HEAVY METAL DISTRIBUTION IN SEWAGE SLUDGE-TREATED SOIL PROFILES

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ABSTRACT

In this work we studied the total content of heavy metals (Cd, Cu, Cr, Ni, Pb and Zn) in a soil treated with different sewage sludges and the distribution of these metals in the soil profile (0-50 cm) as a function of the type and dose of sludge added, of the residence time of the sludge in the soil, and of the successive addition of sludges to the soil. The study was carried out on experimental plots and two sludges from different water treatment plants were added at doses of 40t/ha and 100t/ha. The concentrations of metals in the soil of the control plots were low at the surface and remained almost constant down the soil profile. The application of sludges to the soil did not always lead to a significant increase in the metal contents in soils. The concentrations of Zn and Cd increased in the soil treated with respect to the control soil, but those of Pb, Cu and Ni only increased in some cases, and that of Cr did not increase. The most significant increase was found in the upper layer of the soil profile (0-10 cm) with the highest dose of the sludge applied. The results reveal that almost no redistribution of the metals present in the sludges in the profile of the amended soils had taken place, indicating that under the experimental conditions used and for the two sludges studied no vertical movement of the metals present in the sludges had occurred from the zone of application of these materials.

INTRODUCTION

The production of sewage sludges from water purification has risen in Spain largely due to the increase in the number of water treatment plants (WTP) constructed in recent years. According to the forecasts of the National Plan for Sewage Sludges from WTP in Spain (2001-2006) (Ministerio de Medio Ambiente, 2001) an amount as much as 1500000 t of dry matter from such sludges could be produced by 2005. As it is known, these wastes have a high content in organic matter (OM) and appropriate nutrient levels to be considered potentially useful as soil amendment material (Korentajer, 1991; Bao-Iglesias, 2002).

However, the presence of heavy metals in these materials always poses an important environmental concern since if the availability of such metals is high they may give rise to contamination within the food chain or may pollute ground waters after application to soils. In this sense, knowledge of the increase in the total heavy metal load in soils treated successively with sewage sludges and the mobility of these metals in the soil profile are of great interest (Berti and Jacobs, 1996; Canet et al., 1997).

In this work we study the total content of metals (Cd, Cu, Cr, Ni, Pb, and Zn) in a soil treated with sludges and their distribution in the soil profile as a function of the type and dose of sludge added, of the residence time of the sludge in the soil, and of the successive addition of the sludges to the soil. The work was carried out on experimental plots and the sewage sludges were from two different WTPs in the province of Salamanca (NW-Spain) that process raw water of different quality and with different treatments.

MATERIALS AND METHODS

The experiments were carried out at the experimental farm of the Institute of Natural Resources and Agrobiology (IRNA, Salamanca, Spain). The soil was a sandy loam, and its characteristics were: pH of 6.8, OM content of 1.22%, clay content of 16.5%, silt content of 5.2 and sand content of 78.3%. The individual plots were 3 m x 3 m and the treatments were replicated four times in a randomized block design. The experiments were begun in June 2001 and the plots were kept uncultivated. The climatic conditions after application of the sludges (July) were: mean temperatures of 30.5ºC (maximum) and 12.5ºC (minimum) and mean rainfall of 32.6 L/m^2. The soil was kept at an appropriate degree of humidity by weekly waterings of 20 L/m^2 over the first three months. Overall, the plots received an annual amount of water of 450 L/m^2) in the form of irrigation and/or rain. Two types of sewage sludges (W1 and W2) from different WTP in the province of Salamanca (Spain) were used in the study. The sewage sludges were selected owing to their different characteristics. W1 was a sludge from domestic wastes subjected to an anaerobic stabilisation procedure and W2 was a sludge mainly from agricultural-food industry wastes subjected to an aerobic stabilisation procedure. The sludges were applied at doses of 40 t/ha (a) and 100t/ha (b) (referred to dry weight), except on the control plot, and application was repeated in 2002 on two of the plots corresponding to each treatment and type of sludge. The materials were added manually to the first centimetres of the soil as they were received from the WTPs; i.e., with no further treatment. Table 2 shows some of the characteristics of the sludges.

