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THE POTENTIAL USE OF *ATRIPLEX NUMMULARIA* PLANT AS CONTAMINATION INDICATORS OF HEAVY METAL IN DIFFERENT SOILS

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Abstract

This study was concerned with the assessment of soil environment quality and to test the suitability of *Atriplex nummularia* for bio-indicating of soils heavy metals. To achieve these goals were examined the concentrations of Pb, Cd, Co, Ag and Cr accumulation in the different organs of plants in the context of different soil in Al Najaf- Al Ashraf, Iraq in 2016. The heavy metals in Deserts soil were found to increase in the order of Cr< Ag < Cd < Co <Pd , while in agriculture soil were increased in Cr < Ag < Cd <Pd< Co. Deserts soil was the highest concentration of heavy metal except for Co. The soils contents of Cd were about five times and Co were about one and a half times above the worldwide range. On the other hand, Cr, Ag and pb concentrations were below the reference ranges of the United States and Chinese soils. The heavy metal bioaccumulation decreased according to the order of root> leaf for Pb and Cd ; and leaf > root for Co, Ag andCr. The mean (transfer factor from root to stem) TF(Rt/SE) in desert soil for (Pb, Cd, Co and Cr) and the mean (transfer factor from above ground to below ground) TF (AG/BG) for Pb were more than one. Agricultural soil showed that the mean TF(Rt/SE) for (Cd and Cr) and the mean TF (AG/ BG) for Co were more than one. The higher transmission ratio of this metal in *Atriplex nummularia* shoots make it suitable for phytoextraction from soil. There was a significant linear correlation between the concentration of heavy metals in the root of *Atriplex nummularia* and that in the soil. This result suggests that *Atriplex nummularia* can be regarded as bio-indicator for heavy metals pollution of soils.

Key words : *Atriplex nummularia*, bio-indicators, Al Najaf- Al Ashraf, heavy metals.

Introduction

Old Man Saltbush (*Atriplex nummularia*) originated from Australia and had spread to arid and semi-arid parts of the world (Osman and Ghassaeli, 1997). *Atriplex nummularia* is an erect shrub belonging to the family chenopodiaceae. It is often grown as fodder plant in drier areas because of its great resistance to drought and salt tolerance (Abou El Nasr *et al*., 1996). It grows well in deep soils with only 150- 200 mm of rainfall annually. Resists temperatures as low as -10^0C and as high as 50^0C (El Shaer *et al*., 2000). Heavy metals are serious pollutants in natural environments due to their toxicity, persistence and bioaccumulation problems. The accumulation of heavy metals in the environment has become a concern due to the health risks to humans and animals. The problem is not restricted to soils with high metal levels, such as mining areas, but also includes those with moderate to low contamination of metals. These toxic elements are present at elevated levels mainly through human activities, as smelting, refining of non-ferrous metals, electroplating, agricultural practices, and industrial and municipal waste disposal on land (Laeuchi and Luettge, 2002). Recently, there has been an increasing interest in using biological indicators such as plants for monitoring soil, air and water pollution (Peng *et al*., 2008). Halophytes plants like *Atriplex nummularia* play an important role in heavy metals cycling in the soil due to uptake, storage and release processes. Specifically, plants with potentially high annual primary production can extract large amounts of heavy metals from their environment

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and store these metals in biomass (Reboreda and Cacador, 2007). There is little information about many species of Atriplex grown in contaminated soils, on another hand perception the environmental pollution by using biological indicators is a cheap, reliable and simple alternative to the conventional sampling methods (Eid *et al*., 2012). In the present study, Pb, Cd, Co, Ag and Cr concentrations in the plant and soil samples were analyzed in order to investigate possible relationships between heavy metal concentrations in the plant and soil in order to improve if this plant can be used as an indicator for the heavy metal contamination of the study area.

Materials and Methods

Study area

To investigate the possibility of using *Atriplex nummularia* plants as bio-indicator for heavy metals pollution of soils. Two types of soils in Al Najaf-Al Ashraf Governments were taken for comparing the effectiveness of *Atriplex nummularia* plants in up taking heavy metals. The first soil is desert sand from the arid region. Its coordinates are 3210^0 05.6" N and 4416^0 14.6" E at 36 m. above sea level. The second soil was taken from an agricultural region. Its coordinates are 32.03^0N and 6348^0, 44.371" E. for six replicates per area (fig. 1). The two soils, belongs to the arid region where the climatic conditions are hot summers (35°C – 50°C) and mild winters (10°C-20°C).

