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This is a refereed journal and all articles are professionally screened and reviewed **ORIGINAL ARTICLE**

Nickel uptake from Enriched Sewage Sludge Amended Soil by Cabbage (*Brassica oleracea* L.) through Phytoremediation Technology

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ABSTRACT

Cabbage (*Brassica oleracea*) plants capability of removing nickel (Ni) from a soil polluted with enriched sewage sludge had investigated in a field experiment conducted at the experimental field station of King Abdulaziz University. The mobility of nickel from root to head and its effects on studied agronomic traits were evaluated. The findings of this investigation study indicated that cabbage plants showed potential for use in the phytoremediation. The results also showed that Ni had significant effects at ($p \leq 0.01$) on all studied traits. As Ni concentration in the sewage sludge amended soil increased, Ni in each plant part significantly increased. Ni concentrations were in root system > head. Moreover, cabbage uptake of Cd ranged between 61 to 75 % from the Ni content of the polluted soil without toxic effects on plants during the two successive growth seasons (2011-2012). Cabbage plants could be used as phytoemediators to decrease toxicity of heavy metal from polluted soils for human health.

Key words: Phytoremediation, Ni, Cabbage, Agronomic traits, Sludge, Heavy metals, Soil pollution.

Introduction

Sewage sludge, in many countries, is used as soil additives to improve the soil physicochemical proprieties, growth conditions and as a good source of plant nutrients but this sewage sludge almost contain many toxics such as heavy metals which can cause a major problem for plants and environmental qualities and their impact on human health, for example, heavy metals accumulated in the soil due to sewage sludge amendment had negatively affected the physiological and metabolic processes of plants like *Beta vulgaris,* leading to yield reduction [37].

There are social and legal concerns of uncontrolled use of sewage sludge for agriculture due to potential problems of elevated transfer of heavy metals to the food chain, causing threat to human health, [38].

In plants, some metals play an important role as micronutrients, being essential for growth at low concentrations. Most of them are cofactors of enzymes and are involved in important processes such as hydrolysis of urea into carbon dioxide and ammonia (Ni) [16]. The finding obtained by Chhotu *et al*., [8] and Rengel [31] showed that the low doses of Ni applied stimulated the root and shoot elongation of plants such sunflower plants but at higher concentrations, i.e. 40 and 50 ppm of those heavy metals significantly reduced germination(%) and plant growth specially root and shoot elongation. Plants like cabbage grown in sewage sludge amended soils showed higher concentrations of Ni, Cd, Cr, Co, Cu, Pb and Zn as compared to those grown in unamended soil [36].

Nickel (Ni) is a naturally occurring element that exists mostly in the form of sulphide ores found underground, and in silicate minerals, found on the surface. In the environment, Ni is found primarily combined with oxygen (oxides) or sulphur (sulfides). Elevated levels of Ni (Ni^{++}) can pose a major threat to both human health and the environment [17].

The soil has been traditionally the site for disposal for most of the heavy metal wastes which needs to be treated. [1]. The use of conventional to clean up metal-contaminated soils is typically invasive and expensive. In recent years, scientists and engineers have started to generate other technologies, cost effective and friendly to the environment which

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includes use of microorganisms/ biomass or live plants for cleaning of polluted areas, in other meaning bioremediation [29].

Phytoremediation, the use of plants for environmental restoration, is a novel clean up technology. It is defined as the use of plants to remove pollutants from the environment or to render them harmless [33]. Recently, the use of plants to remediate polluted soils, has appeared as an alternative more reliable [5]. Phytoremediation is used as a green technology and can be applied to both organic and inorganic pollutants present in soil water or the air [15,33].

For heavy metal hyper accumulator plants, 1,000 mg kg^{-1} of Ni in kg. of dry weight was suggested by Pulford and Watson [28] for any plant can be considered as hyperaccumulator for nickel without evident symptoms of toxicity.

