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Original Research

Removal of Lead from Enriched Sewage Sludge-Amended Soil by Canola (*Brassica napus* L.) through Phytoremediation Technology

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Abstract

Lead (Pb) in sewage sludge, used as a soil additive, is a major problem for soil quality. A field experiment was conducted during the two successive growth seasons (2011-12) at the experimental station of King Abdulaziz University. The objective of this study was to investigate the capability of canola (*Brassica napus* L.) plants to uptake lead (Pb) from soil contaminated with lead-enriched sewage sludge. The translocation of lead from root to shoot system then to seed and its effects on studied agronomic traits (plant root length, plant height and seed yield/plant besides seed yield/ha were evaluated. The study outcomes showed that Pb had significant effects (at $p \leq 0.01$) on all evaluated traits. As Pb concentration in the sewage sludge amended soil increased, Pb in each plant part significantly increased. Pb concentrations in root system were more than in shoot system and in shoot system were more than in seeds. Moreover, canola removal of Pb ranged between 44 to 67% from the Pb content of the polluted soil before phytoremediation, without toxic effects on plants during growth. Canola plants could be used as phytoremediators to eliminate or reduce heavy metal concentrations of polluted soils for environmental and human health.

Keywords: phytoextraction, Pb, canola, agronomic traits, sludge, heavy metals, soil pollution

Introduction

Heavy metals such as lead are important environ-mental pollutants, particularly in areas with high anthro-pogenic pressure. Their presence in the atmosphere, soil, and water, even in trace amounts, can cause serious problems to all organisms, and heavy metal bioaccumulation, especially in the food chain, can be highly dangerous to human health [1]. Sewage sludge in many countries is used as a soil additive to improve soil physicochemical proprieties, growth conditions, and as a good source of plant nutrients, but this sewage sludge often contains many toxins, such as heavy metals. To confirm this information, Singh and Agrawal [2] conducted an experimental study on the effects of sewage sludge amendment on heavy metal accumulation and the consequent responses of *Beta vulgaris* plants. Final results showed that Pb, Zn, Cd, Ni, Cr, and Cu concentrations in shoots and roots of plants grown in sewage sludge-amended soils were significantly higher as compared to

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those in unamended soil. The use of plants to remove heavy metals from soil "phytoremediation" is expanding due to its cost-effectiveness as compared to conventional methods, and it has revealed great potential [3].

It was shown that the absorption of heavy metals, from polluted soil, by the plant roots and their accumulation in different parts of the plant caused a reduction in the growth of those plant parts [4].

Al-Dhaibani [5] found that root length, plant height, and seed yield of sunflower plants were affected by highly cadmium-polluted sewage sludge-amended soil. Toxic metal ions primarily restrict root growth, thereby impairing nutrient uptake and reducing shoot growth [6]. Lead as a toxic heavy metal has attracted more and more attention for its widespread distribution and potential risk to the environment. Pb contamination in soils does not only cause changes of soil microorganisms and their activities, resulting in soil fertility deterioration, but also can directly change physiological indices and, furthermore, yield decline [7].

The findings obtained by Chhotu [8] showed that low doses of Pb, Cd, and Ni stimulated the root and shoot elongation of sunflower plants. He also found that at higher concentrations, i.e. 40 and 50 ppm of those heavy metals, the ability of germination was significantly reduced, and as a result plant growth and root and shoot elongation were all affected. *Sesbania drummondii* growth was significantly inhibited with metal treatments of lead and nickel, *S. drummondii* accumulated substantially higher concentrations of metals in the roots than shoots. The uptake of metals followed the order Pb>Ni in roots and shoots [9]. For *Brassica oleracea* plants, application of soil amendments increased both shoot and root biomass significantly, as compared to the control treatment [10]. In a study conducted by Radi [11], it was found that lead inhibited the growth of radish plants and in another study retarded shoot growth due to the presence of the root environment with excess Pb. In a study conducted by Pichtel [12] on distribution of Pb and Cd in soils and plants of two contaminated sites (battery dump sites), plant tissue Pb concentration means were 326.3 and 600.0 mg/kg in shoot and root of the *Aesculus glabra* plant, respectively. *Noea mucronata* is the best accumulator for Pb, Cd, and Ni among five dominant vegetations tested for accumulation of heavy metals. Phytoremediation potential of canola species grown on a multi-metal contaminated soil was studied by Marchiol [13] and his findings illustrated that canola was more effective in the uptake of Pb and other heavy metals than mustard, while heavy metal uptake by roots of both species was higher than heavy metal uptake by shoots. Results obtained by Turan and Esringu [3] showed that heavy metal concentrations in roots were about 4-6 times higher than in shoots. Root accumulation was also confirmed by results obtained by John [14], who found that more accumulation of Pb and Cd was observed in roots than shoots in *Brassica junce* L.

