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MOBILITY AND LEACHING OF HEAVY METAL THROUGH SOIL LAYERS AS AFFECTED BY THE APPLICATION OF DIFFERENT LEVELS OF Cd, Ni AND Pb ON CORN PLANTS

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ABSTRACT

A laboratory experiment was designed to study the mobility of heavy metals through soil layers by corn plants. This experiment were conducted at the National Research Center (NRC) in order to satisfy the objectives of the current investigation. The obtained results can be summarized as follows: 1. The application of NPK fertilizers increased the fresh and dry weight of corn plants as compared with the application of heavy metals. 2. The small additions of heavy metals (H.M) with NPK fertilizers resulted in an increase in the dry matter production of corn shoots. By increasing the added amounts of Cd, Ni and Pb, the dry matter production decreased, and it was the lowest in the heavy metal treatment as the recorded reductions were obtained with 150 ppm, 100 ppm and 50 ppm, respectively. 3. The reduction in corn growth was associated with an increase in heavy metals concentration in corn shoots. The percentages of increases were 115-161%, 115-174% and 10-37% for Cd, Ni and Pb, respectively as percent of their corresponding controls. 4. The data showed that in the presence of heavy metals in the soil, the overdosing of fertilizers would increase the concentration of heavy metal inside the plant tissues. So, it is recommended not to overdose fertilization as it causes the introduction of larger amounts of heavy metals into the food chain, which indicated the accumulation of large amounts of Cd, Ni and Pb in the soil. 5. The DTPA–extracted heavy metals at the end of the experiment increased in the surface layer of the soil column. 6. The low additions of Pb and Ni (50 ppm) stimulated the growth of corn plants and the dry matter production increased 2 and 3 times as compared with the control treatment in the soil, respectively. 7. By increasing Cd or Ni or Pb –levels, the production of dry matter (shoots) decreased.

Keywords: Leaching of heavy metals, NPK fertilizers, DTAP- extract.

INTRODUCTION

Phytoremediation is the use of a plant's natural ability to contain, degrade, or remove toxic chemicals and pollutants from soil or water. It can be used to clean up metals, pesticides, solvents, explosives, crude oil, and contaminants that may leak from landfill sites (called leachates). The term phytoremediation is a combination of two words: phyto, which means plant, and remediation, which means to remedy. Scientists are investigation phytoremediation's potential by using plants such as sunflower, ragweed, cabbage and geranium, as well as other less known species. The plants are often used in combination with other traditional technologies for cleaning up contaminated sites because of the phytoremediation's limitations. Mirsal, (2008) investigated the pollution of soil may arise from a wide range of sources. These might be discrete point sources, or diffuse sources, and the pollution process itself may be deliberate, as in fertilization processes or following an accident, as in the case of radio nuclear accidents or oil spills.

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Taradellas and Brecon (1997) reported that organic compounds used as pesticides, however, have more far reaching effects for the whole community depending on soil ecology. The use of pesticides in agriculture has been steadily increasing in the last 40 years. Mirsal (2008) found that the bioremediation is an easy and effective method resulting in the changing of organic contaminants, such as fuels or other oil products, into carbon dioxide and water. However, the time required for complete remediation will depend upon whether the process is carried out in situ, or in special facilities where excavated soil material is transported. Ex situ technologies are normally faster and more effective than in situ processes. Castro *et al.* (2003) found that sunflowers *(Helianthus annuus)* can take up and incorporate benzotriazoles out of hydroponic solutions in which they were grown. Some pesticides were also found to be susceptible to phytodegradation, as was shown by Li *et al.* (2002); Knuteson *et al.* (2002) and many others. Some explosives can also be degraded in soils by the action of plants.

The present study amied to investigate the mobility of heavy metals through soil layers as affected by the application of different levels of Cd, Ni and Pb on corn plants.

MATERIALS AND METHODS

This experiment was conducted to study the mobility of heavy metals in soil column and to investigate the distribution of inorganic pollutant elements in clayey soils samples (0-30 cm depth) taken from Diarb Nigm district, Sharkia Governorate to investigate the previous topics cultivation of *Zea mays L.* The soil samples were air–dried and ground to pass through a 2mm sieve.