Heavy metals when present at an elevated level in soil are absorbed by the root system, accumulate in different parts of plants, reduce their growth and impair metabolism [19]. Toxic metal ions primarily restrict root growth, thereby impairing nutrient uptake and reduce shoot growth [31]. Nickel concentration in shoots of faba, wheat and sorghum was increased with increasing application rate of nickel, addition of 60 ppm nickel increased Ni content in plants to about 20 ppm. In a study about the effects of nickel and cadmium on rice plants growth, Rubio *et al*., [32] found a great increase in Ni content measured in Ni-treated plants (22 fold higher than in controls).

Blaylock *et al.,* [6] reported that the Indian mustard accumulated large amounts of Ni, Pb and Cd in shoots but its translocation from root to shoot was low and did not correlate well with Ni accumulation from soils. Panwar *et al*., [27] indicated that *Brassica juncea* has the potential to be hyperaccumulator of Ni. Data obtained by Rabie [30] showed an insignificant increase in both straw and grain yield was obtained when Ni was applied in various levels, especially 60 ppm and a significant gradual increase in Ni content of wheat grains parallel with that of shoots. Malan and Farrant [23] reported that nickel is readily transported from roots to over ground soybean plant tissues, where it is accumulated in high amounts. Ciura *et al*., [10] stated that the possibility of nickel accumulation were within the range of 270 (*Beta vulgaris*) to 5,271 (*Hordeum vulgare*) $mg \cdot t^{-1}$ fresh weight. Ni concentrations level in shoot ranged from 0.0 to 300 mg/kg in shoot of sunflower and between 0.0 to 80 mg/kg in roots while for the alfalfa plant, Ni concentration level in shoot ranged from 0.0 to 450 mg/kg and between 0.0 to 138 mg/kg in its roots [25]. Results obtained by Motesharezadeh and Savaghebi-Firoozabadi [25]demonstrated that by increasing the nickel concentration in soil, its absorption by the plants has increased significantly. The highest concentration of nickel was found in shoot of Amaranthus (176.83 mg kg^{-1}) and in the root of plants, in alfalfa (462.73 mg kg^{-1}) at $P<0.05$. Linger *et al.,* [22] reported that the concentrations of Cd in *Cannabis sati*va L. were eight to 26 times lower than the Ni concentrations. However, when comparing the heavy metal concentrations of the soil with these in the plants, it was found that the concentration of Ni in the soil is only four times higher than that of Cd. Therefore, there must be different mechanisms for uptake and accumulation for nickel, lead, and cadmium in general and also for the different plant parts themselves. Ni concentrations were reached to 746.3, 264.3 and 139.1 mg/kg in *Salix Acmophylla* root, stem and leaf, respectively under the effect of 10000 mg/kg of Ni, [2]. Sauerbeck *et al.*, [35] found that the highest Ni contents were found in the roots comparing with shoots of 13 plant species grown in polluted soils.

Material and Methods

Cabbage (*Brassica oleracea* L.) was used as a phytoremediator of nickel heavy metal from highly polluted soil. This study was carried out at the Agricultural Research Station, King Abdulaziz University during the two successive seasons of 2010/2011 and 2011/2012. Experimental soil was polluted with sewage sludge amendments (40 t of sewage sludge /ha) and four concentrations of Ni, were mixed with soil in each experimental plot before planting in both seasons for additional nickel. The normal agricultural practices in this experiment were carried out from planting to harvesting. Planting dates were November 25, 2010 and November, 15 in 2011. Plants were sown at 40 cm as distance between plants. Drip irrigation system was used in this experiment. Plants were was fertilized with NPK fertilizer (20:20:18) with the rate of 400 kg/ha added in 3 equal doses, the 1st dose after 10 days, 2nd dose after 40 days and the 3rd dose after 60 days from planting.

Initial soil and sewage sludge analysis:

Sewage sludge was obtained and three random samples of sewage sludge were analyzed before adding sludge to soil. Three random samples of experimental soil were collected at depth of 0.0 to 20.0 cm and analyzed. Soil and sewage sludge physical and chemical analysis were done according to Pansu and Gautheyrou [26] (Table 1).

