

Phytoremediation of some heavy metals using *Prosopis juli flora* and *Conocarpus lancifolius*– Soil analysis

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Abstract

Environmental pollution is causing damage to the flora and fauna, resulting in a number of negative impacts on the environment. The present study aims towards evaluation of soil heavy metals (chromium, lead, and nickel) from different locations of Jeddah using leaves of two plant species. Two naturally grown plant species, *Prosopis juli flora* and *Conocarpus lancifolius* were collected from four different sites. The soil samples were collected near the factories, main roads, and branch roads in Jeddah. The soil samples were dried and sieved through a 2mm plastic sieve to remove large gravel-sized materials. Soil texture, pH, and EC evaluation were conducted. The amount of Cr, Pb, and Ni was determined using Atomic Absorption Spectrophotometer Model Inductivity coupled plasma emission spectrometer ICP (PARKIN ELEMER). SPSS, ANOVA, and Post-Hoc Test were used to analyze the data. The results showed that the amount of heavy metal in the soil of *Prosopis juli flora* were between 0.74-54.0µg/g D.wt. for Cr, 0.31-4.64 µg/g D.wt. for Pb and 1.22-24.5 µg/g D.wt. for Ni. The range of Cr, Pb and Ni in the leaves were between 0.04-13.3.0µg/g D.wt. for Cr, 0.06-20.0 µg/g D.wt. for Pb and 0.16-9.0µg/g D.wt. for Ni. For the soil of *Prosopis juli flora*, the EC ranged between 0.27- 1.05 mS/cm; whereas, pH ranged from 7.29-7.55 and 78.5-96.5% for sand, 1.0-16.5% for silt, and 1.0-6.0 for clay. There was a significant correlation between the soil textures, clay, and silt at selected sites. Phytoremediation is an effective strategy to overcome the effects of heavy metals including Cr, Pb, and Ni that are being absorbed in plants.

Keywords: *Conocarpus Lancifolius*, Hazard, Heavy Metals, *Prosopis Juliflora*, Soil Analysis.

Introduction

The high release of heavy metals into surface, ground water, soils and the biosphere is observed through human activities such as industrial production, agriculture, mining, and transportation (Nazir et al., 2015). The probability of food contamination through the soil root interface increases the concern towards the accumulation of heavy metals in crop plants (Nazir et al., 2015). Heavy metals are found in the soil and geology of earth. These heavy metals can significantly influence the physiological and anatomical feature of plants such as stomata density of the leaves (Gomes et al., 2011). On the other hand, anthropogenic activities result in an increase in the concentration of such elements, which in turn, causes dangerous side-effects to flora and fauna.

The heavy metals including Chromium (Cr), Nickel (Ni), and Lead (Pb) are not essential for plant growth; however, they are taken up and accumulated inside the plant tissues in toxic forms. An important role is played by the heavy metal concentration in the soil to control the metal bioavailability to the plants. The concentration of heavy metals in the soils is likely to increase over the permissible limit if they have been

irrigated with contaminated water since a long time. However, the factor affecting the ability of plants to take up heavy metals include; the type of soil, type of plant species and growth stage of the particular plant (Khan et al., 2011).

Plant species, such as *Bruguiera sexangula* and *Zygophyllum* sp. were also found to be subjected to the accumulation of heavy metals (Gupta and Chakrabarti, 2013; Morsy et al., 2012). Chromium (Cr) is widely used for chromate plating and stainless steel. Wood preservatives and pigments are highly prepared by Cr (both +3 and +6) in the chemical industries. Moreover, green tints, for various purposes are also prepared by the same element. Cr compounds are especially utilized in large amounts for leather tanning. Additionally, the metal is also used in bulk quantity in paper manufacturing (Kabata-Pendias, 2010). Nickel (Ni) is further released into the soil through various sources during anthropogenic actions (Alt, 2000). Furthermore, Lead (Pb) is mainly and extensively used in lead-acid batteries, cables, chemicals, and for several other purposes. On the other hand, Pb-containing paints in soil are found in garden or home areas as other sources of lead

(Kabata-Pendias, 2010). Therefore, the present study aims to determine the amount of pollution by heavy metals, such as chromium (Cr), lead (Pb), and nickel (Ni) pollutants in soil and in leaves of two plant species (*Prosopis juli flora* and *Conocarpus lancifolius*) growing naturally in the contaminated soils in Jeddah, Saudi Arabia.

