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THE EFFICIENCY OF NERIUM OLEANDER PLANT IN PHYTOREMEDIATION OF SOILS CONTAMINATED WITH LEAD AND CADMIUM

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ABSTRACT : The study included conducting a phytoremediation experiment by planting Nerium oleander. Two soils of different textures (silty clay, silty loam) were selected, aerobically dried and passed through a sieve with holes 4 mm in diameter and then filled into 15 kg plastic pots. These pots were filled with (10 kg) soil and the Water hyacinth waste represented by the dried Water hyacinth powder. Besides, the Water hyacinth compost manufactured by the Ministry of Agriculture in proportions (0%, 5%, 10%, 15%) mixed with the soil, as the Nerium oleander plant was planted on 1/ 9 / 2020. The total concentration of heavy metals in the soil has been estimated before and after the experiment. On the other hand, the shoot and roots of the plant were washed first with tap water, then with distilled water. Afterward, it was dried and ground to conduct a digestion process for the root and shoot of the plant to know the plant's ability to absorb heavy and polluting elements as a focus of phytoremediation. Thus, plant pollution standards, the Bioconcentration Factor BCF, the Bioaccumulation Coefficient BAC and the Translocation Factor TF were adopted. The results showed an increase in the concentrations of heavy metals under study in the roots and shoot of the Nerium oleander plant by increasing the levels of addition of both types of Water hyacinth waste, which was accompanied by an increase in the total concentration of the soil. It was also found that the BCF, BAC, and TF for the elements lead and cadmium of Nerium oleander are more than one, which indicates the plant efficiency in the phytoremediation of soils contaminated with these elements. The Nerium oleander plant accumulates these two elements. The results showed that the cadmium element is more mobile from the roots to the shoot inside the Nerium oleander plant, followed by the lead element.

Key words : Nerium oleander plant, soils, lead, cadmium.

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INTRODUCTION

Environmental pollution is the undesirable change in the chemical, physical and biological properties of soil, water and air and may cause damage to living organisms and facilities. Pollution is also defined as any direct or indirect change that occurs to any part of the environment as a result of the emission, sedimentation, and discharge of waste. Otherwise, materials in quantities affect the environment in a harmful way that threatens the safety of both plant and animal organisms of all kinds (Low *et al*, 2000 and Al-Hassan, 2019). Heavy elements such as lead and cadmium are among the most dangerous substances pollute soil, water and air. The soil is generally exposed to pollutants from several sources, including factory waste, vehicle exhaust, emissions from smokestacks of electric power generators, coal combustion and metal smelting (Awadh, 2013). The phytoremediation process is an inexpensive, economically, and environmentally friendly process. Certain types of plants can collect high concentrations of pollutants in their tissues without showing signs of toxicity. Such plants are successfully used to remove heavy elements from contaminated soils, and nearly 400 species belonging to 45 families are called accumulators plants. These plants are characterized by the ratio of the element accumulation in the shoot to the root greater than one; in other non-accumulators plants, the ratio is less than one (Bennett *et al*, 2003 and Al-Wahaibi, 2007). The accumulator's plants that are used in phytoremediation have a high ability to absorb heavy elements or extract them inside the roots and have a remarkable ability to accumulate and have a high growth rate. Plus, they can form a high-weight live mass and transfer heavy elements to the upper parts represented by the stem and leaves (Mahmood, 2010). The origin of the word reclamation or phytoremediation goes back to two syllables, the first syllable expresses the plant and is taken from the Greek word (Phyto) and the second is (remedium), which means the treatment or cleaning. Phytoremediation can be defined as an on-site remedial strategy that uses plants and their associated microbes and agricultural techniques to remove, contain, or render harmless environmental pollutants. It is also called green plant technology to facilitate the removal of pollutants from the soil environment using plants (Gunther *et al*, 2000; Helmisaari *et al*, 2007; Pandy *et al*, 2016). This technique can be applied to organic or mineral pollutants in soil, water, and air. Therefore, the current study aims to know the extent of the ability and efficiency of the Nerium oleander plant in treating and reclaiming soils contaminated with lead and cadmium. Following approved international standards represented by the Bioconcentration Factor BCF, the Bioaccumulation Coefficient BAC, and the Translocation Factor TF.

METHOD OF WORK

Two types of water hyacinth waste were selected: the decomposed, represented by the compost produced by the Ministry of Agriculture and the live Water hyacinth plant, where the live Water hyacinth plant was selected and collected. The plant samples were taken and washed well with tap water, then dried aerobically using an electric oven at a temperature of 70°C for 48 hours. Then they were ground with a stainless electric grinder and passed through a sieve with (0.5-1) mm holes diameter. The two species of Water hyacinth waste were analyzed after digestion, using concentrated acids according to the method described by Jones *et al* (2001) and shown in Table 1.

Table 1 : Chemical characteristics of the two species of Water hyacinth.

Property	Water hyacinth compost	Dried Water hyacinth	Unit
PH	7.11	6.16	—
5:1 EC	9.07	13.86	$ds.m^{-1}$
N	28.30	14.15	$mg.g^{-1}$
P	5.10	1.81	
K	4.70	22.48	
Pb^{+2}	414.70	685.92	$mg.kg^{-1}$
Cd^{+2}	70.30	14.90	
C/N	19.26	24.98	—

As two soil sites were selected, soil samples were taken at a depth of (0-30) cm from Al-Diwaniyah Governorate. The first site (S1): Al-Furat neighborhood, about 700 m from the electric power station and 5 m from the main street. Conversely, the second site (S2): agricultural land from Al-Nouriah area in Al-Diwaniyah Governorate. The physical and chemical analyzes required for the soils under study and shown in Table 2 were carried out according to (Day *et al*, 1965 and Page *et al*, 1982). The total heavy metal concentration (lead, cadmium) was also estimated using the method described by Jones (2001) before and after the end of the experiment.

