Graduate College Journal – NU
Vol.15 -2020, No. (6)
ISSN: 1858-6228, http://www.neelain .edu.sd

مجلة الدراسات العليا - جامعة النيلين
المجلد (15) –2020، العدد (6)
الرقم الدولي الموحد للدوريات: 1858-6228

Application of Phytoremediation Technology as Tool for Remediation of Waste Waters from Tannery in Sudan

Khadiga G. Abd Elaleem[1,2*], Ahlam S. Mohamed[3,4], Elbushra Elsheikh Enur[5], Abd Alwahab Hassan Abdalla[6] , Amani Algali Alawad[3] and Hagir G. Abd Elaleem[7]

[1]Department of Biology and Biotechnology, Faculty of Science and Technology, AL Neelain University, Khartoum, Sudan.
[2]Department of Biology, University College in Alkhafji, Hafr Elbatin University, Saudi 2Arabia
[3]Department of Research Services, Industrial Research and Consultancy Centre, Sudan.
[4]Department of Biology, University College at Qaria Alolya, Hafr Elbatin University, 4Saudi Arabia
[5]Faculty of Science, Khartoum University, Sudan
[6]Faculty of Agriculture, Khartoum University, Sudan
[7]Department of Physics, Faculty of Art and Science, Al-Aardha, Jazan Uneversity, Saudi Arabia
Corresponding author E-mail: khadigaalaim@hotmail.com

Abstract

The present study was carried out to evaluate the potentials value of three Sudanese plants namely: *Zea mays*, *Calotropis procera* and *Prosopis chilensis* for phytoremediation of six heavy metals from Khartoum tannery waste water using two types of wastewater (W1 and W2) at five concentrations (0.0%, 25.0, 50.0, 75.0 and 100.0) percentage. Plants were tested for heavy metal accumulation using X-ray fluorescence machine. The results obtained are: For Chromium: *Zea mays* plant showed highest accumulation rate when treated with the W1 at concentration 100 with the accumulation rate as 3782.32. Manganese: The highest absorption rate of manganese obtained by *Zea mays* treated with the W1 at concentration 50 with an accumulation rate as (2937). For Iron: The highest accumulation rate was achieved by *Calotropis prosera* plant when treated with the W2 at concentration 100 with an accumulation rate as (240.2). For Cobalt: *Zea mays* plant treated with the W1 at concentration 50 showed the highest accumulation average as (177.7), followed by the *Calotropis procera* plant treated with W2 at concentration 25 with rate percentage (177.6). On the other hand the *Prosopis chilensis* plant showed a low accumulation rate than the control with all treatments except when treated with the W1 at concentration 25 as (134.4) average. For Nickel: *Calotropis procera* with W2 exhibited an increase over the control to Ni content at all concentration with a maximum absorption at 50% for with (220) rate. For Copper: The highest copper accumulation rate was obtained by *Prosopis chilensis* when treated with W1 at concentration 50 with an accumulation rate as (124.9). So due to the results of this study there is variation in heavy metals accumulation depend on plant species, type and concentration of polluted water.

Keywords: Waste water, Heavy metal, *Calotropis procera*, and Phytoremediation

Introduction

Phytoremediation is a technology which uses plants for the remediation of contaminated soils and water, it is an environmentally friendly, safe and cheap technique used to eliminate pollutants from an environment such as heavy metals (Susarta *et al.,* 2008; Jadia and Fulekar 2009 and Zhang *et al.,* 2010). Basically, phytoremediation of contaminants is categorized under five major sub-groups phytoextraction, phytostabilisation, phytofiltration, phytovolatilisation, and phytodegradation (USEPA, 2000); Ward and Singh 2004). The idea of using metal accumulating plants to remove heavy metals was first introduced more than 300 years ago (Henry, 2000).

Heavy metals are natural constituents of the earth's crust (Jadia and Fulekar 2008 and Ismail *et al*., 2013). Their principal characteristics are an atomic density greater than 5 g cm^{-3} and an atomic number are generally given as greater than 20 (Jadia and Fulekar 2008). The most common heavy metal contaminants are Cd, Cr, Cu, Hg, Pb, and Zn. The occurrence of heavy metals in soils can result of two main sources:

Heavy metals occur naturally in the soil environment from the pedogenetic processes of weathering of parent materials at levels that are regarded as trace and rarely toxic (Wuana, and Okieimen., 2011; and Parizanganeh *et al*., 2012).

Human activities, such as mining, smelting, electroplating, energy and fuel production, power transmission, intensive agriculture, sludge dumping, and melting operations, are the main contributor to heavy metal contamination (Ismail, *et al*., 2013; Dembitsky., 2003 and Ali *et al*., 2013). Heavy metals in the soil from anthropogenic sources tend to be more mobile, hence bioavailable than pedogenic, or lithogenic ones (Wuana., and Okieimen, 2011; Kaasalainen and Yli-Halla, 2003; and Bolan *et al*., 2010). The industry of mining and processing metals is a major source of farmland heavy metal contamination (Navarro *et al*., 2008).

