ASSESSMENT OF THE ROLE OF COMPOST IN REMEDIATION OF CD-CONTAMINATED SOIL IN SUDAN

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Abstract

Purpose: The aim of this research is to study the effect and role of compost in adsorbing metals and in remediation of polluted soil.

Design/methodology/approach: A laboratory experiment was conducted under normal air temperature. Composted bagasse (sugarcane byproduct) of known quality was added to sandy soil samples with different mixing ratios: 1:1; 1:2; 1:3; 1:4 (w/w) loading rates. Cadmium sulphate solutions with different concentrations (Cd_1-Cd_6) were added to the compost:soil mixture. The mixtures were mixed for one hour, allowed to stand for 24 hr under room temperature (35°C) and then filtered. Cadmium concentration in the filtrate was determined in ppm. The data were statistically analyzed using analysis of variance.

Findings: Results showed that compost addition significantly increased the sorption of cadmium, in linear correlation with the amount of compost added. The sorption coefficient was reached at Cd5 concentration. The results also revealed the importance of compost use in remediation of metal-contaminated soils.

Key words: Compost use, Polluted soil, Soil remediation

International Journal of Innovation and Knowledge Management in Middle East & North Africa Vol. 3 No. 1, 2014

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INTRODUCTION

Metal-contaminated soils are the results of the combustion of petroleum fuels, the application of chemical fertilizers and pesticides and irrigation with illegal wastewater effluent (Kabata-Pendias and Pendias, 2001). The total concentration of cadmium (Cd) in the crust is in the region of 0.3-11 mg/kg, but mostly below 1 mg/kg (Alloway, 1995). Agricultural irrigation using river water contaminated with metals is the primary reason for the contamination of cropped lands in many developing countries. Consumption of vegetables grown in the contaminated soils of these lands leads to the accumulation of metals in edible tissues, causing harm to human health (Chen *et al.*, 2010). Such negative effects on health could be reduced if these concentrations in the vegetables grown in contaminated soil are significantly lowered (Jarvis *et al.*, 1976).

Heavy metals and metalloids cannot be degraded. Therefore, they persist in soils and are subjected to transport by and into water, where they may become a threat to ecosystems, enter the food chain and threaten human health (Eapen and D'Souza, 2005; Khan, 2005). Risk management may require remediation of contaminated soils, but current physicochemical technologies to remove metals from soil, such as chemical washing and thermal treatments, are costly and deeply alter soil biological functions.

In most of the standards in the world, the tolerance level for Cd concentration in vegetable is less than 0.2 mg kg^{-1}.The maximum level of Cd set by the Joint FAO/WHO Food Standard Program (2002) is 0.05 mg/ kg for the edible parts of vegetables and 0.2 mg/kg for wheat, rice, soybean and peanut (Chen *et al.*, 2010).

Many remediation techniques are commonly used in developed countries to treat metal-contaminated soils. These include methods for acid washing and soil turnover/dilution. Taiwan's EPA spent about US$ 10 million (2003–2007) to remediate these metals-contaminated lands. The soil turnover/dilution method was the most commonly used and involves mixing the soils in the surface layer and lower layer to reduce the metal concentration, because surface soil always has a higher concentration compared to the subsoil. While the total amount of metals in soil remains unchanged, soil characteristics manifest change after treatment with this method (Chen *et al.*, 2010). Further application of fertilizers or organic materials, however, is necessary for soil fertility to recover (Lai *et al.*, 2007).