Twenty one columns of PVC with diameter 10 cm and 60 cm length. The columns were filled with 3.5 kg soil up to a height of about 50cm. The upper layer (10 cm) is treated with heavy metals such prepared elements Cd, Ni and Pb, also, the NPK soluble fertilizer was applied to evaluate the mobility of N, P, K beside the heavy metals and it was applied for all treatments. The following treatments were tested:

1. Control (NPK) as recommended rate (130 N, 60 P_2O_5 and 60 K_2O mg kg^{-1} soil).
2. 50, 100 and 150 mg kg^{-1}soil for Cd as $CdSO_4.6H_2O$.
3. 50, 100 and 150 mg kg $^{-1}$soil for Pb as Pb $(CH_3 COO)_2$.
4. 50, 100 and 150 mg kg^{-1} soil for Ni as $NiSO_4.6H_2O$.

The heavy metals were added and mixed with the upper 10 cm of the soil column. Five uniform corn seeds were sown in each column and covered with 2 cm layer of soil material. The columns were maintained at 70% of field capacity throughout the experiments with distilled water. At the end of first month, they were irrigated by 50% over the field capacity and the leachates were collected for chemical analyses every week. Plants in columns were harvested 4 times with each leachate except the first one.

At the end of the experiment, the soil in each column was taken out from the column and segmented into 3 layers corresponding to (0-15), (15–30) and (30–50) cm after leaving the upper most 10cm of the column for applying irrigation water. The soil of every segment (layer) was analyzed for heavy metals (Cd, Ni and Pb).

Physical and chemical analysis of investigated soil are presented in Table 1.

Methods of Analysis

Mechanical analysis was determined according to the international Pipette method and calcium carbonate content of the soil was determined volumetrically using Calcimeter as described by (Piper, 1950).

Soil pH measured using a glass-electrode pH at extract 1 : 2.5 (Cottenie *et al.*, 1982).

Organic matter was determined by Walkley and Black's method and soluble ions meq/100g soil were determined in (1:5) soil water extract according to (Hesse, 1971).

Available nitrogen in the soil was extracted using 2.0 M Kcl according to (Hesse, 1971) and determined by micro-Kjeldahl apparatus

Lead, Ni and Cd were determined in leachates and soil DTAP extract using flameless atomic absorption (Perken-Elmer- 2380).

Table 1. Physical and chemical properties of the studied soil

Soil characteristics	Soil content
Mechanical analysis:	
Fine sand%	24.66
Coarse sand	9.92
Silt%	12.80
Clay%	52.62
Textural	Clayey
Chemical analysis:	
Organic matter%	1.88
pH *	8.01
EC(dScm^{-1})**	0.15
CaCO$_3$ g kg^{-1}	0.22
Soluble ions ** (mmol$_c$l^{-1}):	
Ca^{++}	0.46
Mg^{++}	0.28
Na^{+}	0.84
K^{+}	0.08
CO$^{-}_3$	-
HCO$^{-}_3$	0.56
Cl^{-}	0.40
SO$^{-}_4$	0.70
Available-N (g kg^{-1})	3.61
Available-P (g kg^{-1})	1.62
Available-K (g kg^{-1})	0.81

* Soil-water suspension 1:2.5 ** Soil water extract 1:5

RESULTS AND DISCUSSION

Distribution of heavy metals within different contaminated soil profiles is a major environmental concern because of their toxicity and transport through the soil layers, which may eventually lead to deterioration of ground water. Such approach was thought to be performed through experiments including, an evaluation for behavior of the studied heavy metals of Cd, Ni and Pb contaminating the studied fertilizer; leachability through the studied soil columns was of concern.

Fresh Weight of Corn Plant

Data presented in Table 2 show the fresh weight of corn plants, grown on soils treated with heavy metals and soluble NPK fertilizers. Results indicate that the growth of corn plants increased by soluble NPK fertilization and then the growth was inhibited by the addition of heavy metals. This trend was clearly observed in 4 weeks after sowing.

Dry Weight of Corn Plants

The data in Table 3 showed that the dry weight of shoots of corn plants increased by soluble fertilizers compared with the addition of heavy metals. Data indicated that, in general, mineral fertilization, as compared with control treatments (without heavy metals application) was positively affected. The response was dependent on the applied heavy metals type, rate of application, as well the concerned pollutant and plant species. According to David *et al.* (2007), dry weight of corn shoots have depended upon soil type, fertilizer type and the amount of existing heavy metals.