Results and Discussion

Soil analysis of heavy metals (Cr, Pb and Ni) in leaves of *Prosopis juli flora*

The data presented in Table 1. reveals the content of heavy metals (Cr, Pb and Ni) in the soil and in *Prosopis juli flora* leaves. The ranges of heavy metal in the soil (under natural grow of *Prosopis juli flora*) were between 0.74-54.0 µg/g D.wt. for Cr, 0.31-4.64 µg/g D.wt. for Pb and 1.22-24.5 µg/g D.wt. for Ni. The results for polluted sites were higher than unpolluted (control) but lower than normal amount for heavy metal in soil for Cr, Pb are 100 µg/g and for Ni is 50 µg/g (Chiroma et al., 2014).

The quantity of heavy metals in plant shows that the range of Cr, Pb and Ni in the leaves were between 0.04-13.3.0 µg/g D.wt. for Cr, 0.06-20.0 µg/g D.wt. for Pb and 0.16-9.0 µg/g D.wt. for Ni (Table 1). The results for polluted sites were higher than non-polluted sites. Furthermore, higher than normal amount of heavy metals (Cr, Ni are 0.1-5 µg/g and Pb 5-10 µg/g) in plant species were detected (Butkus and Baltrėnaitė, 2007). The data shown in Table 2 show that the EC for the soil of *Prosopis juli flora* ranged between 0.27-1.05 mS/cm, pH from 7.29-7.55 and 78.5-96.5% in sand, 1.0-16.5% in silt and 1.0-6.0 in clay soils. The results presented significant correlation between the soil textures, clay and silt at selected sites. A previous study has shown that the accumulation of heavy metals on several plant species was due to their capability of accumulating and removing heavy metals (Markert, 1993). Environmental degradation is caused when these metals from the environment accumulate on woody plants (Agbogidi et al., 2013). Hence, there are significant correlations between amount of Cr, Pb, and Ni in soil and, Pb and Ni in plant. In addition, there was a high significance between Pb in soil and Pb in plant as shown in Table 3.

Soil analysis of heavy metals (Cr, Pb and Ni) in leaves of *Conocarpus lancifolius*

The data shown in Table 4 has elucidated the amount of heavy metals Cr, Pb, and Ni in the soil and leaves of *Conocarpus lancifolius*. The ranges of heavy metal in soil of *Conocarpus lancifolius* sites are between 1.1-133.3 µg/g d.wt for Cr, 0.27-128.8 µg/g D.wt. for Pb and 9.4-36.2 µg/g D.wt. for Ni. The contaminations were higher for polluted sites as compared to the low polluted sites. However, lower than normal (standard) amount for heavy metal in the soil was observed for Cr, Pb are 100 µg/g and for Ni is 50 µg/g (Chiroma et al., 2014). Moreover, except the first site (PR) near Petroleum Refinery, the soil had more amount of lead than the leaves of *Conocarpus lancifolius* and more than normal (standard) amount for heavy metal in soil (Pb 100 µg/g). Pb concentration

was found to be more in the leaves compared to its presence in the park locations. The roots were found to contain more heavy metals as compared to leaves. Thus, air pollution can be considered as another reason for metal pollution in trees. Heavy metals levels in plants have increased noticeably due to traffic pollution especially from consumption of leaded petrol and exhaust fire (Aslam et al., 2012).

