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Evaluation some ornamental species cultivated in Tehran, in terms of refining ability heavy metals from soil

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Abstract

Heavy metal pollution is as nowadays pollutions that its span is increasing. Modification of soil with plants is one of the strategies against heavy metal pollutions and organic pollutants (phytoremediation) that base on plant growth rate (biomass) and accumulation of heavy metals (gr/kg fw). This study was exerted to analysis the efficiency of pollutant absorption by plants at two Tehran's parks (Mellat and Shariati) and was made in factorial based on completely randomized design with three repetitions. Results showed that the mean absorption of copper in Shariati Park (26.6 ppm) was higher than Mellat Park (26 ppm) in depth of 0-15 cm, whereas absorption of lead in Mellat Park was higher than Shariati Park in both of depth 0-15 and 15-30 cm. The evergreen trees had the highest cadmium absorption but in terms of copper and zinc, the deciduous trees had the highest absorption. Based on results, deciduous trees such as *Fraxinus excelsior* (0.41 ppm) and *Morus alba* (0.5 ppm), and evergreen trees especially *Cupressus arizonica* (1.01 ppm) could be suitable trees for cultivation in pollution areas because of maximum absorption of cadmium. Finally, results showed that deciduos trees have high ability in absorbtion of heavy metals (especially Zn and Cu) than others, and they are recommended to refining of heavy metals in polluted soils.

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Introduction

Heavy metals are a group of chemical elements, which regardless of their abundance in the Earth's crust, are found at little amount in plant and other organisms. If the amounts of them increased slightly, they caused toxic effects. The most common heavy metal pollutants were related to metals such as cadmium, chromium, copper, mercury, lead and zinc (Dabiri, 2000). Of the important properties of metals, is their persistence in environment that caused special problems. Metals unlike organic pollutants could not decompose through biological process in nature. The persistence of metals allowed transferring with water or air at considerable distance and metal levels in the higher members of the food chain were accumulated in multiplied volume (the amount of existed in water or air). As result the plant and animal health, which they used them as nutrient, would endanger. Because of long half-life some elements (1460 days for lead and 200 days for cadmium), the human body tended to accumulated them (Dabiri, 2000). The harmful effects of lead are due to low ability of translocation in environment and its high sedimentation (Garbisu and Alkorta, 2001;Reeres and Baker, 1930).

Currently most of the methods were done for cleaning of soil from heavy metal, based on excavation and exploration operations in direct and physical manner. Fixation and extraction by physical technique is expensive and only used in little areas that need rapid and complete cleaning (Martin and Bardos, 1996). So application of strategies with minimal technologies and cost such as phytoremediation is considered. Phytoremediation was one of the bioremediation of soil that got more attention in last decade. In this method resistance plants were used for refining polluted soil to organic and mineral compounds. In one research (Nylund, 2003) *Salix viminalis* and two cultivars of spring wheat were evaluated in terms of cadmium absorption. The amount of cadmium in soil and in soil extract was examined. The results of these researchers showed that in three studied plants the amount of existed cadmium in plant was correlated with the amount of soil cadmium and with increasing of soil cadmium, its adsorption was increased without reduction in plant yield or growth and introduced them for remediation of cadmium from soil. In the research that evaluates the ability of sunflower, cotton and maize in sorption of cadmium were reported that generally maize has the highest ability in the sorption and translocation of lead (Kiasari *et al.,* 2010).

This method compared with other methods has advantages including: easiness, the possibility of utilization in vast level, decontamination of metal along with partial derivatives of pollutants, protection of biological and physical structure of soil, low cost and biological recovery of metals (Baker *et al.,* 1991; Mattina *et al.,* 2003; Baker *et al.,*1994). Phytoremediation is the autotroph system with mass biomass that needs a little amount of nutrient and could remove the pollutions from soil and accumulate them in the aerial parts of plants. Furthermore, these plants have conservation roles against water and wind erosion of soil and prevented the pollution dispersion (Klute, 1956).

The object of this study was the evaluation of some cultivated ornamental species in Tehran's landscapes in terms of the amount of heavy metal absorption and accumulation of them in their tissues, in other that to introduce best species to use the potential of these plants in remediation of heavy metal from pollutant soil especially in agricultural regions. With identifying resistance ornamental species, we could recommend them for landscaping in pollution regions.