Sample collection

Sample was carried out at two locations of Al Najaf-Al Ashraf and six sampling sites were randomly chosen in each location (fig. 1). In each sampling site, leaves and roots of *Atriplex nummularia* were collected twice at 2016 from more than 10 individual plants within a 100 m^2 and then they were mixed up to form a composite sample. At each sampling site, one soil sample was collected near sampling plant as a profile of 20 cm depth.

Sample analysis

The plant samples were cleaned well with tap water and rinsed with DW. water, then an oven dried at 65°C to constant weight after that was ground into a powder by using a plastic mill. The soils were air dried up at room temperature and passed through 2 millimeter sieve. Plant samples were digested with concentrated HNO_3 and $HClO_4$ (4:1, v/v), while soil samples with concentrated HF:HNO_3:$HClO_4$ (4:1:1 v/v) (Zhao, 1994). Estimation of Pb, Cd, Co, Ag and Cr was carried out by Atomic absorption (Shimadzu AA-6200). Each one of these procedures are according to Allen (1989).

Statistical analysis

All statistical analyses were carried out using software SPSS version 15.0 of Statistical Software Package (SPSS, 2006). The translocation of heavy metals from soil to plant tissues was assessed following transfer factor (TF). It was calculated to determine the relative uptake of heavy metals by the plants with respect to soil (Chamberlin, 1983) :

TF = Concentration of metals in plant body (ppm)/ Concentration of metals in soil (ppm) at that site.

Results

The heavy metals in Deserts soil were found to increasing in the order of Cr< Ag < Cd <Co <Pd, while in agricultures soil were increased in Cr < Ag < Cd < Pd < Co. The concentrations mean of Cr are -4.17; Ag are 0.96 ppm; Cd 4.16 ppm; Co 16.76 ppm; Pd 48.56 ppm the same in Agricultures soil except for Pd< Co. The concentrations mean of Cr are -12.5, Ag are -2.65ppm, Cd 3.41 ppm, Pd 14.33 ppm, Co 35.04 ppm. The results showed that desert soil was the highest concentration of heavy metal except for Co (table 1).

Heavy metals concentrations in the soils and organs of *Atriplex nummularia* are shown in figs. 2, 3, 5 and 6. The bioaccumulation increased according to the order of soil< root < leaf for Pd, Cd, Cr and Ag but Co showed revers bioaccumulation soil > root > leaf (fig. 4). It was found that *Atriplex nummularia* had a significant differences in heavy metals concentrations. Pb, Cd, Co, Ag and Cr mean concentrations are 41.4, 4.37, 37.48, -27 and 0.96 ppm in root; 48.56, 4.16, 16.76, 8.33 and 4669.06 ppm in leaves respectively in desert soil (figs. 2, 3, 4, 5 and 6). While, in Agricultures soil the Pb, Cd, Co, Ag and Cr mean concentrations are 15.92, 4.26, 34.73, -12.5 and 9.38 ppm in root; 14.33, 3.41, 35.04, 4.17 and -4.57 ppm in leaves, respectively (figs. 2, 3, 4, 5 and 6).

The transfer factors of Pb, Cd, Co, Ag and Cr from soil to roots were more than one in desert and agriculture soil, except Pb and Co inagriculture soil. Ag had the

Table 1 : Soil characteristics ofPb, Cd, Co, Ag and Cr concentrations in two type of soilin Al Najaf- Al Ashraf (mean ± SE).