The amount of these metals in the samples of plants (as shown in the Table 4), especially in leaves, was between 9.2 - 30.7.0 µg/g D.wt. for Cr, 6.0 -57.4 µg/g D.wt. for Pb and 0.6.5-19.6 µg/g D.wt. for Ni. The results for polluted sites were found to be higher than the results obtained for unpolluted sites. Moreover, the normal value of Cr, Ni were (0.1-5) µg/g in plants (Butkus & Baltrėnaitė, 2007) and higher than standard for Pb (5-10) µg/g. There was a significant correlation between sand (%) and silt (%) in soil and Pb in the leaves of *Conocarpus lancifolius* and Ni in plant. Table 5 has shown that EC for the soil of *Conocarpus lancifolius* ranged between 0.35-1.44 mS/cm, pH from 6.79-7.7 and 77.0-94.5% for sand, 1.0-20.5% for silt, and 2.0-4.54% for clay. Results presented significant correlation in EC, pH, sand %, and silt % in selected sites.

A high significant difference between Ni in soil and Pb in plant was shown in Table 6. Ni, Cu, Zn, and Cd are released from industrial metallurgical processes in high percentages. On the other hand, Ni, Cd, Zn, and Pb might be present in high quantities in exhaust production from gasoline (Samara and Voutsas, 2005). The uptake of metals from the soil depends on different factors, such as their soluble content, soil pH, plant species, fertilizers, and soil type (Naser et al., 2011). Comparison of lead amount in *Conocarpus lancifolius* and *Prosopis juli flora* in King Faisal road proved that *Conocarpus lancifolius* accumulates led more than *Prosopis juli flora*. The accumulator collects high amount of metals in the plants and low metal concentration in the soil (Aslam et al., 2012). Phytoremediation is a promising technology and a sub-type of bioremediation, which is firmly applied to the use of green plants for the remediation of organic as well as inorganic contaminants from polluted soil, water or air (Salt et al., 1998). It was found that Ziziphus tree leaves, were extensively subjected to hazardous metals due to industrial actions, which resulted in the growth of micro-nutrients on the surface of tree leaves. Paints, paper, and chemical industries were found as the heaviest metal releasing entities as suggested by the presence of Cd, Cr, Ni, and Pb concentrations on leaves of the trees near such industries (Shaheen et al., 2014). Metal accumulation on plants depends on different factors, such as uniqueness of metals, genetics, distance from pollution sources, and climatic factors such as soil properties, wind direction, and intake from soil (Osma, 2013).

Materials and methods

Collection of soil and leaves

All sites were selected in Jeddah according to traffic density and industrial activities. Four sites were chosen from different location in Jeddah. Samples were taken from areas near factories, main roads and branch roads and samples were collected during March 2015 (Figure 1).

Table 1. The amount of heavy elements mean \pm SD in the leaves of *Prosopis juliflora* sites (n = 2) *: Statistically significant at $p \leq 0.05$ and LSD (5%)

Site	Soil (mg/g d.wt)			Plant (mg/g d.wt)		
	Cr	Pb	Ni	Cr	Pb	Ni
IF	54.0 ^a \pm 12.8	0.43 ^b \pm 0.06	24.5 ^a \pm 0.09	9.1 ^{ab} \pm 0.71	8.6 ^{abc} \pm 1.7	7.2 ^a \pm 1.41
FR	25.9 ^{bc} \pm 6.6	3.7 ^a \pm 0.14	12.6 ^b \pm 1.84	10.9 ^a \pm 3.8	16.9 ^{ab} \pm 10.04	8.8 ^a \pm 0.85
JMR	43.1 ^{ab} \pm 4.0	4.64 ^a \pm 1.18	21.6 ^{ab} \pm 0.57	13.3 ^a \pm 7.21	20.0 ^a \pm 2.26	9.0 ^a \pm 2.83
SRB	41.4 ^{ab} \pm 17.9	1.54 ^b \pm 0.47	19.3 ^{ab} \pm 7.64	10.1 ^a \pm 1.84	6.1 ^{bc} \pm 0.42	5.8 ^a \pm 1.41
Control (Non-polluted)	0.74 ^c \pm 0.14	0.31 ^b \pm 0.37	1.22 ^c \pm 0.04	0.04 ^b \pm 0.04	0.06 ^c \pm 0.08	0.16 ^b \pm 0.04
F	7.875 [*]	21.529 [*]	13.904 [*]	3.661	6.035 [*]	10.266 [*]
P	0.022 [*]	0.002 [*]	0.006 [*]	0.094	0.037 [*]	0.013 [*]
LSD (5%)	26.75	1.533	9.0542	9.6512	12.003	4.1003