Materials and methods

The research was exerted in two parts: soil and vegetative parts. In vegetative parts, the most effective plant species in terms of air pollution absorbent were identified among trees and shrubs that had the highest cultivation level in Tehran parks. This species were belonged to five different groups including deciduous trees, evergreen trees, shrubs, covering plants and hedging plants (table 1). This study was exerted at two parks (Shariati and Mellat) in region three of Tehran.

Collection of plant materials

Soil samples were taken in two depth 0-15cm and 15-30cm. To analyses the absorption of pollution by different plants, sampling were done from each plant at three repetitions and were taken every time from all parts of the crown in July. Leaf samples were air-dried in laboratory at shadow and then analyzed for determination of the amount of lead, cadmium, zinc and copper elements.

Measuring of soil elements

Measuring the amounts of total heavy metals was exerted using *DIETHYLENE TRIAMINE PENTAACETIC ACID* (D.T.P.A) (Lindsay and Norvell, 1978) extraction method.

Measurement of plant sample elements

The plant samples were primarily washed with tap water and then rinsed with distilled water. The washed plant samples were taken in oven and dried completely at 60˚C for 48h. With assist of grinding, the dried plant samples were completely powdered, so they could be passing through 0.5mm sieve. Measurement of nitrogen, phosphorus and potassium were done via wet digestion method. The amount of nitrogen in digested samples was measured by *KEJEL TAQ*, phosphorus via calorimetric method (yellow color of molybdic and vanadate) in spectrophotometer and potassium via flame measuring and with flame photometry. To measure the amount of heavy metals, the dried digestion method was used.

In this method the specific amount of powdered plant samples were incinerated in the electric furnace. Then the ash were dissolved in *HCL* 2M and finally was brought to a certain volume with distilled water. The amount of different elements in digestion samples were measured by atomic absorption device (Emami, 1996).

Experimental design and statistical analysis

This research was done in factorial based on completely randomized design with three repetitions and two factors. These two factors included site (Mellat and Shariati parks) and type of plant species (200 species). The achieved data were analyzed by SAS and SPSS Software and the related graphs were drowning by Excel software. The comparison of means were done using Duncan test in probability of 5%.

Results and discussion

Amount of elements in soil

The amount of measured cadmium in the soil was trivial. The amount of zinc (Fig. 1) and copper (Fig. 2) in superficial layer of soil in Shariati Park were higher than mellat. However, the amounts of these elements in the deep layer of soil were higher in mellat Park rather than shariati, which indicating the mobility of zinc and copper in the soil and the role of soil texture in mobility of these elements (Fig. 3).

Results showed that the amounts of zinc, copper and lead in the superficial layer of soil in both parks were higher than deep layer of soil. It indicated that pollution was likely caused environmentally and as the mobility of heavy elements in the soil was slowly, the high amount of them were observed in superficial layer. As can be seen the amounts of zinc, copper and lead in superficial layer of soil in both Parks were achieved much more than specified standard. For each of these elements, there was a permissible range, which an example of them is given in Table 2.

Amount of plant sample elements

Based on results, the effect of site on cadmium and copper concentrations were significant at 1% probability levels, respectively, and there were no significant differences in terms of other elements in both Parks (Table 3). It is found that effects of plant type on absorption of elements had a significant difference among plants in 1% probability level, and also were observed that the maximum absorption of zinc, copper, potassium, phosphorus and nitrogen were related to deciduous trees and the maximum absorption of cadmium was related to evergreens (Table 3).

According to the table 4 and 5, the mean amount of copper in Shariati Park was higher than Mellat and

for cadmium Mellat Park was higher than Shariati. In the research project of the evaluation of air pollution on vegetative covering in Cheetgar Forest Park confirmed that Tehran pine (*Pinus eldarica*) in the vicinity of Tehran-Karaj highway absorbed 22 mg/kg lead in its leaves, however in the internal part of Park and away from highway, pines absorbed 7 mg/kg lead (Salahi, 2004).

It has been observed that copper absorption by ash and Mulberry trees in Mellat Park and cadmium absorption by Silver Cedar have been at maximum rate. And also the rates of zinc, potassium and nitrogen uptakes by Poplar trees, Privet, Hollyhock and Mulberry trees in Mellat Park were higher than Shariati. In the study, which exerted by Rafaati *et al.* (2011), observed that white Mulberry was suitable for high harvesting of nickel and cadmium.

Table 1. Botanical characterizations of studied ornamental species in this experiment.

