

ORGANIC AND INORGANIC REMEDIATIONS OF CONTAMINATED SOILS WITH HEAVY METALS RESULTED FROM SOME ANTHROPOGENIC ACTIVITIES

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ABSTRACT:

Soils can naturally reduce mobility and bioavailability of heavy metals as they are retained in soil by sorption, precipitation and complexation reactions. These natural processes can be accelerated by addition of some soil amendments, which converting the soluble forms to more geochemical stable solid phases. Hence, the current study represents a trial towards ameliorating soils polluted with heavy metals resulted from some anthropogenic activity. To achieve this target, in situ an incubation experiment was executed on two soil samples taken from El-Gabal El-Asfar farm (Qalubia Governorate) and El-Saff (Giza Governorate), subjected to heavy metals pollution due to irrigating with sewage effluent and industrial wastes, respectively. The studied two soils were mixed thoroughly in pots of 200 g soil capacity with some soil amendments, i.e., poultry manure, organic compost and bentonite at a rate of 2 %, then the pots were daily wetted with distilled water to reach a constant moisture content (field capacity) and incubated under room temperature at different periods of 0, 25, 50 and 75 days.

Soil samples were taken to identify the effective role of the applied soil amendments throughout the different incubation periods, however, the values of EDTA-extractable Ni, Co and Cd were determined. The most important obtained results could be summarized in the following:

1. EDTA-extractable amounts of Ni, Co and Cd showed a progressively decreased in both amended soils with poultry manure, with a more effective role by increasing time of incubation period. The removed amounts of the studied metals for both investigated soils followed the descending order: Ni > Co > Cd. Also, the removal capacity of poultry manure seemed a highest figure with Ni, lowest with Co and intermediate with Cd.
2. Application of organic compost led to minimize the value of EDTA-extractable Ni, Co and Cd in both soils under study. The adsorbed amounts of these metals in El-Gabal El-Asfar soil exceeded obviously the corresponding ones in El-Saff soil. This trend was emphasized by the removal capacity of the compost for Ni, Co and Cd, which was recorded higher values in El-Gabal El-Asfar soil than in El-Saff one.
3. Values of EDTA-extractable Ni, Co and Cd from both the bentonite amended soils also showed progressively decreased with increasing the incubation period. The absolute adsorbed amounts of Ni were the highest, whereas those of Co and Cd were the lowest and intermediate, respectively, in the bentonite amended soils. In general, the removal capacity of bentonite for Ni was higher than Co and Cd over the studied incubation periods. It is noticed that the removal capacity of bentonite for Co was almost similar over all the incubation periods.

Key words: Organic remediation, polluted soil with heavy metals, poultry manure, compost and bentonite as soil amendments

INTRODUCTION:

Rapid industrialization and urbanization in last century due to enormous technological innovations have led to the problem of environmental pollution and ecological concerns. Heavy metal contamination of soil environment has been occurring for centuries, but its extent has increased markedly in the last fifty years due to technological developments. In recent years, widespread concern has arisen over the implications of human health problems from increasing heavy metals in soils (Majid and Argue, 2001; Zhou, 2003). The remained heavy metals in various ecosystems would seep into ground water or even channel into the food chain by crops growing on such a soil (Lin *et al.*, 1998). These heavy metals may adversely affect the soil ecosystem safety, not only agricultural product and water quality, but also the human health (Adriano, 2001; Zhou *et al.*, 2004).

The term heavy metal is widely used although others such as toxic metals, potentially toxic elements and trace elements are possible alternatives. These elements are referred to be as essential trace elements or micronutrient elements. Heavy metals are elements that have metallic properties, atomic number over 20 (Nieboer and Richardson, 1980) and a density higher than 5.0 g/cm³ (Sanita di Toppi and Gabbrielli, 1999).

Heavy metals are released to the environment by a very wide variety of industrial and domestic activities, metal-rich mine tailings, metal smelting, electroplating, gas exhausts, energy and fuel production, downwash from power lines, intensive agriculture, and some sludge dumping are the most important human activities that contaminate soils and aqueous streams with large quantities of toxic metals (Seaward and Richardson, 1990 and Harrison, 1996). The environmental problems associated with pollution with heavy metals have adverse effects on plant and may cause either evolutionary or drastic changes even over short periods of time (Kabata-Pendias and Pendias, 1992). Heavy metals, even at trace concentration, can cause serious problems to all organisms and heavy metal bioaccumulation in the food chain can be highly dangerous (Sanita di Toppi and Gabbrielli, 1999).

