Phytoremediation capabilities of eight wild plants in absorption of three heavy metals (Al, Pb and Zn) in Meyghan Wetland

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Abstract

Phytoremediation plant is one of the proposed methods that by accumulating heavy metals in the aerial parts of plants, it is possible to remove these elements from contaminated soils. The aim of this study was to investigate the situation of removal of three heavy metals, Al, Pb and Zn in the soil based on 8 plant species in Meyghan wetland in Markazi province, Iran. One-way analysis of variance (ANOVA) was used to investigate the difference between of heavy elements in the aerial parts, roots of plant species and soil. The results showed that there were significant difference in the contaminants of Al, Pb and Zn in the aerial, root organs of plant and soil. The results of the study of Al changes in the soil and the studied species showed that the amount of this element in the soil is very high and the studied plants do not have the high adsorption capacity of this element. The results of a study of the amount of Pb in aerial parts and roots of plant species showed that the amount of this metal in aerial parts is higher than the root and *Halocenemum Strobilaceum* has the highest rate of Pb contaminants (0.82 mg/cm^3) among the studied species. The results of Zn change in aerial and root limbs showed that the amount of Zn metal contaminants in aerial organs was higher than the root, and *Scirpus lacustris* (2.14 mg/cm^3) had the highest total absorption rate among the species studied.

1. Introduction

Pollution of wetland ecosystems by heavy metals is one of the most important issues that has received special attention in recent years, and several studies have been conducted in this field (Huang et al., 2020). Because these ecosystems are naturally the ultimate recipients of heavy metals (Freedman, 2013). Heavy metals are important pollutants in natural environments, because due to toxicity, stability and biological decomposition, these elements tend to accumulate in aquatic organisms. Among different types of contaminants, heavy metals, even at low concentrations, have increasingly caused health concerns due to their hazardous bioaccumulation ability through the food chains (Li et al., 2014, Qiu, 2014). Various human activities cause these pollutants to enter the ecosystem. These elements enter the wetland ecosystems through direct or indirect discharge by rainwater runoff as well as through the atmosphere. Major sources include the direct entry of heavy metals into aquatic ecosystems, industrial and municipal wastewater and sewage, agricultural runoff, sailing and mining activities (Rai, 2008, Alloway, 2013).

Due to limited water resources and uncontrolled population growth and the expansion of industry and agriculture, the use of recycled water is essential and inevitable. Wastewater is one of the polluting factors in the environment, which needs to be collected, treated and returned to the natural flow of water (Feigin et al., 2012). Therefore, in order to implement measures to develop and exploit new water resources, especially in the agricultural sector, reuse of industrial, urban and rural effluents can be considered as reliable water resources to compensate for the shortage of agricultural water shortages. Rather, the adverse effects of wastewater waste disposal and its environmental damage should also be avoided. One of the dimensions of wastewater treatment, which is considered today, is biological treatment (Lepp, 2012). The use of plants in wastewater treatment, especially municipal and industrial effluents containing heavy metals, has received much attention. Because plants can grow extensively and absorb toxic metals at a lower cost than other biological treatment methods and are not as harmful to the environment as artificial systems, they are very cost-effective. In this regard, the limitations and standards of using this method should be considered, including care and care of plants and disposal of plant residues containing toxic substances after use in the treatment system (Chibuike and Obiora, 2014).

With the growth of industry and the unprincipled focus of industry, natural resources are at risk of extinction, and the level of biosphere pollution has increased dramatically. Heavy metals cause many problems for human health due to their inseparability in the environment and entering the food chain. Common methods of reducing and removing pollutants from the environment, in addition to being costly, are not able to completely remove pollutants from the environment; While the use of plants to clean the environment, in addition to helping to improve environmental conditions, is able to remove a significant portion of pollutants, especially heavy metals from the environment (Asad et al., 2019).

Over the past few decades, environmental pollutants from mining and industrial activities have increased. Soil contamination with heavy elements is one of the most important environmental problems in many parts of the world. Human activities, especially industrial activities and mineral processes, are the cause of the wider dissemination of these elements. The most important elements in terms of food chain contamination are As, Cd, Hg and Pb (Oves et al., 2012). At the same time, some nutrients, such as Cr, Cu, Ni, and Zn, can cause poisoning at high concentrations in plants and animals. Plants are important components of the ecosystem and are responsible for transporting elements from the environment to living organisms. The main sources of elements entering the plants from the environment are air, water and soil (Glick, 2003).

Phytoremediation plant is one of the methods of soil bioremediation that has received a lot of attention in recent decades (Sharma and Pandey, 2014). Compared to other refining methods, this method is a stable, inexpensive, simple and eco-friendly method. In this method, storage plants are used to purify contaminated soils without destroying the soil structure. Plant accumulators are plants with high growth rate, high biomass and high tolerance of metals (more than 1000 ppm) in harvestable parts of the plant that is able to transfer and accumulate in storage tissues (Tüze, 2003).

Various studies have been conducted on the sequestration of heavy metals in different ecosystems. Sasmmas et al. (2008) examined the role of *Typha latifolia* in the accumulation of heavy metals in the Kehli River. The results showed that the amount of heavy metals in the roots was higher than the leaves. Also, the amount of cadmium in the roots was higher than sediments and in the leaves less than sediments. This result showed that Louis root can be used as an indicator of cadmium contamination in the soil. Singh et al. (2010) states that plants that are able to absorb heavy metals abnormally have the genetic potential to clean up contaminated soils, and in fact the main advantage of these plants is that they can be absorbed and accumulated despite cultivation in contaminated metal or irrigated water. They have metal. Chaoua et al. (2019) investigated the accumulation of heavy metals cadmium, lead (Pb), nickel (Ni) and chromium (Cr) in mangrove swamps on the plant species *S. apetala* and *K. obovata* in

China. *S. apetala* significantly altered the biochemical cycle of cadmium, Pb, Ni and chromium (Cr). In *S. apetala* deposition, TOC plays an important role in the sequence of heavy metals because its positive correlations with zinc and lead are reflected. This study showed the importance of plant species in changing soil quality and accumulation of heavy metals, and *S. apetala* works more efficiently as an inhibitor of contamination than *K. obovata*.