Species	Scientific name	Family	Growth habit
Arizona Ash	*Fraxinus excelsior*	Oleaceae	Deciduous tree
Mulberry	*Morus alba*	Moraceae	Deciduous tree
Fales Acacia	*Robinia pseudoacacia*	Leguminosae	Deciduous tree
Sycamore	*Platanus orientalis*	plantanaceae	Deciduous tree
Poplar	*Populus nigra*	Salicaceae	Deciduous tree
cottonwood	*Populus alba*	Salicaceae	Deciduous tree
Arizona cypress	*Cupressus arizonica*	Cupressaceae	Evergreen
Arbor- vitae	*Thuja orientalis*	Cupressaceae	Evergreen
Pine tree	*Pinus eldarica*	Pinaceae	Evergreen
Firethorn	*Pyracantha coccinea*	Rosaceae	Deciduous shrub
Hibiscus	*Hibiscus syriacus*	Malvaceae	Deciduous shrub
Japanese quince	*Chaenomeles japonica*	Rosaceae	Deciduous shrub
Queen crape Myrtle	*Lagerstroemia* SPP.	Lytheraceae	Deciduous shrub
Spiraea	*Spiraea Arguta*	Rosaceae	Deciduous shrub
Privet	*ligustrum vulgare*	Oleaceae	Hedging
Legacy	*Ligustrum Vulgare*	Oleaceae	Hedging
Barberry	*Berberis thunbergii*	Berberidaceae	Hedging
Box	*Buxus hyracana*	Buxaceae	Hedging
Lavender	*lavandula angustifolia*	Labiatae	Covering plant
Rosemary	*Rosmarinus officinalis*	Labiatae	Covering plant

Grouping of species based on elements absorption

in the classification of different plant species based on the amount of element absorption in relation to nitrogen were observed that, the deciduous trees have the highest nitrogen absorption (Fig. 4) and among them Mulberry has the maximum nitrogen absorption (Table 3). The High content of nitrogen uptake by Mulberry leaves would be the result of extensive leaf area and so resulting in increased photosynthesis. After them, deciduous shrubs and finally hedging plants have been. The lowest amount of nitrogen uptake was recorded in evergreen trees (Fig. 4). In a study was done in Beijing, China on uptake ability and accumulation of heavy metals such as lead and copper on some trees, which cultivated in landscape of this city, were reported that the highest amount of cadmium were observed in leaves of *Populus tomentosa* (0.848 mg/kg), *Sophora japonica* (0.536 mg/kg) and *Catalpa speciosa* (0.493 mg/kg), respectively (Liu *et al.,* 2007).

Table 2. The standard range and maximum permissible amount of heavy metals in soil (Klock *et al.,* 1986).

Elements	Normal rate (ppm)	Maximum rate (ppm)
Cadmium (Cd)	0.1-1	3
Cobalt (Co)	1-10	50
Chromium (Cr)	2-50	100
Copper (Cu)	1-20	100
Nickel (Ni)	2-5	50
Lead (Pb)	0.1-20	100
Zink (Zn)	3-50	300

In terms of potassium uptake, there was no significant difference among different groups, but the covering plants had the highest amount of potassium uptake and the evergreen species had the lowest amount of uptake (Fig. 4).

Table 3. The mean comparisons of the amounts of element absorption in studied species.

