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USE OF SOME ORNAMENTAL PLANTS IN PHYTOREMIDATION TECHNIQUE OF SOIL CONTAMINATED WITH SOME HEAVY METALS (NI, CD, PB).

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Abstract

A potting experiment was conducted in plastic house using soil with loam texture, to studying process of phytoremidation of soil contaminated with some heavy metals (Lead, Cadmium and Nickel) using three ornamental plants: : Ficus elastica (Fix) and Catharanthus vinca and Carissa, to evaluate the efficiency of ornamental plants above in absorbing and accumulating the above heavy metals from soil contaminated with them, and to evaluate the contamination of soil and plants with heavy metals by adopting the concentration according to international standards.Seedlings of ornamental plants were planted at one age (three months), they were fertilized with NPK elements according to fertilizer recommendation. They were irrigated with tap water after depleting 35% of available water. The experiment continued for four months. The experiment was conducted globally according to a completely randomized design (CRD) using three ornamental plants and three levels of three heavy metals Pb, Cd and Ni, namely 0, 100 and 200 mg L^{-1} for Lead, 0, 10 and 15 mg L^{-1} for Cadmium , 0, 50 and 100 mg L^{-1} for Nickel with four replications, so that the number of experimental units is 108. Soil samples were taken before and after the end of experiment, and the available and total heavy metals were estimated. Plant samples (leaves) were also taken after the end of experiment, concentrations of heavy metals were estimated. Results showed an increase in total and available concentrations of heavy metals in the cultivated soil and for all plants after the end of experiment, directly with the increase in levels of added heavy metals. Total concentrations of Lead, Cadmium, and Nickel were (32.27, 28.62, and 33.56), (1.593, 1.009, and 1.326) and (12.17, 8.41, and 10.61) mg kg^{-1} for heavy metals, respectively, for Ficus elastica (Fix) and Catharanthus vinca and Carissa, respectively. Available concentrations, were (12.28, 13.11, 12.63), (0.015, 0.012, 0.022) and (2.5000, 2.247 and 2.453) mg kg^{-1} for the heavy metals respectively for the above ornamental plants respectively. Soil contamination with heavy metals led to an increase in the concentrations of these elements in the plant (leaves) directly with the increase in levels of addition for all plants. Plants can be arranged in terms of their efficiency in absorbing heavy metals as follows: Catharanthus vinca > Carissa > Ficus elastica, which indicates the high ability of plants to transfer and accumulate heavy elements from soil to plant. As for the heavy metals, they can be arranged according to the amount absorbed from them as follows :

Cadmium > Nickel > Lead

Keywords: polluted soil, heavy metals, phytoremidation, ornamental plants.

Introduction

Problem of environmental pollution is one of the most serious problems facing man at present time, especially after industrial expansion , use of modern technologies, which is accompanied by serious pollution that leads to the deterioration of biosphere and causes a defect in it (Al-Ali, 2005).Pollution has become a concern for many countries due to industrial development and high population density (Mireles et al., 2012). Chyad et al. (2022) showed the presence of a high percentage of heavy metals such as Lead, Cadmium, Iron and Manganese in irrigation water due to discharge of water from factories and hospitals. Ben Al-Ani et al. (2016) showed an increasing pollution with heavy metals, especially Lead, at soil of battery factories in Al-Waziriyah has exceeded the internationally permitted limit. Soil is the environmental medium on which most living organisms live and is vulnerable to many pollutants, including toxic heavy metals.The soil represents the final outlet for materials that environment throws at it, both organic and mineral, so soil contaminated with heavy metals has health risks for humans, plants and other living organisms (Soodan et al., 2014). Response of plants to various heavy metals present in soil varies, as well as the toxicity of heavy metals according to plant variety, age, and stage of growth. It is also affected by physicochemical properties of soil, root secretions, concentration of heavy metals in soil, its type, solubility and uptake by plants (Dalcorso et al., 2013). Al-Juboury and Abdul-Hameed (2019) show that water pollution with heavy metals is one of most important environmental problems across the world. Naser (2017) showed that irrigation with water contaminated with heavy metals leads to accumulation of these elements in soil and makes it polluted. These items arise from natural activities or human-made through industrial and agricultural practices without proper control of its emission and discharge to surrounding areas that result in water and soil pollution. Fadhel and Abdulhussein (2022) indicated an increase in cadmium accumulation on roadsides as a result of car exhausts and agricultural sites due to the addition of chemical fertilizers to it. Phytoremidation technology is a set of processes conducted by plants or soil microorganisms to absorb toxic heavy metals from soil and water.It is an excellent technique for removing pollutants, with low cost and high efficiency compared to other chemical methods, and environmentally friendly, where it removes or reduces the harmful effect of pollutants with least undesirable by-products (Goel et al., 2009). World is looking forward to using phytoremediation technology to clean polluted sites, groundwater and polluted soil as an environmentally friendly technology.It is excelled on other engineering cleaning methods as it is economically and technically effective. Plant treatment is a modern technology that enables higher plants to clean the polluted environment. Al-Salman and Ibrahim (2021) showed the possibility of using phytoremidation technology to treat soils contaminated with heavy metals such as Lead and Cadmium using eucalyptus seedlings.Zaki and Rida (2020) explained that the oleander plant has the ability and high efficiency in reclaiming soils contaminated with heavy metals such as Copper. Abdel Karim et, al. (2022) showed when they used Canna Indica plant in technique of phytoremidation of soil contaminated with some heavy metals (Lead, Copper and Cobalt),this plant is one of plants that accumulate heavy metals above and has a high ability to absorb these elements from soil contaminated with it. Carissa, Catharanthus vinca, and Ficus elastica, or the so-called Ficus elastic, are among the evergreen ornamental plants. Research aims to evaluate the efficiency of some ornamental plants in absorbing and accumulating Lead, Cadmium and Nickel from contaminated soil.