Meyghan desert Wetland and its 5459.9 Km^2 of land, despite its diversity of soil and vegetation, beautiful lakes in the heart of the desert and the presence of migratory birds and other ecotourism attractions due to human intervention, its nature has undergone drastic changes. This wetland is considered as a sensitive wetland ecosystem due to its size, ecological and hydrological characteristics and the extent of its impact on the region's climate, especially the city of Arak. The entry of wastewater from the Arak wastewater treatment plant, which is a mixture of municipal and industrial wastewater, is a serious threat to the wetland ecosystem in terms of environmental pollution, especially the presence of heavy metals. Therefore,

the aim of the current study is, investigating the effect of 8 wetlandplant species on the phytoremediation of three heavy metals Al, Pb and Zn in the area around Meyghan Wetland.

2. Material And Methods

2.1. Study Area

Due to its special conditions, Meyghan plain, also called Meyghan wetland and Meyghan desert, is located in the center of Iran, about 8 km northeast of Arak metropolis, in the lowest part of Arak and Farahan plains. Meyghan wetland catchment area with an area of 549578 ha is located in the longitude of 49° 32' to 49° 50' east and latitude 33° 50' to 34° 06' north, located in Zone 39 in the UTM system (Fig. 1). The height of the region is between 1650 and 1750 meters and has a slope of 0 to 5 percent. Also, all the streams and groundwater of Arak basin have been led to this wetland and naturally it is the gathering place of all surface and even subsurface runoff. Meyghan wetland catchment area is between 118.4 and 130 km^2, depending on the flood and different seasons of the year. The depth of water in stream seasons in some parts reaches up to 1.5 meters, but in July, August and September, due to high evaporation, it becomes swampy. Therefore, Meyghan wetland is considered as a seasonal wetland. The rainfall in the study area is about 300 mm. The specific microclimate created by the desert raises the temperature difference of 69 C° between the minimum and maximum temperature of the region, so that the cold of -31.5 C° and the extreme heat of 42 C° originate from the specific climatic position of the region.

2.2. Plant species studied

In this study, 8 wetland species including *Phragmites australis (*P.a), *Typha latifolia* (T.l), *Scirpus lacustris* (S.l), *Halocenemum Strobilaceum* (H.s), *Atriplex Verrucifera* (A.v), *Puccinella distans* (P.d)., *Achillea* (A) and *Cyperus eremicus (*C.e) were studied (Fig. 2).

2.3. Field sampling method

After preliminary visits and determination of the study area, the species that had more vegetation and abundance were identified and selected from three parts of the wetland margin. Then, in June 2018, a tripod of any plant was selected and all the aerial parts and their roots were harvested using shovels. The samples were placed in plastic bags after coding. Also, three soil samples were taken from a depth of 0–30 cm in the soil around the bases of each plant and placed in a plastic bag. The samples were transferred to the laboratory of the Islamic Azad University of Arak.

2.4. Laboratory research method

After washing the aerial parts and roots of the plant species with distilled water, they were left in the open air for a week to dry. In the laboratory, plant specimens were divided into aerial parts and root organs. Then place in an oven at 75 C° for 48 hours. After drying, they were ground to a complete powder, then the molten samples were passed through a 2 mm sieve. Then, 1 g of the powdered sample was weighed and placed in the special crucibles of the digestion furnace and placed in the electric furnace at a temperature of 550 C°for 4 hours. Then 10 ml of 2 N HCL was added to each sample. In this step, by placing the samples on the heater, the temperature was used to complete the digestion. At the end, the soloutions were filtered by Whatman No. 42 in 50 ml balloons and made up to volume with distilled water (Khoshgoftarmanesh, 2015). To determine the total concentration heavy metals in soil, 1 g of soil was digested with 15 mL of 4 M HNO3 at 80°C. After complete digestion, the solutions were filtered through Whitman No. 42 filter paper and diluted in 50 mL balloons with distilled water (Sposito et al., 1982). Finally, using the atomic absorption spectrometer GBC scientific equipment 932 plus, heavy metals were determined .The blank reagent and standard reference material (SRM) were used in the analysis for quality assurance and control. All the analyses were performed out in triplicate. Reagents and chemicals used were supplied by Merck Company, Germany. All glassware and utensils were soaked and they were prewashed several times with soap, distilled water, and 1% HNO3. Moreover, MilliQ water was used to prepare all standard and sample solutions.

2.5. Data analysis

The descriptive statistical analysis was conducted by applying SPSS 20.0. Prior to

One-way analysis of variance (ANOVA), a normality test (Kolmogorov-Smirnov test) was accomplished in order to assess the normality of original concentration data. The

original concentration data, which does not meet the normal distribution, was normalized by the Box-Cox transformation. The differences of heavy metal concentrations were compared from the

different two aerial parts and roots between 8 species studied using the ANOVA test, and after a significant difference between the treatments was identified, the mean difference were compared using the Tukey method (Bose and Bhattacharyya, 2008, Antonious et al, 2007).

3. Results

3.1. Statistical characteristics

The results of the statistical study of 8 wetland species in heavy metal Al, Pb, and Zn sequestration are shown in Tables 1 to 3.

3.2. One-way analysis of variance (ANOVA) analysis

In order to analysis the data, SPSS 20.0 software was used to compare the measured values at 99 and 95% of ANOVA test and to compare the means of Tukey test. The results of analysis of variance of 3 different elements are shown in table 4. Based on the analysis of variance, the studied species had a significant difference of 5% in adsorption of Al, Pb and Zn metals.