Site	plant	Zn	Cu	K	P	N	Cd
MP		22.162	5.438 b	1.534	0.211	2.242	0.549 a
ShM		21.525	6.11 a	1.545	0.200	2.266	0.285 b
	Arizona Ash	21.65 b-e	12.72 a	2.23 a	0.24 c	3.47 b	0.41 def
	Mulberry	22.17 bc	10.7 a	2.34 a	0.30 b	3.88 a	0.50 c-f
	Fales Acacia	19.82 b-e	5.00 c-f	2.44 a	0.21 c-f	3.50 b	0.42 c-f
	Sycamore	18.42 b-e	7.19 bc	1.07 def	0.13 hi	2.16 d	0.15 ghi
	Poplar	25.95 bc	3.86 d-g	1.41 bcd	0.19 c-g	3.02 c	0.34 efg
	cottonwood	61.07 a	2.63 g	0.96 def	0.10 i	1.74 e-h	0.28 e-h
	Arizona cypress	21.65 b-e	4.12 d-g	1.02 def	0.17 fgh	1.40 i	1.01 a
	Arbor- vitae	17.98 b-e	3.77 d-g	0.78 ef	0.19 c-g	1.54 hi	0.71 bc
	Pine tree	16.6 b-e	3.42 fg	0.94 def	0.14 ghi	1.57 ghi	0.38 ef
	Firethorn	22.22 b-e	6.14 cde	1.40 cd	0.17 e-h	2.09 d	0.81 ab
	Hibiscus	22.02 b-e	9.65 ab	2.03 ab	0.44 a	3.46 b	0.51 cde
	Japanese quince	16.22 b-e	3.86 d-g	2.17 a	0.17 d-g	2.00 de	0.47 cde
	Queen crape Myrtle	19.47 b-e	6.58 cd	0.92 def	0.16 f-i	1.69 f-i	0.08 hi
	Spiraea	12.00 e	3.6 efg	0.86 def	0.20 c-f	1.85 d-g	0.15 ghi
	Privet	19.22 b-e	6.05 cd	2.47 a	0.16 fgh	2.06 d	0.74 ab
	Legacy	25.27 b	6.67 c	1.98 abc	0.22 cde	2.11 d	0.23 f-i
	Barberry	12.52 de	4.39 c-g	0.62 f	0.32 b	1.89 def	0.63 bcd
	Box	14.72 cde	3.07 fg	1.22 de	0.19 c-g	1.95 def	0.24 e-h
	Lavender	21.42 b-e	5.18 c-f	2.48 a	0.19 c-h	2.16 d	0.25 e-h
	Rosemary	22.47 bcd	6.84 bc	1.44 bcd	0.22 cd	1.53 hi	0.04 i

The numbers that shared Latin letters were statically taken in one group.

According to the mean comparison of data were shown that deciduous tree group in terms of cadmium uptake was taken in one statically group and were not observed any significant differences among them (Table 3). Evergreen trees showed the highest cadmium uptake (Fig. 4) and among them the highest absorption rate of cadmium was allocated to Silver Cedar (table 6). In the deciduous tree group, the highest rate of cadmium uptake was belonged to Ash (table 3). Sun *et al.* following analyses, which exerted on ornamental plant *Tagetes patula* for cadmium remediating from soil, concluded that the desired species could be suitable for remediation of cadmium-contaminated areas. Based on Duncan test the deciduous trees showed the highest rate of cadmium uptake and Tabriz Poplar had the highest zinc uptake rate in this group (Fig. 5) (Sun *et al.*, 2001).

Table 4. The mean comparisons of the major effects of cupper and cadmium.

plant	Mellat Park (MP)		Shariati Park (ShP)	
	Cu	Cd	Cu	Cd
Arizona Ash	9.83 a	0.75 bcd	15.63 a	0.08 efg
Mulberry	9.83 a	1.01 abc	11.60 ab	0.001 g
Fales Acacia	4.53 d-g	0.62 c-f	5.47 def	0.21 d-g
Sycamore	9.13 ab	0.27 e-i	5.27 def	0.02 g
Poplar	3.17 g	0.63 b-e	4.60 def	0.04 fg
cottonwood	2.63 g	0.28 e-i	2.63 f	0.28 def

The numbers that shared Latin letters were statically taken in one group.

Nylund (2003) observed in their study that the high rate of cadmium (more than 800 mg/kg) and zinc (more than 3000 mg/kg) were accumulated in the leaf of tree species of *Salix viminalis*, whereas the soil contents of these elements were 2.5mg/kg cadmium and 4000 mg/kg zinc (Nylund, 2003). According to table 3 observed that there were significant differences in uptake of other elements except to cadmium.

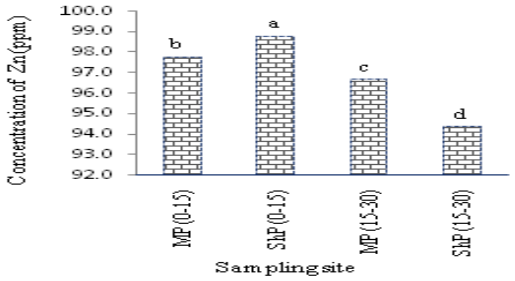

Fig. 1. The amount of zinc in the depth 0-15 and 15-30 cm of soil at the two studied sites; MP= Mellat park and ShM= Shariati park.

The lowest rate of zinc uptake was in poplar and other deciduous trees, which they were taken in one group, and there were no significant differences among them. Tabriz poplar, Ash, Acacia and mulberry had the highest amount of elements of zinc, copper, potassium and phosphorus and nitrogen, respectively (Table 3).