Based on their role on physiological activities, they can be divided in two groups :

Essential heavy metals: (Fe, Mn, Cu, Zn, and Ni) which are micronutrients necessary for vital physiological and biochemical functions of plant growth, they are constituents of many enzymes and other proteins and all plants have the ability to accumulate them from soil solution (Hall., 2002; Djingova and Kuleff., 2000) .

Non-essential heavy metals: (Cd, Pb, As, Hg, and Cr) have unknown biological or physiological function (Subhashini and Swamy 2013; Gaur and Adholeya., 2004) and consequently are non-essential for plant growth.

Both groups are toxic to plants, animals and humans above certain concentrations specific to each element (Adriano, 2001 and Bolan et al., 2010). High contents of both essential and non-essential heavy metals in the soil may inhibit plant growth and can lead to toxicity symptoms in most plants (Ismail, *et al*., 2013; Hall, 2002; Zengin, and Munzuroglu., 2005; and Ochonogor and Atagana., 2014). However, some plant species have the ability to grow and develop in metalliferous soils such as near to mining sites (Gardea-Torresdey *et al*., 2005). Such plants can be used to clean up heavy metal contaminated sites. Willow (Salix viminalis L.), maize (*Zea mays* L.), Indian mustard (Brassica juncea L.) and sunflower (Helianthus annuus L.) has been found to be highly tolerant to heavy metals (Schmidt, 2003; Ahlam *et al*., 2014). All metals are toxic at higher concentrations because they cause oxidative stress by formation of free radical. Phytoremediation employs important role to remove contaminants from polluted soils and water which require decontamination. Commercial strategy is to use phytoremediation as a lower cost alternative to current expensive engineering methods. One of the most important causes of pollution is the high rates of industrialization due to growing population. Different kinds of pollution are known but this study deals only with: Water pollution. Heavy metals dissolved in water can be bio-accumulated into the food chain. The long-term exposure to heavy metals for humans may affect growth, metabolism, reproduction, and even lead to various diseases. Therefore, it is urgent to find suitable plants for remediate the heavy metal pollution by phytoremediation technology. Many plants have been reported to tolerate and accumulate heavy metals, and can be used to eliminate the heavy metal contamination in soils round the world , but there are few studies in the field of the uses of Sudanese plants as remediators for heavy metal, so the aim of this study was to assess the ability of three Sudanese plants namely, *Zea mays* (family Poaceae), *Calotropis procera* (family Ascclepiadaceae) , and *Prosopis chilensis* (family Fabaceae) as remediators for six of the heavy metals(Cr, Mn, Fe, Co, Ni, and Cu) from industrial waste water of Khartoum Tannery, Khartoum, Sudan.

Materials and Methods

Plant Samples:

Three plant species belong to three different families namely *Zea mays* (Family Poaceae), *Calotropis procera* (Family Ascclepiadaceae), and *Prosopis chilensis* (Family Fabaceae) were used to evaluate the ability of these plants for waste water remedy, through their capabilities to absorb and accumulate different elements from waste water under greenhouse conditions.

Water Samples:

Two waste water sample were collected from the tannery production line , analyzed for heavy metals content, water type one (W1) was collected from the tanning stage (after addition of chrome), water type two (W2) was collected from the final waste (disposed water) after the end of tanning proses. For each type of contaminated water (WI and W2) five concentrations (0.0, 25.0, 50.0, 75.0 and 100.0) percentage were prepared, zero concentration referred to the control (tap water). The other concentrations referred to as the ratios of contaminated water samples to control.

Sand Samples:

Sand sample were collected and washed under running tap water

Experimental phase

Plants growth

Sand sample were collected and washed under running tap water. The seeds of mentioned plant species were grown in pots under greenhouse condition and allowed to reach suitable size before transplanting, then transplanted in pots (5 plants in each pot). Ten pots were used for each plant species for one type of contaminated water. All pots were irrigated daily with 300 ml tap water for three to seven days and then by two types of contaminated water (WI and W2) separately with five concentrations (0.0, 25.0, 50.0, 75.0 and 100.0) percentage.

Plants Harvesting

The plant species were carefully harvested after about two month to obtain the maximum recovery of roots. The plants were then rinsed in tap water and subjected to analysis using X-Ray -fluorescence machine (XRF).

Plants Sample preparation and analysis

Plant samples were ground into a fine powder with uniform size similar to Marguí *et al*., (2009). One gram from each sample was pressed into a disc shape pellet (Byers et al., 2016) . As particle size is wave length dependent. Pellets should be thick enough to maximize the count rate for shortest wave length line (Byers *et al.*, 2016). Plant samples were analyzing using X-Ray-fluorescence machine (XRF).

Results and Discussions

Results

Chromium:

Data in Table 1 explained the following: *Zea mays* plant showed the highest rate of accumulation of chromium when treated with the first type of water at concentration 100 with the accumulation rate of (3782.32), followed by the *Calotropis prosera* plant when treated with the first type of water at concentration 50% with an accumulation rate of (3772). On the other hand *Prosopis chilensis* plant expressed accumulation rate less than control with water type two at all concentration, while accumulation rate of the same plant with water type one explained high rate compare to the control.

