growth, while Cr is non-essential metal which is non-essential for plant growth [25, 7].

Bioconcentration factor (BCF)

Bioconcentration factor is the metal concentration ratio of plant roots to soil. The higher BCF values (BCF > 1) were for Cu and Fe with Hamm indicates that Hamm has the ability to absorb metals from soils by roots and limit their mobility to the upper part. It has the characteristics to be used in phytostabilization of Cu and Fe.

Table 2. Bioconsentration factor (BCF)

Metal	*Halo*	*Hamm*
Cu	2.84	0.30
Cr	0.52	0.14
Zn	0.14	0.54
Fe	3.07	0.47

Translocation Factor (TF)

Translocation factor is the ratio of metal concentration in the shoot to the root. If the translocation factors is≥1 it means that the plant is hyperacumulator plants and is able to perform phytoextraction [6, 26]. Translocation of toxic metals form roots to shoots is necessary for an effective phytoextraction protocol because the harvest of root biomass is generally not feasible and needs more special equipments [24, 27, 28].

Table 3. Translocation factor (TF)

	Halo	*Hamm*
Cu	0.06	1.09
Cr	0.37	1.43
Zn	0.54	1.11
Fe	0.22	0.97

Plants with a high biological absorption coefficient value (BAC>1) are more suitable for phytoextraction, and plants with a high Bioconcentration Factor, BCF (BCF>1) and low Translocation Factor, (TF<1) which accumulate the metal ions in the roots are more suitable for phytostabilisation [6, 29, 30].

In case of Hamm, it is a moderate extractor and the TF values are around 1 which means that the concentration in roots is almost same as the concentration in the shoots. Halo was also a moderate extractor according to BAC, and TF values are <1 which means that the concentration in roots is higher than the concentration in the shoots. It tends strongly to phytostabiliztion process in case of Cu and Fe. Both plants are moderate extractor, they tend to phytoextraction process except *Halo* tends strongly to phytostabiliztion process in case of Cu and Fe.

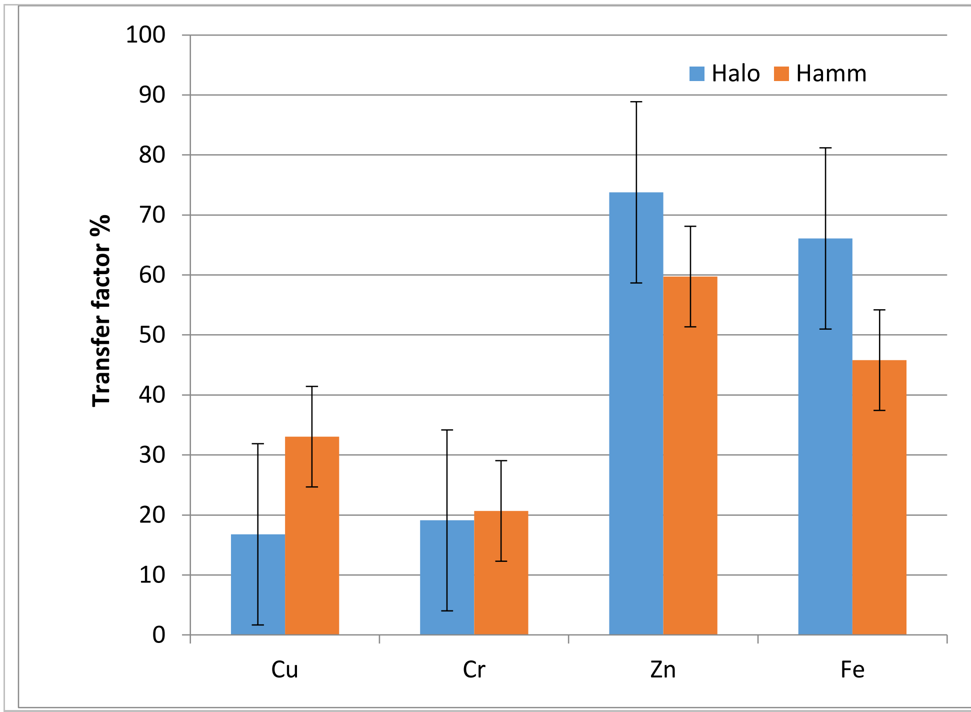


Figure 2. Transfer factor percent.

The percence of the metal in the shoot with respect to the amount of the metal in the soil has been calculated as transfer factor to give a general overview about transferred amount to the shoots, Zn has the highest percent.

Conclusion

The results showed that the *Hammada scoparia* and *Halocnemum Strobilaceum* are moderate accumulator plants for Cu, Zn, Fe, and Cr in the following order: Zn>Fe>Cr>Cu for *Halo* and Zn>Fe> Cu > Cr for *Hamm*. They tend to phytoextraction process except *Halo* tends strongly to phytostabiliztion process in case of Cu and Fe. They are promising plants for phytoremdiation purpose and they can be used as bioindictor for soil conatmination mointoring.

Conflict of interest

We have no conflicts of interest to disclose.

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