Low cost materials such as agricultural wastes and biomass have been investigated as heavy metals sorbents (Khan *et al.*, 2005). A compost filter is a proven technology that can be used to remove heavy metals from storm water runoff (US EPA, 1997). The compost in the filter is usually derived from yard wastes such as leaves. It was found that the leaf compost filter removed 88% of zinc, 61% of chromium and 67% of copper in storm water (Stewart, 1992). The addition of some types of compost also reflects the importance of compost to reduce metals in soils. Compost has advantages to improve environmental quality by absorbing pollutants (Lal and Kimble, 1999). The concentration of Cd in staple crops should be below a standard value; this should not exceed the FGGC (0.005 mg kg^{-1}). Removing heavy metal using soil wash methods is particularly efficacious (Vangronsveld and Cunningham, 1998; Calmano *et al.*, 2001; Mulligan *et al.*, 2001). However, some researchers have used biodegradable agents (Elliott and Herzig, 1999; Mulligan *et al.*, 1999; Hong *et al.*, 2002; Tandy *et al.*, 2004) and although these are favorable washing chemicals from the viewpoint of environmental impact, their costs are relatively high for soil washing. We have thus already addressed the first point: the addition of compost. Studies on the addition of compost to Sudanese soils for the removal of heavy metals are few; therefore, the objectives of this study were to determine new techniques for adding compost to reduce pollution resulting from heavy metals.

MATERIALS AND METHODS

A) Mixing components

1) Soil samples

Soil samples were collected from the surface horizon (0-20 cm). The sampling site was the El Rwakeeb area, which is located about 40 km south-west of Omdurman City. The climate is semi-arid with a warm summer. Mean annual precipitation is 121.4 mm and maximum and minimum mean daily air temperatures are 37 ° C and 21.6 ° C, respectively. The soil material was air-dried and passed through a 2-mm sieve. Particle-size distribution, as determined by the hydrometer method (Bouyoucos, 1962), showed the textural class to be sandy soil. Soil texture showed various capacity in heavy metals adsorption, which is usually attributed to CEC (cation exchange capacity) values and organic matter content (Hanafi and Sjiaola, 1998; Maftoun *et al.*, 2004). Soil pH was measured in saturated paste; the CEC and organic carbon were determined by replacing cations with NaOAc (Chapman, 1965) and the Walkley-Black method (Jackson, 1958), respectively. Cd was determined using Atomic Absorption Spectrometry (Medlen *et al.*, 1969).

2) Compost component

A compost component was derived from the Soil Unit at ENRRI. Bagasse (sugarcane by product) was composted for 8 weeks then used in the experiment. The compost material was passed through a 10 mm sieve to determine its particle size distribution. The pH value of the compost was estimated from a compost sample extracted by CaCl 0.2 M (Kehres and Maile, 1994); ECe was measured from compost:water extract (1:5), organic carbon was determined by the Walkley-Black method (Jackson, 1958). Total nitrogen was estimated by the Kjeldahl method (Bremner, 1965). Trace metals were also estimated.

B) Compost sorbent preparation

Five kg of soil was placed in cylindrical containers of 50 cm height and 50 cm internal diameter, and compost samples were added to the soil material in the following amounts: 5 kg; 10 kg; 15kg; and 20 kg. The loading rate ratios were 1, 2, 3, and 4 (W:W). In adsorption isotherm tests, the change in the mass of the compost changes the solution pH, which could affect the adsorption. A synthetic metal solution of cadmium (Cd) was prepared with different concentrations (Cd_1= 0.1; Cd_2= 0.3; Cd_3 = 0.6; Cd_4 = 1.0; Cd_5 = 2.0; Cd_6 = 3.0 ppm). The cadmium solution was prepared by dissolving cadmium sulphate in distilled water to obtain the desired concentrations. The cadmium solutions with a series of concentrations were added to the compost:soil mixtures. Treatments were replicated three times and the total number of replicate was 48 with Complete Randomize Design (CRD). The containers were incubated in the laboratory at room temperature. The mixtures were mixed, shaken and left for 24 hours. Then the sorbent was filtered and the filterate was analyzed to determine the cadmium concentration using Atomic Absorption Spectrometry.

STATISTICS

The variances and the significance of the differences between Cd concentration and total removal of Cd by the compost, and mixture from contaminated soils were analyzed using analysis of variance. Statistical significance was set to p=0.05.

RESULTS AND DISCUSSION

1) Soil characteristics:
The soil texture of the tested soil was sandy soil (sand = 56.20%, silt = 7.20% and clay = 36.60 %) and the pH value was 8.05. The soil contained 0.12 % organic matter, its water content was 2.81 % and CEC was 7.03 mmol/kg.