An experiment by Sekhar [15] on the crops of cabbage, a*maranthus*, spinach, radish, lady's finger, and forage grasses grown in sewage sludge-amended soils showed higher concentrations of Pb, Cd, Cr, Co, Cu, Ni, and Zn as compared to those grown in unamended soil. Results obtained by Wu [16] showed that up to 94.7 Pb mg kg was found in shoots of *Cynodon dactylon* and it was found that Pb concentrations in shoots were consistently lower than those in roots of *C. dactylon* collected from the metal-contaminated sites. It was also illustrated in a study conducted by Mathew [17] that lead was distributed equally among the root and shoot in the case of sunflower plants grown in low-polluted soil, but on the other hand, in the case of plants from moderately polluted soil, lead concentration is slightly more in roots than in shoots. However, at the same time concentration of lead is more in shoots than the roots in the case of plants from highly polluted soil. Experiments on *Thlaspi praecox* revealed that 80% of the accumulated lead is immobilized in the roots and *Thlaspi praecox* was able to accumulate a considerable amount of Pb from soil with a concentration of 67,940 mg Pb kg^{-1} [18]. The content of Pb in the analyzed plant parts increased following the increase in Pb content in the nutrient medium. This increase was expressed to a higher extent in the roots than in the stems and leaves [19]. Concerning the plants ability to remove heavy metals*, Hemidesmus indicus* has been shown to remove 65% of the lead effectively from a soil having 10,000 ppm of lead concentration [20]. In a study conducted by Turan and Esringu [3], canola root system content of Pb ranged from 30 mg/kg d.w to around 90 mg/kg dw and from 15.0 mg/kg to 65.0 mg/kg dw for shoots. For the heavy metal toxicity to plants, it has been found that a lead concentration of 500 mg/kg is not phytotoxic to *Brassica* species. For heavy metal hyperaccumulator plants, 1,000 mg Pb/kg of dry weight was suggested by Pulford and Watson [21] for any plant to be considered as a hyperaccumulator for lead without evident symptoms of toxicity.

Brassica napus was chosen in this study because many studies have mentioned that Brassicaceae family species have an ability to absorb, accumulate, and survive in soils containing high concentrations of heavy metals. They expected that this plant will act as a promising tool for phytoremediation of highly polluted soils.

Material and Methods

In this study, Canola (*Brassica napus* L.) was used as a phytoremediator of lead heavy metal from highly polluted soil. The crop cultural practices include sowing, irrigation, weeding, fertilization, and harvesting. Experiments were carried out on the selected dates: November 25, 2010 and November 15 in 2011. Plants were sown 40 cm apart. A drip irrigation system was used. Plants were fertilized with NPK fertilizer containing N , P, and k with the ratios of 20, 20, and 18, respectively, with no toxic elements in the fertilizer. The NPK fertilizer was used with the rate of 500 kg/ha added in three equal doses provided after 25 days, 65 days, and 90 days, respectively, of planting. This

Table 1. Initial soil and sewage sludge physical and chemical properties.

Initial properties of the experimental Soil										
pH	EC (mmos)			Organic matter (%)		Organic carbon (%)		Available macro nutrients (%)		
								N	P	K
7.72	1.28			0.8		0.47		0.33	0.073	0.86
Total elements (mg/kg)										
Ca	Mg	Na	Fe	Mn	Cu	Zn	Cd	Pb	Ni	Cr
8220	7678	830	280	160.1	4.67	26.3	0.34	8.1	0.40	0.28
Sandy loam:				Silt = 13		Sand = 76		Loam = 11		
Physio-chemical properties of the used sewage sludge										
pH	EC (mmos)			Organic matter (%)		Organic carbon (%)		Available macro nutrients (%)		
								N	P	K
6.22	7.1			58.63		34.08		2.1	1.66	2.63
Other elements mg/kg										
Ca	Mg	Na	Fe	Mn	Cu	Zn	Cd	Pb	Ni	Cr
58260	38263	11037	1035	592	62.6	398	124.6	204.8	70.6	50.4

investigation was carried out at the Agricultural Research Station of King Abdulaziz University during the two successive seasons of 2010/11 and 2011/12.