Table 2. *Selected characteristics and heavy metal contents (µg/g) of the sludges used.*

Sample	pH	OM%	Dry matter %	N%	C/N	Cr	Cu	Cd	Ni	Pb	Zn
W1	6.6	40.6	22.2	1.57	15.0	39.9	193	3.94	41.3	240	1124
W2	5.7	90.1	25.8	1.66	28.5	21.5	90.4	2.78	49.9	47.6	497

Samples corresponding to soil profiles of 50 cm depth were collected from each plots immediately after application of the sludges (T0) and at 6 months (T1); 12 months (T2) and 24 months (T3) after the first treatment, and at 6 months (T1r) and 12 months (T2r) after re-treatment of the soils with the sludges. To determine the total content of heavy metals in the soil, sludges and amended soil samples, 1 g of finely powdered sample was digested with aqua regia in a CEM microwave oven (MDS-2000). Metal analysis was performed using flame atomic absorption spectroscopy (Varian Spectra 220) and a graphite furnace when necessary. Standard solutions containing the same matrix as the samples were made up at appropriate concentrations for each element. Analytical accuracy in the determination of the total content of elements was checked with the BCR reference materials CRM 141 and CRM 320 and was expressed with a variation coefficient of <10%. All determinations were carried out by triplicate.

RESULTS AND DISCUSSION

Table 3 shows the total metal contents in samples of soil (0-10 cm) treated and re-treated with W1 and W2 immediately after the addition of the sludges (T0) and at 12 months after treatment (T2) and Figure 1 shows the distribution of metals in the soil profile of the plots treated with sludges at 24 months (T3) after treatment. The concentrations of heavy metals in the samples from the control plots are within the range reported by Kabata-Pendias (1992) for soils of the world and are also very similar to the mean values described by Berrow and Reaves (1984)

***Table 3**. Total contents of heavy metals (µg/g) in soil samples (0-10 cm) treated and re-treated with different sewage sludges (W1 and W2) doses (a: 40 t/ha sludge dose added, b: 100 t/ha sludge doses added).*

Soil (S)	Cr	Cu	Cd	Ni	Pb	Zn
At 6 days treatment time after first addition of sludges						
S-Control	7.41±5.06[1]	15.6±2.53	0.53±0.37	11.8±2.07	23.5±8.26	40.2±7.95
S-W1a	10.7±5.53	16.9±2.21	1.61±0.68	12.8±4.78	35.6±12.2	80.7±7.40
S-W1b	11.4±5.07	10.9±3.84	1.26±0.32	8.92±5.40	33.2±11.0	61.2±15.9
S-W2a	8.52±4.29	17.1±0.46	1.40±1.73	18.2±4.90	23.0±6.61	57.7±7.78
S-W2b	13.09±2.20	11.5±5.11	1.63±0.08	10.0±3.43	31.7±6.46	68.9±1.38
At 12 months treatment time after first addition of sludges						
S-Control	7.89±1.86	8.01±1.64	0.31±0.20	11.0±2.88	15.1±5.64	41.5±13.4
S-W1a	9.62±2.66	13.9±0.54	1.22±0.74	12.1±0.64	24.2±7.53	106±7.40
S-W1b	10.6±2.33	17.0±7.39	0.70±0.38	14.1±7.43	22.7±13.1	131±11.4
S-W2a	9.62±1.13	12.9±3.79	0.48±0.19	14.5±3.56	17.5±6.07	53.7±14.9
S-W2b	9.45±2.02	34.9±23.8	0.64±0.32	12.0±4.32	13.9±7.23	112±18.7
At 12 months treatment time after second addition of sludges						
S-Control	8.31±0.17[2]	11.0±0.18	0.45±0.03	13.4±0.02	20.5±1.04	38.6±1.77
S-W1a	12.2±0.50	16.8±0.22	0.59±0.13	14.1±0.03	27.3±0.96	75.7±0.67
S-W1b	13.8±0.61	28.4±0.51	0.53±0.03	18.8±0.23	42.8±2.27	150±6.19
S-W2a	9.32±0.03	14.7±0.04	0.57±0.09	18.5±0.01	18.4±2.33	60.7±2.47
S-W2b	11.5±1.66	18.5±2.28	0.53±0.11	16.4±0.30	17.5±2.19	90.0±10.8

[1] Mean value ± Standard deviation of four replicates; [2] Mean value ± Standard deviation of two replicates

for the mean contents of these metals in soils of the world. These concentrations increase slightly along the soil profile (0-50cm) (Figure 1).