Characteristics / Soil type	EC (<s /cm)	pH	TOC	Pb (ppm)	Cd (ppm)	Co (ppm)	Ag (ppm)	Cr (ppm)
Deserts soil	2080± 45.21	6.94± 0.23	4± 0.01	48.56± 3.54	4.16± 0.03	16.76± 1.6	0.96± 3.31	-4.17± 0.21
Agricultures soil	289± 39.5	7.08± 0.2	6± 0.04	14.33± 1.32	3.41± 0.17	35.04± 2.13	-2.65± 0.2	-12.5±0.62

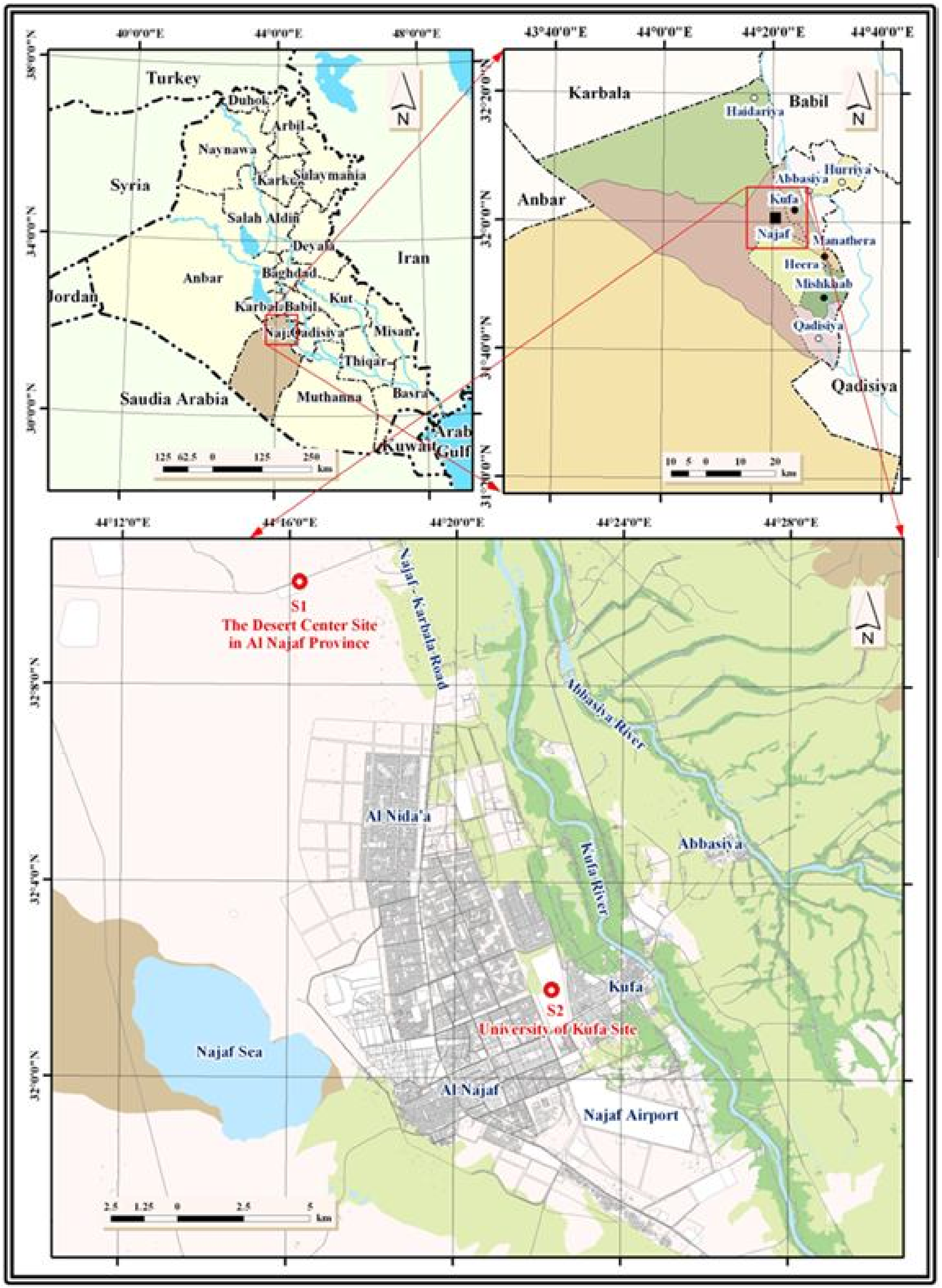

Fig. 1 : Map of study sites in Al-Najaf Al Ashraf Goveronate (Iraq).

maximum transport from below-ground to above-ground organs in desert soil and Co had the maximum transport from below-ground to above-ground organs in agriculture soil, while Ag had the minimum in both soils (table 2). Ag accumulated in higher concentration in shoots grown in soil containing greater amount of this element ($r = 0.551$, $P < 0.01$; table 3). Significantly positive correlation was found between all contents in desert soil but negative correlation between shoot and agriculture soil in Pb and Cd contents ($r = -0.411$ and -0.218, $P < 0.05$).