3.3. Investigate the mean difference

3.3.1. Al

The study results of the mean differences in aerial organs, roots, and total species wetlandand soil in the order of Al content were shown in figure 3. Based on the results of this diagram, there is a difference between aerial parts, roots and total plant species and soil species. The average amount of Al in the soil is 139.69 mg/cm^3, while the highest amount of this element in the aerial parts of *Scirpus lacustris* is 8.54 mg/cm^3. The highest amount of this element was obtained in the root of the plant species *Achillea millefoliom* at the rate of 12.82 mg/cm^3, which indicates the higher contaminants rate of this element in the root than aerial parts. In total, the highest amount of this element was obtained in *Scirpus lacustris* plant species at the rate of 8.03 mg/cm^3 and indicates that the studied plant species are not able to absorb high amounts of soil Al.

3.3.2. Pb

The results of the mean difference in aerial parts, roots and total wetlandspecies and soil in the Pb sequestration were presented in Figure 4. Based on the results of this diagram between the aerial parts of the plant species *Atriplex Verrucifera*, *Halocenemum Strobilaceum*, *Phragmites australis, Puccinella distans*, and soil has a significant difference in Pb contaminants and the amount of Pb in the aerial parts of these species is higher than the average of this element in the soil. However, no significant differences were observed in the aerial parts of the species *Achillea millefoliom*, *Cyperus longus*, *Scirpus lacustris, Typha latifolia* and soil. The average amount of pb in the soil is 0.623 mg/cm^3, while the highest average contaminants of this element in the aerial parts of the plant is *Halocenemum Strobilaceum*. 0.82 mg/cm^3 was obtained and the lowest Pb contaminants was associated with *Typha latifolia* aerobic organ at 0.59 mg/cm^3.

Based on the results of the study of the mean difference in Pb contaminants between root plants and soil, it was observed that there is a significant difference in root uptake between plant species *Achillea millefoliom*, *Cyperus longus*, *Phragmites australis*, *Puccinella distans* with *Halocenemum Strobilaceum.*, which has the highest average contaminants of this element at the root of the *Halocenemum Strobilaceum* 0.68 mg/cm^3 was obtained and the lowest Pb contaminants was related to the root of the *Achillea millefoliom* species at 0.54 mg/cm^3.

Overall, the results of the study of the mean difference showed that there was a significant difference between the plant species *Achillea millefoliom*, *Typha latifolia* and soil with *Halocenemum Strobilaceum* in Pb contaminants. The highest average contaminants of this element in *Halocenemum Strobilaceum* 0.75 mg/cm^3 was obtained and the lowest lead contaminants was related to *Achillea millefoliom* at 0.59 mg/cm^3.

3.3.3. Zn

The results of the study of the mean difference in aerial parts, roots, and total wetland species and soil in Zn sequestration were shown in figure 5. According to the results of this figures, there is no significant difference in aerial parts between *Achillea millefoliom*, *Atriplex Verrucifera*, *Cyperus longus, Typha latifolia* species and soil, while *Halocenemum Strobilaceum, Phragmites australis and Scirpustc lacustris* between the aerial parts and soil there was a significant difference in Zn contaminants. The average amount of Zn in the soil is 0.88 mg/cm^3, while the highest average contaminants of this element in the aerial parts of plants is *Scirpus lacustris*, 2.14 mg/cm^3 and the lowest amount of Zn in *Halocenemum Strobilaceum* was 0.039 mg/cm^3. The results of the mean difference in the roots wetlandspecies and soil did not show a significant difference in Zn sequestration. The highest average contaminants of this element was obtained in the root of *Achillea millefoliom* species at the rate of 0.62 mg/cm^3 and the lowest level of Zn uptake in the root of *Scirpus lacustris* was 0.23 mg/cm^3.

Overall, the results of the mean difference showed that between plant species *Puccinella distans Halocenemum Strobilaceum* there is a significant difference with *Scirpus lacustris* and soil in Zn sequestration. The highest average contaminants of this element in *Scirpus lacustris* plant 1.18 mg/cm^3 was obtained and the lowest Zn sequestration was related to *Halocenemum Strobilaceum* at 0.23 mg/cm^3.

4. Discussion

The results study of Al changes in soil and plant species showed that the amount of this element in the soil is very high and the studied plants do not have the high adsorption capacity of this element, which can cause Al accumulation in different parts of the plant and disruption, in the general metabolism of the plant, which reduces the overall growth of the plant, one of the main reasons for plant weight loss is damage to plant cell membranes, which causes loss of plant water or reduction in water contaminants, and probably because of this change. It is in the blue state that the biomass also decreases

(Thawornwong and Van Diest, 1974, Weis and Weis, 2004). Al reduces growth and reduces plant leaf area. Al is likely to be located in the cell wall and the middle septum of the cells, increasing the cross-linking of pectin to the membrane in the middle septum. This cross-linking can inhibit growth and reduce leaf area. Cell inhibition can also be due to the direct or indirect effects of aluminum on auxin metabolism (Lv et al., 2019).