The human influence is amply manifested by the elevated levels of trace metals now found in soils in urban areas, around industrial installations, in agricultural soils, in forest soils and downwind of industrialized areas (Adriano, 1988). Diels *et al.* (2002) mentioned that in situ application of soil additives modifying the physicochemical properties of the contaminating heavy metals combined with the development of biological communities and plants for further metal immobilization was shown to be a very promising alternative remediation method based on risk reduction and time and cost efficiency. Shuman (1999) indicated that solid organic matter adsorbed heavy metal by physical and chemical adsorption and for soluble organic matter that complexed heavy metal in solution. Yuan and Lavkulich (1997) reported that the adsorption capacity of soil for Zn was reduced by 72%, when 11% of the organic C content was lost.

The current study deals with the effect of three different soil amendments on immobilization of some heavy metal ions (i.e., Ni, Co and Cd) in contaminated soils resulted from some anthropogenic activities.

MATERIALS AND METHODS:

An incubation pot experiment was conducted on two contaminated soils with some heavy metals (i.e., Ni, Co and Cd) collected from El-Gabal El-Asfar farm (Qalubia Governorate) and Arab Abu Said village, El-Saff district (Giza

Governorate), which are irrigated with sewage effluent and industrial-wastes, respectively. Three organic and inorganic soil amendments, i.e., poultry manure, organic compost and bentonite were used for immobilizing the studied heavy metals in both soils under investigation. Some physical and chemical properties of the studied soils and soil amendments are presented in Table (1).

The incubation pot experiment:

Each of the two investigated soils was thoroughly mixed with the tested three soil amendments (i.e., poultry manure, organic compost and bentonite) at a rate of 2 %, then packed in plastic pots of 200 g soil capacity, which categorize into three sets prepared for an incubation experiment. The pots were daily wetted with distilled water to reach constant soil moisture content (field capacity) and incubated at room temperature for different incubation periods of 0, 25, 50 and 75 days, each treatment was repeated three times. Soil samples were taken from the incubated pots, which representing the different treatments and the different incubation periods, for determining the values of EDTA-extractable Ni, Co and Cd by using an Atomic Absorption Spectrophotometer (Perkin Elmer, Model 2380).

Laboratory analysis:

- * Particle size distribution of the studied soils and bentonite was determined by the pipette method (Piper, 1950).
- * Organic matter content was determined according to the modified Walkely and Black's method (Jackson (1973)).
- * Calcium carbonate was determined by using Collin's Calcimeter (Wright, 1939).
- * Soil pH was determined in 1:2.5 soil or amendment water suspension as described by Page *et al.* (1982).
- * ECe and soluble anions ions were determined in soil paste extract according to Jackson (1973).
- * Cation exchange capacity of soil (CEC) was determined according to the method outlined by Jackson (1973).
- * Organic amendments were wet digested for determining the contents of N, P and K according to the methods outlined by Chapman and Pratt (1961).
- * Available contents of Ni, Co and Cd were extracted with EDTA solution (Soltanpour and Schwab, 1977), and determined by using an Atomic Absorption Spectrophotometer (Perkin Elmer, Model 2380).

Table (1): The main physical and chemical properties of the studied soils and soil amendments.