Materials and Methods

Calcareous soil with loam texture was contaminated with solutions of heavy metals Lead, Cadmium and Nickel, where it was added at concentrations (0, 100 and 200) for Lead, (0, 10 and 15) for Cadmium and (0, 50 and 100) mg L^{-1} for Nickel of one of its salts (sulfates of these elements) with a volume of water within field capacity of soil, it was left for a week for equilibrium while maintaining the moisture content of soil by gravimetric method. It was filled with contaminated soil with a capacity of 20 kg and tamped several times to obtain a bulk density close to field soil. Seedlings of young Ficus elastica, Catharanthus vinca and carisia (one-year-age) were planted at rate of a pot $plant^{-1}$, fertilized with N, P, and K fertilizers according to fertilizer's recommendation. (Fertilization by spraying $5gL^{-1}$ of a solution containing the compound fertilizer NPK in a ratio of 20:20:20 twice per season and with a time difference of 20 days between two branches (Al-Falahi and Al-Janabi, 2016). Irrigation was done with tap water after 35% of available water was depleted.

Table 1. Some chemical and physical properties of study soil before cultivation.

Characteristics	Units	Values
electrical conductivity EC 1:1	dS m^{-1}	0.8
pH 1:1	--------------------	7.25
available Nitrogen	mg.kg^{-1}	18.00
available Phosphorous		1.02
available Potassium		59.23
total Lead		12.63
total Cadmium		43.00
total Nickel		18.80
available Lead		0.28
available Cadmium		0.10
available Nickel		0.65
Organic matter (OM)	g.kg^{-1}	5.20

Carbonate minerals		g.kg^{-1}	295.20
dissolved Calcium		meq.L^{-1}	4.21
dissolved Magnesium			1.65
dissolved Sodium			1.45
dissolved Bicarbonate			0.60
dissolved Chlorde			15.20
Sand	soil separates	g.kg^{-1}	880
Silt			36
Clay			84

Results and discussion

Heavy metals in soil after end experiment.

1- Total Lead in soil.

Results in Table 2 indicated that there were highly significant differences between different treatments of one plant. Total Lead concentrations in soil planted with Ficus elastica plants were 2.68, 33.03, and 61.10 mg pb kg^{-1} soil for treatments T0, T1, and T2, respectively, while the concentrations were 2.02, 23.89, and 59.95 mg kg^{-1} of soil for Catharanthus vinca plant, and 2.45, 29.83, and 68.41 mg kg^{-1} of Carissa for treatments T0, T1, and T2, respectively. It is noted from results that highest concentrations were in soil cultivated with Carissa plants, where it amounted to 68.41 mg kg^{-1} for T2 treatment, followed by soil cultivated with Ficus elastica plants, which amounted to 61.10 mg Pb kg^{-1} soil, and finally soil cultivated with Catharanthus vinca plants, amounted to 59.95 mg Pb kg^{-1} soil. for same treatment, From this it turns out that most absorbing plants for element of Lead are Catharanthus vinca plant, then Ficus elastica and finally Carissa. It is also noted that total concentrations of Lead in soil increased with the increase in concentrations added to all plants, as the averages of total concentrations of Lead in soil were 2.38, 28.91, and 33.65 mg pb kg^{-1} soil for the treatments T0, T1, and T2 for all plants, respectively. This is consistent with what was indicated by Yobouet et al. (2010) and Odeh (2018), who showed that addition of Lead to soil increases its total concentration in soil, according to levels of addition.

