Uptake and partitioning of cadmium and zinc in field peas (*Pisum sativum* L.) and their subsequent transfer to the pea aphid (*Acrythosiphon pisum* Harr.) after the agricultural application of sewage sludge.

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Introduction

Sewage sludge represents an important source of nitrogen and phosphorous, which may be exploited agriculturally as a fertiliser (1). The beneficial recycling of these nutrients is constrained by the presence in sewage sludges of many Potentially Toxic Elements (PTEs) (2), including Cd and Zn. To prevent PTEs accumulating in soils to damaging levels, the agricultural use of sewage sludge is controlled in many countries. Although arthropods are ecologically and economically important components of agroecosystems, they have been poorly considered in the drafting of the present controls. Little is known about the transfer of PTEs in agricultural soil-plant-arthropod systems and doubts exists as to the efficacy of the present controls in protecting arthropods (3). This work examines the fate of sludge applied Cd and Zn in a system consisting of pea plants and pea aphids grown in a sandy loam soil.

Materials and Methods

Field peas (*Pisum sativum* cv. Elan) were grown in a series of thirty six 9 m^2 field plots that had been amended with a municipal sewage sludge 3 and 4 years previously. Total sewage sludge amendments were equal to 0, 10, 15, 20, 30 or 40 tonnes dry solids (t.d.s.) ha^{-1} and each treatment was replicated 6 times. Pea aphids (*Acrythosiphon pisum*) were allowed to colonise the crop naturally and in late June soil, plants and aphids were randomly sampled from the centre of each plot. Bioavailable Cd and Zn were extracted from the soil with 0.1 M $CaCl_2$. For all other analyses materials were digested in 70 % HNO_3.

Results

- Zn concentrations differed significantly between treatments in the soil (F = 3.4, $P = 0.014$), Shoots (F = 13.9, $P < 0.001$) and pods (F = 21.6, $P < 0.001$).
- Cd concentrations differed significantly between treatments in the soil (F = 5.7, $P < 0.001$) and Shoots (F = 5.7, $P < 0.001$).
- Both Cd and Zn concentrations fell in the order root-shoot-pod, except for Zn in the 30 and 40 t ha^{-1} amendments, where shoot Zn concentration exceed that of the root (Figures 1 & 2).
- Cd:Zn ratios fell in the order root-shoot-pod-aphid (Table 1).
- There was a significant relationship between the bioavailable concentration of Zn in soil and in pea roots ($r = 0.4$, $P = 0.005$), shoots ($r = 0.74$, $P < 0.001$) and pods ($r = 0.77$, $P < 0.001$) (Figure 3).
- There was a significant relationship between the bioavailable concentration of Cd in the soil and in pea roots (r = 0.45, $P = 0.006$), shoots ($r = 0.44$, $P = 0.008$) and pods ($r = 0.37$, $P = 0.026$) (Figure 4).

Figure 1. Zinc concentrations in soil, pea roots, shoots and pods and pea aphids following the amendment of soil with sewage sludge (error bars ± 1 SE).

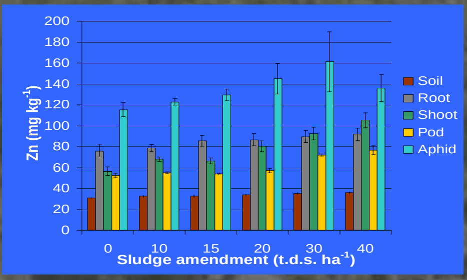


Figure 2. Cadmium concentrations in soil, pea roots, shoots and pods and pea aphids following the amendment of soil with sewage sludge (error bars ± 1 SE).

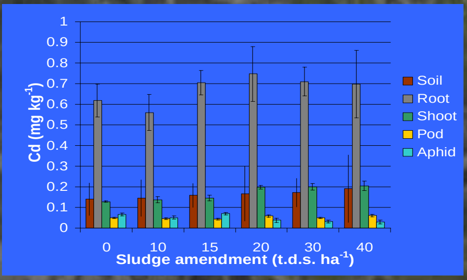


Table 1. Mean (values x10^{-3}) Cd:Zn ratios in soil, pea roots, shoots and pods and pea aphids following the amendment of soil with sewage sludge (t.d.s. ha^{-1}).

	0	10	15	20	30	40
Soil 'Total'	4.5	4.4	4.9	4.9	4.9	5.4
Soil 'Bioavailable'	37.2	32.7	28.6	29.4	29.1	24.0
Root	8.2	7.2	8.3	8.4	7.9	7.7
Shoot	2.3	2.0	2.2	2.5	2.2	2.2
Pod	0.9	0.8	0.8	1.0	0.7	0.8
Aphid	0.6	0.4	0.5	0.2	0.2	0.2

Figure 4. Regression relationships between 'bioavailable' Cd (mg kg^{-1}) in soil and Cd concentration (mg kg^{-1}) in various pea plant tissues and in pea aphids feeding on the plants.

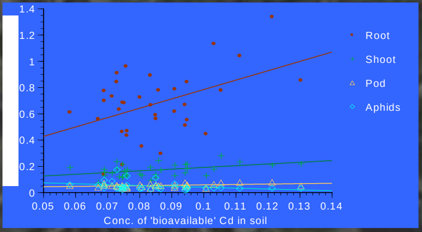
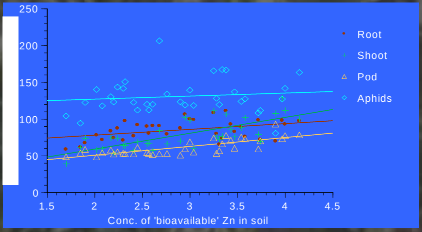


Figure 3. Regression relationships between 'bioavailable' Zn (mg kg^{-1}) in soil and Zn concentration (mg kg^{-1}) in various pea plant tissues and in pea aphids feeding on the plants.



Discussion and Conclusions

- Cd and Zn are considered to exhibit similar behavior in biological systems. However, Cd:Zn ratios demonstrate that in this system Cd and Zn have different transfer dynamics in the root-shoot-pod and shoot-aphid pathways. Cd is much less labile in these two pathways than Zn.
- The concentration of' 'bioavailable' Cd and Zn can be used to predict the concentration of these two metals in certain plant tissues.
- Compared to wheat plants grown in soils with similar sludge amendments and the grain aphids feeding on them (3), concentration of Cd and Zn were higher in shoots, but lower in aphids.
- Unlike in the wheat-grain aphid system (3), sludge amendment of the soil did not result in significantly higher Cd and Zn concentrations in aphids.
- We conclude that the nature of the plant-aphid system plays an important role in the regulation of Cd and Zn transport from the soil to higher trophic levels.

References

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