A phytoremediation experiment was carried out by cultivating Nerium oleander, where the soil was air-dried and passed through a sieve with holes diameter of 4 mm and then packed in plastic pots with a capacity of 15 kg. It was filled with (10 kg) soil, and the Water hyacinth waste was added to it in proportions (0%, 5%, 10%, 15%) mixed with the soil. The Nerium oleander plant was planted on 1/9/2020 and the required quantities of irrigation water were added to reach the limits of field capacity. Irrigation was carried out with tap water according to the gravimetric method, fertilizers were added according to the fertilizer recommendation, and a pesticide (Acetamiprid 20%) was used to control aphids. The total concentration of heavy elements (Pb and Cd) in the soil was then estimated after the end of the experiment on 1/6/2021. The shoot and roots of the plant were washed first with tap water and then with distilled water. Then, dried and ground to conduct a digestion process for the root and shoot of the plant to identify the plant ability to absorb heavy and polluting elements as a focus of phytoremediation by adopting the following plant pollution parameters:

Bioconcentration factor (BCF)

The Bioconcentration factor (BCF) was estimated, which is used to determine the amount of heavy polluting element absorbed by the plant from the soil. It expresses the concentration of the element in the root to its total concentration in the soil according to the following equation (Yoon *et al*, 2006)

$$BCF = {[Metal]_{Root}} / {[Metal]_{Soil}} \quad (1)$$

Bioaccumulation Coefficient (BAC)

The Bioaccumulation Coefficient (BAC), which refers to the element concentration in the shoot, was estimated to its total concentration in the soil according to the following equation (Li *et al*, 2007)

Table 2 : Some chemical and physical characteristics of the study soil.

Property		Site S1	Site S2	Unit
Electrical conductivity EC 1:1		7.88	5.50	$ds.m^{-1}$
pH 1:1		7.51	8.20	——
Cation exchange capacity (CEC)		25.8	24.7	c mole c kg^{-1}
O.M . organic matter		7.30	7.06	$g.kg^{-1}$
Calcium Carbonate $CaCO_3$		271.6	244.5	
Dissolved positive ions	Calcium Ca^{+2}	18.50	7.36	Meq/L
	Magnesium Mg^{+2}	24.50	18.47	
	Potassium K^{+}	2.16	2.534	
	Sodium Na^{+}	13.32	7.625	
Dissolved negative ions	Carbonate CO^{-3}	Nil	Nil	
	Bicarbonate HCO^{-3}	3.20	3.60	
	Sulfate SO_4^{-2}	4.90	4.990	
	Chlorine CL^{-1}	19.08	12.02	
Available elements	Nitrogen	15.68	20.58	$mg.kg^{-1}$soil
	Phosphorous P	2.5	2.78	
	Potassium K	166.01	137.60	
Heavy elements	Total lead Pb^{+2}	159.00	152.00	
	Total cadmium Cd^{+2}	4.04	2.04	
Soil Separators	Sand	135.00	296.00	$g.kg^{-1}$soil
	Silt	455.00	520.00	
	Clay	410.00	184.00	
Texture		Silty clay	Silty loam	
Bulk density		1.42	1.31	$Mg.m^{-3}$
Particle density		2.63	2.66	
Moisture content at field capacity		0.342	0.312	$cm^3.cm^{-3}$

$$BAC = \frac{[Metal]_{Shoot}}{[Metal]_{Soil}} \qquad (2)$$

Translocation factor (TF)

The Translocation factor (TF), which expresses the transfer of the heavy pollutant element from the root to the shoot was estimated according to the equation of Marchiol *et al* (2004):

$$TF = \frac{[Metal]_{Shoot}}{[Metal]_{Root}} \qquad (3)$$

Statistical analysis

The results were statistically analyzed after implementing a factorial experiment according to a Complete Randomized Design (CRD) with three replications and the averages of the treatments were compared with the Least Significant Difference (LSD) test at a probability level of 5% using the GenStat .V.12.1 program.

RESULTS AND DISCUSSION

Heavy elements in the soil after the end of the biological experiment

Table 3 indicates the total lead concentration in the study soils after the end of the biological experiment, which lasted about nine months, represented by the cultivation of Nerium oleander. The results showed significant differences in the average concentrations of the total lead element between the soils treated with dried Water hyacinth powder and Water hyacinth compost by increasing the levels of addition. The highest lead concentration was recorded at the level of addition of 15% of the dried Water hyacinth powder for each soil S1 and S2, reaching 151.46 and 99.48 $mg.kg^{-1}$. In comparison with the addition levels of Water hyacinth compost, it

Table 3 : Total lead concentration in soils understudy after the end of the biological experiment ($mg.kg^{-1}$).

Soil	Waste type	Waste addition percentage %				Soil * Waste type
		0	5	10	15	
S1	Dried Water hyacinth	69.56	80.30	87.50	151.46	97.21
	Water hyacinth compost	69.56	72.34	78.35	132.50	88.19
S2	Dried Water hyacinth	54.37	77.59	84.34	99.47	78.94
	Water hyacinth compost	54.37	75.88	82.58	87.04	74.97
LSD soil = Waste * addition		0.95				0.48
Soil * Addition percentage						
Soil		0	5	10	15	Soil averages
Soil 1		69.56	76.32	82.93	141.98	92.70
Soil 2		54.37	76.74	83.46	93.26	76.96
LSD soil*addition		0.67				0.34
Waste Type * Addition Percentage						
Waste		0	5	10	15	Waste averages
Dried Water hyacinth		61.97	78.95	85.92	125.47	88.07
Water hyacinth compost		61.97	74.11	80.47	109.77	81.58
LSD Waste *addition		0.67				0.34
Addition percentage averages		61.97	76.53	83.19	117.62	
LSD Addition Percentage		0.48				

had lead concentrations of 132.50 and 87.04 $mg.kg^{-1}$ for each of S1 and S2, respectively. The statistical analysis results indicate significant differences for the triple interaction between soil type, additional levels, and waste type.

