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Effect of discharged sewage water on accumulation of heavy metals in three plant *species Zygophyllum album L. Suaeda aegyptiaca and Cyprus rotundus*

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ABSTRACT

This study was conducted to evaluate pollution caused by Jeddah City sewage water discharge on the Red Sea coastal soil and the accumulation of heavy metals in the naturally growing plants: *Suaeda aegyptiaca Forssk. , Zygophyllum album L. and Cypersus jeminicus Rottb*. Metal accumulation in the polluted water, soil, and plants was compared with those parameters in an unpolluted coastal site,30 km south of Jeddah City. The results indicated a significantly high accumulation of metals in seawater, soil, and plants of the polluted site compared to the unpolluted site. Macro – elements Ca, Na, Mg, K and P, and microelements (a heavy and toxic metal) especially Fe, Al, Zn, and Mn were significantly high dominating all other elements. The three species differed in the elements they accumulated, and all of them accumulated more than one element. The different plant parts (leaves, stems, roots) differed in the magnitude of the metals they accumulated. *Suaeda aegyptiaca Forssk*. accumulated 7 elements Zn, Cu, Mn, Cr, Ni, Ba, Al, and *Zygophyllum album* L. accumulated 9 elements, Zn, Mn, Cu, Ag, Co, Al, Ba, Ni, and Cr, while *Cyperus jeminicus Rottb.* accumulated only 3 elements, Zn, Mn, and Ag. These three species may be considered hyperaccumulators to Zn, Ni, and Al metals. According to this study, these three species can be used as phytoremediation to soils polluted with heavy metals.

Key Words, Sewage water, *Suaeda aegyptiaca Forssk. , Zygophyllum album L. and Cypersus jeminicus Rottb, macro-elements, heavy metals*

INTRODUCTION

Sewage water has impacts on the environment because it may contain high concentrations of heavy metals (Al-Musharafi, 2013). Naturally growing grazing plant species like *Zygophyllum album L. Suaeda aegyptiaca and Cyprus rotundus* that grow along the Red Sea Coast may accumulate heavy metals in their tissues due to the sewage water of Jeddah City discharged into the Seawater. Growth of plant species under sewage water may contain high concentrations of heavy metals like Fe, Cu, Zn, Ni, Cd, Mn, Pb, Co (Webber, 1972). Some plant species growing along the Red Sea Coast accumulate heavy metals like CU, Zn, Mn, Mo, B, Ag, Al, As, Ba, Co, Cr, Hg, Pb, Ni, Se (Al-Wehaibi, 2007), and the function of some of these elements is known as that of Cu, Zn, Mn, Me and

Bo, and others nobody knows their function and these always create big problems, (Alkorta et al. 2004). Plant species that can accumulate elements in their tissues at high concentrations are called phytoremediaters, and they help get rid of heavy metals that pollute soil and water (Lasat, 2002; Whiting et al. 2002; Hambidge, 2000). Plants absorb metals from polluted water and soil in different ways as suggested by (Prasad, 2004; Flathman and Lanza, 1998) and this will lead to removal or reservation or analysis of the different contaminants. Elements and heavy metals are absorbed by plans in the process of phytoremediation by different methods and ways as suggested by (Flathman and Lanza, 1998): phytodegradation, phytostimulation, phytovolatization, phytoextraction, rhizofiltration, phytostabilization. Plant species vary in their ability to accumulate heavy metals in their parts, (Khairia, 2012) found that seven plant species, *Calotropus procera, Citrullus colocynthis, Rhazya stricta, Cassia italika, Phragmite australis, Cyprus laevigatus, and Argemone maxicana* in the Reiyad area in Saudi Arabia accumulated the heavy metals Fe, Zn, Cu, Cr, Ni, Co, Pb, Cd, and the highest accumulation was in the roots, seconded by the stem, and then the leaves with the lowest concentrations, except Cd which nearly accumulated equally in the root, stem, and leaves, and the two species *Phragmite australis, Cyprus laevigatus* were the highest heavy metal accumulators compared to the other species. *Panicum turgidum* growing along the Arabian Gulf Coast accumulated a high concentration of heavy metals particularly in its leaves and roots (El-Sheikh et al., 2012). Al-Sodany et al. (2012) found that concentration of the heavy metals in the forage plant *Phragmite australis* growing along Elberla Lake in Egypt was very high in the root than in the stem and then in the leaves, and also they found a significant relation between heavy metal concentration in the plant parts and their concentration in the lake water. This study aims to assess the effect of Jeddah City sewage water discharged in the Red Sea on the accumulation of heavy and toxic metals in three plant species *Zygophyllum album L. Suaeda aegyptiaca and Cyprus rotundus* and to compare the concentration of these metals in the same species growing in unpolluted site 30 km away.

