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Mobility of Cadmium in Distributed Desert Soil Column Amended by Sewage Sludge

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حركة الكادميوم في عمود من التربة الصحراوية الرملية المفككة والمعالجة بإضافة حمأة الصرف الصحي

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Abstract

The main aim of this research is to predict the movement of cadmium (Cd) ions in sewage sludge-amended soil columns. Sewage sludge impact on the mobility of cadmium was studied using disturbed soil columns, to assess the vertical movement of Cd in desert soil treated with different rates of sewage sludge, i.e., (T_1= 0, T_2= 20, T_3=40, and T_4= 60 *ton/hectare*). The obtained results showed that the physiochemical properties of the studied soil had improved significantly due to sewage sludge addition. Soil organic matter and porosity increase the water-holding capacity and structure of studied soil. Sewage sludge had the ability to increase soil fertility.

In contrast, the excess of some heavy metals in the amended soil is the negative impact of using sewage sludge. Cadmium concentrations were greater at a higher rate (T_4) of sludge treatment (14.2 *mg/kg*). According to the findings, the sewage sludge addition to the tested columns yielded considerable Cd concentrations in their leachates. Whereby, leachates of the soil column amendment with 60 *ton/hectare* contained higher Cd concentration (3.03 *mg/l*).

Moreover, after leaching the soil cadmium concentration differ according to the addition rate, leading to this trend: (T_1) < (T_2) < (T_3) < (T_4). Distribution of Cd in soil columns after the leaching process distributed on the soil layers. Overall, Cd movement in sludge-amended soil was correlated with organic matter and pH with r= (0.71439 and 0.0.94886) and r= (0.70965 and 0.99047) respectively.

Keywords: *Sewage sludge, Cadmium, Arid soil, Mobility, Leaches.*

الملخص

الهدف الرئيسي من هذا البحث هو التنبؤ بحركة أيونات الكادميوم في عمود التربة المعامله بحمأة المجاري. حيث تمت دراسة تأثير إضافة الحمأة على حركية ايونات الكادميوم باستخدام أعمدة التربة، ولتقييم الحركة الرأسية للكادميوم في التربة الصحراوية المعاملة بمعدلات مختلفة من حمأة المجاري (T_1 = 0، T_2 = 20، T_4 = 60 و T_3 = 40 طن/هكتار). وقد أظهرت النتائج المتحصل عليها أن الخصائص الفيزيائية للتربة المدروسة تحسنت بشكل ملحوظ بسبب إضافة حمأة المجاري؛ وان المادة العضوية في التربة ومساميتها تؤدي إلى زيادة قدرة الاحتفاظ بالمياه وهيكل التربة المدروسة. حمأة الصرف الصحي لديها القدرة على زيادة خصوبة التربة، وفي المقابل فان ارتفاع بعض المعادن الثقيلة في التربة المعاملة له تأثير سلبي على إعادة الاستخدام. كانت تراكيز الكادميوم أعلى عند معدل الإضافة (T_4) حوالي (14.2 مجم/كجم). ووفقًا للنتائج، أسفرت إضافة حمأة المجاري إلى الأعمدة المختبرة عن تراكيز كبيرة من الكادميوم في مياه الراشح. حيث احتوت مياه راشح عمود التربة عند معدل الإضافة 60 طن/هكتار على تركيز أعلى من الكادميوم (3.03 مجم/لتر). علاوة على ذلك، يختلف تركيز أيونات الكادميوم في التربة وفقًا للمعالجات مما أدى إلى التتابع التالي

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(T4) > (T3) > (T2) > (T1). وقد تباين توزيع ايونات الكادميوم على طبقات التربة في العمود الواحد. وبشكل عام، وجد ارتباط وثيق بين حركة عنصر الكادميوم في التربة المعاملة بالحمأة بالمواد العضوية ودرجة الحموضة (r = 0.71439) و (r = 0.0.94886) و (r = 0.70965) و (r = 0.99047) على التوالي.