Based on the results of this diagram between the aerial parts of the plant species *Atriplex Verrucifera*, *Halocenemum Strobilaceum*, *Phragmites australis, Puccinella distans*, and soil has a significant difference in Pb contaminants, and the amount of Pb in the aerial parts of these species is higher than the average of this element in the soil. Sabir et al (2022) reported the concentrations of Pb in plant roots and shoots ranged from 123 to 678 and 29 to 287 mg kg −1,

respectively. However, no significant differences were observed in the aerial parts of the species *Achillea millefoliom*, *Cyperus longus*, *Scirpus lacustris, Typha latifolia* and soil. Based on the results of the study of the mean difference in Pb contaminants between root plants and soil, it was observed that there is a significant difference in root uptake between plant species *Achillea millefoliom*, *Cyperus longus*, *Phragmites australis*, *Puccinella distans* with *Halocenemum Strobilaceum.* The results of the study of the amount of Pb in the aerial parts and roots of the studied plant species showed that the amount of this metal in the aerial parts is more than the roots. The results of a general study of lead between soil and *Halocenemum Strobilaceum* showed that there was a significant difference in Pb contaminants in this species, while in other species there was no significant difference. Pb reduces leaf growth, photosynthetic pigmentation content, and enzymatic activity for CO2 uptake by inhibiting chlorophyll biosynthesis, reducing total chlorophyll content and chlorophyll a and b ratios. Replacing central chlorophyll magnesium with Pb prevents light and Pb to photosynthetic defects, so the plant species under study cannot absorb this metal to a certain extent due to the above (Liu et al., 2007, Zhong et al, 2007). Due to the changes in the average of this metal, it was found that the average of this metal in Halocenemum Strobilaceum is higher than its average in soil, which indicates the contaminants and storage of this metal in plant organs. Bobtana et al. (2019) in their study of *Halocenemum Strobilaceum* concluded that this species has the ability to properly absorb Pb metal.

The results of the study of Zn contaminants levels in the aerial parts of the studied species showed that there was a significant difference in soil between the aerial parts of *Halocenemum Strobilaceum, Phragmites australis* and *Scirpus lacustris*. So that the highest average contaminants of this element in the aerial parts of the plant species Scirpus lacustris. 2.14 mg/cm3 was obtained and the lowest amount of zinc uptake in *Halocenemum Strobilaceum* was 0.039 mg/cm^3. Examination of the changes in the roots of plant species showed that there was no significant difference in the contaminants of this metal with the soil. A general study of the rate of Zn depletion in the studied species showed that *Halocenemum Strobilaceum* and *Phragmites australis* had the lowest Zn contaminants compared to other species. Also, all species except *Scirpus lacustris* have less Zn than soil. Increased Zn levels increase malondialdehyde, hydrogen peroxide, antioxidant enzymes, free amino acid content, cell death, potassium leakage, and electrolyte leakage, so high Zn levels can act as stress (Peltier et al, 2003, Deng et al, 2004). They act to reduce the plant's ability to inhibit plant growth, and as a result, plants can absorb and store this metal to a certain extent. A study of the average amount of Zn in the plant species *Scirpus lacustris* shows that this plant has the ability to absorb and store Zn so that the amount of Zn in this plant is more than soil.

The results of this study are inconsistent with the results Phill et al. (2015) In their study of the effect of three plant species on the contaminants of heavy, Pb and Zn metals in the wetland area, they concluded that the contaminants rate of these elements in plant roots is higher than in the aerial parts.

5. Conclusion

In this study, the heavy metal Al, Pb, and Zn were studied in 8 plant species in Meyghan wetland, which is one of the most important wetlands in Iran in Markazi province, which is affected by industrial and domestic effluents. The results of the study of heavy metal deposition showed that there was a significant difference in the contaminants of these metals in the aerial and roots organs of the species studied with the soil. The results of the study of Al changes in the soil and the studied species showed that the amount of this element in the soil is very high and the studied plants do not have the high adsorption capacity of this element. Examination of the amount of Pb in the aerial parts and roots of plant species showed that the amount of this metal in the aerial parts is more than the root and *Halocenemum Strobilaceum* has the highest amount of Pb contaminants among the studied species. Also, changes in Zn in the aerial and root limbs showed that the amount of Zn metal adsorption in the aerial parts was higher than in the roots, and *Scirpus lacustris* had the highest rate of Zn adsorption among the species studied. Therefore, in the studied species, they have the ability to absorb different amounts of heavy metals in the study area. However, the studied species *Halocenemum Strobilaceum* and *Scirpus lacustris* showed a good ability to absorb heavy Pb and Zn metals. Due to the existence of industrial factories such as machinery, aluminum manufacturing and a large number of companies and industrial and manufacturing factories in the vicinity of Meyghan Wetland, which causes the effluent of Arak wastewater treatment plant, which is a mixture of urban and industrial wastewater.

Declarations

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Authors' contributions

Raziyeh Faraji: Writing - Original Draft, Investigation, Methodology; **Nourollah Abdi**: Supervision, Conceptualization, Project administration, Funding acquisition; **Javad Varvani**: Supervision; **Abbas Ahmadi**: Advising; **Hamid Toranjzar**: Advising.

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Tables

Table 1. Descriptive characteristics of Al metal precipitation in aerial organs, roots and total of 8 wetland plant species

Species	Plant parts	Mean	SD	SE
Achillea millefoliom	Aerial limbs	1.040	0.022	0.013
	Root	12.825	0.115	0.066
	Total	6.93	6.46	2.64
Atriplex Verrucifera	Aerial limbs	2.975	0.121	0.070
	Root	11.020	0.190	0.110
	Total	7.00	4.41	1.80
Cyperus longus	Aerial limbs	1.192	0.066	0.038
	Root	11.325	0.098	0.057
	Total	6.26	5.55	2.27
Halocenemum Strobilaceum	Aerial limbs	1.409	0.076	0.031
	Root	10.183	0.492	0.201
	Total	5.80	4.59	1.33
Phragmites australis	Aerial limbs	1.837	0.365	0.122
	Root	10.506	2.258	0.753
	Total	6.17	4.73	1.11
Puccinella distans	Aerial limbs	3.660	0.607	0.248
	Root	11.966	0.655	0.268
	Total	7.81	4.38	1.26
Scirpus lacustris	Aerial limbs	8.541	0.115	0.067
	Root	7.519	0.036	0.021
	Total	8.03	0.56	0.23
Typha latifolia	Aerial limbs	3.464	1.657	0.676
	Root	7.922	0.339	0.139
	Total	5.69	2.59	0.75
Soil		139.694	68.571	12.519