The dry weight of corn shoots varied for the different heavy metal levels, it increased in the order:

50 mg kg^{-1} > 100 mg kg^{-1} > 150 mg kg^{-1}.

It is noticed that the application of low concentrations of heavy metals combined with NPK fertilizers have stimulated the growth of corn

Table 2. Fresh weight of corn plant (g/plant) after application of heavy metals

Treatments	Rates ppm	Number of plant samples			
		1 week	2 weeks	3 weeks	4 weeks
Control		2.13	2.20	3.06	3.53
Cd	50	0.98	1.63	1.87	1.93
	100	0.99	1.25	1.66	1.73
	150	0.86	1.22	1.68	1.78
Ni	50	0.95	1.36	1.54	1.63
	100	1.24	1.65	1.98	1.99
	150	1.33	1.84	1.89	1.92
Pb	50	1.49	1.55	1.71	1.65
	100	1.23	1.69	1.72	1.82
	150	1.45	1.61	1.69	1.72

Table 3. Dry weight of corn plant (g/plant) after application of heavy metal

		Number of plant samples			
Treatment	Rate mg kg^{-1}	1 week	2 weeks	3 weeks	4 weeks
Control		1.23	1.32	1.40	1.21
Cd	50	0.66	0.21	0.69	0.85
	100	0.43	0.35	0.74	0.95
	150	0.62	0.50	0.83	0.88
Ni	50	0.75	1.05	1.32	0.45
	100	0.98	0.99	1.06	0.82
	150	0.85	0.85	1.11	0.95
Pb	50	1.45	1.13	1.42	1.41
	100	1.21	1.17	1.22	1.52
	150	1.02	1.11	1.12	1.21

plants at all the studied ages of corn growth and under the conditions of the tested soil. On the other hand, growth reductions were found with the higher levels of heavy metals applied with NPK fertilizers at all plant ages. Both growth stimulations and growth reductions have been found as a result of varying the heavy metals combinations. This synergetic effect was postulated to some degree that the presence of heavy metals in soil may have influenced the uptake of the other elements (Youssef *et al.*, 1993). However, it had been suggested by Sandalio *et al.* (2001) growth of corn plants with $CdCl_2$ can induce a concentration dependent oxidative stress situation in leaves, characterized by an accumulation of lipid peroxides and oxidized proteins as a result of the inhibition of the antioxidant systems. These results, together with the ultrastructural data, point to a possible induction of leaf senescence by cadmium. Cocucci *et al.* (1980) suggested that some heavy metals inhibit the transport of the ATP asses of the plasma lemma of roots. Nagajyoti *et al.* (2010) showed that the plants growing in metal-polluted sites exhibit altered metabolism, growth reduction, lower biomass production and metal accumulation. Various physiological and biochemical processes in plants are affected by metals. The contemporary investigations into toxicity and tolerance in metal-stressed plants are prompted by the growing metal pollution in the environment. A few metals, including copper, manganese, cobalt, zinc and chromium are, however, essential to plant metabolism in trace amounts. It is only when metals are present in bioavailable forms and at excessive levels, they have the potential to become toxic to plants.

The relative increments and reductions of dry weight of shoots as a result of application of heavy metals with NPK fertilizers are listed in Table 3. The increase in dry weight due to the application of small concentrations ranged between 0.43 to 1.50 g/plant. This could be rendered to the very low buffering capacity of the soil which helps in immobilizing the received heavy metals. So, the applied amounts of heavy metals showed a direct deleterious effect on plant growth. Consequently, the plants were clearly damaged at the latter stage of growth so, the reduction in dry matter could be considered 100%. This was less severe in tested soil due to their high buffering or immobilization capacity. Singh and Nayyar (1990) found that the application of a Cd containing NPK fertilizers (40 mg Cd/kg) at the rate of 30mg P/ kg soil did not increase the Cd concentrations in oat and rape. However, the same fertilizer at a higher rate of application (90 mg P/kg) increased the Cd concentration in both crops.

Concentrations of Heavy Metals in Shoot Tissues of Corn Plants

Data presented in Table 4 show the concentrations of heavy metals (Cd, Ni and Pb) in shoot tissues of corn plant. Depression of dry matter production of corn plant was often accompanied by a concomitant increase in the concentration of heavy metals in the plant tissues. However, the extent of dry weight depressions and final metal concentrations in plant tissues both vary considerably depending on soil type, amount of heavy metals associated with fertilizers type.