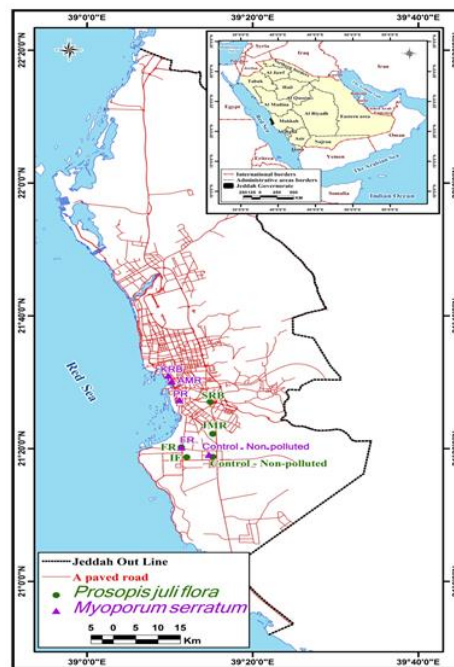


Fig 1. Map of study area Source: Google Earth Pro 2017

Table 2. Ec, pH and proportions of soil particles to soil sites *Prosopis juliflora* mean \pm SD (n = 2) *: Statistically significant at $p \leq 0.05$ and LSD (5%)

Site	EC (mS/cm)	pH	Soil Texture%		
			Sand	Silt	Clay
IF	0.91 ^a \pm 0.85	7.29 ^a \pm 0.14	82.5 ^{cd} \pm 3.54	16.5 ^a \pm 3.54	1.0 ^b \pm 0.0
FR	0.87 ^a \pm 0.25	7.42 ^a \pm 0.04	91.5 ^b \pm 0.71	3.5 ^{bc} \pm 0.71	5.0 ^a \pm 0.0
JMR	1.05 ^a \pm 0.47	7.39 ^a \pm 0.35	78.5 ^d \pm 0.71	15.5 ^a \pm 2.12	6.0 ^a \pm 1.41
SRB	0.27 ^a \pm 0.01	7.55 ^a \pm 0.09	86.5 ^c \pm 2.12	7.5 ^b \pm 2.12	6.0 ^a \pm 0.0
Control (Non-polluted)	0.52 ^a \pm 0.0	7.47 ^a \pm 0.01	96.5 ^a \pm 0.71	1.0 ^c \pm 0.0	2.5 ^b \pm 0.71
F	1.007	0.577	27.459 [*]	22.136 [*]	20.200 [*]
P	0.483	0.693	0.001 [*]	0.002 [*]	0.003 [*]
LSD (5%)	1.153	0.4533	4.9446	5.3921	1.8177

Table 3. Correlation among different parameters of *Prosopis juliflora* sites. r: Pearson coefficient *: Statistically significant at $p \leq 0.05$ (n = 8).

Parameter	Plant (mg/g d.wt)					
	Cr		Pb		Ni	
	r	p-value	r	p-value	r	p-value
EC (mS/cm)	-0.119	0.778	0.490	0.217	0.414	0.308
pH	-0.493	0.214	0.002	0.996	-0.546	0.161
Sand%	-0.230	0.583	-0.181	0.668	-0.088	0.837
Silt%	0.157	0.711	0.037	0.930	0.092	0.828
Caly%	0.127	0.765	0.330	0.424	-0.039	0.927
Cr Soil	0.002	0.997	-0.147	0.728	-0.486	0.222
Pb Soil	0.604	0.112	0.708*	0.049	0.659	0.075
Ni Soil	0.124	0.769	-0.160	0.705	-0.284	0.496

Table 4. The amount of heavy elements in the leaves of *Conocarpus lancifolius* sites, mean \pm SD (n = 2) *: Statistically significant at $p \leq 0.05$ and LSD (5%).