Table 2. Descriptive characteristics of Pb metal precipitation in aerial organs, roots and total of 8 wetland plant species

Species	Plant parts	Mean	SD	SE
Achillea millefoliom	Aerial limbs	0.645	0.023	0.013
	Root	0.541	0.010	0.006
	Total	0.593	0.059	0.024
Atriplex Verrucifera	Aerial limbs	0.809	0.009	0.005
	Root	0.576	0.000	0.000
	Total	0.692	0.128	0.052
Cyperus longus	Aerial limbs	0.662	0.009	0.005
	Root	0.558	0.010	0.006
	Total	0.610	0.057	0.023
Halocenemum Strobilaceum	Aerial limbs	0.822	0.146	0.060
	Root	0.679	0.020	0.008
	Total	0.751	0.124	0.036
Phragmites australis	Aerial limbs	0.720	0.128	0.043
	Root	0.584	0.042	0.014
	Total	0.652	0.116	0.027
Puccinella distans	Aerial limbs	0.753	0.015	0.006
	Root	0.554	0.025	0.010
	Total	0.654	0.106	0.031
Scirpus lacustris	Aerial limbs	0.748	0.018	0.010
	Root	0.584	0.010	0.006
	Total	0.666	0.091	0.037
Typha latifolia	Aerial limbs	0.593	0.037	0.015
	Root	0.597	0.054	0.022
	Total	0.595	0.044	0.013
Soil		0.623	0.067	0.012

Table 3. Descriptive characteristics of Zn metal precipitation in aerial organs, roots and total of 8 wetland plant species

Species	Plant parts	Mean	SD	SE
Achillea millefoliom	Aerial limbs	0.228	0.036	0.021
	Root	0.620	0.043	0.025
	Total	0.424	0.218	0.089
Atriplex Verrucifera	Aerial limbs	0.686	0.054	0.031
	Root	0.438	0.033	0.019
	Total	0.562	0.142	0.058
Cyperus longus	Aerial limbs	0.156	0.036	0.021
	Root	0.490	0.011	0.006
	Total	0.323	0.184	0.075
Halocenemum Strobilaceum	Aerial limbs	0.039	0.043	0.017
	Root	0.428	0.036	0.015
	Total	0.233	0.207	0.060
Phragmites australis	Aerial limbs	0.126	0.157	0.052
	Root	0.461	0.175	0.058
	Total	0.294	0.236	0.056
Puccinella distans	Aerial limbs	0.624	0.464	0.190
	Root	0.562	0.039	0.016
	Total	0.593	0.316	0.091
Scirpus lacustris	Aerial limbs	2.145	0.092	0.053
	Root	0.235	0.036	0.021
	Total	0.235	0.036	0.021
Typha latifolia	Aerial limbs	0.824	0.445	0.182
	Root	0.274	0.034	0.014
	Total	0.824	0.445	0.182
Soil		0.877	0.652	0.119

Table 4. Results of heavy metal variance analysis

Heavy metals	Plant parts	df	F	Sig
Al	Arial parts	8	17.48	0.0004**
	Root	8	15.61	0.0003**
	Total	8	34.51	0.0002**
Pb	Arial parts	8	7.44	0.007**
	Root	8	3.86	0.001**
	Total	8	3.26	0.002**
Zn	Arial parts	8	7.37	0.0008**
	Root	8	2.23	0.036*
	Total	8	4.54	0.0009*