Manganese:

As shown in Table 2: All plants under study showed a high accumulation rate of manganese compared to the control, except *Prosopis chilensis* plant treated with the first type of water at concentration 50% where the accumulation rate was (58.1). The highest absorption rate of manganese was made by *Zea mays* treated with the first type of water at concentration 50 with an accumulation rate of (2937), followed by the same plant at the concentration of 25 in the same water (W1) at the rate of (353.3).

Iron:

Data in Table 3 represented the flowering: *Calotropis prosera* plant obtained high accumulation rates of iron with all treatments, while *Prosopis chilensis* showed lower accumulation rate than control in all treatments, *Zea mays* plant treated with the first type of water showed lower accumulation rates than control, while water type two represented high accumulation rate of iron compare to control in the same plant. The highest accumulation rate was achieved by *Calotropis prosera* plant when treated with the second type of water at concentration 100 with an accumulation rate of (240.2).

Cobalt:

Data in Table 4 represented the following: *Zea mays* plant treated with the W1 at concentration 50% showed the highest accumulation average of cobalt as (177.7) average, followed by the *Calotropis procera* plant treated with W2 at the concentration 25 with percentage (177.6). On the other hand the *Prosopis chilensis* plant showed a low accumulation rate than the control with all treatments except when treated with the first type of water at concentration 25 as (134.4) average

Nickel:

Data in Table 5 represented that treatment with water type one (W1) showed an uptake decrease in Nickel below the control in the whole plants with *Zea mays*, *Calotropis procera* and *Prosopis chilensis* , except Prosopis chilensis at concentration 25% the Nickel uptake is equal to control (100). With water type two (W2) treatment, *Zea mays* recorded slight increase only at 75% and 100% concentrations, with a maximum at 100 % concentration (155.7). *Calotropis procera* with W2 exhibited an increase over the control to Ni content at all concentration with a maximum absorption at 50% for with (220) average. *Prosopis chilensis* has shown an uptake decrease of Ni below the control for the whole plants watered with W1 and W2.

Copper:

As shown in Table 6, *Zea mays* plant showed a low accumulation rate of copper than the control with all treatments, while the *Prosopis chilensis* plant showed a higher accumulation rate than the control with all treatments except when treated with the first type of water at concentration 100% as (85.9) average. The highest copper accumulation rate was obtained by *Prosopis chilensis* when treated with the first type of water at concentration 50% with an accumulation rate of (124.9).

Discussions

Chromium (Cr):

As shown in Table 1 an increase over the control was shown by *Zea mays* at both low and high concentrations when the plants were watered with W1, the highest value was obtained at 100% concentration with a value of (3782.32) over the control. For *Calotropis procera* grown in W1 the high value for Cr was obtained at 50 % concentration (3772.) *Prosopis chilensis* plant grown in W1 gave an increase over the control at both low and high concentrations. The highest uptake value for Cr was obtained at 100 % concentration (1167). The increase in uptake of Cr at high concentrations, in W1, is in agreement with the work of (Barocsi *et al*., 2003; Garcia *et al*., 2004; and Weis and Weis 2004) who noticed an increase in Cr uptake with the increase of concentration in the growth media. In this experiment, higher Cr uptake was reported at the highest concentration (100%), except for *Calotropis procera* which showed higher uptake at 50% concentration. Similar results were reported by (Chandra and Sinha 1997) who studied the ability of *Sctipus lausiris*, *Phraginites karka* and *Bacopa monnier* for heavy metal accumulation and observed that all three plant species were able to accumulate Chromium in their roots.

Manganese (Mn):

Manganese is an essential element for plant to grow. The available form of manganese is the divalent type which may be found dissolved in the soil solution or as an exchangeable ion absorbed by the soil colloids. Toxic level of manganese fell in the range of 1000-12000 mg/kg (Reeves and Baker, 2000). The accumulation of manganese in the three investigated plant species, with the two types of waste water, did not exceed the toxic levels and they showed different levels of manganese uptake. *Zea mays* plant gave significant differences of manganese uptake between WI and W2. With W1, *Zea mays* showed higher values of manganese over the control except at 100% concentration. The highest uptake was shown at 50% concentration with a value of (2937) over the control, followed by a value of (353) at 25 % concentration (Table 2). Calotropis *procera* with W1, showed slight increase over the control at 25%, 50%and 75% concentrations with a maximum 139 % at 50% concentration, with W2, *Calotropis procera* plant exhibited slight increase in uptake over the control at all concentrations with a maximum value of (173) at 100 % concentration. The *Prosopis chilensis* plant exhibited high uptake patterns for manganese when grown in both types of waste water (WI and W2) at all concentration except W1at concentration 50% , with higher accumulation rate (239.5) with W2 at concentration 50%. This is in agreement with the work of (Blayloch and Huang, 2000) who reported that there were significant differences in the uptake of manganese between plant species. Also manganese level in this investigation agreed with the work of Sharma and Dubey (2005) who observed that manganese and Copper concentrations generally decreased with the increase in Cr and Zn levels and is limited to the roots and stems. Moreover, the results are in agreement with data reported by (Wange *et al.,* 2003).