Table 2. Total Lead (Pb) concentration in soil (mg kg^{-1} soil) planted with different plants for different treatments after end experiment.

Plants	Lead concentration			
	0 mg kg $^{-1}$ (T0)	100 mg kg $^{-1}$ (T1)	200 mg kg $^{-1}$ (T2)	Average
Ficus elastica	2.68	33.03	61.10	32.27
Catharanthus vinca	2.02	23.89	59.95	28.62
Carissa	2.45	29.83	68.41	33.56
LSD 5%	3.54**			2.04**
Average	2.38	28.91	63.15	
LSD 5%	3.54**			

2- Available Lead in soil.

Results in Table 3 indicated that there were significant differences between the different treatments of one plant. Available Lead concentrations in soil planted with Ficus elastica plants were 0.23, 16.30 and 20.31 mg pb kg $^{-1}$ soil for treatments T0, T1 and T2, respectively, while concentrations were 0.35, 17.08, and 21.90 mg kg $^{-1}$ of soil for Catharanthus vinca plant, 0.28, 16.75, and 20.86 mg kg $^{-1}$ of Carissa for T0, T1, and T2 treatments, respectively. Interaction between different factors showed that highest concentrations were in soil cultivated with Catharanthus vinca,as it yield 21.900 mg kg $^{-1}$ for T2 treatment, followed by soil cultivated with Carissa plants, it amounted to 20.86 mg Pb kg $^{-1}$ soil, and finally the soil cultivated with Ficus elastica plants amounted to 20.31 mg Pb kg $^{-1}$ soil for same treatment. From this it turns out that most Lead-absorbing plants are Carissa plant, then Ficus elastica, and finally Catharanthus vinca. The average Lead concentrations for different treatments were 12.28, 13.11 and 12.63 mg Pb kg $^{-1}$ soil for Ficus elastica, Catharanthus vinca and Carissa plants, respectively. It is also noted that available concentrations of Lead in soil increased with increase in concentrations added to all plants, as the averages of available concentrations of Lead in soil were 0.28, 16.71 and 21.02 mg pb kg $^{-1}$ soil for T0, T1 and T2 treatments for all plants, respectively. This is consistent with what was indicated by Yobouet et al. (2010) and Odeh (2018), who showed that addition of Lead to soil increases its available concentration in soil, according to levels of addition.

Table 3. Concentration of available Lead in soil (mg kg^{-1} soil) planted with different plants for different treatments after end of experiment.

Plants	Lead concentration			
	0 mg kg^{-1} (T0)	100 mg kg^{-1} (T1)	200 mg kg^{-1} (T2)	Average
Ficus elastica	0.23	16.30	20.31	12.28
Catharanthus vinca	0.35	17.08	21.90	13.11
Carissa	0.28	16.75	20.86	12.63
LSD 5%	NS			NS
Average	0.28	16.71	21.02	
LSD 5%	2.49**			

3- Total Cadmium in soil

Results in Table 4, indicated that there were highly significant differences between different treatments of one plant. Total Cadmium concentrations in soil planted with Ficus elastica plants were 0.002, 1.588, and 3.190 mg Cd kg^{-1} soil for T0, T1, and T2 treatments, respectively.

Table 4. The concentration of total Cadmium (Cd) in soil (mg kg^{-1} soil) planted with different plants for different treatments after end of experiment.

Plants	Cadmium concentration			
	0 mg kg^{-1} (T0)	100 mg kg^{-1} (T1)	200 mg kg^{-1} (T2)	Average
Ficus elastica	0.002	1.588	3.190	1.593
Catharanthus vinca	0.001	1.058	1.968	1.009
Carissa	0.001	1.338	2.638	1.326
LSD 5%	0.449*			0.260**
Average	0.001	1.328	2.599	

LSD 5%	**0.449****	

Whereas concentrations were 0.001, 1.058 and 1.968 mg kg^{-1} of soil for Catharanthus vinca plant, and 0.001, 1.388 and 2.368 mg kg^{-1} of Carissa for T0, T1 and T2 treatments, respectively. Highest concentrations were in the soil cultivated with Chinese rubber plants, with a yield of 3.190 mg kg^{-1} for T2 treatment. Concentrations were 0.001, 1.058 and 1.968 mg kg^{-1} of soil for Catharanthus vinca plant, and 0.001, 1.388 and 2.368 mg kg^{-1} of Carissa for T0, T1 and T2 treatments, respectively . Highest concentrations were in soil cultivated with Ficus elastica plants, with a yield of 3.190 mg kg^{-1} for treatment T2.It is also noted a high significant increase in the concentrations of Cadmium in soil with increase in concentrations added to all plants, where average concentrations of Cadmium in soil were 0.001, 1.328 and 2.599 mg Cd kg^{-1} soil for T0, T1 and T2 treatments for all plants, respectively.