Sig=* 95% and ** 99%

Figures

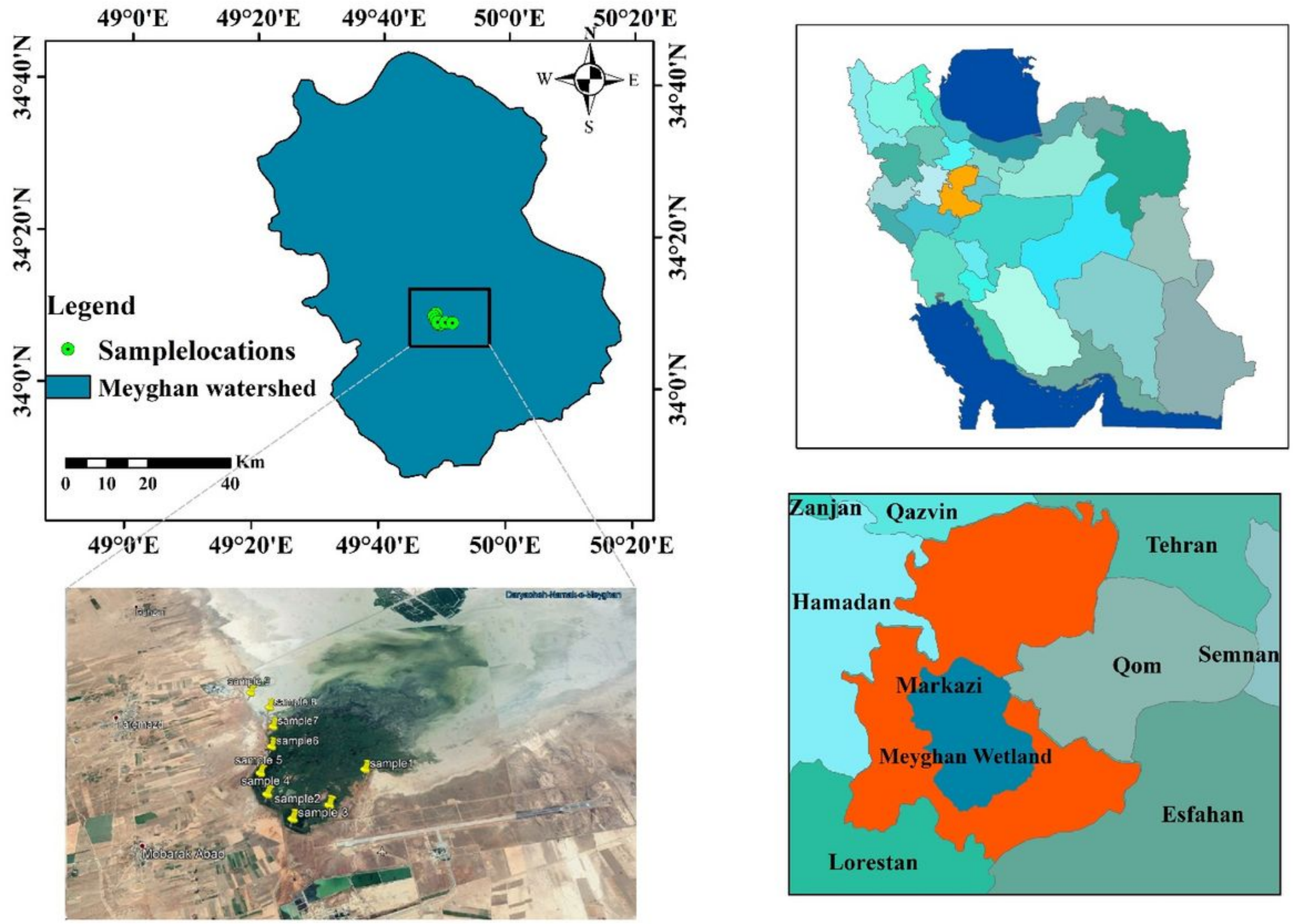

Figure 1

Study area and sample locations in Meyghan wetland, Markazi province, Iran

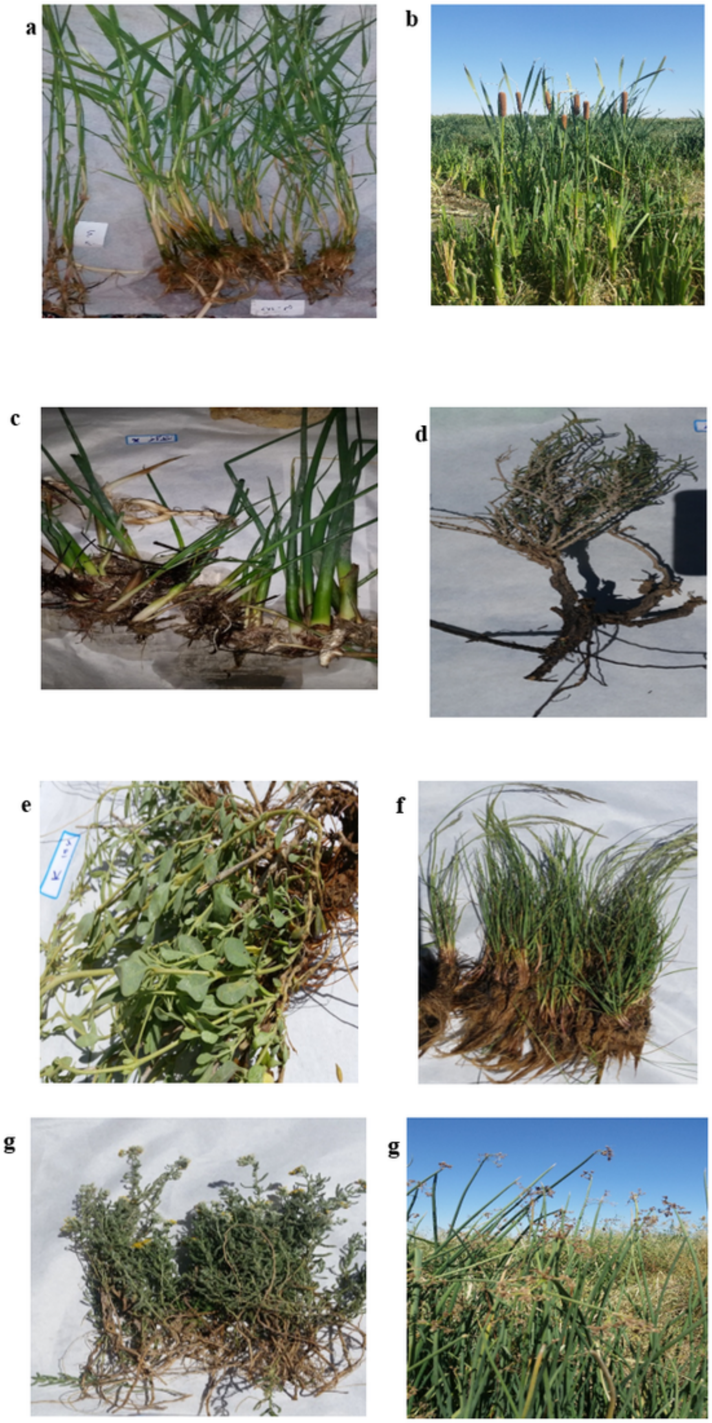

Figure 2

Study wetland plant species in Metghan wetland: a) *Phragmites australis,* b) *Typha latifolia,* c) *Scirpus lacustris,* d) *Halocenemum Strobilaceum,* e) *Atriplex Verrucifera,* f) *Puccinella distans,* g) *Achillea*and h) *Cyperus eremicus*