Heavy metal treatments application:

Sewage sludge (40 t/ha) was amended with 4 concentrations of nickel (Ni), as Ni(NO3)2.6H2O, 0, 10, 20 and 30 mg/kg in each plot of soil. Each quantity of sewage sludge was amended with one concentration of Ni and incubated in its soil plot for 15 days before planting. One sample of enriched sewage sludge amended soil was taken from each plot for heavy metal analysis before planting 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 Ni concentrations. Plot size was 2 m length and 2.4 m as width.

Plant traits measurements and sample preparation:

At harvesting 10 guarded random plants in each plot were tagged and plant root length (cm), dry root weight/plant(g) and head fresh weight/plant (g) were measured besides head fresh yield/ha(t) determined in each experimental unit (plot) and three of them ad a representative cabbage plants /plot were taken and separated into root system and heads. The plant samples from each part were washed with tap 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 70º C for 24 hours, and separately grinded with an electric mill to fine powder and saved as dried powder to be considered for chemical toxic metals analysis.

Determination of toxic metals in plant parts:

The grinded powder plant samples were prepared to chemical analysis as described by A.,O.,A.,C. [4]. Plant materials were analyzed for the concentrations of Ni, Cd, Pb and Cr (mg/kg) of dry weight using Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES).

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

Final Soil Chemical Analysis:

Soil Ni, Cd, Pb and Cr concentrations in each plot were determined after harvesting using Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES). All safety rules were carried out according to European Cooperation in the Field of Scientific and Technical Research, COST 859, (2008).

Statistical Analysis:

The obtained data were statically analyzed according to the used design and the means were statistically compared using the Revised Least Significant Difference (RLSD) test at $p \le 0.05$ after application the analysis of variance assumptions [12] using SAS program [34].

Results:

Agronomic Traits:

Data in Table (2) illustrated cabbage agronomic trait means under the effects of Ni treatments during the two successive seasons of 2011 and 2012. Using of RLSD test for each trait means comparison showed significant decreasing in cabbage head weight as Ni in soil increased from 0.0 to the higher Ni treatments.

The highest head weight was found at 0.0 Ni with values of 1184.5 g/plant and 1138.75 g/plant in 2011 and 2012 seasons, respectively and the lowest head weight g/plant was found under the effects of the maximum Ni treatment of 30.0 mg Ni/ kg polluted soil with values of 711.5 g and 684.0 g in 2011 and 2012 seasons.

As for head yield/ha**,** it was found that the yield was significantly decreased with increasing of Ni in sewage sludge amended soil from 0.0 mg/kg to of 30.0 mg/kg. The maximum head yield was found under Ni treatment of 0.0 concentration with values of 11.85 t/ha and 11.39 t/ha and the lowest was 7.12 t/ha and 6.84/h(t) under the effects of 30.0 mg Ni /kg in 2011 and 2012, respectively.

Comparison of the root length means using RLSD test at $p \le 0.05$ showed significant differences between root length means as a response for all Ni treatment levels during the seasons of 2011 and 2012.

The maximum root length was 32.0 cm as a response to the 0.0 Ni treatment and the minimum was around 18.25 cm as a response to the effects of 30.0 mg Ni /kg of sewage sludge amended soil in the 1st season and means were decreased in the 2nd season where the maximum root length was 29.0 cm under no nickel and the shortest root length was 18.25 cm under the highest level of Ni as shown in Table (2).

Concerning to the cabbage root weight /plant, the statistical analysis and means comparing using RLSD test at $p \leq 0.05$ showed high significant differences between root weight means in 2011 and 2012 at Ni concentration of 0.0, 10.0 and 20.0 mg/kg and the root weight means were not significantly differ at 30.0.0 mg/kg.

The root weight ranged from 34.25 g to 21.5 g under 0.0 and 30.0 mg/kg Ni in 2011 seasons. In 2012 season root weight ranged from 29.25 g under 0.0 Ni to 18.5 g under 30.0 mg Ni /kg of polluted soil.