MATERIALS AND METHODS

Jeddah sewage water:

In 2005 the Ministry of Water and Electricity (200%) estimated that the sewage water discharge from Jeddah City into the Red Sea water may reach up to 1149200 m^3/day in 2019. The discharged sewage water is treated and untreated, and it contains both municipal and industrial wastes which contain heavy and toxic metals. Table (1) illustrates the results of the heavy and toxic metals analyzed in the normal water, and treated and untreated sewage water. Most of these metals are present in high concentrations in untreated and secondary treated sewage water, while the metals Mo, Cd, Ag, Al, Co, and Se are present in very low concentrations in all types of water.

Table (1): Heavy metals (mg/L) in normal water, treated and untreated sewage water

element	Zn	Cu	Mn	B	Mo	Cr	Ni	Pb	As	Ba	Hg	Cd	Ag	Al	Co	Se
Normal water	3.3	2.8	0.9	4.8	≤0.1	1.6	4.1	0.5	0.13	10	≤0.1	≤0.1	≤0.1	≤0.1	≤0.1	≤0.1
Treated water	0.2	0.3	0.1	219	≤0.1	0.3	≤0.1	0.1	0.1	≤0.1	≤0.1	≤0.1	≤0.1	≤0.1	≤0.1	≤0.1
Untreated water	25.8	5.6	60.2	1296	≤0.1	20.5	10.2	0.6	6.6	23.7	≤0.1	≤0.1	≤0.1	≤0.1	≤0.1	≤0.1

This sewage water discharging may have harmful effects on the grazing plant communities growing along the Red Sea Coast thus accumulating toxic metals that enter bodies of the animals grazing on them and consequently enter the human bodies who feed on these animals.

Locations:

Two locations were chosen to run this study, the first is the polluted area along the Red Sea Coast south Jeddah Province and it represents the area near the sewage water discharge. The other location is 30 km away from the polluted site and it represents the control. Three naturally growing plant species (*Zygophyllum album, Suaeda aegyptiaca, and Cyprus rotundus)* were selected for analysis of their contents of heavy metals.

Samples collection:

Fresh plant samples from leaves, stems, and roots were collected from the species *Zygophyllum album, Suaeda aegyptiaca*, while for *Cyprus rotundus* only the shoot and root systems were prepared. The samples were placed in plastic bags, then cleaned from debris and dust by brushing, and roots were immersed in distilled water for washing from dust. The plant samples were then dried for 48 hours in an oven at 75 °C and crushed into a fine powder and put into glass containers tidily closed.

Digestion of the samples:

The plant samples were digested using Hamphries, (1956) method. A weight of 0.1 gm of the plant sample was placed into digestion tube, then 1 ml of concentrated sulphuric acid (H_2SO_4) was added, and the tube was placed in a sand bath at low temperature, then the temperature was raised gradually till the sample changed into a black homogenous fluid. Then the tubes were cooled and 1 ml of concentrated H_2SO_4 and perchloric acid were added (1:1 by volume). Heating of the samples in the tubes was repeated till white fumes appeared and the color of the mixture changed into a colorless watery solution. The content of the digestion tube was poured into a cylinder and distilled water added up to 50 ml. Heavy metals were analyzed from these prepared samples.