Properties	Investigated soils		Investigated soil amendment		
	El-Gabal El-Asfar soil	El-Saff	Bentonite	Organic compost	Poultry manure
<i>Particle size distribution %:</i>					
Coarse sand	49.00	60.39	0.50		
Fine sand	19.20	27.50	4.50		
Silt	23.20	8.17	23.10		
Clay	8.60	3.94	71.90		
Textural class	Sandy loam	Sandy	Clay		
EC (dS/m)	4.10	6.70	2.15	3.18	2.36
<i>Soluble cations (mmol_c L⁻¹):</i>					
Ca ²⁺	17.20	35.80	1.53		
Mg ²⁺	16.20	15.00	2.26		
Na ⁺	9.50	18.50	14.9		
K ⁺	0.98	2.50	0.22		
<i>Soluble anions (mmol_c L⁻¹):</i>					
CO ₃ ²⁻					
HCO ₃ ⁻	6.90	3.00	2.7		
Cl ⁻	20.20	35.00	15.36		
SO ₄ ²⁻	16.78	33.80	0.85		
<i>Available heavy metals (mg kg⁻¹):</i>					
Cd	0.334	0.306	0.015	0.020	0.024
Co	0.182	0.126	0.060	0.036	0.054
Ni	4.116	1.305	0.014	0.257	0.224
pH (1:2.5 soil suspension)	6.05	7.80	7.68	7.60	6.50
CaCO ₃ %	0.39	12.45	1.50		
CEC (cmol _c kg ⁻¹)	12.65	5.72	51.96	509.78	490.98
Organic matter %	3.90	0.94	0.12	43.27	55.47
Organic carbon %				25.16	32.25
Total N %				1.80	2.15
Total P %				0.77	0.90
Total K %				3.13	3.35
C/N ratio				13.98	15.00

RESULTS AND DISCUSSION:***EDTPA-extractable heavy metal ions as affected by the applied different soil amendments:******I. Poultry manure:***

Data presented in Table (2) show the positive effect of applied poultry manure as an amendment on EDTA-extractable Ni, Co and Cd from both soils under investigation. Also, data reveal the effect of contact time of the applied poultry manure on adsorbed amounts and sorption percentages of the concerned metal ions besides the removal capacity of the poultry manure for these metals.

Table (2): Effect of applied poultry manure on EDTA-extractable metal ions and their sorption parameters for both the studied two soils.

Sorption parameter	Incubation period	El-Gabal El-Asfar soil			El-Saff soil		
		Ni	Co	Ni	Co	Ni	Co
Residual amount (mg kg ⁻¹)	0	4.123	0.101	0.339	1.370	0.142	0.309
	25	32.16	0.076	0.281	1.027	0.105	0.250
	50	2.846	0.065	0.254	0.890	0.089	0.227
	75	2.556	0.057	0.235	0.822	0.081	0.210
Sorbet amount (mg kg ⁻¹)	25	0.907	0.025	0.058	0.343	0.037	0.059
	50	1.277	0.036	0.085	0.480	0.053	0.082
	75	1.567	0.044	0.104	0.548	0.061	0.099
Sorbet amount (%)	25	21.99	24.75	17.10	25.03	26.05	19.09
	50	30.97	35.64	25.07	35.03	37.32	26.53
	75	38.00	43.56	30.67	40.00	42.95	32.03
Removal capacity (mg metal g ⁻¹)	25	0.045	0.001	0.003	0.017	0.002	0.003
	50	0.064	0.002	0.004	0.024	0.003	0.004
	75	0.078	0.002	0.005	0.27	0.003	0.005

The obtained data indicate that the EDTA-extractable amounts of Ni, Co and Cd tended to decrease as a result of applied poultry manure, with a more effective role with increasing time of contact between the applied amendment and the investigated soil. The values of EDTA-extractable Ni and Cd were higher in El-Gabal El-Asfar soil (non-calcareous) than in El-Saff one (calcareous), whereas the reverse was true for EDTA-extractable Co. Moreover the adsorbed values of Ni, Co and Cd increased progressively with period of incubation. This trend was occurred over all the investigated incubation periods. Similar results reported by **Badr (2005)** for Cd and **Ismail (2007)** for both Ni and Co.

The effect of the poultry manure on sorption of Ni, Co and Cd metal ions from soil may be attributed to the presence of both COOH and phenolic-OH groups in the humic and fulvic acids released during the decomposition of poultry manure. These functional groups are capable of exerting a variety of reactions, including electrostatic bonding, co-adsorption, complex formation and chelation reactions. In the formation of chelates, the metal ions may connect itself to one or more radicals. The radicals involved may belong to the same or different organic ligands. Also, **Tan (1993)** reported that the organic acids formed due to decomposition of the organic matter bind excessive metal ions in the soil and later release them in smaller amounts. In this way, Ni, Co and Cd toxicity can be controlled because the organic acids prevent buildup of large amounts of available trace metal in soil. Many of the organometal chelates formed are insoluble and prevent the metal from reaching ground water. The later process is an important aspect in environmental quality.