4 - Available Cadmium in soil.

Results in Table 5 indicated that there were significant differences between different treatments of one plant. Concentrations of available Cadmium in soil cultivated with Ficus elastica plants were 0.0012, 0.0140, and 0.0320 mg Cd kg^{-1} soil for treatments T0, T1, and T2, respectively. Whereas, concentrations were 0.003, 0.0015 and 0.0336 mg kg^{-1} of soil for Catharanthus vinca plant, and 0.0031, 0.0013 and 0.0640 mg kg^{-1} of Carissa for T0, T1 and T2 treatments, respectively.

Table 5. Concentration of available Cadmium in soil (mg kg^{-1} soil) planted with different plants for different treatments after end of experiment

Plants	**Cadmium concentration**			
	0 mg kg^{-1} (T0)	**100 mg kg^{-1} (T1)**	**200 mg kg^{-1} (T2)**	**Average**
Ficus elastica	**0.001**	**0.014**	**0.032**	**0.015**
Catharanthus vinca	**0.003**	**0.001**	**0.033**	**0.012**
Carissa	**0.003**	**0.001**	**0.064**	**0.022**
LSD 5%	**0.005****			**0.003****
Average	**0.002**	**0.005**	**0.043**	
LSD 5%	**0.005****			

As for effect of different treatments, we note that highest concentrations were in soil cultivated with Carissa plants, as it amounted to 0.064 mg kg^{-1} for T2 treatment, followed by soil cultivated with Catharanthus vinca, which amounted to 0.033 mg Cd kg^{-1} soil, and finally soil cultivated with Ficus elastica plants amounted to 0.032 mg Cd kg^{-1} soil for same treatment. From this it turns out that most absorbing plants of Cadmium is Ficus elastica plant, followed by Catharanthus vinca and finally Carissa , where average concentrations of Cadmium for different treatments were 0.015, 0.012 and 0.022 mg Cd kg^{-1} soil for Ficus elastica plants, Catharanthus vinca and Carissa . Soil cultivated with Carissa plants differed highly significantly from the Ficus elastica plants and Catharanthus vinca, while there were no significant differences between average concentrations of available Cadmium in soil after end of experiment for the Ficus elastica plants and Catharanthus vinca, this indicates that Ficus elastica plant and Catharanthus vinca have a higher ability to absorb Cadmium from soil compared to Carissa plants.This is in line with what Mostafa et al (1996) pointed out, where they explained that increase in size and weight of root and vegetative system of plant and possibility of providing available elements in soil causes an increase in plant's ability to absorb and accumulate elements in plant tissues.It is noted that available concentrations of Cadmium in soil increased significantly with increase in concentrations added to all plants, where averages of available concentrations of Cadmium in soil were 0.002 and 0.005 and 0.043 mg Cd kg^{-1} soil for T0, T1, and T2 treatments for all plants successively, this is consistent with what Abdel Latif (2016) indicated, who showed that increase in concentrations of available Cadmium in soil after cultivation is directly proportional to amount of Cadmium added to soil before cultivation.

5 - Total Nickel in soil.

Results in Table 6 indicated that there were highly significant differences between different treatments of one plant. Total Nickel concentrations in soil planted with **Ficus elastica** plants were 1.22, 12.60, and 22.69 mg Ni kg^{-1} soil for T0, T1, and T2, treatments respectively. While concentrations were 0.95, 8.98 and 15.31 mg kg^{-1} soil for Catharanthus vinca plant , 1.11, 11.25 and 19.47 mg kg^{-1} soil for Carissa for T0, T1 and T2 treatments, respectively.It is noted from results that highest concentrations were in soil cultivated with Ficus elastica plants, as it amounted to 22.69 mg kg^{-1} for T2 treatment, followed by soil cultivated with Carissa plants, which amounted to 19.47 mg Ni kg^{-1} soil, and finally soil cultivated with Catharanthus vinca plants amounted to 15.31 mg Ni kg^{-1} soil for same treatment. Average Nickel concentrations for different treatments 12.17, 8.41 and 10.61 mg Ni kg^{-1} soil for Ficus elastica plants, Catharanthus vinca and Carissa, respectively. Soil cultivated with Catharanthus vinca differed highly significantly from Ficus elastica and Carissa plants, while there were no significant differences between mean total Nickel concentrations in soil after end of experiment for Ficus elastica and Carissa plants.