Analysis of the heavy metals:

Heavy metals were analyzed in the plants and water samples using the instrument Inductively Coupled Plasma, Optical Emission Spectrometer, Model Optima 4100 DV, Perkin.

Percentage of heavy metals of accumulation in plant tissues:

The concentration of the heavy metal in the shoot system was divided by its concentration in the root system to know whether the plant species is hyperaccumulator or not.

Percentage of metals in plant species in polluted aria related to unpolluted aria:

The concentration of the heavy metal in the plant species growing in the polluted area was divided by its concentration in those growing in the unpolluted area.

Statistical Analysis:

From each sample, three replications were taken and results were analyzed for averages and standard deviation (LSD) and significant differences at (5%) using the one-way analysis of variance, using the SPSS program.

RESULTS

Heavy metal accumulation in *Zygophyllum album*:

The results in table (2) show that Al was the highest metal accumulated in *Zygophyllum album* in location 1 near the sewage water discharge area with a concentration of 3166 mg/L while its concentration in location 2 (unpolluted) is 85.2 mg/L. Seconded by Fe with 2831 mg/L in location 1 and 555 mg/L in location 2 (unpolluted), then Zn with concentration of 416.2 mg/L in location 1 (polluted) and 39.5 mg/L in location 2 (unpolluted), then Mn with concentration of 156.2 mg/L in location 1 (polluted) and 64 mg/L in location 2 (unpolluted) , then Pb with 43.2 mg/L in location 1 and 0.00 mg/L in location 2 , then comes Cu with 42.7 and 23.9, and Mo metal with 37 and 11.46 , then Ba with 27.5 and 3.8 mg/L, then Cr with 19.2 and 4.5 then Ni with 17.13 and 4.25, Co with 1.54 and 0.13 mg/L, then B with 0.04 and o.03 mg/L in location 1 (polluted) and location 2 (unpolluted) respectively. *Zygophyllum album* accumulated in its leaves the heavy metals Al, Fe, Zn, Cu, Mn, Cr, Ni, Cd, B, Ba, Ag at the highest concentration levels compared with those accumulated in the root and stem. And the species accumulated in its stem the heavy metals Mo and Pb at the highest level compared to those accumulated in its leaves and root, and the root accumulated the least accumulation of the metals. The following heavy metals Fe, Zn, Mn, Mo. Ni, Ba, Ag, Pb, Cd accumulated in the plant stem at a higher level than their accumulation in the plant root.