Experimental Soil and Sewage Sludge Analysis

Three random samples of the experimental soil were collected at depths of 0.0 to 20.0 cm and analyzed. Sewage sludge was collected from a wastewater and industrial treatment plant in Jeddah city, Saudi Arabia, and three random sewage sludge samples were analyzed. Soil and sewage sludge physical and chemical analysis were done according to Pansu and Gautheyrou [22] (Table 1).

Treatments Application

Sewage sludge was amended with 4 concentrations of lead (Pb), as $PbNO_2O_5$, 0, 20, 40, and 80 mg/kg, added in a rate of 40 t/ha for each experimental unit in the experimental site and mixed properly with soil in each experimental plot before planting in both seasons. Each quantity of sewage sludge was amended with one concentration of Pb and incubated in its soil plot for 15 days before planting. Four concentrations of Pb were mixed.

Enriched Amended Sewage Sludge Soil Analysis

Soil samples were taken from each plot for chemical analysis before planting with the same methods mentioned in the initial chemical analysis. Heavy toxic metals Pb, Cd, Ni, and Cr were determined in plant parts and soil using inductively coupled plasma atomic emission spectrometry (ICP-AES).

Experimental Design

4 X 4 Latin Square Design was used in this experiment, where the treatments were the 4 Pb concentrations. Plot size was 2 m length and 2.4 m width.

Plant Traits Measurements and Sample Preparation

At harvesting, 10 guarded random plants from each plot were tagged and plant root length (cm), plant height (cm), and seed weight/plant (g) were measured besides determining the seed yield/ha(t). At harvesting, three guarded random representative canola plants/plot were harvested and separated into root system, shoot system, and seeds. The plant samples were washed with tap water and then with deionized water to remove any residual soil or dust and dried under room temperature for 10 days, then in an oven at 70ºC for 24 hours, and separately ground with an electric mill to fine powder and saved as dried powder to be analyzed for chemical toxic metals.

Determination of Toxic Metals

The ground powder plant samples were prepared to chemical analysis as described by AOAC [23]. Plant materials were analyzed for concentrations of Pb, Cd, Ni, and Cr (mg/kg) of dry weight using ICP-AES. Final

Table 2. Means of plant height (cm), root length (cm), seed weight/plant (g.), and seed yield (t/ha) of canola under the effect of Pb concentrations added to sewage sludge amended soil during 2011 and 2012 seasons.

Pb (mg/kg)	Means (mg/kg)							
	Plant height (cm)		Root length (cm)		Seed weight/plant (g)		Seed yield/ha (t)	
	2011	2012	2011	2012	2011	2012	2011	2012
0.0	118.75^{a*}	107.0^{a}	38.5^{a}	35.75^{a}	185.75^{a}	152.25^{a}	1.86^{a}	1.52^{a}
20.0	110.25^{b}	99.25^{b}	28.0^{b}	26.0^{b}	122.0^{b}	100.0^{b}	1.22^{b}	1.0^{b}
40.0	103.25^{c}	93.25^{c}	27.0^{b}	25.0^{b}	101.5^{c}	83.0^{c}	1.02^{c}	0.83^{c}
60.0	94.75^{d}	85.5^{d}	24.5^{c}	22.0^{c}	90.5^{c}	74.0^{c}	0.91^{c}	0.74^{c}

* Means followed by the same letter are not significantly different according to RLSD at $p \leq 0.05$.

soil Pb, Cd, Ni, and Cr concentrations in each plot were determined after harvesting using ICP-AES. All safety rules were carried out according to European Cooperation in the Field of Scientific and Technical Research, COST 859 [24].

Statistical Analysis

The obtained data were statistically analyzed according to the design applied, and the means were statistically compared using the Revised Least Significant Difference (RLSD) test at $p \leq 0.05$ following application of the analysis of variance assumptions [25] using SAS program [26].

Results

Plant Traits

Data presented in Table 2 show means of canola agronomic traits "root length, plant height, and seed yield/plant" under the effects of Pb treatments compared with

Table 3. Means of Cd, Pb, Ni, and Cr (mg/kg) in root, shoot system, and seeds of canola under the effect of Pb concentrations added to sewage sludge-amended soil during 2011 and 2012 seasons.