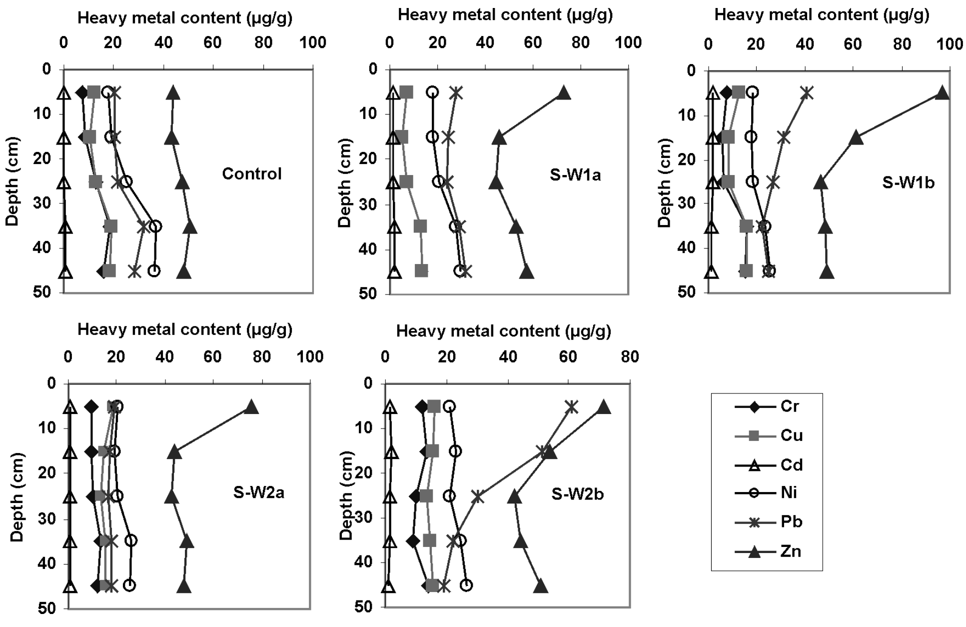

***Figure 1**. Distribution of heavy metals in control soil (0-50 cm) and in amended soils after 24 months treatment time with sewage sludges at different doses*

The effect of sludge application to the soil did not always lead to a significant increase in the metal contents of the treated soils. Only the increase of total contents of Zn and Cd in the soils treated was significant. The greater increase in Zn was found in the upper layers of the soil profile (0-10 cm and 10-20 cm). However the contents of Pb, Cu or Ni only increase significantly after the addition of sludges in some cases and the contents of Cr did not increase in any case. The increases found in the metal contents corresponded to a high load of metals in the sludges, specially in the sludge W1. In general, an increase in dose of the sludges gives rise to an increase in the metal contents in the soil; however, no greater increase in metal contents was observed with an increase in the residence time of sludges in the soil or after re-treatment of the soils with the sludges.

The concentrations of Cd, Cr, Cu and Ni were very similar along the soil profile (Figure 1). However the concentrations of Zn and Pb were high in surface of soils amended with the highest dose of sludge and underwent a decrease with the increase in soil depth.

CONCLUSIONS

The addition of sewage sludges to the soil only give rise to a significant increase in the concentrations of Zn and Cd in the treated soils. The results reveal that almost no redistribution of the metals present in the sludges in the profile of the amended soils have taken place, indicating that under the experimental conditions used and for the two sludges studied no vertical movement of the metals present in the sludges have occurred from the zone of application of these materials.

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