Table (2): Concentration of heavy metals in plan parts of *Zygophyllum album*

Elements	Soil	Leaves	Stems	Roots
Fe	Polluted	1493±13	736±8	602±12
	Unpolluted	328±3	115±10	112±23
	Significance	0.001**	0.005**	0.031**
Zn	Polluted	231± 0,04	104±0,01	83.2±0,01
	Unpolluted	24.3± 0,04	9.6±0,01	5.6± 0,05
	Significance	0.001**	0.001**	0.001**
Cu	Polluted	22.3±0,09	14.3±0,002	17.6±0,002
	Unpolluted	2.2±0,0003	1.3±0,0003	4.2±0,0003
	Significance	0.001**	0.002**	0.006**
Mn	Polluted	88.4±0,008	43.7±0,003	24.1±0,002
	Unpolluted	38.7±0,002	13.1±0,001	12.2±0,002
	Significance	0.004**	0.013*	0.022*
B	Polluted	0.02±0,002	0.01±0,002	0.01±0,002
	Unpolluted	0.01±0,002	0.01±0,002	0.01±0,002
	Significance			
Mo	Polluted	11.7± 0,02	30.8± 0,01	0.5±0,001
	Unpolluted	6.67±0,007	0.55±0,001	0.33±0,003
	Significance	0.017*	0.001**	0.460*
Cr	Polluted	9.2±0,001	4.6±0,001	5.4±0,0002
	Unpolluted	1.6±0,0003	1.4±0,004	1.5±0,0003
	Significance	0.005**	0.001**	0.006**
Ni	Polluted	9.4±0,001	4.2±0,004	3.53±0,01
	Unpolluted	1.28±0,004	1.15±0,003	1.82±0,001
	Significance	0.001**	0.012**	0.040**
Ba	Polluted	21.7±0,003	3.5±0,006	2.3±0,006
	Unpolluted	1.8±0,0001	1.5±0,003	0.5±0,0004
	Significance	0.005**	0.036*	0.001**
Al	Polluted	1472±0,01	723±0,01	991±0,012
	Unpolluted	28.5±0,3	22.4±0,04	34.3±0,01
	Significance	0.009**	0.005**	°°0,002
Ag	Polluted	3.22±0,001	1.07±0,001	0.47±0,001
	Unpolluted	0.12±0,002	0.01±0,001	0.35±0,004
	Significance	0.007**	0.005**	0.036**
Co	Polluted	0,97	0,12	0,45
	Unpolluted	0,08	0,02	0,03
	Significance	0.001**	0.002**	0.002**
Pb	Polluted	8.9±0,002	19.4±0,001	14.9±0,02
Cd	Polluted	0.23±0,001	0.08±00,001	0.02±0,001

Heavy metal accumulation in *Suaeda aegyptiaca* :

The results in a table (3) show that Al was the highest metal accumulated in *Suaeda aegyptiaca* in location 1 near the sewage water discharge area with a concentration of 3141 mg/L while its concentration in location 2 (unpolluted) is 227.4 mg/L. Seconded by Fe with 2092 mg/L in location 1 and 871 mg/L in location 2 (unpolluted), then Mn with concentration of 218.8 mg/L in location 1 (polluted) and 90.9 mg/L in location 2 (unpolluted), then Zn with concentration of 147.3 mg/L in location 1 (polluted) and 36.3 mg/L in location 2 (unpolluted) , then Cu with 42.7 mg/L in location 1 and 23.9 mg/L in location 2 , then comes Mo with 39.4 and 0.14, and Pb metal with 34.8 and 0.00 , then Ni with 16.8 and 5.29 mg/L, then Cr with 12.5 and 3.9 then Ba with 8.7 and 1.9, Ag with 4.76 and 0.48 mg/L, then Co with 0.75 and o.1 , then B with 0.04 and 0.03 mg/L in location 1 (polluted) and location 2 (unpolluted) respectively. *Suaeda aegyptiaca* accumulated in its leaves the heavy metals Al, Fe, Zn, B, Ba, Pb at the highest concentration levels compared with those accumulated in the root and stem. And the species accumulated in its root the heavy metals Cu, Mn, and Cr at the highest level compared to those accumulated in its leaves and stem, and the stem witnessed the highest accumulation of the metal Mo. The metal Ni was equally accumulated in the leaves and root. The plant stem was generally with the lowest metal accumulation compared to the plant leaves and root.