Pb (mg/kg)	Means (mg/kg)							
	Cd		Pb		Ni		Cr	
	2011	2012	2011	2012	2011	2012	2011	2012
Root system								
0.0	18.72^{a*}	19.27^{a}	62.18^{d}	64.1^{d}	22.56^{a}	23.5^{a}	21.42^{a}	21.83^{a}
20.0	19.5^{a}	20.3^{a}	70.47^{c}	72.65^{c}	24.44^{a}	25.46^{a}	22.38^{a}	22.83^{a}
40.0	19.28^{a}	20.15^{a}	82.5^{b}	85.05^{b}	23.83^{a}	24.83^{a}	22.67^{a}	22.22^{a}
60.0	19.17^{a}	20.92^{a}	88.12^{a}	101.15^{a}	20.48^{a}	21.34^{a}	22.88^{a}	22.43^{a}
Shoot system								
0.0	16.72^{a}	17.78^{a}	50.72^{b}	51.75^{b}	16.71^{a}	17.82^{a}	13.77^{a}	13.72^{a}
20.0	17.5^{a}	17.7^{a}	65.37^{a}	66.7^{a}	16.51^{a}	17.55^{a}	14.04^{a}	14.63^{a}
40.0	17.28^{a}	17.61^{a}	72.03^{a}	73.5^{a}	16.26^{a}	17.28^{a}	14.83^{a}	14.53^{a}
60.0	17.17^{a}	17.44^{a}	78.0^{a}	79.6^{a}	16.03^{a}	17.03^{a}	14.7^{a}	14.5^{a}
Seeds								
0.0	13.28^{a}	13.41^{a}	22.0^{b}	23.15^{b}	13.76^{a}	14.96^{a}	10.63^{a}	12.36^{a}
20.0	13.68^{a}	13.50^{a}	23.95^{b}	25.2^{b}	12.42^{a}	13.5^{a}	11.34^{a}	12.18^{a}
40.0	13.34^{a}	13.69^{a}	28.36^{a}	29.85^{a}	13.27^{a}	14.43^{a}	12.42^{a}	12.45^{a}
60.0	13.97^{a}	13.68^{a}	30.16^{a}	31.75^{a}	12.66^{a}	13.76^{a}	12.56^{a}	12.93^{a}

* Means followed by the same letter for each metal in each plant part are not significantly different according to RLSD at $p \leq 0.05$.

RLSD at $p \leq 0.05$. Plant height means have significantly decreased from 118.75 cm and 107 cm under 0.0 to 94.75 cm and 85.0 cm under 60.0 Pb during the 2011 and 2012 seasons, respectively. For the canola root length, significant differences were detected among root length means under the effects of 0.0, 20.0 mg Pb/ kg polluted soil during the 2 successive seasons, and between means under 40.0 and 60.0 mg Pb/kg, but there were no significant differences between root lengths under 20.0 and 40.0 mg/kg Pb in both seasons. The maximum means of root length were 38.5 and 35.75 cm in 2011 and 2012 seasons, respectively, while the minimum means of root were 24.5 and 22.0 cm in 2011 and 2012 seasons, respectively. Concerning the seed weight/ plant and seed yield/ha data in Table 3, they show a gradual decrease in both traits, with significance between the 40.0 and 60.0 Pb treatments. The highest seed yield/ha under 0.0 Pb treatment were 1.86 and 1.52 t/ha in both seasons, respectively, while the lowest canola seed yield/ha were produced under the highest Pb level with values of 0.90 and 0.74 t/ha in both studied seasons, respectively.

Toxic Metals Contents in Canola Plant Parts

The statistical comparisons between the four mean metal concentrations in canola root, shoot and seed under the effects of the 4 Pb concentrations using RLSD test at $p \leq 0.05$ are were presented in Table 3.