Iron (Fe):

Data in Table 3 explained that, the uptake of iron obtained decrease below the control with *Zea mays* plant grown in WI. With W2, *Zea mays* plant showed an increase over the control with maximum uptake when plant treated with W2 at 75 %

concentrations, with a mean of (178) over the control. For *Calotropis procera* plant grown in W1, an increase over the control was observed at all concentrations with a maximum at 25 concentrations (170.5). With W2 *Calotropis procera* plant indicated an uptake increase over the control, with a maximum at 100 % concentration, 240 % over the control In case of *Prosopis chilensis* plant a decreasing pattern was observed in both types of waste water, this is in agreement with the work of Brown et al., 1994, who noticed that the availability of iron for the plant is controlled, rather sharply, by the pH and that the concentration of iron arc normally below 1000 micro-g /gram (Reeves *et al*., 1999).

Cobalt (Co):

Uptake of Cobalt by *Zea mays*, *Prosopis chilensis* and Caloropis *procera* plant in the two types of tannery waste water recorded very low values as shown in Table 4. Few cases are known in which Cobalt is accumulated by plant species (Brooks *et al*., 1977). The low values obtained in this experiment, within the range of 0.03-2.0 mg/kg, are in agreement with the findings of Reeves and Baker (2000) who concluded that values obtained for plant did not exceed 20mg/kg even in Co enriched soils. *Zea mays* plant treated with W1 showed an increase over the control at 50 % and 75 % concentrations with a value of 177% and 166 % respectively. *Zea mays* plant treated with W2 showed an increase over the control at 50 % and 100 % concentrations with a value of 172% and 144 % respectively. *Calotropis procera* plant treated with W1 and W2 resulted in an increase over the control with the highest value (128%) at 75% concentration for WI and at 50 % concentration (223%) for W2. For *Prosopis chilensis* plant treated with W1, an increase over the control was shown only at 25% concentration with a value of 134.3%. Accumulation of cobalt differed among plants is in agreement with what reported by Wang *et al*., (2003)

Nickel (Ni):

Although Nickel occurs in soil as an inorganic compound or bound to forms of organic matter and clays, yet it is present in very low values in plants. It is also known that low concentration of Nickel may stimulate germination and that high concentration of the element inhibits shoot and root growth (Brune and Dietz, 1995).Table (5) represented that treatment with water type one (w1) showed an uptake decrease in Nickel below the control in the whole plants with *Zea mays*, *Calotropis procera* and *Prosopis chilensis* , except *Prosopis chilensis* at concentration 25% the Nickel uptake is equal to control (100). With water type two (W2) treatment, *Zea mays* recorded slight increase only at 75% and 100% concentrations, with a maximum at 100 % concentration (155.7%). *Calotropis procera* with W2 exhibited an increase over the control to Ni content at all concentration with a maximum absorption at 50% for with (220) %. *Prosopis chilensis* has shown an uptake decrease of Ni below the control for the whole plants watered with W1 and W2. This result are in agreement with the findings of (Schat *et al*., 2000), who recorded that; Ni uptake occurs under combined metal exposure in Alyssum species.

Copper (Cu):

The importance of Copper for plants metabolism had been shown by Marschner, (1995) who indicated its essentiality as an enzyme co - factor.

The water soluble Copper in soil does not normally exceed 1 % of its total content and the normal concentration of Cu in plants is within the range of 5-25 mg/kg (Reeves and Baker, 2000). It is well known that Cu at super levels is highly toxic to plants (Murphy *et al*., 1999). The three plant species watered with two types of tannery waste water (WI and W2) at four concentrations (25 %, 50 %, 75 % and 100 %) exhibited low Cu uptake.

Zea mas gave uptake values for the whole plants below the control with W1 and W2 (Table 6). *Calotropis procera* plant showed (Table 6) an uptake decrease below the control with W 1 and slight increase with W2 at 25 % and 75 % concentration with a maximum at 25 % concentration (110%).

Prosopis chilensis . The examined whole plants exhibited a slight increase in Cu over the control at all concentrations with W2, with a maximum at 50% concentration (120 %). It was noticed that the Cu content in this experiment was very low. This is in agreement with the findings of (Salt and Kramer, 2000) who reported that plants Cu concentrations are controlled with remarkable narrow range. So depend on the results of this study there is differences in percentage absorption due to variation in plants, type and concentration of polluted water.

Table 1: Mean Chromium content (PPM) in *Zea mays*, *Calotropis procera* and *Prosopis chilensis* whole plants grown in sand at different concentration of two types of waste water (W1 and W2).