Rate of heavy metal has a distinguished effect on the concentrations of Cd, Ni and Pb in corn tissues. The magnitude of the variation in concentration for each element varied from soil to another at the same plant age and fertilizer treatment. The highest values for the concentrations of Cd, Ni and Pb in corn tissues were in counted in young plants. In contrast, the lowest values of Cd, Ni and Pb concentrations were detected in older plants. This reduction in concentrations of heavy metals with increment of plant ageing may be due to the differences between rate of absorption of heavy metals and the rate of growth, which is well known as "dilution effect". Therefore, the concentration of heavy metals in corn plant decrease with age in the order:

plant1 > plant 2 > plant 3 > plant 4

As seen in Table 4 the values of heavy metals concentrations in plant tissues were increased in the following order:

Cd < Ni < Pb < NPK

These results are in harmony with the results obtained by Taylor and Allinson (1981), Allinson and Dzialo (1981).

Table 4. Concentration of the studied contaminating heavy metals of Cd, Ni and Pb in corn plants

Treatment	Rates ppm	Cd				Nii				Pb			
		Number of plant sample				Number of plant sample				Number of plant sample			
		1	2	3	4	1	2	3	4	1	2	3	4
Control		7.85	6.54	5.27	3.80	4.32	3.27	3.04	2.09	1.46	1.31	1.23	1.09
Cd	50.	6.31	5.70	4.43	1.90	3.49	2.66	2.32	1.66	7.40	5.92	5.18	2.95
	100	6.33	5.06	3.17	0.63	3.82	2.49	2.82	1.16	9.62	5.64	5.18	2.14
	150	6.33	5.13	3.28	0.48	3.82	2.16	2.32	1.99	8.88	6.66	5.92	2.11
Ni	50	7.60	6.33	5.06	2.53	4.15	2.82	3.15	1.33	8.14	7.40	4.44	2.96
	100	6.33	5.06	7.70	3.17	3.15	2.99	2.99	1.99	8.88	7.40	5.92	2.96
	150	7.15	4.43	5.06	1.90	3.82	2.99	2.66	1.82	9.62	5.18	4.44	2.94
Pb	50	5.70	5.06	3.17	3.70	3.49	3.51	2.99	1.83	9.62	6.66	5.18	2.70
	100	6.33	5.70	3.21	4.43	3.28	3.82	2.32	1.66	11.1	7.46	6.66	2.96
	150	6.97	5.70	4.43	4.43	3.32	2.99	3.41	1.83	11.8	6.66	5.16	3.70

Therefore, the application of fertilizers to improve crop production either directly or indirectly by improving the soil fertility as a rooting medium, can also degrade the plant environment by heavy metals associated with fertilizers.

The data show also that the magnitude of increase in heavy metal concentrations of shoots due to increasing the amount of applied heavy metals was not linear. This indicate that the absorbed of heavy metals may be controlled by biological metabolism and the chemical reactions. The addition of supplemental heavy metals to NPK treatments resulted in increases of all studied elements in corn tissues. Data representing the content of cadmium in shoots of the studied corn plant as affected by different rates showed positive responses compared to control (without heavy metals). Similar trend was obtained by Kirkham *et al.* (2006), for red radish and lettuce, they mentioned that high ability of roots to accumulated high amounts of Cd was suggested and the differences in the Cd concentration in roots and shoots could be taken to judge the mobility of such elements inside the plant. According to Drazic and Mihailovic (2004), the high retention of Cd in roots, presumably due to existing two mechanisms:

- The first mechanism appeared to be characterized as exchange adsorption; the exchange sites are filled non-selectively with the transition type metals.
- The second appeared to involve a non metabolic irreversible sequestering of Cd to a fixed number of binding sites which may be present on cell wall constituents or other macromolecules within the cell.