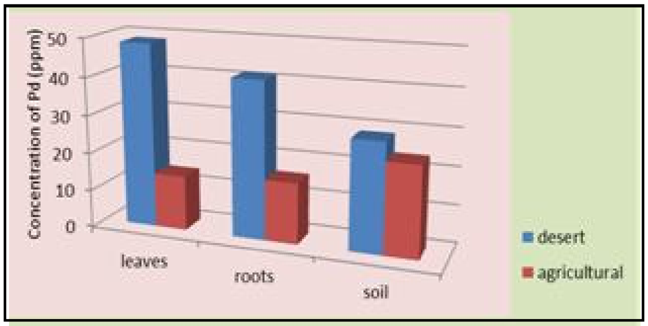

Fig. 2 : Pb concentrations of soil and plant organs of *Atriplex nummularia* in two type of soil in Al Najaf-Al Ashraf.

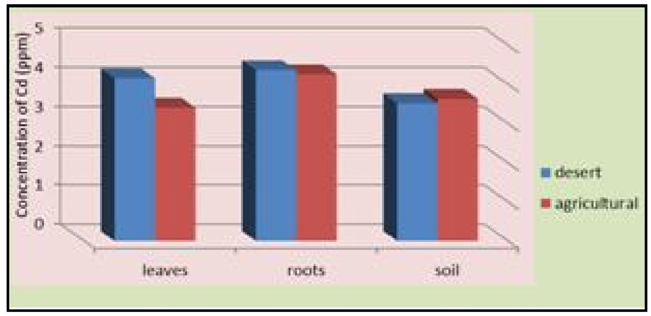

Fig. 3 : Cd concentrations of soil and plant organs of *Atriplex nummularia* in two type of soil in Al Najaf-Al Ashraf.

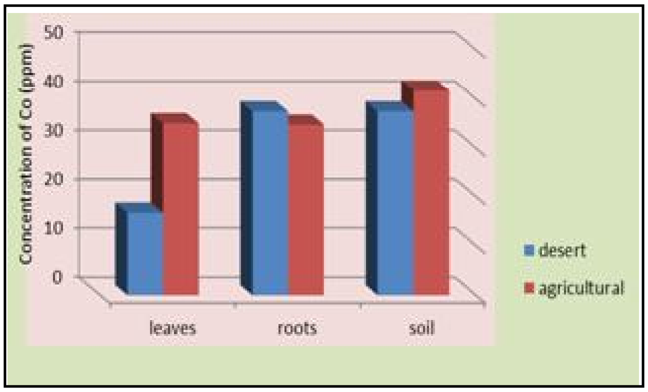

Fig. 4 : Co concentrations of soil and plant organs of *Atriplex nummularia* in two type of soil in Al Najaf-Al Ashraf.

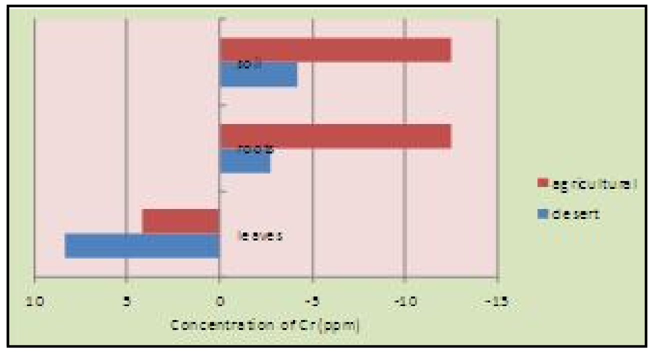

Fig. 5 : Cr concentrations of soil and plant organs of *Atriplex nummularia* in two type of soil in Al Najaf-Al Ashraf.