Table (3): Concentration of heavy metals in plan parts of *Suaeda aegyptiaca*

Element	Soil	Leaves	Stem	Roots
Fe	Location 1 (polluted)	831±19	688 ±10	573±6
	Ulocation (unpolluted)	322±15	307±3	242±6
	significance	0.003**	0.007**	0.003**
Zn	Location 1	78.1± 0,01	36.7±30,01	32.5±0,01
	Location 2	21.1± 0,01	10.1±0,05	5.1± 0,01
	significance	0.021*	0.015*	0.001**
Cu	Location 1	16.2±0,02	9.1±0,004	17.3±0,001
	Location 2	8.3± 0,004	6.4±0,003	9.2±0,001
	significance	0.004**	0,613	0.011**
Mn	Location 1	73.1±0,003	51.1±0,002	94.4±0,012
	Location 2	0,0316.4±	23.6±0,002	0,005 ±50,9
	significance	0.001**	0.018*	0.019*
B	Location 1	0.02±0,002	0.01±0,002	0.01±0,002
	Location 2	0.01±0,002	0.01±0,002	0.01±0,002
	significance	0.012*		
Mo	Location 1	8.1±0,02	30.8±0,01	0.5±0,001
	Location 2	0,001±0,51	0,001 ±0,55	0.33±0,003
	significance	0.001**	0.001**	0.460
Cr	Location 1	4.5±0,005	2.4±0,001	5.6±0,001
	Location 2	1.4±0,005	1.4±0,005	1.1±0,002
	significance	0.026*	0.054*	0.006*
Ni	Location 1	5.71±0,004	4.67±0,002	5.7±0,001
	Location 2	1.87±0,002	1.4±0,003	1.95±0,002
	significance	0.019*	0.031*	0.039*
Ba	Location 1	5.3±0,001	2.2±0,0002	1.2±0,002
	Location 2	1.7±0,0002	0.1±0,0001	0,001 ±0,1
	significance	0.013**	0.008**	0.01**
Al	Location 1	2022±0,1	586±0,1	0,07±533
	Location 2	137.3±0,1	57.5±0,1	32.6±1,2
	significance	0.004**	0.012**	0.003**
Pb	Location 1	16.3	5.7	12.8

Heavy metal accumulation in *Cyprus rotundus*:

The results in ***Cyprus rotundus*** table (4) show that Al was the highest metal accumulated in location 1 near the sewage water discharge area with a concentration of 3245 mg/L while its concentration in location 2 (unpolluted) is 197.7 mg/L. Seconded by Fe with 3868 mg/L in location 1 and 1988 mg/L in location 2 (unpolluted), then Zn with concentration of 258 mg/L in location 1 (polluted) and 67.3 mg/L in location 2 (unpolluted), then Mn with concentration of 156 mg/L in location

1 (polluted) and 82.3 mg/L in location 2 (unpolluted) , then Ba with 45.4 mg/L in location 1 and 3.9 mg/L in location 2 , then comes Cu with 43.4 and 18.1, and Pb metal with 37.6 and 0.00 , then Cr with 19.7 and 3.3 mg/L, then Ni with 17.07 and 2.86 then Mo with 10.43 and 7.06, Co with 1.85 and 0.18 mg/L, then Ag with 1.64 and o.03 , then B with 0.04 and 0.03 mg/L in location 1 (polluted) and location 2 (unpolluted) respectively. ***Cyprus rotundus*** accumulated in its shoot system 8 heavy metals Al, Zn, Mn, B, Mo, Ag, Co, Cd, at the highest concentration levels compared with those accumulated in the root system. And the species accumulated in its root system 7 of the heavy metals Fe, Cu, Cr, Ni, Ba, Pb, Se, at the highest level compared to those accumulated in its shoot system.