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

Ni (mg/kg)	Means (mg/kg)							
	Head weight/plant (g)		Head Yield/ha (t)		Root Length (cm)		Root weight/plant (g)	
	2011	2012	2011	2012	2011	2012	2011	2012
0.0	1184.5^a	1138.75^a	11.85^a	11.39^a	32.0^a	29.0^a	34.25^a	29.25^a
10.0	949.0^b	912.5^b	9.49^b	9.13^b	25.25^b	23.25^b	28.5^b	24.5^b
20.0	783.75^c	753.75^c	7.84^c	7.54^c	22.0^c	20.0^c	23.5^c	20.25^c
30.0	711.5^d	684.0^d	7.12^d	6.84^d	20.25^d	18.25^d	21.5^c	18.5^c

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

Comparisons between the toxic metal means:

The statistical comparing between the four toxic metal means in cabbage root system and cabbage head under the effects of the 4 Ni concentrations using RLSD test at $p \leq 0.05$ were presented in Table (3).

Root system:

Comparison of heavy metal means using RLSD $p \leq 0.05$ (Table 3) showed significant differences between all Ni concentration means in cabbage root system under the effects of Ni treatments during both of season 2011 and 2012. The lowest Ni concentrations were 21.12 mg/kg in 2011 season and 22.0 mg/kg in 2012 season under the Ni 0.0 treatment, increased significantly to 32.11 and 33.45 mg/kg under the effects of the highest Ni level (30.0 mg Ni/kg of polluted soil) during 2011 and 2012 seasons, respectively.

As for the root contents from of Pb, Cd and Cr as Ni into soil increase, the results showed no significant differences were illustrated for the 3 elements (Table 3). Pb concentrations ranged from 59.32 to 58.22 mg/kg in 2011 season, and from 59.55 to 59.51 mg Ni/kg in 2012 season under the 0.0 and 30.0 mg/kg of Ni, respectively. Cd in root systems under the effects of Ni levels in soil ranged from 47.61 and 49.69 mg/kg to 48.36 and 50.19 mg/kg in 2011 and 2012, respectively. Cr concentrations in cabbage root system under the Ni levels in soil ranged from 22.6 to 22.12 mg/kg in 2011 season and from 23.1 to 24.65 mg/kg in 2012 under the 0.0 and 30.0 mg/kg Ni levels amendment to the soil.

Cabbage head:

Cabbage head contents of the studied heavy metals under the effects of the 4 Ni treatments were presented in Table (3). Significant increasing in head Ni concentrations as Ni in soil increased during 2011 and 2012 seasons. Ni concentrations in cabbage head ranged from 19.93 to 27.27 mg Ni/kg under 0.0 and 30 mg Ni/kg, respectively in the 1st season while in the 2nd season it ranged from 20.98 to 28.7 mg/kg under 0.0 and 30.0 mg Ni/kg, respectively.

For the other 3 metals available in sewage sludge amended soil, the results in Table (4) revealed no significant differences between their concentration means were found. In general, these concentrations of the 4 heavy metals in cabbage head were less than in the roots.

Cabbage Ni content positively responded by absorbing and accumulating high amount of Ni from the contaminated soil in root and head as Ni concentrations in the soil increased especially when the Ni rates in soil were higher than 20.0 mg/kg. Cabbage root system absorbed high amount of Ni and as the *Brassicaceae* behavior, high amount translocated and stored in head. These high Ni concentrations adversely affected on head yield of cabbage through the effects on the metabolism and dry matter accumulation in plant , but the plant uptake high amount from the Ni in the polluted soil. The positive benefit was accordingly it may be in cleaning and bio-controlling the pollution with heavy metals in soil.

Toxic heavy metals in soil:

By using Inductively Coupled Plasma Atomic Emission spectrometry (ICP-AES), toxic metals (Ni, Cd, Pb and Cr) were determined in the enriched sewage sludge amended soil before and after phytoremdiation with canola plants.