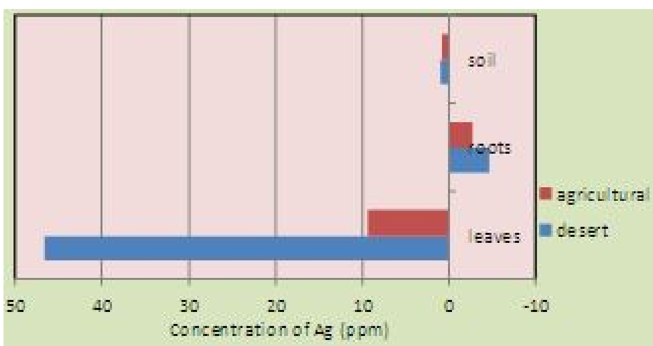

Fig. 6 : Ag concentrations of soil and plant organs of *Atriplex nummularia* in two type of soil in Al Najaf-Al Ashraf.

Discussion

Soils throughout the world contain, as reported in various countries are mean concentrations ≤250 ppm (Kabata-Pendias, 2011). In the present study, Pd concentrations in both soils were in the world range. The phytotoxic Pd concentrations range widely among plant species and cultivars from 30 to 300 ppm (Zhao *et al*., 2012). The mean Pd values detected in *Atriplex nummularia* organs were below the phytotoxic range (30 - 300ppm).

There is no evidence of an essential role of Cd in plant metabolism. Soils throughout the world contain Cd in the very low range, however its mean concentrations, in Desert soils about (0.08-0.47) ppm , while in agriculture soils were (0.13-0.55) ppm (Kabata-Pendias, 2011). In the present study, Cd concentrations in both soil were above the world range. The phytotoxic Cd concentrations range among plant species from 5 to 3o ppm (Zhao *et al*., 2012); (Swartjes *et al*., 2007) found the Cd concentrations in different plants species about (0.07-0.27 ppm). The mean Cd values detected in *Atriplex nummularia* organs were below the phytotoxic range (5 - 30 ppm).

Co in plants is important due to its catalytic functions and levels are often <5 ppm dry weight (Kabata-Pendias, 2011). The range of Co in reference soil samples of United States is from 5.5 to 29.9 ppm and in Chinese soils, in the range of 5.5 - 97.0 ppm (Govindaraju, 1994). In the present study, Co concentrations of both soil were above the reference ranges of the United States and within the range of Chinese soils. Different concentrations of Co in plant tissues have been reported to produce toxicity symptoms, as follows (in ppm): 43-142 in *Phaseolus vulgaris* (Wallace *et al*., 1977); 19-32 in *Sorghum sudanense* (Gough *et al*., 1979) and 6 in *Hordeum vulgare* seedlings (Davis *et al*., 1978). However, commonly reported critical Co levels in plants range from 15 to 50 ppm (Macnicol and Beckett, 1985). In the present study, Co concentrations of *Atriplex nummularia*

Table 2 : The transfer factor of Pb, Cd, Co, Ag and Cr concentrations from soils to roots (RT/SE), soils to below- to above-ground organs (AG/BG) in *Atriplex nummularia* in two type of soilin Al Najaf- Al Ashraf (mean ± SE).

Characteristics / Soil type	Pb (ppm)	Cd (ppm)	Co (ppm)	Cr (ppm)	Ag (ppm)
Deserts soil					
(RT/SE)	1.4445± 0.005	1.2414± 0.017	1± 0.035	6.4748± 0.054	-4.76042±0.487
(AG/BG)	1.1729±0.032	0.9519± 0.052	0.4471±0.013	-0.3085±0.002	-10.2166±1.003
Agricultures soil					
(RT/SE)	0.6666±0.021	1.1735± 0.071	0.8320±0.022	1±0.067	-3.0814±0.053
(AG/BG)	0.9001± 0.054	0.8004±0.03	1.0089± 0.006	-0.3336± 0.031	-3.5396±0.021

Table 3 : Pearson correlation coefficient (r-values) between Pb, Cd, Co, Ag and Cr concentrations of soil and plant organs of *Atriplex nummularia* in two type of soilin Al Najaf- Al Ashraf. The significant values are in the bold letters. *P < 0.05, **P < 0.01.