Site	Soil (mg/g d.wt)			Plant (mg/g d.wt)		
	Cr	Pb	Ni	Cr	Pb	Ni
PR	133.3 ^a \pm 91.4	128.8 ^a \pm 115.0	28.1 ^{bc} \pm 0.61	30.7 ^a \pm 3.0	20.4 ^b \pm 1.7	19.6 ^a \pm 7.6
FR	49.3 ^{ab} \pm 3.7	5.8 ^a \pm 4.7	21.6 ^c \pm 1.8	17.1 ^{bc} \pm 2.1	57.4 ^a \pm 7.6	9.1 ^{ab} \pm 0.71
AMR	96.0 ^{ab} \pm 13.5	1.5 ^a \pm 1.7	36.2 ^a \pm 3.2	24.6 ^{ab} \pm 5.9	15.2 ^b \pm 11.0	14.1 ^{ab} \pm 47.7
KRB	67.5 ^{ab} \pm 1.6	56.9 ^a \pm 52.7	31.5 ^{ab} \pm 2.1	15.3 ^c \pm 1.8	6.0 ^b \pm 0.85	8.3 ^{ab} \pm 0.71
Control (Non-polluted)	1.1 ^b \pm 0.28	0.27 ^a \pm 0.01	9.4 ^d \pm 3.9	9.2 ^c \pm 0.57	7.7 ^b \pm 2.1	6.5 ^b \pm 4.38
F	2.882	1.935	31.913*	13.426*	23.395*	2.825
P	0.138	0.243	0.001*	0.007*	0.002*	0.142
LSD (5%)	106.32	145.51	6.6826	8.3138	15.767	11.514

Table 5. Ec, pH and proportions of soil particles to soil *Conocarpus lancifolius* sites, mean \pm SD (n = 2) *: Statistically significant at $p \leq 0.05$ and LSD (5%).

Site	EC (mS/cm)	pH	Soil Texture%		
			Sand	Silt	Clay
PR	0.56 ^{bc} \pm 0.11	7.59 ^a \pm 0.10	80.0 ^c \pm 0.0	18.0 ^{ab} \pm 0.0	2.0 ^b \pm 0.0
FR	0.65 ^b \pm 0.22	7.63 ^a \pm 0.03	85.0 ^b \pm 2.83	13.0 ^b \pm 2.83	2.0 ^b \pm 0.0
AMR	0.75 ^b \pm 0.04	7.73 ^a \pm 0.14	77.5 ^c \pm 0.71	20.5 ^a \pm 0.71	2.0 ^b \pm 0.0
KRB	1.44 ^a \pm 0.04	7.64 ^a \pm 0.01	77.0 ^c \pm 2.83	20.0 ^a \pm 4.24	3.0 ^{ab} \pm 1.41
Control (Non-polluted)	0.35 ^c \pm 0.01	6.79 ^b \pm 0.04	94.5 ^a \pm 0.71	1.0 ^c \pm 0.0	4.5 ^a \pm 0.71
F	26.420*	47.237*	31.074*	24.811*	4.800
P	0.001*	<0.001*	0.001*	0.002*	0.058
LSD (5%)	0.2923	0.2058	4.7399	5.9179	1.8177

Table 6. Correlation between Plant with different parameters of *Conocarpus lancifolius* sites, r: Pearson coefficient *: Statistically significant at $p \leq 0.05$ (n = 8).