الكلمات الدالة: حمأة الصرف الصحي، الكادميوم، ترب جافة، الحركية، الترشيح.

1. Introduction

Libya is the third largest country in Africa with a surface area about 1.757 million km^2, the desert of Sahara covers around 90% of the national territory. Generally, desert soils are low in nutritional elements; its productivity is increased by using fertilizers. Sewage sludge addition could be useful as a source of plant nutrients and organic matter to soil and vegetation (Alvarenga *et al.*, 2015; and Aishah *et al.*, 2016). Sewage sludge volume has grown year after year, around $30×10^6$ *tons* of municipal sludge are produced yearly in the world. In Libya, municipal sewage sludge is produced mostly from light industrial areas and domestic areas. There are different types of hazardous waste in household products, such as cleaners, paints, solvents, pesticides, as well as automotive maintenance products (Adriano, 2001). Methods of disposal of sludge currently in use include landfill, ocean dumping, and land use in agriculture. Between these, the land application is the most attractively employed method since dewatered sewage sludge can serve as a valuable resource of soil conditioner or fertilizer which facilitates nutrient transport and increases water retention (Mayouf *et al.*, 2014). Sewage sludge recycling is the most environmentally friendly methods to solving the issue of waste disposal. Application of sludge on soils offers multiple benefits and adverse environmental effects. Furthermore, sewage sludge can improve the soil physical properties by reducing soil erosion and promoting soil structure development. In contrast, the toxic substances in sludge can pose a risk to the environment because of the transfer of pollutants to soils and subsequently to groundwater and plants (Mamindy-Pajany *et al.*, 2013). Variety pollutants are eventually transported to the environment, including heavy metals. Cadmium is a toxic metals with high risk of soil contamination (Arao *et al.*, 2010; and Aishah *et al.*, 2016). According to Alvarenga *et al.* (2015) the transfer of heavy metals from sewage sludge to soil, plants and groundwater poses environmental and health risks. Soil contamination via heavy metals has become more and more serious, which not only causing degradation of soil fertility, crop quality and reduced yields, but also endangering human health through food chain (Wang *et al.*, 2017). Heavy metals play an important role in the biosphere, acting as essential plant micronutrients. However, when these metals are found at high concentrations they are toxic to superior organisms such as Cd, Pb, and As. Cadmium has adversely affected human health through edible vegetation grown on soils polluted with high levels of Cd (Florin-Constantin, 2017). The Council for Agricultural Science and Technology (CAST, 1976) classified Cd, Zn, Cu, Mo, as well as Ni as potential hazards in recycling of municipal sludge. Soil contamination caused by the adding of phosphate fertilizers (containing 2 to 200 *mg* Cd/*kg*), sewage sludge, mining and metallurgical activities. Cadmium can move easily in light soils, but in presence of organic matter it will act as a sink for Cd and decrease the rate of its movement. However, heavy metal mobility primarily depends on soil properties (Sherene, 2010). Cd and Cd compounds are relatively soluble compared to other heavy metals and are therefore generally more mobile. Increases in Cd concentration lead to increased plant uptake, as even slightly higher concentrations of Cd in food can have significant long-term effects (Mayouf *et al*., 2014). Heavy metals downward movement is an important problem to be studied to determine the ability of heavy metals to contaminate subsoil and groundwater. However, pH, organic and inorganic ligands are the key factors controlling their mobility (Violante *et al.*, 2010). Leaching heavy metals from contaminated sites is a significant method to disperse them into the wider environment (Milinovic *et al.*, 2014). Consequently, it appears necessary to study the mobility of Cd in sludge treated soil. The main purpose of this study is to study the effect of different treatment rates of sludge addition on desert soil properties, mobility of Cd in disturbed soil columns and to clarify the relationship between and Cd leaching and soil properties.