The reason for these differences may be attributed to the original content of lead in Water hyacinth powder, and soil S1 is more significant than it is in compost and S2 in Tables 1 and 2. It is evident from these results that there is an immediate increase in the concentrations of the lead elements by increasing the levels of addition from both species of Water hyacinth waste and for both soils. The statistical analysis results also showed that there were significant differences in the bilateral interaction between the type of waste and the levels of addition. Since the highest concentration of total lead was recorded at the level of addition 15% of Water hyacinth powder, reaching 125.47 $mg.kg^{-1}$ compared with the level of addition 15% of the Water hyacinth compost, which amounted to 109.77 $mg.kg^{-1}$. It was also observed from the results of the statistical analysis that there are significant differences for the interaction between the soil and the levels of addition, as soil S1 was significantly superior, and the lead concentration rate in it reached 92.70 $mg.kg^{-1}$ compared with its average concentration in soil S2 of 76.96 due to an increase in its original concentration in soil S1 compared to S2, which reflected on the results harmoniously. When comparing the total concentrations of lead for the study soils with the International Health and Food Organization determinants, it can find that they are within the permissible limits of 100 $mg.kg^{-1}$. Except for the addition level, 15% of the two types of Water hyacinth waste in soil S1 amounted to 141.91 $mg.kg^{-1}$. However, the study soils were before planting classified as lead-contaminated soils for exceeding the determinants of the International Health and Food Organization. This indicates the transfer of lead element from the soil to the plant, which raises fears of applying the Water hyacinth compost, which contains high concentrations of heavy elements, especially the element lead, to move it through the food chain and this was indicated by Singh (2005) and Mashavira *et al* (2015).

Lead and cadmium are among the elements that can be absorbed and transferred to the plant and enter the food chain. Suppose the Water hyacinth compost is used without specific considerations. In that case, the heavy elements accumulated in it can poison crops, posing a potential danger to human health even at low concentrations. Table 4 indicates the total cadmium concentration, although there were no significant differences due to the triple interaction between soil type, levels of addition and type of waste. But there was an immediate increase in total cadmium concentration by increasing the addition levels from Water hyacinth waste.

Table 4 : Total cadmium concentration in the study soils after the end of the biological experiment (mg.kg^{-1}).

Soil	Waste type	Waste addition percentage %				Soil * Waste type
		0	5	10	15	
S1	Dried Water hyacinth	1.02	1.50	1.80	2.67	1.75
	Water hyacinth compost	1.02	1.45	2.01	2.82	1.83
S2	Dried Water hyacinth	0.98	1.04	1.11	1.26	1.10
	Water hyacinth compost	0.98	1.13	1.21	1.31	1.16
LSD soil= Waste *addition		N.S				N.S
Soil * Addition Percentage						
Soil		0	5	10	15	Soil averages
Soil 1		1.02	1.48	1.91	2.75	1.79
Soil 2		0.98	1.09	1.16	1.29	1.13
LSD soil*addition		0.11				0.05
Waste Type * Addition Percentage						
Waste		0	5	10	15	Waste averages
Dried Water hyacinth		1.00	1.27	1.46	1.97	1.42
Water hyacinth compost		1.00	1.29	1.61	2.07	1.49
LSD Waste *addition		N.S				0.05
Addition percentage averages		1.00	1.28	1.53	2.02	
LSD Addition Percentage		0.07				

Table 5 : Lead concentration in the roots of Nerium oleander plant after the end of the biological experiment (mg.kg^{-1} dry matter).

Soil	Waste type	Waste addition percentage %				Soil * Waste type
		0	5	10	15	
S1	Dried Water hyacinth	157.40	158.95	187.23	190.78	173.59
	Water hyacinth compost	157.40	164.25	166.55	174.78	165.75
S2	Dried Water hyacinth	146.23	164.78	175.68	179.83	166.63
	Water hyacinth compost	146.23	151.95	166.58	170.45	158.80
LSD soil= Waste *addition		0.08				N.S
Soil * Addition Percentage						
Soil		0	5	10	15	Soil averages
Soil 1		157.40	161.60	176.89	182.78	169.67
Soil 2		146.23	158.37	171.13	175.14	162.72
LSD soil*addition		0.05				0.03
Waste Type * Addition Percentage						
Waste		0	5	10	15	Waste averages
Dried Water hyacinth		151.82	161.87	181.46	185.31	170.11
Water hyacinth compost		151.82	158.10	166.57	172.62	162.27
LSD Waste *addition		0.05				0.03
Addition percentage averages		151.82	159.98	174.01	178.96	
LSD Addition Percentage		0.04				

The highest concentration was recorded at the level of addition 15% of the two types of Water hyacinth waste; it reached 2.02 mg.kg^{-1}, compared to the control treatment, which amounted to 1.00 mg.kg^{-1}. This increase is attributed to the original content of those residues from cadmium, which was consensually reflected in the results.

Table 6 : Cadmium concentration in the roots of Nerium oleander plant after the end of the biological experiment (mg.kg^{-1} dry matter).

Soil	**Waste type**	**Waste addition percentage %**				**Soil * Waste type**
		0	**5**	**10**	**15**	
S1	Dried Water hyacinth	2.20	2.46	2.80	3.23	2.67
	Water hyacinth compost	2.20	2.67	3.03	3.07	2.74
S2	Dried Water hyacinth	2.10	2.19	2.43	3.61	2.58
	Water hyacinth compost	2.10	2.35	2.41	3.88	2.69
LSD soil= Waste *addition		0.17				N.S
Soil * Addition Percentage						
Soil		0	5	10	15	Soil averages
Soil 1		2.20	2.57	2.92	3.15	2.71
Soil 2		2.10	2.27	2.42	3.75	2.63
LSD soil*addition		0.12				0.06
Waste Type * Addition Percentage						
Waste		0	5	10	15	Waste averages
Dried Water hyacinth		2.15	2.33	2.62	3.42	2.63
Water hyacinth compost		2.15	2.51	2.72	3.48	2.71
LSD Waste *addition		N.S				0.06
Addition percentage averages		2.15	2.42	2.67	3.45	
LSD Addition Percentage		0.08				

The statistical analysis results showed that there were no significant differences for the bilateral interaction between the type of waste and the levels of addition. While there were significant differences for the interaction between soil type and levels of addition, as soil S1 significantly exceeded, reaching its total concentration at the level of addition 15% of 2.75 mg.kg^{-1} compared to soil S_2 where its concentration at the level of addition 15% of Water hyacinth waste 1.29 mg.kg^{-1}. This is due to its high original concentration in soil S1 compared to soil S2, as shown in Table 2. However, when comparing these concentrations with the determinants of the World Health and Food Organization (WHO/FAO, 2007), it can find that it is below the critical limit (3.00) mg.kg^{-1}. A significant decrease in the total concentration of cadmium was noted, which indicates the transferability of cadmium from the soil to the plant has reached below the critical limits set by the WHO. Thus, it raises the fear of applying Water hyacinth waste as compost in fertilizing the soil for its transmission through the food chain. These results are consistent with what was indicated by Walter *et al* (2006) to prevent the use of compost containing heavy non-degradable elements in fertilizing agricultural lands.