Data showed that the concentration of Cd in the dry matter of corn plant shoots of different rates. It reveal that by increasing the applied Cd concentration in the soil, the Cd concentration in corn shoots increased in different manners. Cd concentration in corn plant tissues were consistently lower in the second period compared to the first one. This could be rendered to the "dilution effect" inside the plant tissue that getting older as well as the lower amounts of available Cd-remaining in the soil. As seen in Table 4. The values of heavy metals concentrations (Pb) in plant tissues were increased by increasing the Pb-levels added to the soil. The highest Pb concentration was recorded in shoots grown with the highest rate, which confirmed the previous findings with Ni. It is worthy to mention that Pb-concentrations in corn shoots were much higher than that of Ni, which indicated that Pb is high toxic than Ni for corn plants. This could be attributed to the higher affinity of Pb to be retained in the investigated soil compared to Ni, which was confirmed by Sipos *et al.* (2008) and Dayton *et al.* (2009).

The data presented in Table 4 showed that the addition of small concentrations of Pb up to 50 ppm with NPK fertilizers to soil enhanced the growth of corn plants. The decrease in dry matter production was about 200% that of the control upon the addition of 50 ppm Pb to the soil. This is in agreement with the findings of Dayton *et al.* (2009) by increasing Pb-stresses up to 150 ppm the dry matter production decreased by different magnitudes due to the phyto-toxicity of lead.

Data in Table 4 show the concentration of Ni in corn tissues. There is no evidence of an essential role of Ni in plant metabolism although the reported beneficial effects of Ni on plant growth have stimulated speculation that these metals may have some function in plant. Ni recently has become a serious pollutant that is released in the emissions from metal processing operations and from the increasing combustion of coal and oil. The application of sludge and certain phosphate fertilizers also may be important sources of Ni. This experiment aimed to study the phytotxic level of nickel to corn plant. It showed that to low levels of Ni addition, the plant growth was stimulated and the dry matter production increased. The magnitude of stimulation was remarkably higher in case of tested soil as its dry matter production was higher at 50 ppm Ni level. The plant growth stimulation by low concentration of Ni was reported by Zhang *et al.* (2007) who suggested that more Ni remained soluble and phytoavailable in soil amended with Ni $(NO_3)_2$, thus significantly inhibting seed germination High-Ni leaves shed by hyperaccumulators did not appear to create a " toxic zone" around the plants and inhibit germination or growth of competing plants.

Barbara *et al.* (2002) reported that with plants under Ni stress, the absorption of nutrients, roots development and metabolism are strongly retarded. Before the acute Ni toxicity symptoms are evident, elevated concentrations of this metal in plant tissues are known to inhibit photosynthesis and transpiration also, indicated that the activity of microorganisms in soil can be stronger than soil amended with heavy metals.

Concentrations of Heavy Metals in Leachate

Data presented in Table 5 show the concentrations of heavy metals (Cd, Ni and Pb) in leachates. The prediction of heavy metal movement is very complex since it involves numerous chemical reactions in the soil. The movement of heavy metals in soil is very much restricted, thus they stay in the application zone. Table 5 shows the concentration levels of heavy metals in leachates. This data indicated that the amount of heavy metals leached out the soil column was increased in the presence of heavy metals in all heavy metals treatments compared with NPK fertilizers treatment. In the same Table, the concentration of Pb in leachates increased with the addition of Pb. And the concentration of Ni in leachates increased with the addition of Ni. The concentration of Cd in leachates increased with the addition of Cd.

Rate of fertilizers has a distinguished effect on the concentrations of Cd, Ni and Pb in leachates. The magnitude of the variation in concentration for each element varied from soil to another at the same leachate and heavy metal treatment. The highest values for the concentrations of Cd, Ni and Pb in leachates were in counted in the first leachate. In contrast, the lowest values of Cd, Ni and Pb concentrations were detected in leachate 4. Therefore, the concentration of heavy metals in leachates decrease with leaching in the order:

Leach1 > leach 2 > leach 3 > leach 4 >

The values of heavy metals concentrations in leachates were increased by increasing the heavy metals-levels added to the soil Table (5). These results confirmed by Sipos *et al.* (2008) and Dayton *et al.* (2009).