2. Materials and Methods

Topsoil (0-20 *cm* depth) samples were taken from uncultivated sites located in Sebha city, Libya. Sebha region characterized by hot wheatear and rare rainfall, i.e., desert climate. The climate belongs to the type III semiarid of the African zonation (Griffiths, 1972). Sewage sludge obtained from the Municipal Wastewater Treatment Plant in Sebha city, Libya. The resources of wastewater originate from mainly household activities; as very limited industrial activities exist. The samples of sewage sludge and soil were air dried at room temperature, passed through 2 *mm* mesh sieved and prepared for their physico-chemical analyses.

Before packing the columns, dried soils were thoroughly homogenized. The bottom of each column were covered at by a permeable inert tissue to avoid soil losses; 500 *g* was filled into each column. Then after, the soil columns were incubated at 25 ^oC for 12 *weeks* .

For leaching study, 12 PVC plastic columns were used (20 *cm* diameter), each column was arranged based on Complete Randomized Design (CRD). Four treatments, i.e., T_1, T_2, T_3, and T_4 in three replicates. Where T_1 is untreated soils (control), T_2, soil treated with 20 *ton/hectare* sewage sludge, T_3, treated with 40 *ton/hectare* sewage sludge and T_4, soil treated with 60 *ton/hectare* sewage sludge. Deionized water was added based on water holding capacity (WHC) for 12 *weeks*, and controlled to make sure that waterlogging condition was avoided. Each column leachate was collected using polyethylene container (PET), filtered and preserved with nitric acid to $pH < 2$. Soil columns were divided to three equal segments (5 *cm* each) and allowed to dry. Soil samples were collected to examine Cd distribution in the soil profile .

Soil pH was measured using a 1:1 (*w:v*) soil : solution. Organic matter in the soils was determined using Walkley-Black method (Nelson and Sommers, 1982). Pipette method was used to determine soil texture (Kettler *et al.*, 2001). The pycnometer method was used to measured soil particle density (Grossman and Reinsch, 2002). Particle density of soil is expressed the ratio of total mass of soil to their volume (*g/cm³*) and porosity was calculated according to Anderson and Ingram (1993);

$$Porosity\ (\%) = [1- (Bulk\ density/Particle\ density)] \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (1)$$

Sewage sludge and soil organic matter content (OM %) were determined using loss on ignition method (ASTM, 2000);

$$OM\ (\%) = Total\ C \times 1.724 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (2)$$

Cadmium concentrations were extracted by aquaregia digestion. Cadmium contents in soil extracts and leachates were determined using Atomic Absorption photometer (AAS) Philips Unicam PU9100, (Justin *et al.*, 2011). Data collected from this study were statistically analyzed using ANOVA and Tukey for mean comparison, also Pearson correlation coefficient was conduct using statistical program, SAS (Ver. 9.4, Institute Inc. Cary N.C., USA).

3. Results and Discussion

3.1. Raw Soil and Sewage Sludge Properties

The general physical and chemical characteristic of the studied soil and sewage sludge are summarized in Table (1). Texture of the used soil was sandy loam soil according to the USDA triangle, slightly alkaline reaction (pH 7.35) and well aerated and permeable. Low water hold capacity value (WHC) 13.97%. Bulk density (ρ_b) of soil was 1.65 g/cm^3, ρ_b is an important physical attribute in reproducing the field condition of soils in the laboratory. Particle density (ρ_s) was 2.5 g/cm^3; particle density and bulk density data were used to calculate the porosity (P), whereby P of tested soil was 34%.