The relative efficiency for the poultry manure amended soils in removing the studied metal ions was highest with Co, lowest with Cd and intermediate with Ni. In this concern, **Cast (1976)** reported that, generally, ions with smaller hydrated sizes are preferably adsorbed. The values of the removal capacity of the poultry manure were seemed to be the highest with Ni, lowest with Co and intermediate for Cd although they were closer to those of Co than the corresponding ones of Ni. The higher removal capacity of the poultry manure for Ni is probably due to its association with O⁻ and OH⁻ ligands. Accordingly, it can

be deduced that the removal of the metal ions from the investigated soils by poultry manure as organic material is an important mechanism that controls metal concentration in aqueous system since about 80% of the organic material consists of humic substances which provide important sources of the adsorbent organic ligands, and therefore they are expected to reduce the availability of metal ions in aquatic systems (Liu and Gonzalez, 1999).

The values of removal capacity of poultry manure for the studied metal ions were generally higher in El-Gabal El-Asfar poultry manure amended soil than in El-Saff poultry manure amended soil. Such a variation can be attributed mainly to the initial higher values of EDTA-extractable metal ions in El-Gabal El-Asfar soil than El-Saff soil. Moreover, the original organic matter content of El-Gabal El-Asfar soil is higher than that of El-Saff soil which means providing more organic ligands for complexing the metal ions in the former soil than the latter one. These findings emphasized by both Badr (2005) and Ismail (2007) who reported that organic matter is considered an important factor for Ni, Co and Cd removal from soil.

2. Organic compost:

Effects of compost on the amounts of EDTA-extractable Ni, Co and Cd as well as their sorption parameters are shown in Table (3).

Table (3): Effect of applied organic compost on EDTA-extractable metal ions and their sorption parameters for both the studied two soils.

Sorption parameter	Incubation period	El-Gabal El-Asfar soil			El-Saff soil		
		Ni	Co	Ni	Co	Ni	Co
Residual amount (mg kg ⁻¹)	0	4.086	0.083	0.333	1.328	0.127	0.304
	25	3.432	0.068	0.299	1.062	0.099	0.268
	50	3.187	0.062	0.248	0.982	0.091	0.254
	75	3.023	0.058	0.269	0.942	0.087	0.235
Sorbent amount (mg kg ⁻¹)	25	0.654	0.015	0.034	0.266	0.028	0.036
	50	0.899	0.021	0.085	0.346	0.036	0.050
	75	1.063	0.025	0.064	0.386	0.040	0.069
Sorbent amount (%)	25	16.00	18.07	10.21	20.03	22.04	11.84
	50	22.00	25.30	25.52	26.05	28.34	16.44
	75	26.01	30.12	19.21	29.06	31.49	22.69
Removal capacity (mg metal g ⁻¹)	25	0.033	0.001	0.002	0.013	0.001	0.002
	50	0.045	0.001	0.004	0.017	0.002	0.003
	75	0.053	0.001	0.003	0.019	0.002	0.003

Results reveal that application of compost to both El-Gabal El-Asfar (non-calcareous) and El-Saff soils (calcareous) could minimize or immobilize the values of EDTA-extractable Ni, Co and Cd in situ. These results are in well agreement with those obtained by Takamatsu and Yashida (1978) who pointed out that organic amendments such as organic compost contains a high proportion of organic matter can decrease the availability of heavy metals in soils by adsorption and by forming stable complexes with humic substances. The humic substances consist of a heterogeneous mixture of interacting functional groups, which include strong acidic (sulfonic acid-SO₂OH), weak acidic (carboxyl-COOH, hydroxyl-OH) as well as carbonyl (-C=O) and amine (-NH₂) groups. These organic ligands form relatively weak complexes through either cation exchange capacity or strongly bound inner-sphere complexes (Sposito, 1984).