Mean comparisons:

Statistical comparisons using RLSD test between the 4 Ni treatments at $p \leq 0.05$ showed no significant differences between Ni concentration means in sewage sludge amended soil after harvesting during both of seasons between the first 2 Ni treatments (0.0 and 10.0 mg Ni/kg polluted soil), but significant differences were found after 10.0 level. It is clear from the data presented in Table (4) that Ni concentrations in soil after harvesting ranged from 30.04 and 31.6 mg/kg under 0.0 mg Ni/kg in 2011 and 2012 seasons up to 30.41, 32.0 mg/kg under 10.0 Ni levels, then increased in to 31.79 and 33.47 mg Ni under the 20.0 Ni level in 2011 and 2012, respectively and 32.5 and 34.21 mg/kg Ni under 30.0 mg/kg Ni treatments in both seasons, respectively.

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

Ni (mg/kg)	Means (mg/kg)							
	Cd		Pb		Ni		Cr	
	2011	2012	2011	2012	2011	2012	2011	2012
Root System								
0.0	47.61^{a}*	49.69^{a}	59.32^{a}	59.55^{a}	21.12^{d}	22.0^{d}	22.6^{a}	23.1^{a}
10.0	48.12^{a}	49.61^{a}	59.09^{a}	59.7^{a}	23.98^{c}	24.98^{c}	21.95^{a}	23.7^{a}
20.0	48.21^{a}	50.13^{a}	58.82^{a}	58.15^{a}	30.24^{b}	31.5^{b}	22.05^{a}	24.05^{a}
30.0	48.36^{a}	50.19^{a}	58.22^{a}	59.51^{a}	32.11^{a}	33.45^{a}	22.12^{a}	24.65^{a}
Head								
0.0	31.78^{a}	33.1^{a}	51.69^{a}	52.76^{a}	19.93^{d}	20.98^{d}	18.85^{a}	20.03^{a}
10.0	32.41^{a}	33.76^{a}	51.62^{a}	52.59^{a}	23.33^{c}	24.55^{c}	19.36^{a}	20.58^{a}
20.0	32.36^{a}	33.71^{a}	50.73^{a}	52.33^{a}	25.13^{b}	26.45^{b}	19.03^{a}	20.35^{a}
30.0	31.27^{a}	32.57^{a}	50.17^{a}	51.78^{a}	27.27^{a}	28.7^{a}	19.09^{a}	20.48^{a}

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

No significant differences were found between the concentrations of Pb, Cd and Cr after cabbage harvesting in the 2 seasons (Table 4).

As a positive effect for using cabbage plants as a phytoremediant for higher levels of the toxic metals (Ni) in the soil, the results of Table (4) showed that Ni concentrations decreased by around 61%, 69%, 69% 75% from the Ni concentrations in the soil before planting under 0.0, 10.0, 20.0 and 30.0 mg Ni/kg incorporated into soil as a result of growing cabbage in the contaminated soil with Ni but under the higher Ni level, the potentially of cabbage plants to remove Ni from the contaminated soil is decrease.

These results related to the interaction between the genetic makeup of cabbage and the mechanisms of absorbing, translocation and accumulation of heavy metals in plants parts, the soil conditions and environmental factors. As a conclusion, cabbage plants can be used as Environmental Quality Bio Safety (EQBS),especially in the cleaning process of the polluted soil sites with Ni heavy toxic metal.

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

Cd (mg/kg)	Means (mg/kg)															
	Ni				Cd				Pb				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	78.52^{c*}	82.65^{c}	30.04^{a}	31.6^{a}	90.47^{a}	90.7^{a}	38.04^{a*}	39.78^{a}	134.48^{a}	135.1^{a}	78.88^{a}	78.83^{a}	82.4^{a}	82.3^{a}	47.1^{a}	48.5^{a}
10.0	97.23^{b}	102.35^{b}	30.41^{a}	32.0^{a}	91.73^{a}	91.06^{a}	38.07^{a}	40.46^{a}	136.16^{a}	134.99^{a}	77.11^{a}	78.37^{a}	82.01^{a}	82.12^{a}	47.63^{a}	48.07^{a}
20.0	103.48^{b}	108.92^{b}	31.79^{a}	33.47^{a}	91.71^{a}	91.04^{a}	38.7^{a}	41.12^{a}	135.92^{a}	134.72^{a}	77.67^{ba}	78.63^{a}	82.63^{a}	82.81^{a}	47.69^{a}	48.71^{a}
30.0	135.02^{a}	142.12^{a}	32.5^{a}	34.21^{a}	91.21^{a}	90.5^{a}	38.81^{a}	41.3^{a}	136.25^{a}	135.09^{a}	77.79^{a}	78.37^{a}	82.64^{a}	82.93^{a}	47.39^{a}	48.89^{a}