Table 1. Soil properties and sewage sludge

Parameters	Unit	Soil	Sewage sludge
pH		7.35	5.99
WHC	%	13.97	-
ρ_b	g/cm^3	1.65	-
ρ_s	g/cm^3	2.5	-
P	%	34	-
OM	%	1.2	60
Cd	*mg/kg*	2.37	13.14
Sand	%	73.96	-
Silt	%	9.94	-
Clay	%	16.10	-
Texture	(USDA)	sandy loam	-

WHC= water holding capacity, ρ_b= Bulk density, ρ_s= Particle density, P= porosity, OM=Organic matter

Tested soil contains organic matter (OM) 1.2 %. Desert soil in dry conditions often shows low levels of organic matter. The dry hot climate plays a vital role in determining the amount of organic material because the area is poor in vegetation cover. High temperatures affect all soil biological, physical and chemical reactions because high temperatures encourage the rapid disintegration and disappearance of organic residues from desert soil. The concentration of Cd in soil under study was 2.37 *mg/kg*. Cadmium concentrations in the soil depend on the quantities in the parent rocks from which the soil is formed, the quantities added in the form of fertilizers and soil amendments. According to (Heinrichs *et al.*, 1980; and Cook and Morrow, 1995) the natural cadmium level in the earth crust is known normally from 0.1 to 0.5 *mg/kg*, but higher and lower values have been cited depending on number of soil properties. Igneous as well as metamorphic rocks tend to show lower Cd values (0.02 - 0.2 *mg/kg*) and ranged from 0.1 to 25 *mg/kg*) for sedimentary rocks.

According to Table (1), the pH of sewage sludge was significantly lower than that of tested soil with a value of 5.99. On the other hand, sewage sludge contains 60% of organic matter which may enhance desert soil productivity and develop soil characteristics. Heavy metals concentrations in sewage sludge had taken attention due to their possible toxicity to the environment. The Cd concentration in sewage sludge was 13.14 *mg/kg*, this was within the safe limits reported by U.S. EPA (1993).

3.2. Sewage sludge addition impact on soil properties

The changes in treated soil properties can be seen in Table (2). Sewage sludge treatment seemed to influenced the properties of the amended soil. The results showed significant differences ($P < 0.05$) in soil pH, WHC, ρ_b, P, OM, and Cd level due to sludge addition.

Table 2. The effect of sewage sludge on soil properties

Parameters	Unit	T_1	T_2	T_3	T_4
pH	-	7.35^a	6.46^b	6.31^c	6.24^d
WHC	%	13.97^d	15.96^c	16.09^b	17.63^a
ρ_b	*g/cm³*	1.65^a	1.56^b	1.53^c	1.50^d
ρ_s	*g/cm³*	2.50^a	2.50^a	2.50^a	2.50^a
P	%	34.00^d	37.60^c	38.80^b	40.00^a
OM	%	1.20^d	5.60^c	7.60^b	15.40^a
Cd	*mg/kg*	2.37^d	7.89^c	8.68^b	14.20^a

T_1= Untreated soil (control); T_2= Soil treated with 20 *Ton/hectare* sewage sludge; T_3= Soils treated with 40 *Ton/hectare* sewage sludge; T_4= Soils treated with 60 *Ton/hectare* sewage sludge.
WHC= water holding capacity, ρ_b= Bulk density, ρ_s= Particle density, P= porosity, OM=Organic matter.
a, b, c, and d; The mean in the same row with the same letter were not significantly different at $p<0.05$.