Evangelou *et al.* (1999) reported that metal ions formed stronger complexes with humic fraction that contained more carboxylic groups. Senesi and Sakellariadout (1997) reported that humic substances may interact in several ways with metal ions including ion exchange, complexation, adsorption & desorption, precipitation and dissolution, thus affecting several physical and chemical properties of metal ions including their oxidation state and chemical form, apparent solubility, phase distribution and speciation. These conditions will influence the metal mobility and transport, immobilization and geo-accumulation. Also, Kaschl *et al.* (2002) found that N-containing groups in organic matter interacted strongly with the trace metal ions.

The effect of organic compost on reducing the amounts of EDTA-extractable metal ions seemed more pronounced by prolonging period of incubation between the organic substances and both the investigated calcareous and non-calcareous soils, yet such an effect seemed more obvious in the non-calcareous soil than the calcareous one. Accordingly, it was found that adsorbed amounts of Ni, Co and Cd in El-Gabal El-Asfar soil exceeded obviously the corresponding adsorbed amounts of these metal ions in El-Saff soil. On the other hand, the sorption or removal percentages of the concerned metal ions in the calcareous soil of El-Saff exceeded obviously the corresponding sorption percentages of the non-calcareous soil of El-Gabal El-Asfar, where CaCO₃ of the former soil might enhance the sorption effect of the applied compost for Ni, Co and Cd. Moreover, the higher pH value of El-Saff soil is thought increase the pH- dependent charge of the soil minerals as well as that of the organic colloids (humic substance in the mature sewage) and hence increases the ability of this soil to adsorb more mineral ions (Spark *et al.*, 1995 a & b). The adsorbed amounts of the concerned metal ions were increased with prolonging the period of incubation between organic compost and the investigated soils.

Removal capacity of the compost for Ni, Co and Cd was obviously of higher values in the non-calcareous soil of El-Gabal El-Asfar than in the calcareous one of El-Saff. Such a result may be attributed to the higher amounts of EDTA- extractable metal ions found primarily in El-Gabal El-Asfar soil than in El- Saff soil, and hence the effect of the applied compost on removal of the studied heavy metals from the former soil seemed more pronounced.

3. Bentonite:

Data presented in Table (4) reveal that values of EDTA-extractable Ni, Co and Cd from both El-Gabal El-Asfar and El-Saff soils tended to decrease with increasing time of incubation period between soil and bentonite. Also, it is observed that the rate of reduction in EDTA-extractable Ni, Co and Cd tended to decline as incubation period progressed. These results stand in well agreement with those of Usman *et al.* (2004) who concluded that the addition of clay minerals, especially bentonite, decreased the extractability of heavy metals during incubation. Consequently, it was found that values of sorbed Ni, Co and Cd increased in both the investigated soils with increasing time of incubation period between the investigated soils and bentonite. The reduction in EDTA-extractable Ni, Co and Cd can be explained by their sorption or retention by bentionte-amended soils.

Table (4): Effect of applied bentonite on EDTA-extractable metal ions and their sorption parameters for both the studied two soils.

Sorption parameter	Incubation period	El-Gabal El-Asfar soil			El-Saff soil		
		Ni	Co	Ni	Co	Ni	Co
Residual amount (mg kg ⁻¹)	0	4.038	0.078	0.333	1.282	0.123	0.304
	25	3.553	0.067	0.306	1.076	0.100	0.276
	50	3.392	0.064	0.296	1.038	0.096	0.264
	75	3.230	0.060	0.089	0.974	0.089	0.246
Sorbet amount (mg kg ⁻¹)	25	0.485	0.011	0.027	0.206	0.023	0.028
	50	0.646	0.014	0.037	0.244	0.027	0.040
	75	0.808	0.018	0.244	0.308	0.034	0.058
Sorbet amount (%)	25	12.01	14.10	8.11	16.06	18.69	9.21
	50	15.99	17.94	11.11	19.03	21.95	13.15
	75	20.01	23.07	13.27	24.02	27.64	19.07
Removal capacity (mg metal g ⁻¹)	25	0.024	0.001	0.001	0.010	0.001	0.001
	50	0.032	0.001	0.002	0.012	0.001	0.002
	75	0.040	0.001	0.012	0.015	0.002	0.003