Table 6. Total Nickel concentration in soil (mg kg^{-1} soil) cultivated with plants different treatments for different treatments after end of experiment.

Plants	Nickel concentration			
	0 mg kg^{-1} (T0)	100 mg kg^{-1} (T1)	200 mg kg^{-1} (T2)	Average

Ficus elastica	**1.22**	**12.170**	**22.69**	**0.015**
Catharanthus vinca	**0.95**	**8.413**	**15.31**	**0.012**
Carissa	**1.11**	**10.610**	**19.47**	**0.022**
LSD 5%	**2.26****			**1.309****
Average	**1.09**	**10.94**	**19.15**	
LSD 5%	**2.26****			

This indicates that Catharanthus vinca has a higher capacity and higher efficiency in Nickel absorption of soil compared to Ficus elastica and Carissa plants.It is also noted that total concentrations of Nickel in soil increased with increase in added concentrations of all plants, as the average concentrations of Nickel in soil were 1.11, 10.25, and 19.15 mg Ni kg^{-1} soil for T0, T1, and T2 treatments for all plants, respectively.

6- Available Nickel in soil.

Results in Table 7 indicated that there were no significant differences between different treatments of one plant. Concentrations of available Nickel in soil cultivated with Ficus elastica plants were 0.12, 2.63, and 4.75 mg Ni kg^{-1} soil for T0, T1, and T2 treatments, respectively, while concentrations were 0.09, 1.64 and 5.01 mg kg^{-1} soil for Catharanthus vinca plant, 0.10, 1.85 and 5.41 mg kg^{-1} soil for Carissa for T0, T1 and T2 treatments, respectively.With regard to interaction between different factors, highest concentrations were in soil cultivated with Carissa plants, as it reached 5.41 mg kg^{-1} for treatment T2, followed by soil cultivated with Catharanthus vinca, which amounted to 5.01 mg Ni kg^{-1} soil, and finally soil cultivated with Ficus elastica plants amounted to 4.75 mg Ni kg^{-1} soil for same treatment. From this it turns out that most Nickel-absorbing plant is the Ficus elastica plant, followed by Catharanthus vinca and finally Carissa, where the average of Nickel concentrations for different treatments were 2.50, 2.24 and 2.45 mg Ni kg^{-1} soil for Ficus elastica plants, Catharanthus vinca and Carissa, and there were no significant differences

Table 7. Concentrations of available Nickel in soil (mg kg^{-1} soil) cultivated with different plants for different treatments after end of experiment.

Plants	**Nickel concentration**			
	0 mg kg^{-1} (T0)	**100 mg kg^{-1} (T1)**	**200 mg kg^{-1} (T2)**	**Average**
Ficus elastica	**0.12**	**2.50**	**4.75**	**0.015**
Catharanthus vinca	**0.09**	**2.24**	**5.01**	**0.012**

Carissa	**0.10**	**2.45**	**5.41**	**0.022**
LSD 5%	**NS**			**NS**
Average	**0.10**	**2.04**	**5.05**	
LSD 5%	**1.02****			

between average concentrations of available Nickel in soil after end of experiment for different plants, this indicates that Ficus elastica plants, Catharanthus vinca, and Carissa have ability to absorb Nickel from soil.The reason may be due to fact that plants have ability to absorb Nickel from soil in close quantities, because Nickel is one of micronutrients that plant needs.This is consistent with what Alpaslan and Gunes (2004) concluded, as they showed that nickel is one of basic elements in plant nutrition, which works to be absorbed from the soil by plants and when comparing concentrations of available Nickel in soil cultivated with Ficus elastica plants, Catharanthus vinca and Carissa, with global limits of Food, Agriculture and World Health Organization (WHO/FAO,2007) of 50 mg Ni.kg^{-1} soil,We find that it did not exceed critical limits. It is also noted that there is a significant increase in concentrations of available Nickel in soil with increase in concentrations added to all plants. Average of available concentrations of Nickel in soil were 0.103, 2.040, and 5.057 mg Ni kg^{-1} soil for T0, T1, and T2 treatments for all plants, respectively. This is consistent with what was indicated by Al-Shammari (2009), who indicated that the reason for increase in soil contamination with Nickel is due to addition of high concentrations of Nickel to soil before cultivation or contamination by residues of industrial areas and factories, which helps in increasing concentrations of available Nickel in soil.