Root System

Based on results of analysis of variance, the canola root system contents of toxic heavy metals have shown significant response only for Pb treatments on the Pb concentrations in root systems, but not for the other three metal concentrations. Means of Pb concentrations have significantly increased as Pb added to soil increased in the 2 seasons. The root system was able to up gradually absorbs increments of Pb starting by around 8 mg at 20.0 treatment and reaching to around 26 mg Pb at the maximum Pb treatment (60 mg Pb/kg). The lowest Pb concentrations were 62.18 and 64.1 mg/kg under 0.0 while the highest Pb concentrations were 88.12 and 101.15 mg/kg under the highest Pb level (60 mg/kg) in the 2 seasons, respectively (Table 4). Cd concentrations in root system ranged from 18.72 to 19.17 mg/kg in the 2011 season, and from 19.27 to 20.92 mg/kg of dry weight in the 2012 season under the 0.0 and 60.0 mg/kg of Pb, respectively. Ni in root systems under the effects of Pb treatments ranged from 22.56 and 23.5 mg Pb/kg to 20.48 and 21.34 mg/kg in the 2 successive seasons of 2011 and 2012, respectively. Cr concentrations under the Pb levels ranged from 21.42 and 21.83 mg/kg in 2011 season to 22.88 and 22.43 mg/kg in 2012 under the 0.0 and 60.0 mg/kg Pb levels amendment to the soil as shown in Table 3.

Shoot System

Statistical comparison between the means of Cd, Pb, Ni, and Cr concentrations using RLSD test at $p \leq 0.05$ during

Table 4. Means of Pb, Cd, Ni, and Cr (mg/kg) in soil before planting and after harvesting canola under the effect of Pb concentrations added to sewage sludge-amended soil during in 2011 and 2012 seasons.

Pb (mg/kg)	Means (mg/kg)															
	Pb				Cd				Ni				Cr			
	Before planting		After harvesting		Before planting		After harvesting		Before planting		After harvesting		Before planting		After harvesting	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
0.0	159.11^{d*}	178.78^{d}	83.31^{a}	85.00^{a}	90.70^{a}	91.64^{a}	40.76^{a}	40.96^{a}	72.32^{a}	72.12^{a}	28.21^{a}	29.38^{a}	73.90^{a}	84.23^{a}	44.38^{a}	45.29^{a}
20.0	171.81^{c}	193.04^{c}	83.9^{a}	85.61^{a}	90.40^{a}	91.55^{a}	40.17^{a}	41.41^{a}	71.87^{a}	71.65^{a}	28.74^{a}	29.94^{a}	74.36^{a}	84.79^{a}	44.75^{a}	45.67^{a}
40.0	200.1^{b}	224.83^{b}	84.41^{a}	86.13^{a}	89.28^{a}	90.42^{a}	40.93^{a}	42.2^{a}	71.55^{a}	71.31^{a}	28.96^{a}	30.16^{a}	75.14^{a}	85.74^{a}	45.36^{a}	46.28^{a}
60.0	259.2^{a}	291.24^{a}	84.9^{a}	86.63^{a}	89.01^{a}	90.28^{a}	41.28^{a}	42.56^{a}	71.08^{a}	70.82^{a}	29.72^{a}	30.96^{a}	75.12^{a}	85.76^{a}	45.81^{a}	46.75^{a}

* Means followed by the same letter for each metal are not significantly different according to RLSD at $p \leq 0.05$.

the 2011 and 2012 seasons showed noticeably significant differences between Pb means in the shoot system only under the effects of 0.0 and 20.0 mg Pb/kg treatments in the two seasons, while no significant differences were detected between shoot system Pb content means at treatment 20.0, 40.0, and 60.0 mg/kg (Table 4). Maximum shoot Pb contents were 78.0 mg and 79.6 mg under the highest Pb treatment (60.0 mg/kg) during the 2011 and 2012 seasons. Concerning Cd, Ni, and Cr concentrations, the statistical comparison showed no significant differences between their means in shoot system under the effect of Pb treatments (Table 3).

Seed

As a result of the RLSD test at $p \leq 0.05$, the Pb means of the canola seed under the four Pb treatments in the two seasons, significantly divided into two groups, the first included treatments of 0.0 and 20.0 Pb and the second included both 40.0 and 60.0 Pb concentrations (Table 4). The highest Pb content in seed were shown under 40.0 mg/kg and 60.0 mg/kg with values of 28.36 mg/kg 30.16 in 2011 and values of 29.85 mg/kg and 31.75 mg/kg in 2012, respectively.

Seeds accumulated around 44% and 35% of shoot Pb content at 0.0 and 20.0 mg Pb/kg soil, respectively, and around 38% under the effects of both 40.0 and 60.0 mg/kg during the 2012 season. The other three toxic metals contents in canola seed did not significantly differ as the studied concentrations of Pb increased (Table 3).