Heavy elements in Nerium oleander

Heavy elements in plant roots

The results of Table 5 generally indicate a high concentration of the lead element in the roots with an increase in the addition levels from both types of Water hyacinth waste in both soils. The highest concentration was recorded at the level of addition 15% of the Water hyacinth waste so that the concentration of lead in the roots of Nerium oleander plant reached 178.96 mg Pb.kg^{-1} dry matter compared to the level of addition 0% of waste, which had a concentration of 151.82 mg Pb.kg^{-1} dry matter in the roots. The statistical analysis results indicate significant differences in the interaction between the type of waste and the levels of addition, as the highest concentration was recorded at the level of addition 15% of dried Water hyacinth powder. Bringing its concentration in the plant roots reached 185.31 mg.kg^{-1} compared with the level of addition 15% of Water hyacinth compost, which is 172.62 mg Pb.kg^{-1} dry matter.

The statistical analysis results also indicate significant differences for the bilateral interaction between soil type and levels of addition, as the highest concentration was recorded at the level of addition 15% of Water hyacinth waste at soil S1. Therefore, the concentration of lead in the roots of the Nerium oleander plant reached 182.78 mg Pb.kg^{-1} dry matter compared with its concentration in the roots of the Nerium oleander plant grown in soil S2 of 175.14 mg Pb.kg^{-1} dry matter. This is an expected result for the content of the Water hyacinth waste and soil S1 of lead with high concentrations. In contrast, the

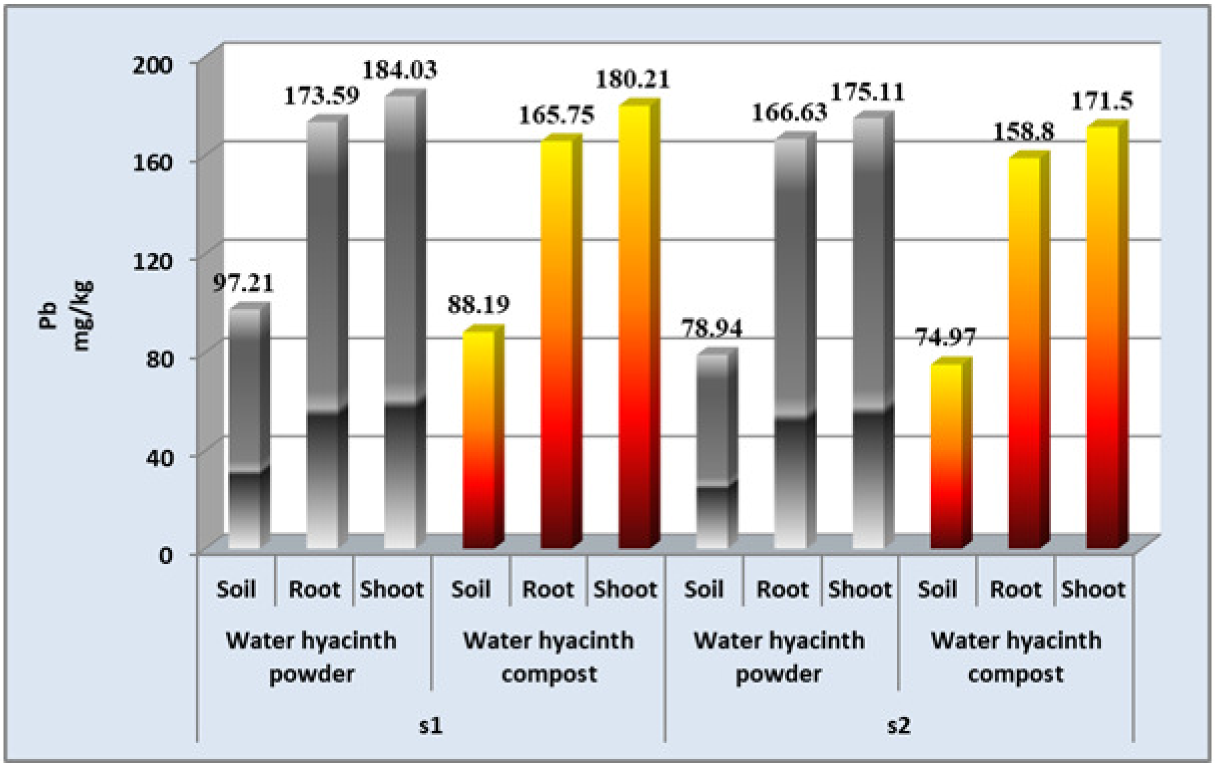

Fig. 1 : Average values of lead in the study soil and Nerium oleander plant parts (mg.kg^{-1}).

statistical analysis results show that there are no significant differences in the interaction between the type of soil and the type of waste. Table 5 shows a significant increase in the concentrations of a lead element with an increase in the levels of addition from Water hyacinth waste, as the level of addition 15% of dried Water hyacinth powder in soil S1 and S2 significantly exceeded. They are bringing its concentration in the roots to 190.73 and 179.83 mg Pb.kg^{-1} dry matter, respectively, followed by the level of addition 10% of Water hyacinth powder to reach 187.23 and 175.68 mg Pb.kg^{-1} dry matter in the roots of plants grown in soil S1 and S2. Furthermore, the concentrations of lead in the roots have exceeded the critical limits of 5 mg.kg^{-1} dry matter according to the World Food and Health Organization determinants. The increase in the concentration of lead in the roots of the Nerium oleander plant may be attributed to the increase in the levels of addition from the Water hyacinth waste. It was reflected in its concentration in the plant, which indicates the transfer and absorption of lead by the roots of the Nerium oleander plant.