The mean of soil pH decreased significantly ($P < 0.05$) in the treated soils. pH analysis clearly indicates the acidification of desert soil owing to sewage sludge treatments. The pH of treated soil was decreased from 7.35 in T_1 to 6.24 in T_4. The lowest pH value was for soil treated with 60 *ton/hectare* sludge. This finding is in harmony with Benitez *et al.* (2001) who found that sludge application decreased soil pH. The changes in soil pH indicated a radical change in soil characteristics. According to Sterritt and Lester (1980) soil properties are usually affected by the pH levels. Moreover, there were positive correlations between WHC, porosity, OM and Cd, where the highest values were found in the soil treated with 60 *ton/hectare* sludge (T_4). The application of sludge to desert soil has led to an increases in the water holding capacity (WHC) from 13.97 to 17.63%. This can reduce the stress of water during the growing season. In addition, organic matter, which constitutes approximately 60% of the sludge, improves the physical condition of the tested soil. Organic matter was significantly ($P < 0.05$) high in the higher treatment of sludge as shown in Table (2). An increase in OM content decreases bulk density from 1.65 to 1.50 g/cm^3, and modify the soil porosity, these results are in line with (Blanco and Lal, 2010). However, Steriti and lester (1980) showed that the recycling of sludge has increased porosity in sandy loam soil as well as loamy soil, and suggested that increases in the stability of aggregate is the greater advantage than any changes in the water holding capacity. However, soil organic matter increases soil porosity and water holding capacity increase, providing more water availability for plants, and increases soil productivity as a result of increasing the amount of water available to crops. The afore-mentioned findings clearly indicated the enhancement the fertility of desert soil resulting from sludge application. As shown by the results in Table (2), the sludge is an important source of Cd in desert soil. The findings indicated significant differences ($P < 0.05$) between the sludge treatments in Cd concentration. Cadmium concentration increase has been noted in the soil amended with 60 *ton/hectare* sludge, that means the application of sewage sludge increased the concentration of Cd in the tested soil. This is shown by his high concentration (14.2 *mg/kg*) in T_4. Adding of municipal sludge can provide enough organic matter to the soil to bind other toxic heavy metals like Cd, Zn, and Pb. However, on close examination of the results, we believed that continuous sludge application in the long run would accumulate Cd to the toxic levels. This notion was confirmed by study of Bettiol and Ghini (2011). High soil heavy metals concentration can cause bioaccumulation in plant tissues and in human organs causing health problems (Shaheen and Iqbal, 2018).

Pearson correlation coefficient was selected to find the correlation between some soil properties and sewage sludge treatments, indicating how sewage sludge additions affect soil properties. The Pearson correlation shown in Table (3) shows the significance correlation between sewage sludge treatments and WHC ($r=0.95569$), porosity ($r=0.95571$), OM ($r= 0.97005$) and Cd concentrations ($r= 0.96760$). While particle density (ρ_s) cannot make a valuable relation.

3.3. Cadmium in Leachate

The quantities of Cd eluted from soil columns are described in Figure (1.a-d). Leaching experiment results are presented as breakthrough curves. The results of the leaching study showed positively that the adding of sewage sludge to soil columns yielded noticeable Cd concentrations in their leachates. It is of interesting to indicate that the highest concentration of Cd in the leachate was found in the soil treated with 60 *ton/hectare* sewage sludge (T_4) compared to other treatments (T_1, T_2 and T_3).

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Table 3. Pearson Correlation Coefficients between sewage sludge treatments and soil properties

	T	pH	WHC	ρ_b	ρ_s	p	OM
pH	0.87237* P=0.0002						
WHC	0.95569* P<.0001	0.92004* P<.0001					
ρ_b	0.94622* P<.0001	0.96659* <.0001	0.96046* P<.0001				
ρ_s	0.00000 P=1.0000	0.00000 P=1.0000	0.00000 P=1.0000	0.00000 P=1.0000			
P	0.95571* P<.0001	0.97612* P<.0001	0.97014* P<.0001	0.99027* P<.0001	0.02817ns P=0.9307		
OM	0.97005* P<.0001	0.79881* P=0.0018	0.96225* P<.0001	0.89615** P<.0001	0.00179ns P=0.9956	0.90367* P<.0001	
Cd	0.96760* P<.0001	0.88574* P=0.0001	0.99566* P<.0001	0.94463 P<.0001	0.00341ns P=0.9916	0.95474* P<.0001	0.98300* P<.0001