Table (4): Concentration of heavy metals in plan parts of *Cyprus rotundus*

Elements	Soil	Shoot system	Root system
Fe	Polluted	2211±62	3657±16
	Unpolluted	990±8	998±2
	Significance	0.003**	0.001**
Zn	Polluted	152± 0,01	106±0.01
	Unpolluted	38.8± 0,02	8.5±0,02
	Significance	0.001**	0.001**
Cu	Polluted	18.5±0,002	24.9±0,002
	Unpolluted	5.5± 0,001	12.6±0,001
	Significance	0.002**	0.005**
Mn	Polluted	86.9±0,03	69.1±0,008
	Unpolluted	48.9±0,01	33.4±0,0003
	Significance	0.020*	0.020*
B	Polluted	0.03±0,002	0.01±0,002
	Unpolluted	0.02±0,002	0.01±0,002
	Significance		
Mo	Polluted	7.2± 0,02	3.23±0,15
	Unpolluted	4.89±0,01	2.17±0,01
	Significance	0,061	0,089
Cr	Polluted	3.5±0,001	16.2±0,001
	Unpolluted	1.6±0,0003	1.8±0,004
	Significance	0,061	0.003**
Ni	Polluted	7.97±0,001	9.1±0,004
	Unpolluted	1.33±0,004	1.53±0,003
	Significance	0.009**	0.005**
Ba	Polluted	19.3±0,003	26.1±0,006
	Unpolluted	1.8±0,0001	2.2±0,003
	Significance	0.007**	0.002**
Al	Polluted	923±0,1	2322±0,1
	Unpolluted	82.6±0,3	114.1±0,04
	Significance	0.008**	0.006**
Ag	Polluted	1.17±0,001	0.47±0,001
	Unpolluted	0.12±0,002	0.18±0,001
	Significance	0.002**	1.58*
Co	Polluted	0,27	0,13
	Unpolluted	0,05	0,02
	Significance	0.001**	0.021*
Pb	Polluted	9.2±0,002	28.4±0,001
Cd	Polluted	1.23±0.001	1.08±0,001
Se	Polluted	6.4	8.1
	Unpolluted	0.23	0.63
	Significance	0.001**	0.001**

Biological Absorption Factor:

It is the division of the concentration of the metal in the shoot system by its concentration in the root system to see whether the plant species is a metal accumulator or not. The results in a table (5) illustrate that *Zygophyllum album* growing in polluted soil with sewage water accumulated 14 heavy metals, Fe, Al, Zn, Cu, Mn, Ni, Cr, Ba, Mo, Pb, B, Co, Ag, and Cd in its shoot system at higher concentrations than their concentration in its root system, and the plant species *Suaeda aegyptiaca* accumulated 11 heavy metals, Fe, Al, Zn, Cu, Mn, Ni, Cr, Ba, Mo, Pb, B, while the plant species *Cyprus rotundus* accumulated 7 heavy metals from polluted soil with sewage water, Zn, Mn, Mo, B, Ag, Cd, As at higher concentrations than their roots.

Table (5): The Biological Absorption Factor of the plant species:

	Accumulation (%)															
	Fe	Al	Zn	Cu	Mn	Ni	Cr	Ba	Mo	Pb	B	Co	Ag	Cd	As	Se
Zygophyllum album	3.7	2.2	4	2.1	5.5	3.9	2.6	10.9	1.14	1.9	3	2.4	9.1	1.5	--	--
Suaeda aegyptiaca	2.8	5	3.5	1.5	1.3	1.8	1.2	6.3	78	1.8	3	--	--	----	--	--
Cyperus rotundus	0.6	0.2	1.6	0.7	1.3	0.9	0.2	0.7	2.2	0.32	3	0.2	2.5	1.1	1.07	0.78

Which of the three plant species is a hyper accumulator:

The percentages of accumulation of heavy metals by the plant species growing in the sewage water polluted site were divided by the accumulation values by these species in the unpolluted location 2. The results are presented in table (6). The results indicated that concentrations of all studied heavy metals in all parts of the studied plant species are higher than the concentrations of these metals in the same plant species growing in the unpolluted location. Aluminum is very highly accumulated in the shoot system compared to its concentration in the root system of the species, particularly in the *Zygophyllum album.*

Table (6): Percentages of accumulated **heavy metals in polluted site to values accumulated in the unpolluted site:**

Accumulation (%)												
	Fe	Al	Zn	Cu	Mn	Ni	Cr	Ba	Mo	B	Co	Ag
Zygophyllum album	4.8	37.2	10.5	7.03	2.4	4.03	4.3	7.2	3.2	1.3	11.8	--
Suaeda aegyptiaca	2.5	13.8	4.05	1.7	2.4	3.03	3.2	4.5	2.8	1.3	7.5	9.9
Cyperus rotundus	2.9	16.3	3.8	2.4	1.9	5.2	8	11.6	1.4	1.3	10.2	5.5