2) Compost characteristics:
The pH value of the composted bagasse was 7.16, the ECe was 0.319 dS/m, and the texture was fractioned as follows:
> 2mm = 16.30 %; 2-0.85 mm = 26.10 %; 0.85-0.25 mm = 47 %; < 0.25mm = 10.60 %

The total nitrogen was 3.18 %, the organic carbon was 36.94 %, and the C/N 11.61. The water content was 11.1%, and the compost bulk density was 0.176 g/cm^3.

Trace metal concentrations were 26.86 ppm for iron, 0.127 ppm for copper, 0.675 ppm for zinc and 0.030 ppm for molybdenum.

3) Cd Sorption coefficient (Kf) values:
Figures 1--4 show the amount of cadmium (ppm) sorbed by the compost alone with different loading rates. With the minimum loading rate (Figure 1), the amount of Cd sorbed by the compost showed a positive linear relationship with the amount of Cd concentration added and R^2 = 98 %.

Similar results (Figures 2, 3 and 4) were obtained with the other loading rates with R^2 = 91%.

The amounts of Cd sorbed by the mixture with different Cd concentrations added are shown in Table 1.

The table revealed the significant increase of Cd sorbed with compost alone, and also the significant increase with Cd concentration added.

The amount of Cd sorbed by the mixture is shown in Figures 5–10. Results reveal the positive linear relationship of Cd sorbed versus the concentration of Cd added in all treatments, except with 0.1 ppm concentration, where the relation was negatively correlated.

Calculation of the Cd sorption coefficient (Kf values) versus compost organic matter are shown in Table 2 and Figures 11–14, which reveal that the sorbed Cd had a linear positive relation with the concentration of Cd added approaching the isotherm at Kf values 24.5405, 24.5366, 24.6056 and 24.7275.

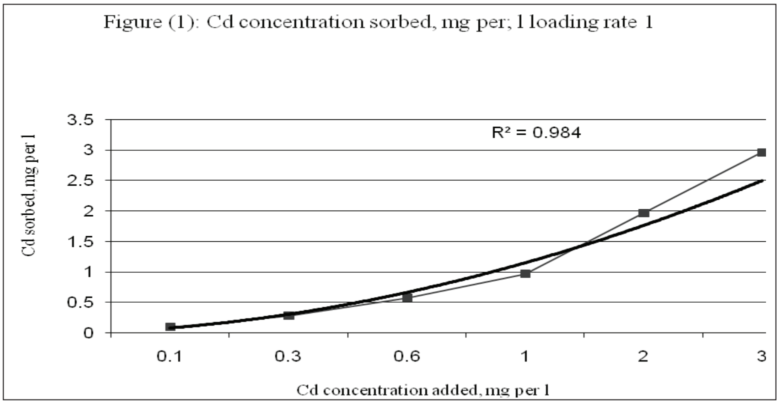
Treatments	Cd sorbed by the mixture ppm	Cd sorbed by the compost ppm
Cd_1	0.0081 a	0.0094 b
Cd_2	0.0116 a	0.0172 b
Cd_3	0.014 a	0.0224 b
Cd_4	0.0308 a	0.0256 b
Cd_5	0.0318 a	0.0244 b
Cd_6	0.0390 a	0.0381b

Mean values, replicate (n) = 3, values followed by different letters were significantly different at p=0.05

Table 1. Cd concentration sorbed by the mixture and compost in ppm

Cd Concentrations	1	2	3	4
Cd_1	2.8808	2.6872	2.7425	2.4064
Cd_2	4.9464	5.0558	5.1145	4.4407
Cd_3	7.8393	7.9175	7.9888	8.0826
Cd_4	11.3086	11.3371	11.3469	11.4512
Cd_5	24.5405	24.5366	24.6056	24.7275
Cd_6	23.8425	23.8504	23.8556	24.0869