ns= not significant at probability p<0.05; * =Significant at probability p<0.05

The leaching pattern of Cd was approximately 0.029-3.03 *mgl/1*. The greatest concentrations of Cd occurred at the 4th, 5th, 6th and 7th leachate period for all treatments (1.78, 1.98, 2.07 and 3.03 *mg/l*). Then, the concentrations of the metals declined rapidly. Mostly, it is understandable that the leachability of Cd ion tended to decrease with time of leaching. Bozkurt and Cimrin (2003) found that concentrations of Cd in the leachate of sludge-amended soil decreased over time. The leachability of Cd means that during rainy season or by irrigation heavy metals could be moved down through soil profile. It is clear that water is able to enhance Cd mobilization in tested soil columns. However, Cd in soils may become more mobile under certain conditions such as increased soil acidity and its cadmium level could be increased by the sewage sludge. This investigation demonstrates that sewage sludge added to the desert soil under study significantly enhanced the levels of Cd eluted from column of soil. The increases were greater from soil treated with 20, 40 and 60 *ton/hectare* sewage sludge are attributed mainly to the increase in soluble metal ion. The leaching of this metal could lead to a significant redistribution with risk of pollution of groundwater. Previous studies confirmed that water hydrogen ions release the cations leading to increase their concentrations in the soil solution (Zheng *et al.*, 2012). However, in order to protect the environment, information about leaching processes of heavy metals like Cd in soils is needed. Heavy metals leaching from polluted soils lead to accumulate nearby (Sundstrom *et al.*, 2002). According to Aishah *et al.*, (2018), heavy metals release from the amended soil is significantly correlated with the sludge application rate, pH, CEC, and OM. The mobility of heavy metals in soil depends on metals concentration and solubility. Numerous causes, i.e., pH, soil texture, structure and porosity can affect the leaching of Cd in soil columns. Csavina *et al.* (2012) stated that the solubility of heavy metals increased with soil acidity.

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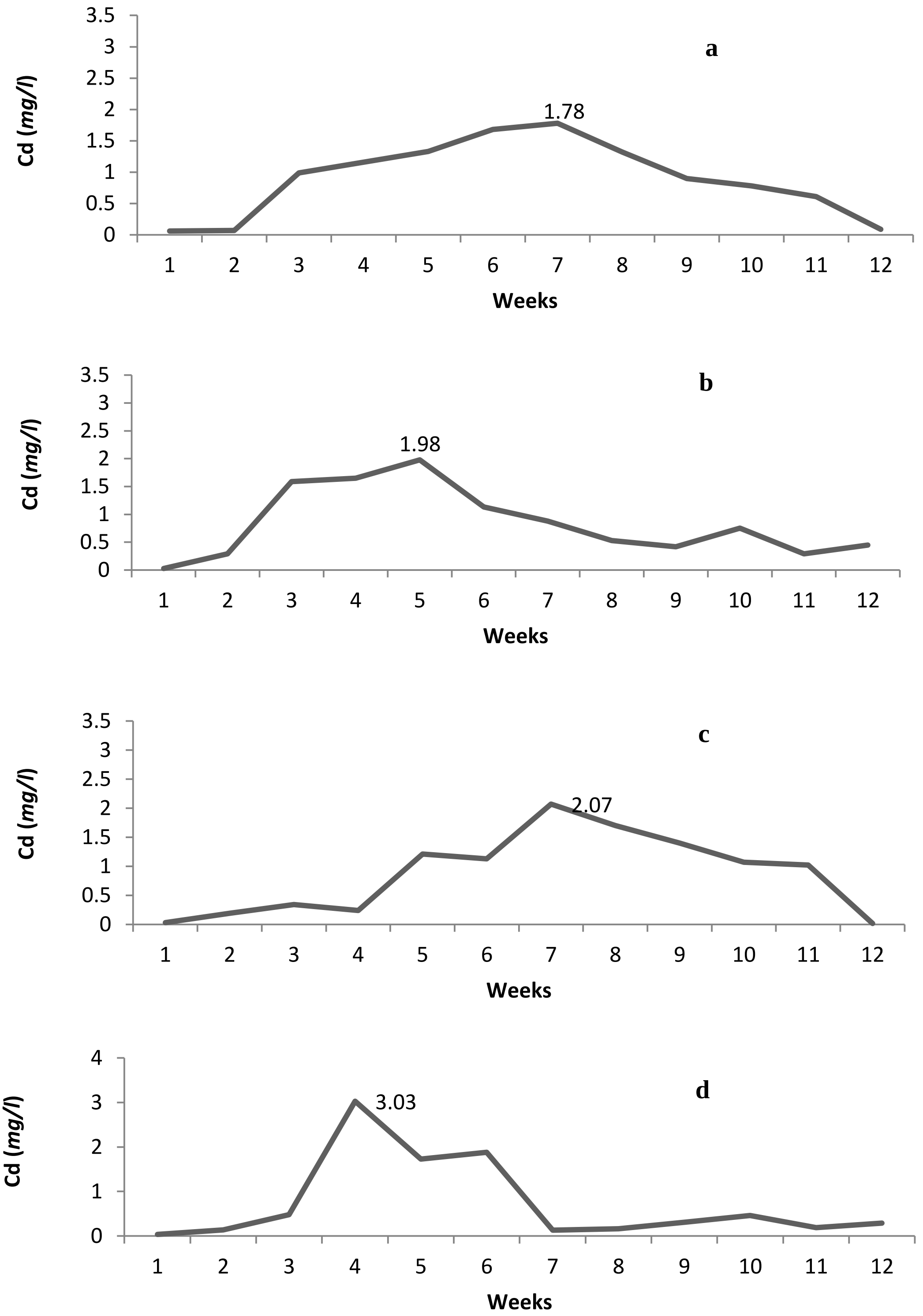

