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Ecological Engineering 25 (2005) 322–331
ECOLOGICAL ENGINEERING
www.elsevier.com/locate/ecoleng

The role of different organic wastes on zinc bioaccumulation by earthworm *Lumbricus terrestris* L. (Oligochaeta) in successive Zn added soil

Rıdvan Kızılkaya *

Department of Soil Science, Faculty of Agriculture, Ondokuz Mayıs University, 55139 Samsun, Turkey

Received 23 September 2004; received in revised form 6 May 2005; accepted 7 June 2005

Abstract

Organic matter strongly adsorbs zinc and is also the preferred food of the earthworm *Lumbricus terrestris.* Earthworms have the potential to accumulate significant levels of zinc, and thus earthworm ingestion may result in zinc transfer to higher trophic levels (e.g. various birds and small mammals). This study examines the zinc bioaccumulation by earthworm *L. terrestris* and Zn contents in casts due to ingestion of different organic wastes in successive doses of Zn (0, 50, 100, 250, 500, and 1000 $\mu g\, g^{-1}$) added soil. Twenty-one days after organic wastes treatment, the cast and earthworm bodies receiving the highest Zn dose showed significantly higher Zn content than the non-treated soil. At all Zn doses, earthworms from soils treated with organic wastes of high C/N ratio (wheat straw and hazelnut husk) had the highest Zn concentrations. In addition, the lowest bioaccumulation factor (BAF) value occurred in low C/N ratio of organic wastes (tea and tobacco production waste). Furthermore, except for the 0 $\mu g\, Zn\, g^{-1}$ doses, the highest BAF value occurred in 100 $\mu g\, Zn\, g^{-1}$ at all organic waste treatment soils.

Keywords: Organic waste; Earthworm; Cast; Bioaccumulation; Zinc; Soil

1. Introduction

The increasing exploitation of natural resources by human activities during the past few centuries has adversely affected the global balance of heavy metals (Nriagu, 1990), causing a gradual increase of concentrations of metals in soil ecosystems (Beyer et al., 1985; Zöttl, 1985). Heavy metals may be important trace elements in the nutrition of plants, animals or humans (e.g. Zn, Cu, Mn, Cr, Ni, and V), while others are not known to have positive nutritional effects (e.g. Pb, Cd, and Hg). However, all of these may have toxic effects (some of them at a very low content level) if they occur excessively (Kızılkaya and Aşkın, 2002; Kızılkaya et al., 2004). The bioaccumulation of heavy metals over large territories and long time periods, which may result in the gradual damage to living organisms, necessitates careful monitoring of the input, mobility, and effects of these pollutants (Spiegel, 2002).

* Tel.: +90 362 457 60 20; fax: +90 362 457 60 34.
E-mail address: ridvank@omu.edu.tr.

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doi:10.1016/j.ecoleng.2005.06.006

The bioaccumulation of heavy metals in living organisms and biomagnification in them means or describes the processes and pathways of these (possible) pollutants from one trophic level to another, thus exhibiting the larger bioaccumulation ability in organisms related to the higher living status. Increasing concentration through the food chain is caused by a higher retention time of toxic substances than of the general food components in the organisms (Kenega, 1987).

Heavy metals are emitted from a great number of sources which contribute to metal loads in terrestrial food chains. These elements are released into the environment as a result of a wide range of industrial activities as well as from the combustion of fossil fuels (Adriano, 1986; Spiegel, 2002). Zn is one of the most commonly encountered heavy metals in contaminated agricultural soils. Zn sources that are becoming more important are municipal refuse, sewage sludge, animal waste, Zn-containing fertilizers and pesticides (Petruzelli, 1989; Panda et al., 1999). The deposition of metals at higher concentrations in soil may disturb soil ecosystems by affecting the populations and activity of soil organisms (Tiller, 1989). Contamination of agricultural soils by heavy metals leads to an increasing uptake of metals by soil invertebrates (Beyer et al., 1985; Hunter et al., 1987), and hence to adverse effects of toxic elements on the agricultural invertebrate fauna (van Straalen and Bergema, 1995), or on the functioning of the soil ecosystem as a whole (Strojan, 1978).

Earthworms constitute an important group of soil organisms in term of biomass, as food for many animals and in maintaining soil structure and fertility (Lee, 1985; Kızılkaya and Hepşen, 2004). They ingest large quantities of soil and are in full contact with the substrate they consume. They constitute up to 92% of the invertebrate biomass of soils and participate in many food chains, acting as a food source for a wide variety of organisms including birds, fish, insects, various mammals and reptiles (Ireland, 1983). Potential hazards of environmental pollutants to soil earthworms are commonly assessed by "bioaccumulation factor" (BAF: the ratio of a metal concentration in living tissue to its concentration in the earthworm's diet) (Pearson et al., 2000). Tissue metal concentrations and BAF may give information about the exposure of earthworms to metals, because earthworms accumulate metals when exposed to metal contaminated soil (Ireland and Wooton, 1976; Ireland, 1979; Morgan and Morgan, 1988,1992,1999; Nahmani et al., 2003; Kızılkaya, 2004). The amount accumulated depends on some factors such as the metal concentration and organic matter content (Beyer et al., 1987; Morgan and Morgan, 1988; Amador et al., 2003). The uptake of most metals by earthworms follows the route of food uptake via the alimentary tract (Hopkin, 1989; Dallinger, 1993); moreover, it has to be assumed that agricultural earthworms do not possess efficient mechanisms allowing them selectively to exclude certain metals from being absorbed through the wall of their gut. Concentrations of metal in soil organic matter or additional organic wastes on which the earthworms feed are, therefore, the primary extrinsic factors which determine the rates of metal uptake (Dallinger, 1993).

Organic wastes such as green manure, farmyard manure and biosolid are important sources of organic matter. The use of organic wastes was widely practiced in Turkey in agricultural soils in the past, but the interest declined with the increase in cropping intensity and ready availability of chemical fertilizer in the last few decades. With energy shortages, increased fertilizer cost, deterioration in soil health and environmental concerns, the use of organic wastes has again become important.

The experiment in the present study were conducted in the laboratory, simulating field conditions of organic matter management with different organic wastes in successive doses of Zn added soil. Our objectives were (i) to determine the effects of the organic wastes on organic matter content and C/N ratio in earthworm *Lumbricus terrestris* casts, (ii) to determine the Zn uptake by earthworm and bioaccumulation factors in successive doses of Zn added soil and (iii) to determine cast Zn at different organic waste treated and Zn added soil.

2. Material and methods

2.1. Soils and earthworms

Surface soil (0–20 cm) was taken from the experimental station in the campus of Ondokuz Mayıs University Agricultural Faculty. The soil has developed from basalt and contained 31.2% clay, 36.2% silt, and