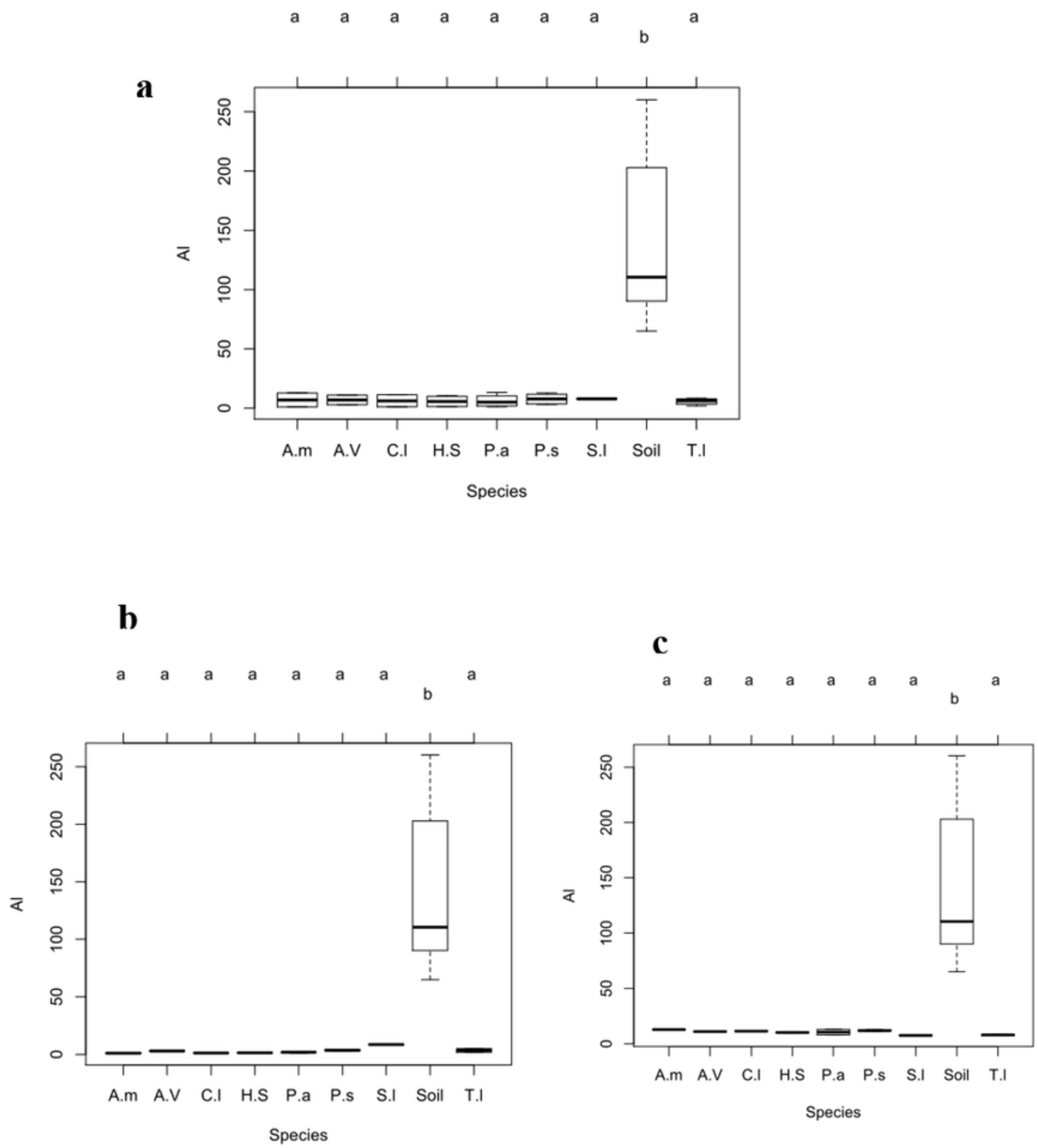

Figure 3

The study results of mean difference in Al uptake in 8 wetland plant species and soil: a) aerial parts b) root c) total