DISCUSSION

Jeddah City sewage water (municipal and industrial) is discharged into the Red Sea water south of the city. This study was undertaken to assess the impact of this polluted sewage effluent on the habitat of this region especially on plant species growing in this area. Three plant species of those growing naturally in this area were chosen for this study, to determine the heavy and toxic metals accumulated in their tissues, and to compare it with the concentrations of these metals accumulated in the tissues of the same plant species growing naturally in a different habitat

located 30 km away from this polluted site, to see whether planting of such plant species can eliminate and alleviate toxic heavy metals from contaminated soils with the sewage water. The results indicated variation between the three plant species in their capability of accumulating heavy metals in their tissues, and variation between the different plant parts (leaves, stem, root) in the magnitude of the heavy metal concentrations they can accumulate and the type of the heavy metal they can select. Also, the metals varied in their concentrations in the plant tissues. The species growing in the polluted site near the sewage water discharged area significantly accumulated high concentrations of heavy metals compared to those growing in the unpolluted area. This agrees with the findings of many researchers (Garcia et al., 2004) who found a significant increase in heavy metal concentration in tissues of the plant *Piptatherum miliaceum* (Smilo grass) under irrigation with sewage water compared to the concentration of these metals in the same species when irrigated with normal water. Al-Jaloud et al. (1995) and Al-Jaloud, (1994) irrigated field crops with sewage water and found a significant increase in heavy metal concentrations in their tissues compared to those irrigated with normal water. And (Baeshen, 2008) found high heavy metal concentrations in the desert plants growing east of Jeddah city in Saudi Arabia and irrigated with the sewage water. The three plant species differed in the quantities of heavy metals they accumulated in their tissues, and in the types of heavy metals, they accumulated in their different parts and the types of heavy metals selected by each plant species.

The heavy metals accumulated by *Zygophyllum album* are Al, Fe, Zn, Cu, Mn, Cr, Ni, Ba, Cd, Ag, Co, and Pb, and nearly all of them except Mo and Pb are accumulated in the leaves at higher levels compared to their concentrations in the stem and root, with the lowest concentrations of these metals in the plant root. The heavy metals accumulated by *Suaeda aegyptiaca* growing along the Red Sea Coastal polluted area near the sewage water discharge are Al, Fe, Mn, Zn, Cu, Mo, Pb, Ni, Cr, Ba, and 5 of them dominated in the leaves (Fe, Zn, Al, Ba, Pb), and 3 dominated in the root (Cu, Mn, Cr) and only one dominated in the stem (Mo). The plant species *Cyprus rotundus* accumulated in its shoot system the metals Fe, Zn, Mn, B, Mo, Ag, and Cd at higher concentrations than in its root system, and accumulated in its root system the metals Cu, Cr, Ni, Ba, Al, Pb, and Se at higher concentrations than in its shoot system.

Zygophyllum album can extract and accumulate 13 heavy metals, Fe, Al, Zn, Cu, Mn, Ni, Cr, Ba, Mo, Pb, Co, Ag, and Cd from polluted soil with sewage water, and the plant species *Suaeda aegyptiaca* can extract and accumulate 10 heavy metals, Fe, Al, Zn, Cu, Mn, Ni, Cr, Ba, Mo, Pb, while the plant species *Cyprus rotundus* can extract and accumulate 7 heavy metals from polluted soil with sewage water, Zn, Mn, Mo, B, Ag, Cd, As.