Table 2. Kf values of compost organic matter: Loading rates



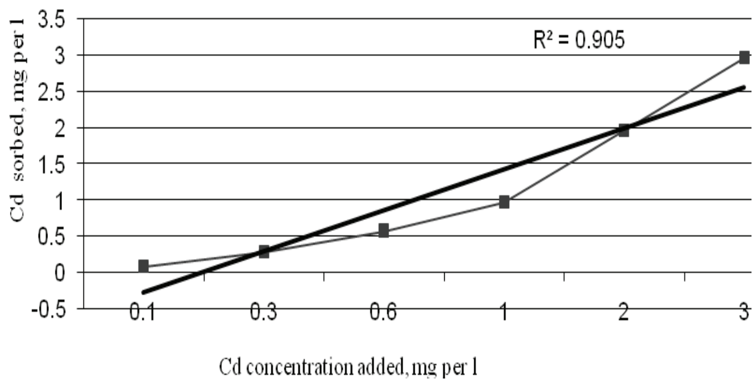


Figure (2): Cd concentration sorbed by the compost, mg per l; loading rate 2

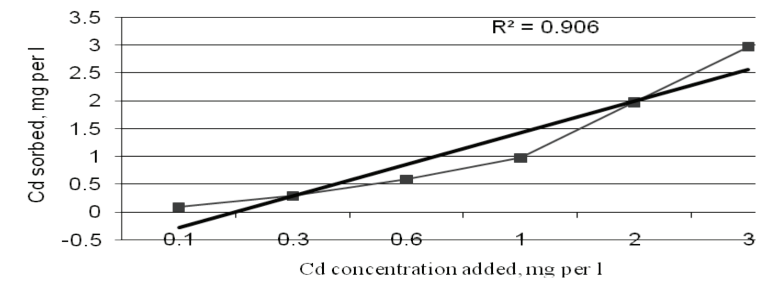


Figure (3): Cd concentration sorbed by the compost, mg per l loading rate 3

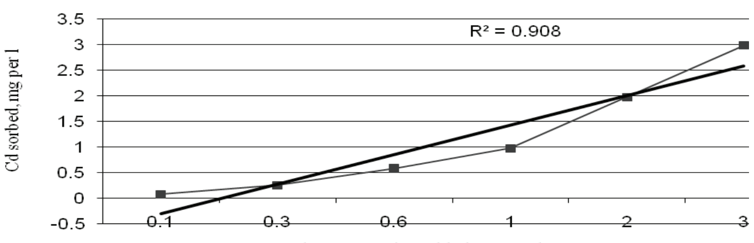


Figure (4): Cd concentration sorbed by the compost , mg per ; loading rate 4

Figure (5): Concentration of Cd sorbed by the mixture, mg per l
Added Cd concentration 0.1 mg per l

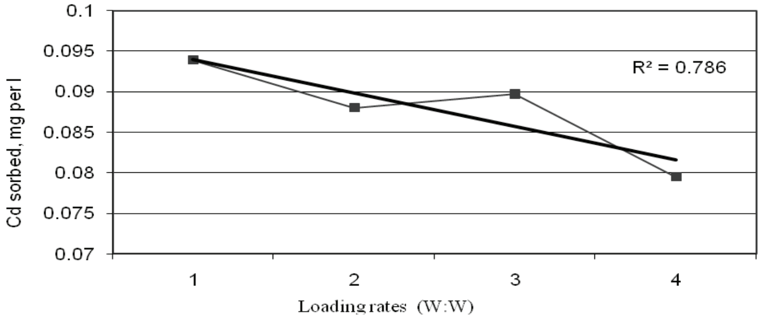


Figure (6): Concentration of Cd sorbed by the mixture, mg per l
added Cd concentration 0.3 mg per l

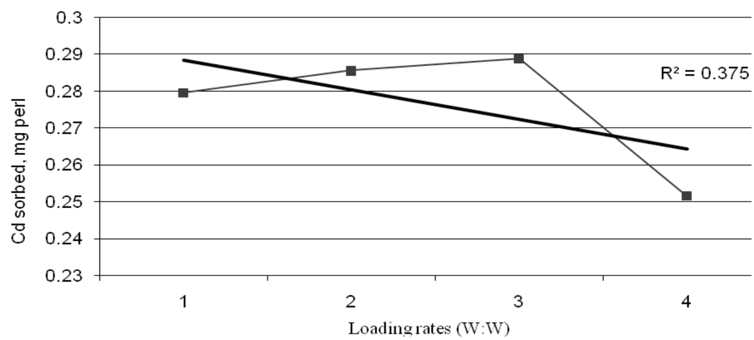


Figure (7): Concentration of Cd sorbed by the mixture, mg per l
added Cd concentration 0.6 mg per l