Conc. %	*Zea mays*			*Calotropis procera*			*Prosopis chilensis*		
	W1	W2	Mean ±SD	W1	W2	Mean ±SD	W1	W2	Mean ±SD
0	104.54 (100%)	104.54 (100%)	-	93.34 (100%)	93.34 (100%)	-	33.4 (100%)	33.4 (100%)	-
25	317.1 (303.33)	14.11 (13.5)	165.62 ±151.5	239.13 (256.1)	33.04 (35.3)	136.0 ±103.05	229.05 (685.7)	21.55 (64.8)	125.3 ±103.8
50	573.09 (548.2	88.93 (85.07)	331.01 ±242.08	3521.15 (3772)	25.28 (27.08)	1773.2 ±1747.94	229.05 6 (685.7)	14.62 (43.7)	121.8 ±107.2
75	547.14 (523.37)	13.81 (13.22)	280.48 ±266.67	383.5 (410.8)	107.25 (114.9)	245.38 ±138.13	210.32 (630.8)	17.88 (53.5)	114.3 ±96.4
100	3954.03 (3782.32)	190.05 (181.8)	2072.04 ±1881.99	700.27 (750.8)	28.77 (30.8)	364.52 ±335.75	389.99 (1167.6)	17.8 (53.2)	203.9 ±186.1
Mean	1347.84	76.7	712.27 ±635.5	1211.01	48.4	629.7 ±581.2	264.7	17.9	141.3±123.4

(Figures between brackets are the mean expressed as percentage over the control)

Table 2: Mean Mn content (PPM) in *Zea mays*, *Calotropis procera* and *Prosopis chilensis* whole plants grown in sand at different concentration of two types of waste water (W1 and W2).

Conc. %	*Zea mays*			*Calotropis procera*			*Prosopis chilensis*		
	W1	W2	Mean ±SD	W1	W2	Mean ±SD	W1	W2	Mean ±SD
0	88.24 (100%)	88.24 (100%)	-	134.42 (100%)	134.42 (100%)	-	65.4 (100%)	65.4 (100%)	-
25	311.76 (353.3)	156.57 (177.4)	234.17±77.60	152.34 (113.3)	144.67 (107.6)	148.51±3.84	82.31 (126.7)	82.31 (125.8)	82.61±0.30
50	2591.66 (2937)	98.96 (112.11)	1345.31±1246.35	187.19 (139.2)	217.35 (161.69)	202.27±15.08	38.04 (58.1)	156.66 (239.5)	97.4±59.30
75	282.83 (320.5)	118.71 (134.5)	200.77±82.06	171.79 (127.8)	193.66 (144.0)	182.73±10.94	137.08 (208.6)	70.5 (107.7)	103.8±33.30
100	40.59 (45.9)	124.82 (141.4)	82.7±34.39	124.11 (92.3)	233.64 (173.8)	178.88±54.77	105.88 (161.8)	80.2 (122.6)	93.04± 12.80
Mean	806.71	124.76	465.71±340.97	158.8	197.33	178.06±19.2	90.9	97.4	94.15±3.25

(Figures between brackets are the mean expressed as percentage over the control)

Table 3: Mean Fe content (PPM) in *Zea mays*, *Calotropis procera* and *Prosopis chilensis* whole plants grown in sand at different concentration of two types of waste water (W1 and W2).

Conc. %	*Zea mays*			*Calotropis procera*			*Prosopis chilensis*		
	W1	W2	Mean ±SD	W1	W2	Mean ±SD	W1	W2	Mean ±SD
0	7525.9 (100%)	7525.9 (100%)	-	2279.09 (100%)	2279.09 (100%)	-	2133.9 (100%)	2133.9 (100%)	-
25	3055.65 (40.6)	12975.02 (172.4)	8015.35 ±4959.69	3885.9 (170.5)	2625.52 (115.2)	3255.71 ±630.19	1816.53 (85.10)	1911.69 (89.50)	1864.10 ±47.6
50	2246.98 (29.8)	10560.7 (140.3)	4603.64 ±4157.06	2908.25 (127.6)	2664.59 (116.9)	2786.42 ±121.83	855.6 (40.09)	1218.83 (57.10)	1037.22 ±181.8
75	2307.42 (30.6)	13387.34 (177.8)	7847.38 ±5539.96	3493.79 (149.5)	3136.97 (137.64)	3315.38 ±178.41	1631.11 (76.40)	975.37 (45.70)	1303.22 ±327.9
100	3823.7 (50.8)	9554.15 (126.8)	6688.93 ±2865.23	2626.2 (115.2)	5474.45 (240.2)	4050.30 ±1424.13	1779.12 (83.30)	1047.88 (49.10)	1413.50 ±365.6
Mean	2858.30	16619.3	7238.8 ±4380.5	3228.5	3475.3	3351.9 ±123.4	1520.59	1288.40	1404.40 ±116.09

(Figures between brackets are the mean expressed as percentage over the control)

Table 4: Mean Co content (PPM) in *Zea mays*, *Calotropis procera* and *Prosopis chilensis* whole plants grown in sand at different concentration of two types of waste water (W1 and W2).