Figure 1. Variation in the concentrations of Cd eluted from **a)** untreated soil (control T_1); **b)** Soil treated with 20 *Ton/hectare* sewage sludge $T_{2;}$ **c)** Soil treated with 40 *Ton/hectare* sewage sludge; and **d)** Soil treated with 60 *Ton/hectare* sewage sludge T_4

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The texture of the soil plays a dynamic role in soil heavy metals movement. Clay and OM are important soil components as they have a considerable capacity to hold water and improve the soil structural (Sterritt and Lester, 1980). The downward migration of Cd was positively correlated with the fine sand content, suggesting that high soil macro porosity increases the mobility of heavy metals (Sherene. 2010).

3.4. Downward Movements and Distribution of Cd in Soil Columns

The distribution of Cd ions in the studied layers of soil columns are shown in (Table 4).

Table 4. Some properties of amendment soil at the end of study (after 12 weeks)

		T_1	
Depth (*cm*)	**pH**	**OM (%)**	**Cd (*mg/kg*)**
0-5	7.86^{b}	$0^{a}2.4$	2.37^{a}
5-10	7.99^{a}	$0^{b}1.9$	1.578^{b}
10-15	7.98^{a}	$0^{c}0.4$	0.098^{c}
		T_2	
Depth (*cm*)	**pH**	**OM (%)**	**Cd (*mg/kg*)**
0-5	6.46^{b}	5.00^{a}	11.04^{a}
5-10	6.31^{c}	4.60^{b}	8.68^{b}
10-15	6.77^{c}	$0^{c}3.8$	5.52^{c}
		T_3	
Depth (*cm*)	**pH**	**OM**	**Cd (*mg/kg*)**
0-5	6.41^{b}	12.20^{a}	12.62^{a}
5-10	6.42^{b}	9.40^{b}	10.25^{b}
10-15	6.47^{a}	9.40^{b}	3.94^{c}
		T_4	
Depth (*cm*)	**pH**	**OM**	**Cd (*mg/kg*)**
0-5	6.14^{a}	27.60^{a}	13.41^{a}
5-10	6.13^{a}	19.60^{b}	15.8^{b}
10-15	6.15^{a}	10.25^{c}	6.31^{c}