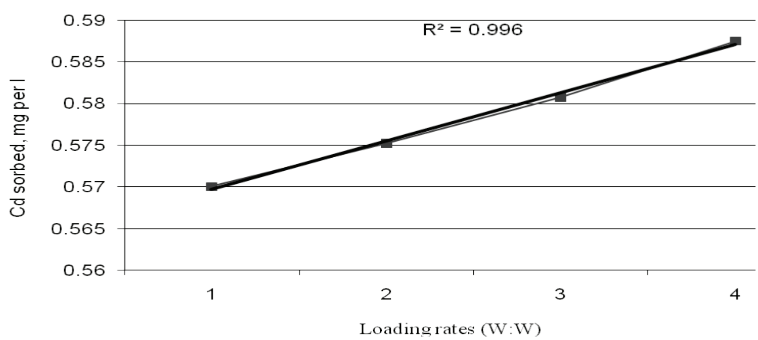


Figure (8): Cd concentration sorbed by the mixture, mg per l added Cd concentration 1 mg per l

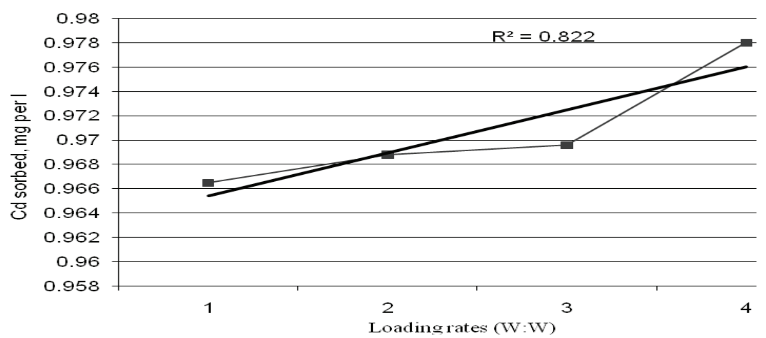


Figure (9): Concentration of Cd sorbed by the mixture, mg per l added Cd concentration 2 mg per l

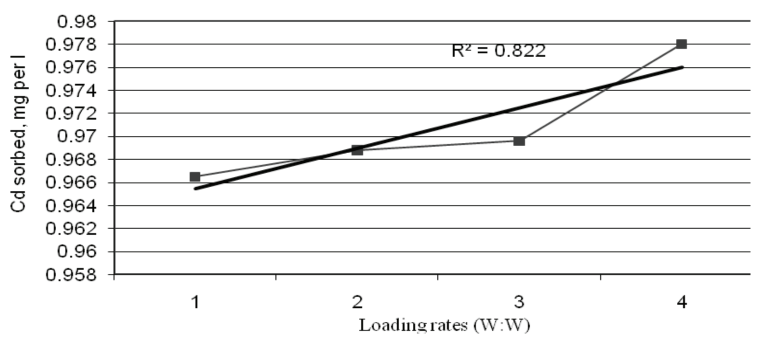


Figure (10): Concentration of Cd sorbed by the mixture, mg per l added Cd concentration 3 mg per l

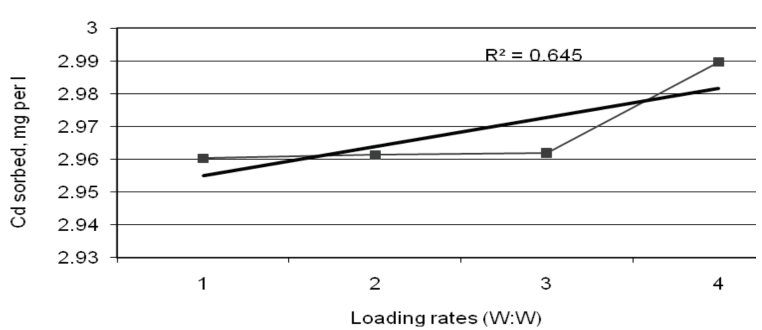


Figure (11): Cd sorption coefficient versus compost organic carbon loading rate 1