Heavy metals in plants (leaves)

1 - Lead

Results in Table 8 indicated that there were significant differences between different treatments of one plant. Lead concentrations in stem of the Ficus elastica plant were 3.20, 28.06, and 51.98 mg pb kg^{-1} dry matter for T0, T1, and T2 treatments, respectively, while concentrations were 3.45, 32.12 and 59.18 mg kg^{-1} dry matter for Catharanthus vinca , 3.31, 29.61 and 56.60 mg kg^{-1} for Carissa for T0, T1 and T2 treatments, respectively. Results showed that highest concentrations were in leaves of Catharanthus vinca plant, as it reached 59.18 mg Pb kg^{-1} for T2 treatment, followed by leaves of Carissa plant amounting to 56.60 mg Pb kg^{-1} soil, and finally Ficus elastica plant amounted to 51.98 mg Pb kg^{-1} dry matter for same treatment.from this it turns out that most Lead-absorbing plants are Catharanthus vinca and Carissa , and finally Ficus elastica plant, where average of Lead concentrations in leaves for different treatments were 27.74, 31.58, and 29.84 mg Pb kg^{-1} dry matter for Ficus elastica, Catharanthus vinca, and Carissa, respectively. Concentrations of Lead in leaves of Ficus elastica plant were significantly different from those of Catharanthus vinca and Carissa, while there were no significant differences between mean concentrations of Lead in leaves of Catharanthus vinca and Carissa, this indicates that Catharanthus vinca and Carissa have a higher ability to absorb Lead from soil compared to Ficus elastica plant. It is noted that concentrations of Lead increased significantly in leaves with increase in added concentrations of all plants, where average concentrations of Lead in leaves were 3.32, 29.93, and 55.92 mg pb kg^{-1} soil for T0, T1, and T2 treatments for all plants, respectively. Increase in concentration of Lead absorbed by leaves is directly proportional to amount of available Lead in cultivated soil.

Table 8. Lead (Pb) concentrations in leaves (mg^{-1} kg dry matter) of different plants and for different treatments after end of experiment.

This is in line with what was stated by Garcia and others (2004), who showed that there is a direct

Plants	Lead concentration			
	0 mg kg $^{-1}$ (T0)	100 mg kg $^{-1}$ (T1)	200 mg kg $^{-1}$ (T2)	Average
Ficus elastica	3.20	27.74	51.98	0.015
Catharanthus vinca	3.45	31.58	59.18	0.012
Carissa	3.31	29.84	56.60	0.022
LSD 5%	2.88*			1.66**
Average	3.32	29.93	3.32	
LSD 5%	2.88**			

increase in concentration of Lead in leaves of plants with an increase in its concentration in medium in which plants grow. Concentrations of Lead in leaves of all plants exceeded the limits allowed internationally by WHO/FAO (2007).

2- Cadmium

Results in Table 9 indicate that there are significant differences between different treatments of one plant. Concentrations of Cadmium in leaves of the Ficus elastica plant were 0.003, 3.700 and 5.000 mg Cd kg^{-1} dry matter for T0, T1 and T2 treatments, respectively, while concentrations were 0.003, 3.940 and 5.680 mg kg^{-1} dry matter for Catharanthus vinca plant , 0.003, 3.830 and 5.210 mg kg^{-1} dry matter for Carissa plants for T0, T1 and T2 treatments, respectively.As for the effect of different treatments on concentrations of Cadmium, highest concentrations were in leaves of Catharanthus vinca plant, which amounted to 5.680 mg kg^{-1} for treatment T2, followed by leaves of the Carissa plant, which amounted to 5.210 mg Cd kg^{-1} soil, and finally Ficus elastica plant reached 5.000 mg Cd kg^{-1} dry matter. for the same treatment, It was found from this that most absorbing plants of the Cadmium are Catharanthus vinca and Carissa, and finally Ficus elastica plant, where the average concentrations of Cadmium in leaves for different treatments were 2.901, 3.208 and 3.014 mg Cd kg $^{-1}$ dry matter for Ficus elastica plants, Catharanthus vinca and

Carissa.There were no significant differences between mean concentrations of Cadmium in leaves of plants.