Ayari *et al.* (2005) reported that sorption reactions involve adsorption of metal-ions on the solid-solution interface, precipitation and polymerisation. Faust and Aly (1987) reported that adsorption of metals at the mineral-water interface is often initially fast followed by a decrease in the adsorption rate. Sparks (1995) revealed that adsorption is much faster process than precipitation. Moreover, Ayari *et al.* (2007) reported that there are two types of reactions necessary to explain ion adsorption on clay surfaces. The first one is a cation-exchange mechanism that occurs on the interlayer and basal planes. It originates from the presence of a permanent negative structural charge in the alumina silicate layer created by isomorphous substitution in the latter. The quantity of exchange sites can be derived from the structural formula, and it is compensated by "exchangeable cations" that generally form outer sphere complexes with siloxane cavities (Sposito, 1981 and 1984). The second type of reaction is the pH-dependent specific sorption on the clay minerals edges (Baeyens and Bradbury, 1997 and Fletcher and Sposito, 1989).

Absolute values of sorbed Ni were the highest over the all periods of incubation, whereas those of the corresponding sorbed ones of Co were the lowest and those of sorbed Cd were intermediate although they were more nearer to those of Co than those of Ni. On other words, the metal sorbed onto bentonite-amended soils varied in the following descending order: Ni > Cd > Co. However, sorption percentages of Co were shown to be highest within the first and second periods of incubation (i.e. after 25 and 50 days) in El-Gabal El-Asfar soil amended with bentonite and over the whole period of incubation in El-Saff soil amended with bentonite. The percentage of Cd sorbed on the bentonite amended soil of El-Gabal El-Asfar seemed lowest values after 25 and 50 days of incubation. Likewise, the percentage values of Cd sorbed on the bentonite-amended soil of El-Saff were shown to be lowest over the whole periods of incubation. Meanwhile, sorption percentage of Ni showed intermediate values over the whole periods of incubation for El-Saff soil with bentonite as well as the first and second periods of incubating El-Gabal El-Asfar soil with it, however, the third period of incubation was characterized by the lowest sorption percentage of Ni as compared with the other two studied metal ions of Cd and Co.

The aforementioned results may lead to conclude that percentages of the metal ions sorbed on the bentonite-amended soils might follow a trend quite that shown by their sorbed amounts. For example, the studied metal ions could be arranged according to their sorbed amounts on both the investigated soils in the following descending order: Ni > Cd > Co, whereas they followed the descending sequence: Co > Ni > Cd according to their sorption percentages over the whole incubation periods of El-Saff soil and both the first and second incubation periods of El-Gabal El-Asfar soil. The third incubation period of El-Gabal El-Asfar soil with bentonite was characterized by the following descending order for the studied metal ions according to their sorption percentages: Cd > Co > Ni.

Data presented in Table (2) reveal that removal capacity of the bentonite varied according to type of the metal ion itself as well as type of the investigated soil. In this concern, the bentonite showed the highest removal capacity for Ni, whereas its capacity for removing Cd and Co were far lower than the corresponding ones of Ni over the different studied incubation periods, which were characterized, generally, by increasing the removal capacity by progressing time. Yet, it is worthy to indicate that removal capacity of bentonite for Co remained almost constant over the different periods of incubation. The abundance of bentonite and its low cost are likely to make it a strong candidate as an adsorbant for the removal of heavy metals from polluted soils.

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المعالجة العضوية والغير عضوية للأراضى الملوثة بالعناصر الثقيلة نتيجة بعض الأنشطة البشرية