T= Treatment; T_1= Untreated soil (control); T_2= Soil treated with 20 *Ton/hectare* sewage sludge; T_3= Soils treated with 40 *Ton/hectare* sewage sludge; and T4= Soils treated with 60 *Ton/hectare* sewage sludge
a, b, c, and d; The mean in the same column for the same treatment with the same letter were not significantly different at $p<0.05$

Heavy metals accumulate in soil when sewage sludge is applied for disposal or intended useful use. The concentrations of leached Cd ion in soils differs depending on the treatments. Data showed the following order: control: (T_1) < 20 *ton/hectare* (T_2) < 40 *ton/hectare* (T3) < 60 *ton/hectare* (T_4).

Most of Cd ions concentration was accumulated in the first layers (0-5 *cm*) with T_1, T_2, and T_3 treatment, while in case of T_4 cadmium was accumulated in second layers (5-10 *cm*). Organic matter has a similar trend as that of Cd being much higher at the layers (0-5 *cm*) and decreased through (10- 15 *cm*). This result showed the relatively little downward movement of Cd during 12 *weeks*. Several studies on soil heavy metals distribution that treated with sludge have shown relatively little downward movement of heavy metals in the short term (Alloway and Jackson, 1991). However, several factors such as pH and OM can

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control cadmium ions movement and accumulation in soils. The high levels of organic matter in sewage sludge might prefer metal organic matter complexation to decrease mobility of cadmium sludge amended soils

Table 5. Pearson Correlation Coefficients of Cd levels and soil properties

	Depth	pH	OM	Cd
T_1				
Depth	1.00			
pH	0.82158* P=.0.0066	1.00		
OM	0.95637* P<.0001	0.63077^{ns} P=.0.0685	1.00	
Cd	0.98505* P <.0001	0.71439* P=.0.0306	0.98937* P <.0001	1.00
T_2				
Depth	1.00			
pH	0.66012* P=.0.0530	1.00		
OM	0.97949* P<.0001	0.7766* P=0.0138	1.00	
Cd	0.99651* P<.0001	0.72048* P=0.0286	0.99047* P<.0001	1.00
T_3				
Depth	1.00			
pH	0.89113* P=0.0013	1.00		
OM	0.86437* P=0.0026	0.59910^{ns} P=0.0882	1.00	
Cd	0.96733* P<.0001	0.94886* P<.0001	0.70965* P=0.0322	1.00
T_4				
Depth	1.00			
pH	0.35355^{ns} P=0.3506	1.00		
OM	0.97940* P<.0001	-0.22498^{ns} P=0.5606	1.00	
Cd	0.99799* P<.0001	0. 93094* P=0.02982	0.96471* P<.0001	1.00

ns= not significant at probability p<0.05; * =Significant at probability p<0.05.

The Pearson correlation shown in Table (5) presents the significance correlation between Cd concentration and organic matter at all of treatment applied. Where by r= 0.98937, 0.99047, 0.70965 and 0.96471 for T_1, T_2, T_3, and T_4 respectively. Soil organic matter is a very important adsorptive medium for heavy metals. Whereby, organic matter complexes with heavy metals by chemisorption and exchange reactions. According to Udom *et al*. (2004) Changes in the dissolved organic matter can prevent soil heavy metals movement. The low-molecular-weight compounds were able to increase Cd solubility in soils through the formation of soluble Cd organic complexes (Adriano, 2001). According to Camobreco *et al*., (1996) heavy metals movement below sludge disposal ponds was correlated with soil chemical oxygen demand, suggesting that the heavy metals were elated through the soil as metal-organic complexes. Similarly, the pH has a significant effect on Cd mobility in soils. Where by r= 0.71439, 0.72048, 0.94886, and 0. 93094 for T_1, T_2, T_3, and T_4 respectively.

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