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

Comparing **Ni** contents in cabbage plants after application of the phytoremediation technology with the phytotoxic standards Table (5), it was showed that **Ni** concentrations in the aerial parts of the cabbage studied plants did not exceeded the critical limits of the phytotoxicity standards, hence, the recommendation is to remove the phytoremediator plant according to COST [11]. Comparing soil contents from the element after the application of phytoremediation technology with cabbage plants, with the phytotoxic limit standards, Ni was in the permissible standard limit of toxicity .Accordingly, another plant phytoremediation cycle(s) is not required.

Table 5: Range of Nickel in the studied crop plant parts and soil and the photoxicity standards.

Ni	Plant and soil Nickel detected concentrations (mg/kg)			Standards	
	Root	Head	Soil	Plant *	Soil**
	21.12-33.45	19.93-28.70	30.04-34.21	10-100	75

* Kitagishi (1981), Chaney (1989) and WHO/FAO. (2007),
** European Union Standards (EU,2002).

Discussion:

The studied phytoremediator plant (Cabbage) agronomic traits negatively responded to the increasing of Ni concentrations in their soil before planting and this caused adverse effects on yield and yield components. These negative effects might been due to the highest Ni accumulated concentrations which, significantly caused a decrease of the photosynthetic rate, inhibited the biosynthesis of the plant metabolites and a affected the cell membrane and cell pressure adjustment. On the other hand these crop plants absorbed high Ni amount from the soil and a translocation into shoot and seed, causing high concentrations of Ni accumulation in root, shoot and/or seed. These results might been due to the uptake, translocation and metabolism mechanisms of the plant species and the interaction with the soil pollution. These results were confirmed with Laurent [21], Ewais [14] and Alkbas [3].

As a positive effect for using cabbage plants as a phytoremediant for higher levels of the toxic metals (Ni) in the soil, the results of Table (4) showed that Ni concentrations decreased by around 61%, 69%, 69% 75% from the Ni concentrations in the soil before planting under 0.0, 10.0, 20.0 and 30.0 mg Ni/kg incorporated into soil as a result of growing cabbage in the contaminated soil with Ni but under the highest Ni level, the potentially of cabbage plants to remove Ni from the contaminated soil was decreased.

These results were in agreement with the results of a study conducted by Christensen [9] on the growth and nickel content of cabbage plants watered with nickel solutions. This study showed that a higher content of nickel was found in the plants exposed to more concentrated nickel solutions. The successive increasing of nickel in the experimental soil led to increasing in nickel contents in cabbage plant pars, this was the same of results obtained by Rengel, [31], Rubio *et al.* [30] and Motesharezadeh and Savaghebi-Firoozabadi [25]. These results related to the interaction between the genetic makeup of cabbage and the mechanisms of absorbing , translocation and accumulation of heavy metals in plants parts, the soil conditions and environmental factors. As a positive and promising results of phytoremediation of Ni, cabbage removed more than 50% from the soil Ni concentration, these results were similar with the results of Panwar *et al*. [27], Ciura *et al.*, [10], Mojiri *et al*. [24] and Motesharezadeh and Savaghebi [25].

Conclusion:

This study showed that cabbage can be used as a phytoremediator for nickel removal from the high polluted soil used in this study whereas, cabbage could remove around (61% to 75%) Ni from the initial soil concentrations of Ni heavy metal. Cabbage can be recommended either alone or in conjunction with traditional method for the remediation of contaminated environmental sites.

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