These results are consistent with Odah (2018), Farhan and Al Jubouri (2019) findings that the source of pollution has a significant impact on the concentration of lead in plants. Besides that, its concentration in the root increases due to the increase in lead concentrations added to the soil before planting. Thus, the Nerium oleander plant is one of the Hyper accumulator's plants that can be used in the phytoremediation of lead element in a good manner due to its ability to accumulate lead element in its tissues and in high concentrations that exceeded its concentrations in the soil. These results are consistent with what Schnoor *et al* (2007) indicated about the ability of some plants to accumulate heavy elements in their bodies, whether in the root or shoot, with concentrations exceeding their concentrations in the soil. Table 6 shows the concentration of cadmium in the roots of Nerium oleander plant, as the results indicate that the concentration of cadmium in the comparison treatment is less than it is in the rest of the levels of addition of Water hyacinth waste, it was relatively high at the level of addition 10% and 15% of the two types of Water hyacinth waste for both soils, where there is a significant and clear increase with the increase in the levels of addition. Moreover, the level of addition 15% of the Water hyacinth waste exceeded, to record the highest concentration of 3.45 mg Cd.kg^{-1} dry matter, followed by the 10% and 5%, as its concentration in the roots of the plant reached 2.67 and 2.33 mg Cd.kg^{-1} dry matter, respectively, compared to the level of addition 0% of 2.15 mg Cd.kg^{-1} dry matter. This increase is directly proportional to the increase in the levels of addition. These results are consistent with what Lacatusu (1998) indicated that increasing the concentration of the heavy elements in the soil affects its concentration in the growing plant. Organic fertilization has a role in increasing the

Table 7 : Concentration of Pb^{+2} in the shoot of Nerium oleander plant after the end of the biological experiment ($mg.kg^{-1}$ dry matter).

Soil	Waste type	Waste addition percentage %				Soil * Waste type
		0	5	10	15	
S1	Dried Water hyacinth	165.25	185.28	190.90	194.70	184.03
	Water hyacinth compost	165.25	180.3	185.15	190.15	180.21
S2	Dried Water hyacinth	160.38	171.45	177.33	191.28	175.11
	Water hyacinth compost	160.38	163.93	172.7	188.98	171.50
LSD soil= Waste *addition		0.22				0.11
Soil * Addition Percentage						
Soil		0	5	10	15	Soil averages
Soil 1		165.25	182.79	188.03	192.43	182.12
Soil 2		160.38	167.69	175.02	190.13	173.30
LSD soil*addition		0.16				0.08
Waste Type * Addition Percentage						
Waste		0	5	10	15	Waste averages
Dried Water hyacinth		162.82	178.37	184.12	192.99	179.57
Water hyacinth compost		162.82	172.12	178.93	189.57	175.86
LSD Waste *addition		0.16				0.08
Addition percentage averages		162.82	175.24	181.52	191.28	
LSD Addition Percentage		0.11				

concentration of heavy elements in the plant either directly through the content of the fertilizer used from these elements or indirectly by reducing the degree of soil interaction. Accordingly, these heavy elements become ready to be absorbed by the plant, which indicates that the source of this increase is the addition of both types of waste and for both soils, especially at the level of addition 15%. It was observed that cadmium concentrations in the roots of the Nerium oleander plant and at all levels of addition of Water hyacinth waste of both types had exceeded the critical limits of the World Health and Food Organization of 0.20 mg $Cd.kg^{-1}$ dry matter. This is due to the high concentration of cadmium in Water hyacinth waste added to the study soil before planting, as shown in Table 1. The statistical analysis results showed no significant differences for the bilateral interaction between the type of waste and the levels of addition. The highest concentration was recorded at the level of addition 15% of Water hyacinth compost and dried Water hyacinth powder to reach a concentration of 3.48 and 3.42 mg $Cd.kg^{-1}$ dry matter, respectively. The statistical analysis results also show that there are significant differences in the bilateral interaction between soil type and levels of addition. However, soil S1 was significantly superior, so that the average concentration of cadmium in the plant roots reached 2.71 mg $Cd.kg^{-1}$ dry matter compared to the roots of Nerium oleander plant in soil S2, which reached 2.63 mg $Cd.kg^{-1}$ dry matter. This is due to its high total concentration in soil S1 before planting, which amounted to 04.04 $mg.kg^{-1}$, which affected its concentration in the plant compared to its concentration in soil S2 that amounted to 2.083 $mg.kg^{-1}$.

Heavy elements in the shoot

Table 7 shows the concentration of the lead element in the shoot of the Nerium oleander plant. However, the results indicate significant differences in the average concentration of the lead element in the shoot by increasing the levels of addition from the two types of Water hyacinth waste and for both soils. as it reached 191.28 mg $Pb.kg^{-1}$ dry matter at the level of addition 15 % of waste, while its average concentration in the control treatment was 162.82 mg $Pb.kg^{-1}$ dry matter. When comparing those concentrations with the World Health and Food Organization determinants, it can find that they have exceeded the critical limit of 5 mg $Pb.kg^{-1}$ dry matter. Whereas the nature of the interaction between the study factors had a significant effect, the statistical analysis results showed significant differences as a result of the interaction between the type of waste and levels of addition. Moreover, as the dried Water hyacinth powder significantly exceeded the level of addition 15%, the lead concentration in the shoot was 192.99 mg $Pb.kg^{-1}$ dry matter compared to the level of addition 15%

Table 8 : Concentration of Cd^{+2} in the shoot of Nerium oleander plant after the end of the biological experiment ($mg.kg^{-1}$ dry matter).