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 الأراضى كأنظمة طبيعية تستطيع تثبيت حركة وتيسر العناصر الثقيلة من خلال تفاعلات الأدمصاص أو الترسيب أو تكوين معقدات غير ذائبة، ويمكن زيادة المقدرة الطبيعية للأراضى على ذلك من خلال إضافة بعض محسنات التربة والتي تحول الصور الذائبة للعناصر الثقيلة إلى أطوار ثابتة جيوكيميائياً.
 وتعتبر هذه الدراسة محاولة نحو معالجة الأراضى الملوثة بالعناصر الثقيلة كنتيجة لبعض الأنشطة البشرية، ولتحقيق هذا الهدف أجريت تجربة تحضين على عينتى تربة مأخوذة من متعقطنى الجبل الأصفر (محافظة القليوبية) والصف (محافظة الجيزة) وهما ملوثتان بالعناصر الثقيلة نتيجة ريها بمياه ملوثة بمخلفات الصرف الصحى وصرف المصانع على الترتيب، حيث تم تحضينهما بعد خلطهما جيداً إما مع زرق الدولجن أو مكمور عضوى (الكبوست) أو رسوبية غنية فى طين البنتونيت بنسبة ٢٪ وذلك فى اصص سعة كل منها ٢٠٠ جرام. وقد تم ترطيب التربة يومياً من خلال إضافة الماء المقطر للوصول إلى محتوى رطوبى ثابت (السعة الحقلية)، وتم الحفاظ على هذا المستوى الرطوبى ثابتاً طوال فترة التحضين. وقد أجرى التحضين تحت درجة حرارة الغرفة (٢٨ ± ٢ °سليزيوس) لفترات صفر، ٢٥، ٥٠، ٧٥ يوماً، وقد أخذت عينات تربة ممثلة للمعاملات المختلفة المستخدمة تحت فترات التحضين السابق الإشارة إليها لتقدير الجزء الميسر من عناصر النيكل والكوبالت والكاديوم عن طريق الإستخلاص باستخدام محلول EDTA وقياسها باستخدام جهاز Atomic Absorption Spectrophotometer. ويمكن تلخيص أهم النتائج التى تم الحصول عليها فيما يلى :

١. تناقص كميات النيكل والكوبالت والكاديوم المستخلصة بمحلول الـ EDTA فى كلا نوعى التربة موضع الدراسة نتيجة تحضينهما مع زرق الدولجن، وكان معدل النقص أكثر وضوحاً بزيادة زمن فترة التحضين. وقد أمكن ترتيب الجزء المستخلص من تلك العناصر تنازلياً حسب الكمية المزالة منها فى كلا نوعى التربة كما يلى: $Ni > Co > Cd$ ، وطبقاً لسعة الإزالة لهذا المحسن فإن الـ Ni يمثل المستوى الأعلى، Co المستوى الأدنى، ما بينهما.
٢. أدى إضافة المكمور العضوى (الكبوست) إلى نقص فى الكميات المستخلصة من عناصر النيكل والكوبالت والكاديوم بواسطة محلول الـ EDTA فى كلا نوعى التربة تحت للدراسة، وبخاصة مع زيادة فترة التحضين، وقد كان هذا التأثير أكثر وضوحاً فى حالة تربة الجبل الأصفر مقارنة بما حدث فى حالة تربة الصف. وكانت الكميات المدمصة من العناصر موضع الدراسة فى تربة الجبل الأصفر لكثير وضوحاً عن تلك المدمصة فى حالة تربة الصف، وهذا الإتجاه قد تؤكد عن طريق سعة الإزالة للمكمور العضوى للعناصر موضع الدراسة (Ni, Co and Cd) حيث سجلت أعلى القيم فى تربة الجبل الأصفر عنه فى حالة تربة الصف.
٣. قيم الكميات المستخلصة من عناصر النيكل والكوبالت والكاديوم بواسطة محلول الـ EDTA من كلا نوعى التربة المعالجة بالبنتونيت تظهر أيضاً تناقص كبير مع زيادة فترة التحضين. كما وأن الكميات المدمصة من عنصر النيكل قد أظهرت أعلى القيم، بينما تلك المدمصة من عنصرى الكوبالت والكاديوم تمثل المستويات الأدنى وما بينهما على الترتيب فى كلا نوعى التربة المعالجة بالبنتونيت. وقد كانت مقدرة أو سعة البنتونيت على إزالة النيكل أعلى عنه فى حالة إزالة الكوبالت والكاديوم على مدى فترات التحضين التى تميزت بزيادة مقدرة البنتونيت على إزالة العناصر الثقيلة موضع الدراسة، فيما عدا عنصر الكوبالت الذى ظلت مقدرة البنتونيت على إزالته ثابتة لا تتغير مع إمتداد فترات التحضين.