Parameter	Plant (mg/g d.wt)					
	Cr		Pb		Ni	
	r	p	r	p	r	p
EC (mS/cm)	-0.601	0.115	-0.570	0.140	-0.578	0.134
pH	0.187	0.658	-0.024	0.954	0.302	0.467
Sand%	-0.156	0.713	0.917*	0.001	-0.086	0.840
Silt%	0.241	0.565	-0.848*	0.008	0.150	0.722
Caly%	-0.450	0.263	-0.363	0.376	-0.340	0.410
Cr Soil	0.534	0.172	-0.277	0.507	0.233	0.579
Pb Soil	0.335	0.418	-0.238	0.570	0.126	0.766
Ni Soil	0.292	0.483	-0.766*	0.027	0.201	0.633

Two plant species were chosen; *Prosopis juli flora* and *Conocarpus lancifolius*, which were collected from 4 sites. These plant species are shrubs or small trees. The sites include; (IF) near Iron Factory, (FR) King Faisal road, (JMR) Jeddah-Jazan road, and (SRB) North Sport Stadium Mohammed Al-Faisal branch road.

In addition, samples were taken from non-polluted sites from house in Alkhumrah, South Jeddah that were considered as control for the study. On the other hand, *Conocarpus lancifolius*, was collected from (PR) area near Petroleum Refinery, (FR) King Faisal road, (AMR) Alandalus road, and (KRB) ALQahirah branch roads. The selected sites were evaluated for their contamination status similar to a previous study conducted by Shirazi et al. (2006). Soil samples from different locations were collected and analyzed for different physio-chemical analysis. In addition, samples were collected from non-polluted sites (control) taken from house in Alkhumrah, South Jeddah. The samples of soil were taken from the same sites of the plant species.

Analysis of soil and heavy metals in soil and plant samples

The soil was collected from (0-30) cm below the surface and all soil samples were air dried. The dried samples were sieved through a 2mm plastic sieve to remove large gravel-sized materials. Soil analyses included; soil texture, pH and EC. The Electrical conductivity (Ec) was obtained using a 1:5 soil water extract and electronic conductivity meter, following the procedure of Rhoades (1996). On the other hand, to determine heavy metals in soil, soil samples and air dried plant leaves were ground and subjected to microwave assisted digestion with $\text{HNO}_3\text{:H}_2\text{SO}_4\text{:HClO}_4$ mixture, an atomic absorption spectrophotometer. Moreover, Atomic Absorption Spectrophotometer model Inductivity coupled with plasma emission spectrometer ICP (*PARKIN ELEMER*) was used to determine the amount of Cr, Pb and Ni following the method of Allen et al. (1974).

Statistical analysis

Data was fed into the computer and analyzed using IBM SPSS software package version 20.0 (Armonk, NY: IBM Corp). ANOVA was used for comparative analysis, Post Hoc test to carry out pair wise comparison and Spearman coefficient was used to carry out correlational analysis. The significance was found to be at 5% level of the obtained results.

Conclusion

Jeddah is a province with large number of population. However, there is a steady increase in the number of cars and number of factories due to industrialization in this region. The present study evaluated the phytoremediation by two plant species of *Prosopis juli flora* and *Conocarpus lancifolius* located in Jeddah, Saudi Arabia. *Prosopis juli flora* is a wild plant, which produces fruit edible by camel and sheep. However, due to the accumulation of heavy metals on the plant, it is dangerous for animals. On the other hand, *Conocarpus lancifolius* fruit is

poisonous. The results showed that this plant can absorb a large amount of heavy metals especially lead, as compared to *Prosopis juli flora*. Growing plant species that can bear pollution and be able to clean up air are highly recommended. The quality of air depends on controlling the air pollution by controlling traffic and industrial activities. The study results have concluded that phytoremediation can be one of the best technologies that use living plants to clean up soil, air, and water contaminated with hazardous chemicals. However, the results are limited because the procedure was not replicated for confirming the obtained results. More studies are needed to obtain definite knowledge regarding effects on plant species due to accumulation of heavy metals.

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