Soil	Waste type	Waste addition percentage %				Soil * Waste type
		0	5	10	15	
S1	Dried Water hyacinth	3.37	3.95	4.02	5.45	4.20
	Water hyacinth compost	3.37	4.25	4.49	6.29	4.60
S2	Dried Water hyacinth	3.07	3.76	4.30	4.83	3.99
	Water hyacinth compost	3.07	4.41	4.6	5.04	4.28
LSD soil= Waste *addition		0.13				0.06
Soil * Addition Percentage						
Soil		0	5	10	15	Soil averages
Soil 1		3.37	4.10	4.26	5.87	4.40
Soil 2		3.07	4.09	4.45	4.94	4.14
LSD soil*addition		0.09				0.05
Waste Type * Addition Percentage						
Waste		0	5	10	15	Waste averages
Dried Water hyacinth		3.22	3.86	4.16	5.14	4.09
Water hyacinth compost		3.22	4.33	4.55	5.67	4.44
LSD Waste *addition		0.09	0.05			
Addition percentage averages		3.22	4.09	4.35	5.40	
LSD Addition Percentage		0.06				

compost which is 189.57 mg $Pb.kg^{-1}$ dry matter. The statistical analysis results also showed significant differences in the bilateral interaction between soil type and levels of addition. Soil S1 was significantly superior, so that lead concentration in the shoot at the level of addition 10% and 15% of Water hyacinth waste reached 184.12 and 192.99 mg $Pb.kg^{-1}$ dry matter, respectively, compared with its concentration in the shoot of soil S2 at the level of addition 10% and 15% of Water hyacinth waste by 178.93 and 189.57 mg $Pb.kg^{-1}$ dry matter. Moreover, the statistical analysis results also showed significant differences for the triple interaction between the type of waste, levels of addition, and soil type. The dried Water hyacinth powder at the level of addition 15% in soil S1 and S2 exceeded, so that its concentration in the shoot reached 194.70 and 191.28 mg $Pb.kg^{-1}$ dry matter, respectively, compared with the level of addition 15% of compost which is 190.15 and 188.98 mg $Pb.kg^{-1}$ dry matter for each of the soil S1 and S2, respectively. The reason for these differences is attributed to the original content of lead in the dried Water hyacinth powder is higher than it is in the compost, which was harmoniously reflected on its concentration in the soil as well as the concentration of the lead element in soil S1 higher than in soil S2 before planting as shown in Tables 1 and 2.

This indicates the ability of the Nerium oleander plant to absorb lead from the soil through the roots and transfer it to the shoot. It is one of the accumulator's plants of this element, which allows it to be used in the phytoextraction technique, which is used to treat soils contaminated by plants by absorbing heavy elements by the roots and then accumulating them in the upper part of the plant. This is consistent with what Mesjasz *et al* (2004), Hamidouche (2014), Cristaldi *et al* (2017) indicated about the high ability of some plants to absorb and accumulate lead in their living tissues, reaching approximately 2,300 $mg.kg^{-1}$ dry matter, and at high concentrations that exceed their concentrations in the soil. This raises concerns about applying fertilizers containing high concentrations of heavy elements, especially the compost made from the Water hyacinth waste. Due to the ability of this plant to absorb heavy elements if the water environment in which it grew is polluted. So the percentage of heavy elements is high compared to other common organic fertilizers in the market. The use of these wastes should be based on special considerations regarding the type of waste collected, the type of soil to which it is added and the type of crops to be cultivated. Taking into account the levels of addition to avoiding the accumulation of heavy elements and soil pollution. This was indicated by Liao and Lian (2004), Wong and Selvam (2006) that the Water hyacinth plant could accumulate heavy metals in its tissues and pose a potential danger to animal and human health through the food chain. Table 8 shows the concentration of cadmium in the shoot of the Nerium oleander plant. In contrast, the results indicate an increase in cadmium concentration in the shoot with an increase in the addition level from Water hyacinth waste for both soils. The level of addition 15% of the two types of Water hyacinth waste achieved significant differences, bringing the average cadmium concentration in the shoot to 5.40 mg $Cd.kg^{-1}$ dry matter, compared with the level of addition 0% of the comparison treatment, which was 3.22 mg $Cd.kg^{-1}$ dry matter. The nature of the interaction between the study factors had a significant effect. The statistical analysis results showed significant differences in the bilateral interaction between the type of waste and the levels of addition. Since the level of addition 15% of Water hyacinth compost significantly exceeded to reach 5.67 mg $Cd.kg^{-1}$ dry matter compared with the level of addition 15% of dried Water hyacinth powder, which amounted to 5.14 mg $Cd.kg^{-1}$ dry matter.

The results also showed significant differences for the interaction between soil type and levels of addition, as soil S1 was significantly superior to reach its concentration at the level of addition 15% to 5.87 mg $Cd.kg^{-1}$ dry matter compared with soil S2, which amounted to 4.94 at the level of addition 15% of Water hyacinth waste. The results show that the Water hyacinth compost significantly increased the cadmium concentration in the shoot and for both soils by increasing the addition levels. Besides, the highest concentration was recorded at the level of addition 15% of compost in soil S1 and S2, which amounted to 6.29 and 5.04 mg $Cd.kg^{-1}$ dry matter, respectively. In comparison, the level of addition 15% of dried Water hyacinth powder amounting to 5.45 and 4.83 mg $Cd.kg^{-1}$ dry matter to each of the soil S1 and S2, respectively. The reason for the increase in the cadmium concentration in the shoot with the increase in the levels of addition from the Water hyacinth waste may be attributed to the content of those waste from cadmium, which in turn was reflected on its concentration in the soil. It also caused an increase in the total concentration of cadmium by increasing the level of addition, which led to an increase in its absorption by the plant and its accumulation in its tissues, as shown in Fig. 2.

This is consistent with what was stated by Aslam *et al* (2012) and Awdah (2018) that cadmium content in plants growing in soils contaminated with this element increased due to its absorption from the soil and its accumulation in plant tissues. Nerium oleander is one of the plants that can accumulate cadmium in the shoot and can be used in the process of plant reclamation of soils contaminated with this element in the technique of

Table 9 : The bioconcentration factor BCF of lead for Nerium oleander plant.

BCF- Pb					
Waste type	**Soil**	**Levels of addition**			
		0%	**5%**	**10%**	**15%**
Dried Water hyacinth	S1	2.26	1.98	2.14	1.26
	S2	2.69	2.12	2.08	1.80
Water hyacinth compost	S1	2.26	2.27	2.13	1.32
	S2	2.69	2.00	2.02	1.96

Table 10 : The bioconcentration factor BCF of cadmium for Nerium oleander plant.