Table 9. Cadmium concentration in leaves (mg kg^{-1} dry matter) of plants different and for different treatments after end of experiment.

This indicates that all plants have similar absorption capacity of Cadmium from soil.It is noted that

Plants	Cadmium concentration			
	0 mg kg^{-1} (T0)	100 mg kg^{-1} (T1)	200 mg kg^{-1} (T2)	Average
Ficus elastica	0.003	3.700	5.000	0.015
Catharanthus vinca	0.003	3.940	5.680	0.012
Carissa	0.003	3.830	5.210	0.022
LSD 5%	NS			NS
Average	0.003	3.823	5.297	
LSD 5%	0.608**			

concentrations of Cadmium increased in leaves with increase in added concentrations of all plants, where the average concentrations of Cadmium in leaves reached 0.003, 3.823, and 5.297 mg Cd kg^{-1} soil for T0, T1, and T2 treatments for all plants, respectively.

3- Nickel

Results in Table 10 indicated that there were no significant differences between different treatments of one plant. Concentrations of Nickel in leaves of Ficus elastica plant were 2.61, 19.73, and 38.11 mg Ni kg^{-1} dry matter for treatments T0, T1, and T2, respectively, while concentrations were 1.500, 21.060 and 40.910 mg kg^{-1} dry matter for Catharanthus vinca , 2.63, 20.50 and 39.24 mg kg^{-1} for Carissa plants for treatments T0, T1 and T2, respectively. Highest concentrations were in leaves of the Catharanthus vinca plant, which amounted to 40.910 mg kg-1 for T2 treatment, followed by leaves of Carissa plant amounted to 39.240 mg Ni kg-1 soil, and finally the ficus elastica plant reached 38.110 mg Ni kg-1 dry matter for same treatment.From this it turns out that most Nickel-absorbing plants are Catharanthus vinca, Carissa , and finally ficus elastica plant. Average concentrations of Nickel in leaves for different treatments were 20,150, 21,157 and 20,790 mg Ni kg $^{-1}$ dry matter for ficus elastica plants, Catharanthus vinca and Carissa. There were no significant differences between average concentrations of Nickel in leaves all plants, this indicates that all plants have similar absorption capacity of Nickel from soil.

Table 10. The concentration of Nickel in leaves (mg kg^{-1} dry matter) of different plants and for different treatments after end of experiment.

Plants	Nickel concentration			
	0 mg kg^{-1} (T0)	100 mg kg^{-1} (T1)	200 mg kg^{-1} (T2)	Average
Ficus elastica	2.61	19.73	38.11	0.015
Catharanthus vinca	1.50	21.06	40.91	0.012
Carissa	2.63	20.50	39.24	0.022
LSD 5%	NS			NS
Average	2.24	20.43	39.42	
LSD 5%	3.12**			

It is noted that concentrations of Nickel in leaves increased with increase in added concentrations of all plants, as the average concentrations of Nickel in leaves were 2.247, 20.430, and 39.420 mg Ni kg^{-1} soil for treatments T0, T1, and T2 for all plants, respectively.

Increase in concentrations of Nickel in plant leaves is directly proportional to added and available concentrations of Nickel in soil. This is consistent with what was mentioned by Garcia et, al. (2004) who indicated that increase in heavy metals accumulated in leaves of plants is directly proportional to increase in concentrations of these elements in soil in which these plants live and grow. Nickel concentrations in leaves and for all plants did not exceed the limits allowed internationally by WHO/FAO (2007).

References

1-AL-Ani, N.H.; Al-Talib, B.K. and Suha, A.I. (2016). Evaluation of Radiological Activity Levels and the Radiation Doses of Soil of Babylon Batteries Plant in Waziriya. Iraqi Journal of Science, 57: 1B 414-422.

2- Abdel Karim,M,K;K,M,Naser;S,L, Assi. 2022 Use of phytoremidation technique in reclamation of soils contaminated with some heavy metals (C0, Cu, Pb) by cultivating Canna generalis plant. . International Journal of Health Sciences, 6(S8), 3896–3908.

3- Abdul Latif, Ali Akram. 2016. The effect of adding sludge on soil and plant contamination with lead and cadmium. Master Thesis. Al-Qasim Green University - College of Agriculture.

4- Al-Ali, Wadad. 2005. Environmental pollution (its concept, civilization, degrees and forms) in the Gulf Cooperation Council countries.

5-Al-Juboury M., and H. Abdul-Hameed. 2019. Using of activated carbon derived from agriculture waste coating by layered double hydroxide for Copper adsorption. Iraqi Journal of Agricultural Sciences. 50 (5):1446–54.