Characteristics / Soil type	Pb (ppm)	Cd (ppm)	Co (ppm)	Cr (ppm)	Ag (ppm)
Deserts soil					
(r-values) root*soil	0.999**	0.999**	**1***	0.545*	0.181**
(r-values) shoot*soil	0.999**	0.999**	0.752*	0.54*	0.551*
(r-values) shoot *root	0.999**	0.997**	0.865**	0.998**	0.617*
Agricultures soil					
(r-values) root*soil	0.988**	0.981**	0.991**	0.946**	0.948**
(r-values) shoot*soil	-0.411**	-0.218**	0.381*	0.999*	0.999*
(r-values) shoot *root	0.628*	0.632*	0.633**	-0.004*	0.005*

organs were within the phytotoxic range (15-50 ppm).

The average Ag content for worldwide soils is estimated as 0.13 ppm and range of its mean contents in soils of various countries is 0.05 and 0.13 ppm (Kabata-Pendias, 2011). In the present study, Ag concentrations of Al Najaf- Al Ashraf desert soils were about 12.5 times above the worldwide range. Concentrations of Ag in plants were reported by Smith and Carson (1977) to range from 0.03 to 0.5 ppm. Chapman (1972) established the intermediate range of Ag in plant foodstuffs as 0.07 to 2.0 ppm. In the present study, the average concentrations of Ag were -4.57 and 46.69 ppm in roots and leaves of *Atriplex nummularia*, respectively in desert soil and -2.65, 9.38 ppm in agriculture soil and these detected values were in the phytotoxic range (> 5.04 ppm) in leave reported by Cunningham and Stroube (1987).

The average Cr content for worldwide soils is estimated as ≤150 ppm (Kabata-Pendias, 2011). In the present study, Cr concentrations of Al Najaf-Al Ashraf desert soils were about -4.17; in agriculture soil -12.5. Concentrations of Cr in plants were reported by Zhao *et al*. (2012) to range from 0.014 to 4.2ppm. In the present study, the average concentrations of Cr were -27 and 8.33 ppm in roots and leaves of *Atriplex nummularia*, respectively in desert soil and -12.5, 4.17 ppm, respectively in agriculture soil and these detected values were below the phytotoxic range (5-30ppm) in leave reported by Kabata-Pendias (2011).

The transfer factor generally showed the transport of heavy metals from soil to root then to shoot, that indicate the efficiency to uptake of the bio-available heavy metals from the external environment and that refer if the plant is an accumulator, excluder or indicator (Bose *et al*., 2008). Zu *et al*. (2005) reported that TF > 1 were determined in metal accumulating plants, whereas TF was typically < 1 in metal excluding and indicator plants. In the present study, the mean TF(Rt/SE) in desert soil for (Pb, Cd, Co and Cr)and the mean TF (AG/ BG) for Pb were more than one.Agricultural soil showed that the mean TF(Rt/SE) for (Cd and Cr) and the mean TF (AG/ BG) for Co were more than one. The higher translocation ratio of this metal in *Atriplex nummularia* shoots make it suitable for phytoextraction from soil. The differences in TF values indicated that each metal has different phytotoxic effect on *Atriplex nummularia* (Ruiz and Velasco, 2010). In addition, these results could be related to differences in solubility and availability of each heavy metal ion in different soils (El Shaer *et al*., 2000). Probably attributed to the fact that the TF was calculated based on the total metal concentrations in soil instead of the bioavailable fractions, which are the dominant form for metal uptake by plant roots (Cardwell *et al*., 2002). The mean TF for Ag and other studied metal from below- to above-ground tissues were lower than one, which means that *Atriplex nummularia* is metal excluding and indicator plant. Or may be also due to compartmentalization and translocation in the vascular system (El Shaer *et al*., 2000). There was a significant linear correlation between the concentration of all metal studied in root of *Atriplex nummularia* and that in soil. This result suggested that *Atriplex nummularia* can be regarded as bio-indicator for pollution of Al Najaf- Al Ashraf, defined as organisms providing quantitative assessment of the environmental quality.

Conclusion

Atriplex nummularia could be regarded as bio-indicator on the Pb, Cd, Co, Cr and Ag pollution and a suitable green filter to reduce the pollution of the soils, if the above-ground biomass is harvested at the maximum biomass. Thus, we recommend removing the shoots immediately after cutting to avoid heavy metals leaching from shoots to soil.

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