As seen in Table 5 the values of heavy metals concentrations in leachates were increased in the following order:

Cd < Ni < Pb < NPK

Table 5. Concentration of the studied contaminating heavy metals of Cd, Ni and Pb in leachates

Treatment	Rates ppm	Cd				Ni				Pb			
		Leaching Number				Leaching Number				Leaching Number			
		1	2	3	4	1	2	3	4	1	2	3	4
Control		3.49	3.17	3.53	1.45	2.21	1.58	1.77	1.38	0.59	0.52	0.30	0.22
Cd	50	6.23	6.33	5.61	4.43	3.15	2.82	2.66	2.16	1.45	1.13	1.06	0.84
	100	6.33	6.23	5.70	3.80	3.65	2.99	2.88	2.66	1.41	1.26	1.18	1.01
	150	7.60	6.70	5.86	4.43	4.15	3.49	2.67	2.82	1.68	1.26	1.18	1.04
Ni	50	6.33	6.31	5.06	4.41	4.48	4.32	4.15	3.15	1.26	1.02	0.74	0.54
	100	7.60	6.34	5.06	5.06	4.81	4.48	4.32	3.82	1.11	1.09	0.74	0.66
	150	7.63	7.60	5.11	4.43	4.84	4.48	4.32	4.12	1.24	1.12	0.84	0.74
Pb	50	7.62	6.33	5.12	4.42	2.99	2.49	.2.32	2.12	1.04	0.67	0.67	0.67
	100	7.64	6.35	5.70	5.61	3.82	2.82	2.49	2.16	1.04	0.74	0.67	0.59
	150	7.76	6.16	5.06	5.06	3.15	3.02	2.49	2.15	1.12	0.87	0.82	0.67

These results are in harmony with the results obtained by Taylor and Allinson (1981); Allinson and Dzialo (1981).

The data showed also that the magnitude of increase in heavy metals concentrations in leachates due to increasing the amounts of applied heavy metals.

Distribution of Dtpa Extractable Forms of Heavy Metals in Soil Columns

The prediction of heavy metal movement is very complex since it involves numerous chemical reactions in the soil. The movement of heavy metals in soil is very much restricted, thus they stay in the application zone. Data in Table 6 shows the concentration levels of DTPA-extractable heavy metals in different layers of soil columns at the end of the experiment. The data indicated that large amounts of applied heavy metals were retained in the top layers. Therefore it could be stated that the top 15 cm of the soil column retained, the highest amount of DTPA-extractable heavy metals then it decreased with the depth of soil column. In this respect, Table 6 represents the depth wise distribution of DTPA- Pb in the soil that received the highest rate of heavy metals. The results show clearly that the accumulation of Pb has occurred in the top layer of the column. This indicated that most of the added heavy metals into the column were bound with soil constituent in top layer allowing only small amounts to move downward layers. These data are consistent with the findings reported by Sun *et al.* (2001).

Results show clearly that the accumulation of Pb has occurred in the top layer of the soil column, the increase was large through the entire column depths, which may be indicate the higher mobility of Pb downward soil column. Also, some sort of Ni mobility downward the tested soil, whereas a great deal of the applied Ni was retained in the top depth layer of soil; as well as, mobility for Cd clear zone of accumulation in the top 5 cm depth layer of soil.

In this respect, Table 6 represents the depthwise distribution of DTPA–Cd that received Cd content with the added of Cd was clearly affected due to the levels of Cd. Cd concentrations increased with the depth of soil column, while vice versa was noticed with treatments of Ni and Pb where the concentration of Cd decreased with the depth of soil column.

Also, Table 6 show the depthwise distribution of DTPA- Ni that Ni content with the treatment of Ni was clearly affected due to levels of Ni. The Ni concentrations increased with the depth of soil column, while vice versa was noticed with treatments of Pb and Cd where the concentration of Ni decreased with the depth of soil column.

Table 6. DTPA-extract of heavy metals distribution in various rates fertilizer at the depth of soil columns at the end of the experiment (ppm)

Treatment	Rate ppm	Cd			Ni			Pb		
		0-15	15-30	30-50	0-15	15-30	30-50	0-15	15-30	30-50
Control		0.20	0.18	0.18	1.00	1.03	0.90	4.06	3.66	3.40
Cd	50	0.34	0.24	0.31	2.00	1.60	1.30	4.60	4.20	4.40
	100	0.16	0.14	0.13	1.60	1.30	1.30	4.60	3.40	4.00
	150	0.19	0.19	0.18	1.30	1.30	1.00	4.30	4.00	4.00
Ni	50	0.14	0.13	0.12	1.32	1.30	1.20	3.40	3.00	3.20
	100	0.16	0.15	0.13	1.20	1.00	1.00	4.80	4.60	4.20
	150	0.26	0.15	0.14	1.30	1.30	1.20	4.60	4.60	4.20
Pb	50	0.15	0.15	0.13	1.20	1.20	0.90	4.20	4.00	4.00
	100	0.17	0.15	0.16	1.60	1.30	1.30	5.60	5.20	4.30
	150	0.16	0.17	0.15	1.20	1.60	1.30	3.80	3.40	3.60

Pb content with the treatment of Pb was clearly affected due to the levels of Pb. Pb concentrations increased with the depth of soil column, while vice versa was noticed with treatments of Cd and Ni where the concentration of Pb decreased with the depth of soil column. The increase was large through the entire column depth, which may indicate the higher mobility of Pb downward the soil column.