Conc. %	*Zea mays*			*Calotropis procera*			*Prosopis chilensis*		
	W1	W2	Mean ±SD	W1	W2	Mean ±SD	W1	W2	Mean ±SD
0	0.36 (100%)	0.36 (100%)	-	0.43 (100%)	0.43 (100%)	-	1.4 (100%)	1.4 (100%)	-
25	0.35 (97.2)	0 (0)	0.18 ±0.18	0.5 (116.2)	0.76 (176.7)	0.63 ±0.13	1.88 (134.3)	1.2 (85.7)	1.54 ±0.34
50	0.64 (177.7)	0.62 (172.2)	0.63 ±0.01	0.52 (120.9)	0.96 (223.2)	0.74 ±0.22	1.27 (90.7)	0.54 (38.6)	0.91 ±0.37
75	0.16 (166.6)	0.28 (77.7)	0.44 ±0.16	0.55 (127.9)	0.55 (127.9)	0.55 ±0	0.21 (15)	0.21 (15)	0.21 ±0
100	0.6 (44.4)	0.52 (144.4)	0.34 ±0.18	0.5 (116.2)	0.67 (155.8)	0.59 ±0.09	0.97 (69.3)	0.86 (61.4)	0.9 ±0.05
Mean	0.43	0.47	0.48 ±0.01	0.51	0.73	0.62 ±0.11	1.08	0.7	0.89 ±0.19

(Figures between brackets are the mean expressed as percentage over the control)

Table 5: Mean Ni content (PPM) in *Zea mays*, *Calotropis procera* and *Prosopis chilensis* whole plants grown in sand at different concentration of two types of waste water (W1 and W2).

Conc. %	*Zea mays*			*Calotropis procera*			*Prosopis chilensis*		
	W1	W2	Mean ±SD	W1	W2	Mean ±SD	W1	W2	Mean ±SD
0	6.9 (100%)	6.9 (100%)	-	13.1 (100%)	13.1 (100%)	-	10.7 (100%)	10.7 (100%)	-
25	4.9 (71)	2.24 (35)	3.67 ±1.25	10.6 (80.8)	22.2 (169.7)	16.4 ±5.8	10.7 (100)	7.9 (74)	9.3 ±1.4
50	3.79 (54.9)	5.9 (85)	4.84 ±1	9.8 (74.8)	28.9 (220)	19.4 ±9.6	8.2 (76)	5.1 (47.7)	6.6 ±1.5
75	3.23 (46.8)	7.5 (108.8)	5.37 ±2.1	9.1 (69.6)	26.5 (202)	17.8 ±8.7	6.4 (60)	5 (47.4)	5.8 ±0.7
100	5.9 (85.6)	10.8 (155.7)	9.44 ±2.4	9.3 (70.8)	23.6 (180)	16.4 ±7.2	10.3 (96.4)	3.6 (33)	6.9 ±3.4
Mean	4.46	6.6	5.5 ±1.1	9.7	25.3	7.5 ±7.8	8.9	5.4	7.2 ±1.7

(Figures between brackets are the mean expressed as percentage over the control)

Table 6: Mean Cu content (PPM) in *Zea mays*, *Calotropis procera* and *Prosopis chilensis* whole plants grown in sand at different concentration of two types of waste water (W1 and W2).

Conc. %	*Zea mays*			*Calotropis procera*			*Prosopis chilensis*		
	W1	W2	Mean ±SD	W1	W2	Mean ±SD	W1	W2	Mean ±SD
0	19.19 (100%)	19.19 (100%)	-	29.20 (100%)	29.20 (100%)	-	17.33 (100%)	17.33 (100%)	-
25	14.72 (76.6)	17.78 (92.6)	16.25±1.53	25.02 (85.6)	32.32 (110.6)	28.67± 3.60	18.96 (109.4)	19.70 (113.6)	19.33± 0.40
50	17.44 (90.8)	18.18 (94.7)	17.81±0.37	27.29 (93.4)	28.61 (97.9)	27.95± 0.66	21.66 (124.9)	20.80 (120.02)	21.23± 0.43
75	16.46 (85.7)	18.74 (97.6)	17.62±1.14	22.99 (78.7)	30.15 (103.2)	26.57± 3.58	17.79 (102.6)	17.50 (100.9)	17.65± 0.15
100	16.92 (88.1)	10.00 (52.1)	13.46±3.46	22.18 (75.9)	28.27 (96.8)	25.23± 3.05	14.90 (85.9)	18.40 (106.1)	16.65± 1.75
Mean	16.30	16.17	16.23±0.06	24.37	29.83	27.1± 2.73	18.3	19.1	18.7± 0.4

(Figures between brackets are the mean expressed as percentage over the control)

Conclusion

The study showed clear differences in the absorption ratio of the heavy metals by the three plants species, as well as differences in absorbance associated with the type of water used compared to the control. The study concluded that for the treatment of chromium and cobalt pollution, it is preferable to use *Zea mays*; the *Calotropis procera* and the *Zea mays* plants to remove the manganese; use of the *Calotropis procera* to remove iron and Nickel; and to remove the copper preferred to sustain the *Prosopis chilensis* plant**.**

References

Adriano, D.C. (2001), "Trace Elements in Terrestrial Environments: Biochemistry, Bioavailability and Risks of Metals", 2nd Edition, Springer-Verlag, New York.