The three plant species growing in the location polluted with sewage water accumulated the 12 studied heavy metals (Fe, Al, Zn, Cu, Mn, Ni, Cr, Ba, Mo, B, Co, Ag) in their different parts (leaves, stem, root) at higher concentrations than their accumulation undergrowth in the unpolluted location 30 km away from the polluted site. The plant species is considered an accumulator of heavy metals if the division of the shot content of a particular metal by its root content is more than one, and it is called unaccumulator if the result of this division is less than one, as was suggested by (McGraw et al. 2002; Zhao et al. 2000) who classified plant species into hyper-accumulators, accumulators and unaccumulators. According to these criteria, the *Zygophyllum album* is a higher accumulator than *Suaeda aegyptiaca* and *Cyprus rotundus* while *Cyprus rotundus* is the least plant accumulator of the three species accumulating only 7 metals. The reason why *Cyprus rotundus* is the least metal accumulator is that metals are accumulated in the root system at higher concentrations than in the shoot system because the species has intensive branching of rhizomes and tubers underground. The domination of plant roots to accumulate trace and heavy metals more than the shoot system is suggested by some researchers (Gupta et al.2008) found that roots of *Pelargonium* plants accumulated a significantly greater heavy metal concentration than aerial organs. Many other researchers reached the same results Khairia, 2012, determined heavy metals in seven plant species in the Reiyad area, Saudi Arabia and Al-Sodany et al. (2013) determined heavy metals in the species *Phragmite australis* in Egypt found the highest heavy metal accumulations were in the roots compared to shoot. Mazhoudi et al., (1997) found aerial parts of plants to accumulate low metal content compared with roots and hypothesized that roots could play an important role in metal retention by preventing an excessive and toxic accumulation in shoots.

Zygophyllum album is a higher extractor (accumulator) of the heavy metals Al, Zn, Cu, Mn, Mo, Co, compared to the other two species *Suaeda*

aegyptiaca and Cyprus rotundus, and *Cyprus rotundus* is a higher accumulator than *Zygophyllum album* and *Suaeda aegyptiaca* for the metals Cr, Ni, Ba, while *Suaeda aegyptiaca* is the higher accumulator for Ag. Aluminum was accumulated at the highest concentration level in the plant tissues compared to the other heavy metals and registered the highest concentration in *Cyprus rotundus* roots (2322 mg/L), and in the leaves of *Suaeda aegypliaca* it reached (2022 mg/L), while in the leaves of it *Zygophyllum album* reached 1472 mg/L, seconded by Zn then Mn, and the concentration of all the other metals decreased in plant tissues. According to the suggestion of (Caille et al. 2005) that metal accumulators adopt three criteria relating to their ability to accumulate metals, summarized in the enhancement of absorption of the metal by the root, efficiency in transferring the metal from the root system to the shoot system, and tolerance of the plant to the high concentration of this toxic heavy metal. So based on these facts *Zygophyllum album* is considered a good heavy metals accumulator, then *Suaeda aegypliaca* while *Cyprus rotundus* is the least heavy metal accumulator of the three species.

CONCLUSION

It can be concluded that the three plant species *Zygophyllum album*, *Suaeda aegypliaca,* and *Cyprus rotundus* can be considered phytoremediators that can accumulate heavy and toxic metals in their tissues after absorbing them from contaminated soils and water. *Zygophyllum album* extracted and accumulated 13 heavy metals, Fe, Al, Zn, Cu, Mn, Ni, Cr, Ba, Mo, Pb, Co, Ag, and Cd from polluted soil with sewage water, and the plant species *Suaeda aegyptiaca* extracted and accumulated 10 heavy metals, Fe, Al, Zn, Cu, Mn, Ni, Cr, Ba, Mo, Pb, while the plant species *Cyprus rotundus* extracted and accumulated 7 heavy metals from polluted soil with sewage water, Zn, Mn, Mo, B, Ag, Cd, As. The concentrations of heavy metals in the tissues of the tested plants are very high for the plants growing naturally near the site polluted with sewage water compared to the same species growing 30 km away in an unpolluted area. Heavy metals accumulated in different concentrations in the different plant parts (leaves, stem, root), and the species *Cyprus rotundus* because of its intensive branching underground rhizome and tubers the concentration of the heavy metals of most of the metals were in the root system compared to the shoot system. The three plant species *Zygophyllum album, Suaeda aegyptiaca, and Cyprus rotundus* can be used as phytoremediators for treatment of polluted soil and water from heavy toxic metals.

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