Toxic Heavy Metals in Soil After Phytoremediation with Canola Plants

Mean Comparisons

As shown in Table 4, a statistical comparison between mean metal concentrations using RLSD test showed no significant differences between Pb toxic element concentration means in the polluted soil after applying phytoremediation technology under the effects of the Pb treatments. The Pb concentrations ranged from 83.31 and 85.00 under 0.0 mg/kg Pb treatment and up to 84.9 and 86.63 under the 60.0 mg/kg Pb treatment during 2011 and 2012, respectively. However, before applying phytoremediation technology, Pb concentrations ranged from 159.11 and 178.78 under 0.0 Pb in 2011 and 2012, respectively, and to 259.2 and 291.24 under 60.0 mg Pb/kg in the two studied seasons, respectively. Concerning the Cd, Ni, and Cr, no significant differences were found between their concentration means after canola harvesting in the two studied seasons.

Comparing Pb contents in canola plants after application of the phytoremediation technology with the phytotoxic standards Table 5, it was shown that the Pb concentrations in the aerial parts of the canola-studied plants did not Exceed the critical limits of the phytotoxicity standards, hence the recommendation is to use the phytoremediator plant in usual uses but not in feeds or edible industrial products because of the plant accumulation process of Pb and its effects on health. Another important result is that the soil content of Pb after the phtoremediation process is within the permissible limits of toxicity and for this reason, no other plant phytoremediation cycle(s) is required. This also confirms that canola plants had a great potential to uptake significant concentrations of Pb from the polluted soil.

Discussion

The reduction in canola traits as the Pb amendment to the soil increases might be due to the adverse effects of the highest Pb concentrations absorbed by canola roots and the translocation of Pb into the shoot system. It might also be due to a decrease in the efficiency of dry matter synthesis and leaf photosynthesis, besides inhibition of the seed filling and decrease in the dry matter accumulation in seeds. Finally, the plant produced a small number of seeds with small size, as reflected by the low seed yield. These findings are in agreement with those found by Chhotu [8] and Rengel [6]. Canola accumulate the highest Pb concentrations in root followed by shoot systems and the lowest Pb concentrations in the seeds. The results might be explained as a result of canola plant high potential in absorbing heavy metals fromcontaminated soil, as this crop of the *Brassicacea* family, is characterized by such botanical, physiological, absorption, and translocation mechanisms and enzyme systems. Our results are in agreement with Grejtovsky and Pirc [31], who indicated that heavy metals contents in root systems were higher than in shoot systems, as well as those of Marchiol [13], who found that Cd, Pb, and Ni were higher in roots than in shoot system of *Brassica napus* and *Raphinus sativus*. Similar results were obtained by Turan and Esringu [3]. Results obtained through this work showed that canola

Table 5. Range of the toxic elements in the studied plant parts and soil and the photoxicity standards.

Pb	Plant and soil heavy metal detected concentrations (mg/kg)				Standards	
	Root	Shoot	Seed	Soil	Plant *	Soil**
	62.18-101.15	50.72-79.60	22.0-31.75	83.31-86.63	30-300	300

* Kitagishi (1981) [27], Chaney (1989) [28] and WHO/FAO (2007) [29].

** European Union Standards (EU, 2002) [30].

plants can be used as phytoremediators for Pb removal from polluted sites because of their efficient ability to remove about 44%, 51%, 58% and 67% from Pb concentrations in the soil. The findings of Sekhar [20] and John [14] show that canola could remove more than 50% of Pb from contaminated soil. The positive results of this study might confirm that phytoremediation by this plant is promising.

Conclusion

Obtained results of this study revealed that canola can be used as a phytoremediator for lead removal from highly polluted environmental sites. Canola could remove around (44% to 67%) Pb from the initial soil concentrations of Pb metal. Lead could become within the permissible limits either in plants or in the soil after the phytoremediation process. It is advised not to use the phytoremediator canola plant in feed and food to avoid lead accumulation impacts, and standard procedures must be used to recycle the phytoremediator plants. Ultimately, this technology is cost effective. It is an economic method compared with the chemical methods of contaminated soil treatment and ecofriendly for pollutants' removal from contaminated soil, sludge, sediment, and/or ground water. It is strongly recommended to use this green technology as an alternative and natural method to remediate heavy metal polluted sites.

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