Ahlam Sirelkhatim, El Bushra Elshiekh Elnur(2014), "Accumulation of Cobalt, Molybdenum, and lead by *Zea mays*, Prosopis chilenus and *Calotropis procera* Plant in Contaminated Soil in the Vicinity of Khartoum Tannery", Idusterial Research Journal vol.I, pp. 01-15.

Ali, H., Khan, E. and Sajad, M.A. (2013), "Phytoremediation of Heavy Metals Concepts and Applications", Chemosphere, 91, pp. 869-881.

Barocsi, A. Csintalan, Z., Kocsanyi, L., dushenkov, S., Kuperberg, M. J., Kucharski, R. and Richter, P. I. (2003), "Optimizing phytoremediation of heavy metal- contaminated soil by exploiting plants stress adaptation", International Journal of phytoremediation . 5(1) , pp. 13-21.

Blaylock, M.J. and Huang, J.W. (2000), "Phytoextraction of metals. In Phytoremediation of Toxic Metals Using Plants to Clean Up the Environment". Raskin, 1. And Ensley, B.D. (eds), John Wiely and Sons Inc New York , pp. 35-70.

Bolan, N., Naidu, R., Choppala, G., Park, J., Mora, M.L., Budianta, D. and Panneerselvam, P. (2010), "Solute Interactions in Soils in Relation to the Bioavailability and Environmental Remediation of Heavy Metals and Metalloids", Pedologist, Vol., 1-18.

Brooks, R.R., Mccleave, J.A. , Sobotied, EK. (1977)," The serpentine vegetation of Goias State, Brazil", In: Baker, A. J. M. Proctor, J. and Reeves, R. Ii, eds. The Vegetation of Ultramafic (serpentine) Soils. Andover, V. K. Intercept Ltd, pp.67-81.

Brown S L, Chaney R L, Angle J S, Baker A J M.(1994), "Phytoremediation potential of Thlaspi caerulescens and bladder campion for zinc- and cadmium-contaminated soil", J Environ Qual.;23, pp. 1151–1157.

Brune, A.and Dietz, K. J. (1995)," A comparative analysis of element composition of roots and leaves of barley seedling grown in the presence of toxic cadmium, molybdenum nickel and zinc concentrations", J. Plant Nutrition 18, pp. 853-868.

Byers, H.L, McHenry, . L.J. and T.J. Grundl. (2016), Forty-nine major and trace element concentrations measured in soil reference materials NIST SRM 2586, 2587, 2709a, 2710a and 2711a using ICP-MS and

wavelength dispersive-XRF Geostandards and Geoanalytical Research, 40 (3) pp. 433-445.

Chandra, P., Sinha, S. Rai, U. N. (1997), "Bioremediation of Chromium from water and soil by vascular aquatic plants, Phytoremediation of soil and water contaminants Washington", USA, American Chemical Society, , pp. 274- 282.

Dembitsky, V. (2003)," Natural Occurrence of Arseno Compounds in Plants, Lichens, Fungi, Algal Species, and Microorganisms" Plant Science, 165, pp. 1177-1192.

Djingova, R and Kuleff, I. (2000), "Instrumental Techniques for Trace Analysis. In: Vernet", J.P., Ed., Trace Elements: Their Distribution and Effects in the Environment, Elsevier Science Ltd., United Kingdom, pp. 137-185.

Garcia, G. Faz, A. and Cunha. M. (2004), "Performance of piptiatherummiliaceum (smilo grass) in edaphic Pb and Zn Phytoremediation over a short growth period", International Biodeterioration and Biodegradation 54, pp. 245 – 250.

Gardea-Torresdey, J.L., Peralta-Videa, J.R., de la Rosa, G. and Parsons, J.G. (2005), "Phytoremediation of Heavy Metals and Study of the Metal Coordination by X-Ray Absorption Spectroscopy", Coordination Chemistry Reviews, 249, pp. 1797-1810.

Gaur, A. and Adholeya, A. (2004), "Prospects of Arbuscular Mycorrhizal Fungi in Phytoremediation of Heavy Metal Contaminated Soils", Current Science, 86, pp. 528-534.

Hall, J.L. (2002), "Cellular Mechanisms for Heavy Metal Detoxification and Tolerance", Journal of Experimental Botany, 53, pp. 1-11.

Henry J. R. (2000), "An overview of phytoremediation of lead and mercury" NNEMS Reports, Washington DC., pp. 3-9.

Ismail, S., Khan, F. and Zafar Iqbal, M. (2013), "Phytoremediation: Assessing Tolerance of Tree Species against Heavy Metal (PB and CD) Toxicity", Pakistan Journal of Botany, 45, pp. 2181-2186.

Jadia C. D. and M. H. Fulekar. (2009), "Phytoremediation of heavy metals: Recent Techniques", African Journal, vol.7, no. 5, pp. 547-558.

Jadia, C.D. and Fulekar, M.H. (2008),"Phytoremediation: The Application of Vermicompost to Remove Zinc, Cadmium,Copper, Nickel and Lead by Sunflower Plant", Environmental Engineering and Management Journal, 7, pp. 547-558.