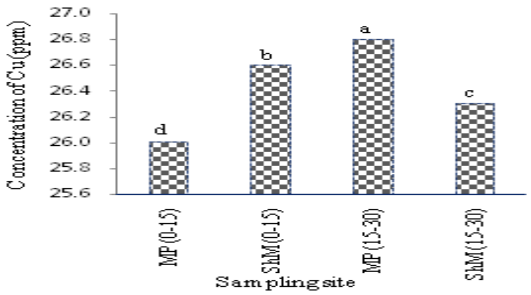

Fig. 2. The amount of copper in the depth 0-15 and 15-30 cm of soil at the two studied sites; MP= Mellat park and ShM= Shariati park.

According to the variance analysis of the evergreen trees were detected that there was no significant difference in absorption of elements except phosphorus. According to the mean comparison at 5% probability observed that Cedar crock has the highest rate of sorption.

There was a significant difference in the uptake of elements except zinc. Based on table of mean comparison at 5% probability level, the highest rate of copper, potassium, phosphorus, nitrogen and cadmium sorption were shown in Hollyhock, Fire Thorn, Japanese quince, respectively (Table 3).

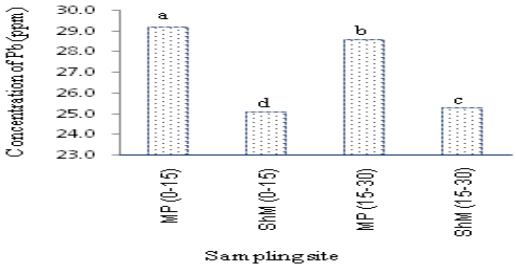

Fig. 3. The amount of lead in the depth 0-15 and 15-30 cm of soil at the two studied sites; MP= Mellat park and ShM= Shariati park.

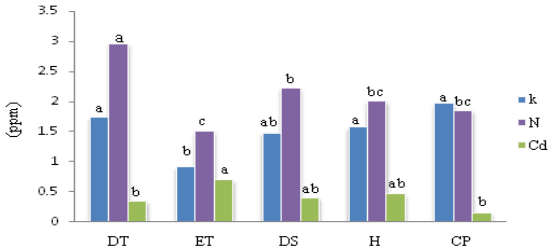

Fig. 4. The mean comparison of the amount of potassium (K), nitrogen (N) and cadmium (Cd) absorption by ornamental studied species classified in five groups according to growth habit. (DT= Deciduous Trees, ET= Evergreen Trees, DS= Deciduous Shrubs, H= Hedging and CP= Covering plant).

In the study like present research, the ability of ornamental aquatic plants in terms of remediation of heavy metals such as copper, cadmium and chromium, total nitrogen and the municipal phosphorus of wastewater were analyzed and observed that the plants were adopted well for such a water and *Iris pseudacorus* L. and *Acorus gramineus* were good selection for remediating infected composite municipal wastewater (Zhang *et al.*, 2007). There were significant differences in the sorption of zinc, copper and potassium by hedging plants, but in absorption of phosphorus, nitrogen and cadmium cannot see any significant differences. Base on Duncan test at 5% probability level were observed

that Thorn had the highest sorption of zinc, Barberry had the highest rate of phosphorus sorption and privet had the highest sorption of cadmium. Furthermore, based on this table were observed in these plants that there was no significant difference in sorption of copper and nitrogen.

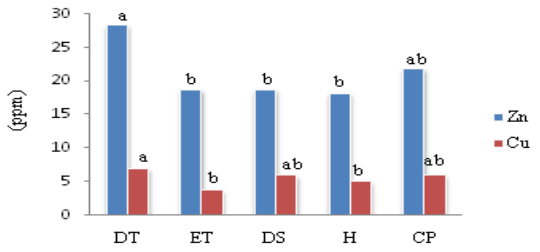

Fig. 5. The mean comparison of the amount of zinc (Zn) and copper (Cu) uptake by studied ornamental species classified according to growth habit in five groups. (DT= Deciduous Trees, ET= Evergreen Trees, DS= Deciduous Shrubs, H= Hedging and CP= Covering plant).

Conclusions

In experiment condition, among the analysis species, deciduous trees specially ash, mulberry and Tabriz poplar in terms of copper, zinc and nitrogen sorption and evergreen trees such as silver Cedar because of maximum cadmium sorption could be suitable trees for landscaping in contaminated areas. According to the characteristics of ornamental ash tree which cultivated in vast areas of urban and countryside and had a wide geographic range and ecological distribution and also easiness and low cost of its cultivation, it seems that for remediating of contaminated soils with copper and zinc metals, the ash could be effective.

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