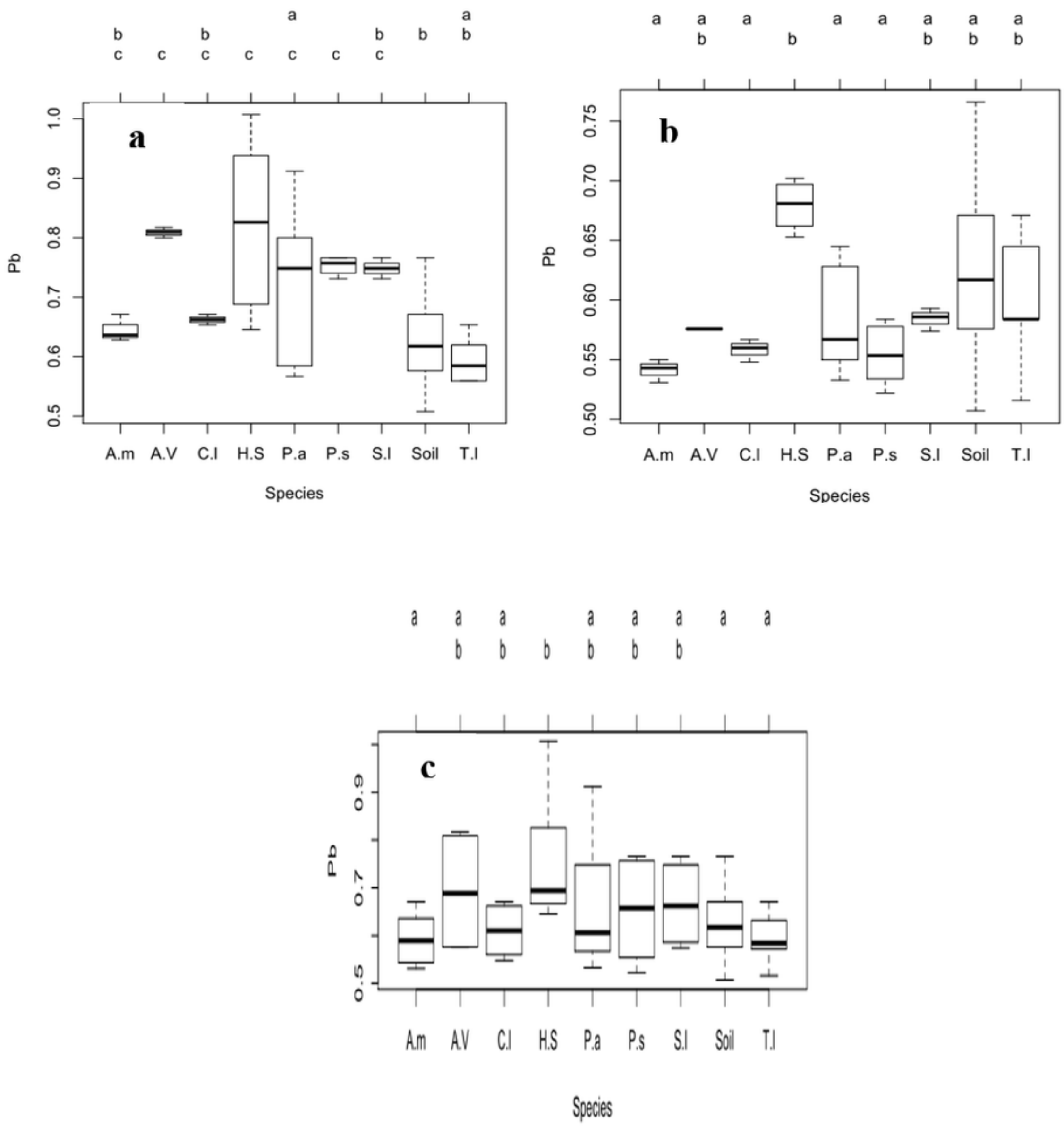

Figure 4

The study results of mean difference in Pb uptake in 8 wetland plant species and soil: a) aerial parts b) root c) total

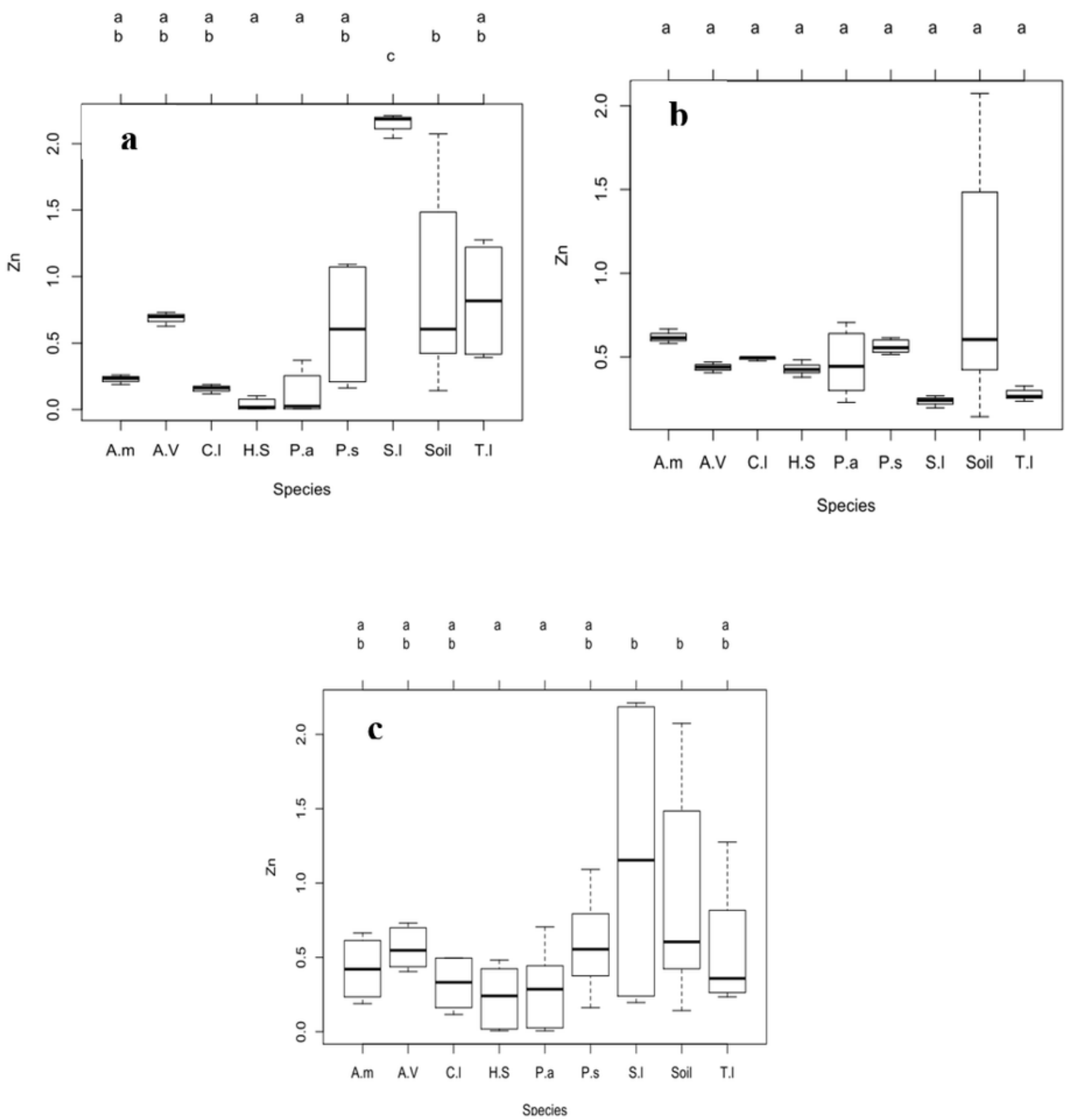

Figure 5

The study results of mean difference in Zn uptake in 8 wetland plant species and soil: a) aerial parts b) root c) total