BCF- Cd					
Waste type	**Soil**	**Levels of addition**			
		0%	**5%**	**10%**	**15%**
Dried Water hyacinth	S1	2.16	1.64	1.56	1.21
	S2	2.14	2.11	2.19	2.87
Water hyacinth compost	S1	2.16	1.84	1.51	1.09
	S2	2.14	2.08	1.99	2.96

Table 11 : The Bioaccumulation Coefficient BAC of lead in Nerium oleander plant.

BAC- Pb					
Waste type	**Soil**	**Levels of addition**			
		0%	**5%**	**10%**	**15%**
Dried Water hyacinth	S1	2.38	2.30	2.18	1.29
	S2	2.95	2.21	2.10	1.92
Water hyacinth compost	S1	2.38	2.49	2.36	1.44
	S2	2.95	2.16	2.09	2.17

Table 12 : The Bioaccumulation Coefficient (BAC) of cadmium in Nerium oleander plant.

BAC- Cd					
Waste type	**Soil**	**Levels of addition**			
		0%	**5%**	**10%**	**15%**
Dried Water hyacinth	S1	3.30	2.63	2.23	2.04
	S2	3.43	3.62	3.87	3.83
Water hyacinth compost	S1	3.30	2.93	2.23	2.23
	S2	3.13	3.90	3.89	3.84

phytoextraction. Iwegbue *et al* (2007) indicated that it mustn't apply Water hyacinth compost in agricultural lands to produce leaf crops due to the ability of Water hyacinth to absorb heavy elements. It raises concerns about the harmful environmental impact of applying Water hyacinth compost on agricultural lands. In addition, when comparing cadmium concentrations in the shoot with the World Health and Food Organization (WHO / FOW, 2007), it can find that they have exceeded the permissible limits of 0.2 mg $Cd.kg^{-1}$ dry matter.

Plant pollution parameters

Nerium oleander bioconcentration factor (BCF)

The bioconcentration factor (BCF) indicates the plant efficiency in extracting heavy metals from the soil and accumulating them in its tissues. This factor represents the relationship between the element concentration in the root and its soil concentration, and whenever its value increases, the plant is more suitable for phytoextraction (Blaylock *et al*, 1997; Yoon *et al*, 2006; Sajad *et al*, 2019). The results of Tables 9 and 10, in general, showed an increase in the BCF values, as they were more significant than one for all levels of addition, which indicates the occurrence of a translocation process for lead and cadmium from the soil to the root. This was indicated by Subhashini and Swamy (2013), Ansari *et al* (2015), that if the BCF is greater than one, this indicates the plant's ability to phytoextraction and it is called accumulators. Table 9 indicates the BCF of lead and the highest value was recorded at the comparison treatment 0% for soil S2, which was 2.69. This may be attributed to the density of the root compared to the rest of the addition levels of the same soil, as well as the decrease in the total lead concentration in the soil at the treatment 0%, which led to an increase in the value of the BCF at the comparison treatment. The high values of the BCF indicate the ability of the oleander plant to absorb lead and accumulate it in the root. The oleander plant is considered one of the good accumulators of the element lead. This was indicated by Azhar *et al* (2006) that lead accumulates mainly in the roots.

As for the bioconcentration factor of cadmium in Table 10, the highest value was recorded at the level of addition 15% of Water hyacinth compost and dried Water hyacinth powder of soil S2, which amounted to 2.96 and 2.87, respectively, followed by the level of addition 10% of dried Water hyacinth powder of soil S2, which amounted to 2.19. The results of the current study agree with the findings of Zaki (2020), which concluded that the oleander plant can be considered as an accumulator plant for cadmium, due to the high values of the BCF of more than 1, which indicates the efficiency of the oleander plant in the phytoremediation of soils contaminated with cadmium. This what Somaratne and Weerakoon (2012) indicated that the increase in the cadmium concentration in the root indicates the ability of the plant to absorb and transfer this element from the soil to the root and then transfer it to the different tissues of the plant.

Bioaccumulation Coefficient (BAC) of Nerium oleander

The BAC coefficient refers to the ratio between the concentration of the heavy elements in the shoot to its concentration in the soil. The results of Tables 11 and 12 shows the values of the BAC of oleander for lead and cadmium ranged between 1.29 -2.95 and 2.04 - 3.90, respectively. These results indicate an increase in the values of the BAC and this is consistent with what was indicated by Malayeri *et al* (2008) that plants with a BAC ranging from 1-10 are known as high-accumulation plants and that these plants are suitable for use in the phytoremediation of heavy metals.

Translocation factor TF for oleander

It is an indicator of the plant's ability to transfer the element from the roots to the shoot and plants that have TF and BAC greater than one are characterized as accumulator plants (Sun *et al*, 2008). The results of Table 13 show the TF of lead for oleander, which ranged between 1.01-1.17, as it was observed that all the values of the TF of lead for the oleander plant and for all levels of addition exceeded the value of one, which indicates the plant ability to transfer lead element from the root to the shoot.

These results are consistent with the findings of Saleh (2011) about the importance of the oleander plant as a vital accumulator of the lead element through its superiority in absorbing this element and its accumulation in the bark and leaves. The results of Table 14 show the

Table 13 : The translocation factor TF for lead in Nerium oleander plant.

TF- Pb					
Waste type	**Soil**	**Levels of addition**			
		0%	**5%**	**10%**	**15%**
Dried Water hyacinth	S1	1.05	1.17	1.02	1.02
	S2	1.10	1.04	1.01	1.06
Water hyacinth compost	S1	1.05	1.10	1.11	1.09
	S2	1.10	1.08	1.04	1.11

Table 14 : The translocation factor TF for cadmium in Nerium oleander plant.