Kaasalainen, M. and Yli-Halla, M. (2003), "Use of Sequential Extraction to Assess Metal Partitioning in Soils", Environmental Pollution, 126, pp. 225-233.

Marguí,E Queralt, I.and Hidalgo M. (2009), Application of X-ray fluorescence spectrometry to determination and quantitation of metals in vegetal material Trends in Analytical Chemistry, 28 (3) , pp. 362-372.

Marschner, H. (1995),"Mineral Nutrition of Higher Plants", second edition. Academic Press. London.

Murphy, A. S., Eisinger, W. R., Shaff, J. E., Kochian, V .and Taiz, L. (1999),"Early copper-induced leaking leakage of K(+) from Arabidopsis seedling is mediated by ion channels and coupled to citrate efflux", Plant Physiol. 121, pp. 1375- 1382.

Navarro, M.C., Perez-Sirvent, C., Martinez-Sanchez, M.J., Vidal, J., Tovar, P.J. and Bech, J. (2008), "Abandoned Mine Sites as a Source of Contamination by Heavy Metals: A Case Study in a Semi-Arid Zone", Journal of Geochemical Exploration, 96, pp. 183-193.

Ochonogor, R.O. and Atagana, H.I. (2014), "Phytoremediation of Heavy Metal Contaminated Soil by Psoralea pinnata", International Journal of Environmental Science and Development, 5, pp. 440-443.

Parizanganeh, A.H., Bijnavand, V., Zamani, A.A. and Hajabolfath, A. (2012), "Concentration, Distribution and Comparison of Total and Bioavailable Heavy Metals in Top Soils of Bonab District in Zanjan Province". Open Journal of Soil Science, 2, pp. 123-132.

Reeves, R. D., Baker; A. J. M. Borhidi, A. and Berazain. R. (1999), "Nickel 1-lyper—accumulating in the serpentine flora of Cuba", Annals of Botany, 1, pp. 29-38.

Reeves, R. D.. and Baker; A. J. M. (2000),"Metal - accumulating Plants In Raskin" 1 and Ensley, B. d., (eds). Phytorcmediation of toxic metals: Using Plants to clean - up the environment. New York, John Wiley andSons, , pp. 193-230.

Salt, D and Kramer, U. (2000),"Mechanisms of metal hyper accumulation in plants. In: Phytoremediation of toxic metals using plants to clean up the environment", Raskin. I. And Ensley, B. D.(eds) chapter 13, John Wiely and sons, New York.

Schat, H., Liugany, M. And Bernhard, R. (2000)," Metal-Specific Patterns of Tolerance, Uptake, and Transport of Heavy Metals in Hyperaccumulating and Non-hyperaccumulating Metallophytes. in: Terry,N.and Banuelos, G eds. Phytorernediation of contaminated soil and water" Florida. CRC press LLC,p. 171 - 185.

Schmidt, U. (2003), "Enhancing Phytoextraction: The Effects of Chemical Soil Manipulation on Mobility, Plant Accumulation, and Leaching of Heavy Metals", Journal of Environmental Quality, 32, pp. 1939-1954.

Sharma. P. and Dubey, R. S. (2005),"Lead toxicity in plants". Braz. J. Plant Physiol., 17(1): 35-52.

Subhashini V, Swamy AVVS (2013), "Phytoremediation of Pb and Ni contaminated soils using Catharanthus roseus (L.)", Universal J. Environ. Res. Technol 3, pp. 465-472.

Susarta, S. Medina, V. F and McCutcheon, S. C.(2008), "Phytoremediation: An ecological solution to organic chemical contamination", Ecological Engineering, vol. 18, no. 5, pp. 647-658.

USEPA (United State Environmental Protection Agency). (2000), "Introduction to phytoremediation, Office of Research and Development", Washington, D.C. EPA/600/R-99/107.

Wang, Q. R. Cui YS. Liu XM. Dong YT. Chrisite P. (2003),"Soil contamination and uptake of heavy metals at polluted sites in China". J. Environ. Sd. Heal. A. 38, pp. 823 – 838.

Ward O. P. and Singh A.(2004), "Soil bioremediation and phytoremediation — An overview, Applied Bioremediation and Phytoremediation", vol. 1, pp. 1-11.

Weis, J. S. and Weis, P, (2004),"Metal uptake, transport and release by wet-land plants: Implications for phytoremediation and restoration", Environment International, 30(5):685-700.

Wuana, R.A. and Okieimen, F.E (2011), "Heavy Metals in Contaminated Soils: A Review of Sources, Chemistry, Risks and Best Available Strategies for Remediation". Communications in Soil Science and Plant Analysis, 42, pp. 111-122.

Zengin, F.K. and Munzuroglu, O. (2005), "Effects of Some Heavy Metals on Content of Chlorophyll, Proline and Some Antioxidant Chemicals in Bean (Phaseolus vulgaris L.) Seedlings", Acta Biologica Cracoviensia Series Botanica, 47, pp. 157-164.

Zhang, B. Y. Zhen J. S, and Sharp R. G. (2010), "Phytoremediation in engineered wetlands: Mechanism and Applications", Procedia Environmental Science, vol. 2, pp. 1315-1325