Table 6 indicates also some sort of Ni mobility downward the soil, whereas a great deal of the applied Ni was retained in the top 30 cm depth of the soil. However it is concluded that, in some cases, heavy metals have moved downward. This was confirmed by Gregorio *et al.* (2005).

This indicated that most of the added heavy metals into the column were bound with soil constituent in surface layer allowing only small amounts to move downward. These data are consistent with the findings reported by David *et al.* (2007).

Conclusion

The obtained results clearly show that the growth of corn plants, grown on soil treated with soluble fertilizers and heavy metals increased by soluble NPK fertilization and then the growth was inhibited by the addition of heavy metals (Cd, Ni and Pb).

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حركة وغسيل العناصر الثقيلة خـــلال طبقات التربة تحت تأثيـر إضـافة مسـتويـات مختلفة من العناصر الثقيلة (الكادميوم - النيكل - الرصاص) على نبات الذرة

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أجريت تجربة معملية لدراسة تأثير إضافة الأسمدة والعناصر الثقيلة على نبات الذرة خلال طبقات التربة فقد أجريت تجربة أعمدة تربة بطول ٦٠سم وقطر ١٠سم وتمت زراعتها بنبات الذرة وتم تسميدها بثلاث مستويات تسميدية هى : ١- ٥٠-١٠٠-١٥٠ جزء فى المليون من الرصاص، ٢- ٥٠-١٠٠-١٥٠ جزء فى المليون من النيكل، ٣- ٥٠، ١٠٠، ١٥٠ جزء فى المليون من الكادميوم. أوضحت النتائج ما يلى: أن الإضافات القليلة للعناصر الثقيلة تؤدى إلى زيادى إنتاج نبات الذرة من المادة الجافة ولكنه يعمل على زيادة محتوى النبات من تلك العناصر. صاحب ذلك زيادة كبيرة فى تركيزات العناصر الثقيلة فى الجزء الخضرى فى النبات، فلقد تراوحت نسبة الزيادة فى تركيز عنصر النيكل بين ١١٥و١١٦% مقارنة بتركيزاته فى المعاملات التى لم يضاف إليها عناصر ثقيلة وبلغت تلك النسبة للرصاص ١١٥-١٧٤% والكادميوم ١٠-٧٣%. أوضحت النتائج أيضاً أن التسميد بمعدلات عالية يؤدى إلى زيادة النمو الخضرى ويؤدى ذلك لزيادة امتصاص العناصر الثقيلة من التربة بكميات تفوق الكميات الطبيعية، حيث زادت كميات العناصر الثقيلة الممتصة بواسطة نبات الذرة وبهذا فإن هذه الكميات الكبيرة تدخل إلى السلسلة الغذائية للحيوان والإنسان؛ ولذا فإن الدراسة توصى بعدم الإسراف فى التسميد فى الأراضى ضعيفة الإنتاج بغرض زيادة المحصول، لأنه قد يؤدى إلى زيادة الكمية المنتجة مع رداءة نوعية الناتج من حيث احتوائه على كميات أكبر من العناصر الثقيلة. أدى التسميد بالعناصر الثقيلة الى امتصاص ٤٠% من الكادميوم المضاف و٢٠% من النيكل و ٨% من الرصاص المضاف مع التسميد مما يعنى انه حدث تراكم لجزء كبير من العناصر الثقيلة فى التربة مع إضافة الأسمدة. فى نهاية التجربة تم استخلاص العناصر الثقيلة المتبقية فى التربة فى صورة قابلة للامتصاص بواسطة DTPA وقد اتضح زيادة تلك الكميات من الرصاص والكادميوم والنيكل، مقارنة بتلك الموجودة فى التربة التى لم يضاف إليها عناصر ثقيلة.