6- Al-Falahi, Thamer Hamid Rajah and Atheer Muhammad Ismail Al-Janabi. 2016. The effect of prasiolanide treatment and spraying with foliar fertilizer Agro leaf on some growth characteristics of local orange grafts. Diyala Journal of Agricultural Sciences. Volume (8) Issue (2): 28-40.

7-Black, C.A. 1965. Methods of soil analysis. Part 2. Chemical and microbilogical properties. Amer. Soc. Agron. Inc. Bublisher Madison. Wisconsin. U.S.A.

8- Chyad,A.A;A.M. Saeed and S.A. Alhendi. 2022. Determination of Heavy Metals in Irrigation Water, Soil, Paddy, and Produced Rice of Some Paddy Fields of Iraq. Iraqi Journal of Science, Vol. 63, No. 11, pp: 4637-4649.

9-Dalcorso ,G ; A.Manara and A.Furini.2013.An over view of heavy metal challenge in plants: from roots to shoots. Metallomics 5;1117-1132.

10-Fadhel,M.A. and F.M. Abdulhussein.2022. Accumulation Detection of Cadmium in some land-use soil of Baghdad city, Iraq. Iraqi Journal of Science, Vol. 63, No. 8, pp: 3570-3577.

11-Garcia ,G ; A. FaZ and M. Cunhe . 2004. performance of pip tatherum miliaceum (Smilo grass)in edaphic pb and Zn Phy toremediation over a short growth period .Int. Biodeter and Biodey 54:245-250

12-Goel, S.; J.A. Malik, and H. Nayyar. 2009. Molecular approach for phytoremediation of metal contaminated sites. Arch. Agron. Soil Sci. 55:451–475

13-Güneş , A ; M. Alpaslan and A . I.nal , 2004. Bitki besleme ve gübreleme. Ankara Üni. Zir. Fak. Yayın No: 1539.

14-Jackson ; M.L.1958.Soil chemical analysis .Prrentic- Hall.Inc.Engelwood.Cliffs N.J. Jones,J.Beton.2001. Labotory gaide for conducting soil test and plant analysis CRC Press LLC.

15-Mireles,F; J-I.Davila; J.L.Pinedo; E.Reyes ; R.J.Speakman and M.D.Glascovk.2012.Assessing urban soil pollution in the cities of Zacatecas and Guaetalupe,Mexico by instrumentsa ineutron activation analysis Microchem J.103:158-164.

16-Mostafa, M.M.; E.H. El-Haddad and M.A. Amer .1996. Effectiveness of foliar nutrition with some micro-elements of chrysanthemum plants. Alex. J. of Agric. Res., 42(1): 81-93.

17- Naser.K.M.2017.Effect of the Diyala River irrigation water in the accumulation of Cadmium and Lead in the soil and plant and some of the chemical Properties of the soil. Research Journal of Pharmaceutical,Biological and Chemical Sciences.8(4). p823.

18- Odeh, Marwan Mahmoud. 2018. The use of white radish and carrots in bioremediation in soil contaminated with some heavy metals. Master's thesis, College of Agriculture, University of Baghdad.

19-Page, E.R.; R.H. Miller, and D.R. Kenny, 1982. Methods of soil analysis, part 2,2nd ed. Agron.9.

20-Soodan, R.K ; Y.B.Pakade ; A.Nagpal and J.K.Katnoria.2014. Analytical techniques for estimation of heavy metals in soil ecosystem:Atabulated review.Talanta,http://dx.doi.org/10.1016/j.talanta.02-033.

21- Suhaib, Waleed Khalid Al-Salmani and Ibrahim Anwar Ibrahim. 2021. Botanical extraction of cadmium and lead from contaminated soil using eucalyptus seedlings. Iraqi Journal of Agricultural Sciences.52 (4): .827-810

22-WHO/FAO. 2007. Joint WHO/FAO. Food standard programme codex Alimentarius commission 13th session.

23-Yobouet Y. A ; K. Adouby ; A. Trokourey and B. Yao .2010. Cadmium, Copper, Lead and Zinc speciation in contaminated soils International Journal of Engineering Science and Technology Vol. 2(5): 802-812.

24- Zaki, Suhair Louay and Muhannad Jassim Muhammad Reda 2020. Phyto-treatment of copper-contaminated processed water using a local plant. Iraqi Journal of Agricultural Sciences. (6): (51) 1612 – 1601.

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