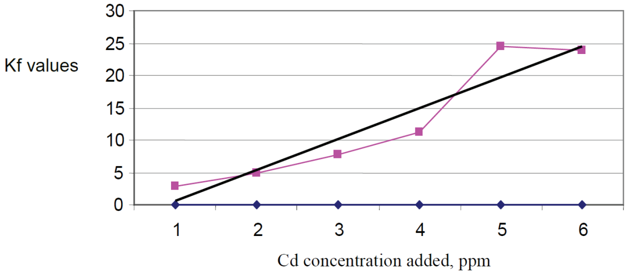


Figure (12): Cd sorption coefficient versus compost organic matter loading rate 2

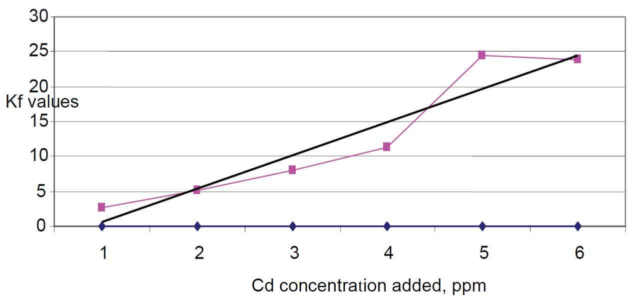
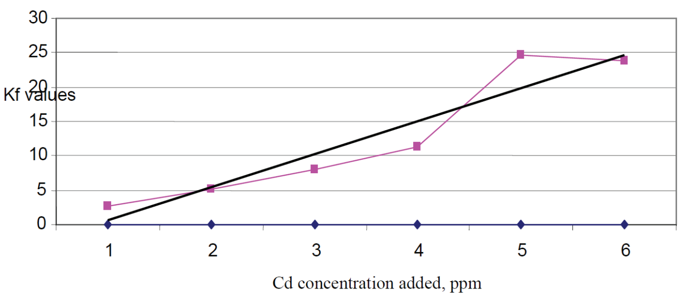
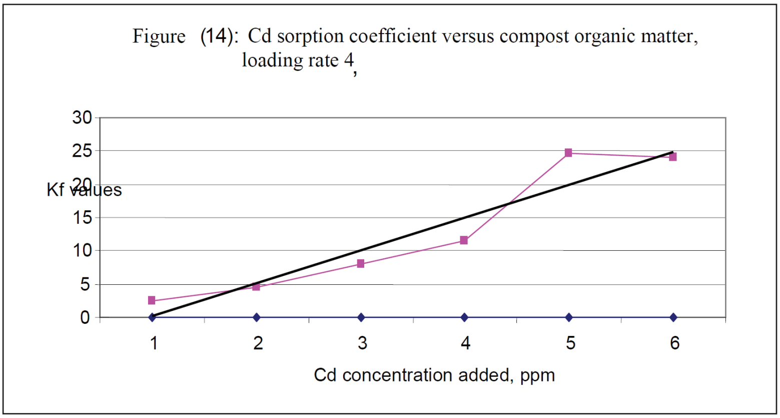


Figure (13): Cd sorption coefficient versus compost organic matter, loading rate 3





Experimental results reveal a significant reduction in Cd concentrations in all treatments with compost addition. A significant reduction was also observed on increasing the amount of compost added. This could be attributed to the fact that compost served as an adsorptive site of contaminants, as organic matter and clay are negatively charged surfaces.

CONCLUSION

Applying composts to polluted soils would be a promising solution to the problem of waste management in many areas, especially in developing countries, where no proper waste management is practiced and is a problem that threatens not only the environment but also human lives.

Using compost in remediation is also economically sound, as compost production is cheap compared to other remediation techniques.

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