TF- Cd					
Waste type	**Soil**	**Levels of addition**			
		0%	**5%**	**10%**	**15%**
Dried Water hyacinth	S1	1.53	1.61	1.44	1.69
	S2	1.46	1.72	1.77	1.34
Water hyacinth compost	S1	1.53	1.59	1.48	2.05
	S2	1.46	1.88	1.91	1.30

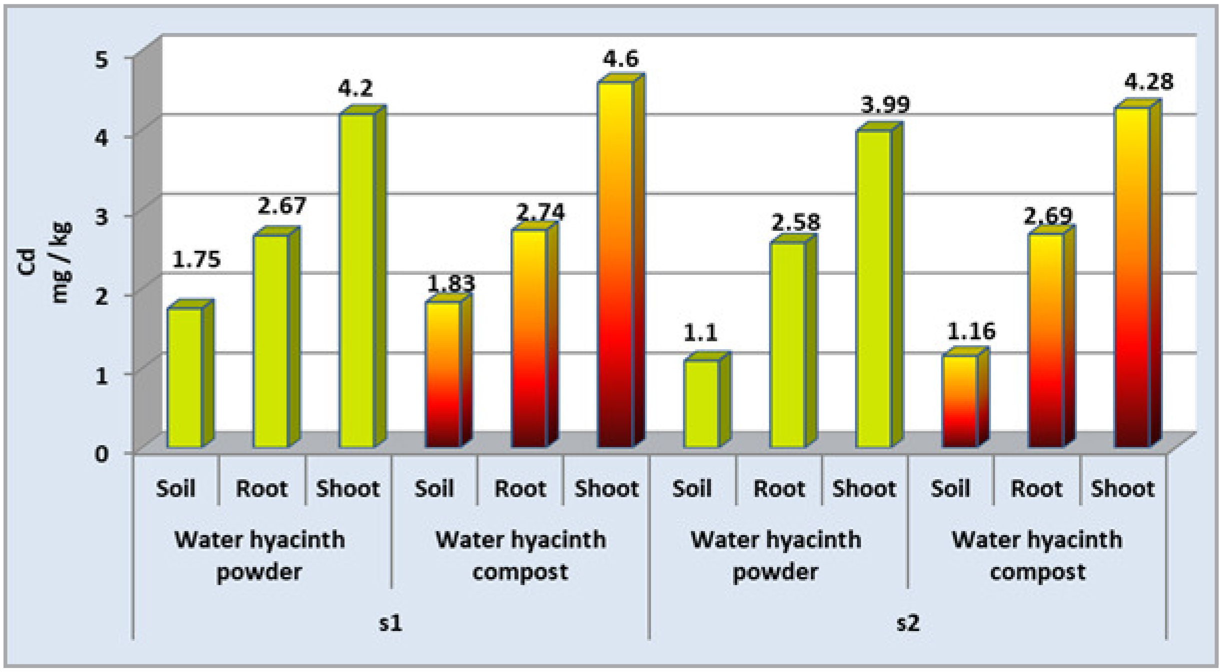

Fig. 2 : Average values of cadmium in the study soil and parts of Nerium oleander (mg.kg^{-1}).

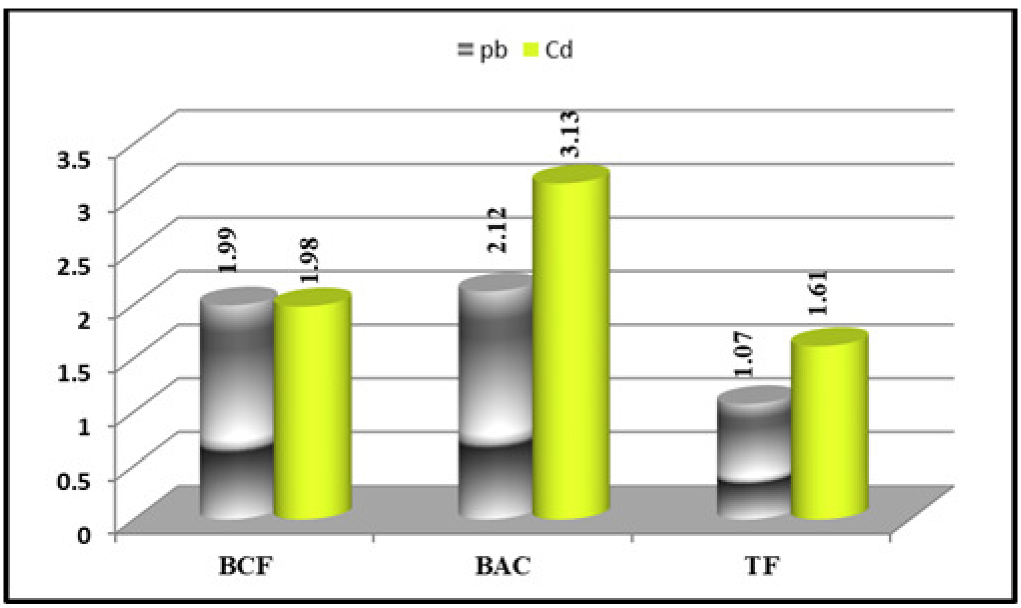

Fig. 3 : Average values of BCF, BAC and TF for heavy metals understudy for oleander.

TF values of cadmium for the oleander plant, which ranged between 1.30 - 2.05, which generally indicate the high values of the TF and for all levels of addition greater than 1, which shows the ability of the oleander plant to transfer cadmium from the roots to the shoot. These results are in agree with Zaki (2020) that the BAC and the TF of oleander were more than one and it could be considered as an accumulator plant for this element, and oleander can be used with high efficiency in the phytoremediation.

This is consistent with what Al-Otaibi (2007) stated, which indicated the possibility of plants growing in contaminated soils from absorbing heavy elements through their roots spread in the contaminated soil to other higher parts of plants. The translocation process depends on the nature of the heavy element, the type of plant grown, and its susceptibility to high concentrations of heavy elements. Based on the above results from the Tables (9, 10, 11, 12, 13, 14) for each of the bioconcentration factor (BCF), the bioaccumulation coefficient (BAC) and the transfer factor (TF) of oleander for lead and cadmium, it can be said that oleander is one of the accumulator plants of these elements because it matches the characteristics of the accumulator plants, which is characterized by a higher value of each of the mentioned factors than one and can be used with high efficiency in the phytoextraction technology of soils contaminated with heavy metals, especially lead and cadmium. Moreover, Fig. 3 showed that the cadmium ranked the first for each of the BCF and the TF, and the second for the BAC, with a very small difference from the element lead. These results are consistent with what was indicated by Wang *et al* (2012) and Al-Halfi (2012).

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