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Earthworms as bioindicator of metals (Zn, Fe, Mn, Cu, Pb and Cd) in soils: Is metal bioaccumulation affected by their ecological category?

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ARTICLE INFO

Article history:
Received 15 May 2007
Received in revised form
6 September 2007
Accepted 12 October 2007

Keywords:
Agro-ecosystem
Anecic
Earthworm
Epigeic
Lampito mauritii
Metaphire posthuma
Metal-bioavailability
Soil pollution
Worm casts

ABSTRACT

The importance of earthworms in metal pollution monitoring is widely recognized in terrestrial ecosystems. Metal bioaccumulation by soil-dwelling earthworms can be used as an ecological indicator of metal availability in soils. In this study, we quantify the level of DTPA extractable metals in casts and tissues of earthworms (endogeic: *Metaphire posthuma* (Vaillant) and anecic: *Lampito mauritii* Kinberg) and ingesting soils, collected form cultivated land, urban garden and sewage soils. Soil and worm casts collected from sewage and cultivated land showed the greater metal concentrations. The concentration of Zn, Fe, Pb and Mn in earthworm casts was in the order: sewage soil > cultivated land > urban garden, while for Cu and Cd the order was cultivated land > sewage soil > urban garden. Data suggested that the level of DTPA extractable metals was higher than that of surrounding soils. We got close relationships between metal concentration in worm tissues and surrounding soils: Zn ($r^2 = 0.94$ and 0.89, $P < 0.01$ for both), Fe ($r^2 = 0.95$ and 0.97, $P < 0.01$ for both), Cu ($r^2 = 0.93$ and 0.96, $P < 0.01$), Pb (0.63, $P < 0.01$ and 0.57, $P > 0.05$), and Cd ($r^2 = 0.15$, $P > 0.01$ and 0.75, $P < 0.01$), respectively, for *M. posthuma* and *L. mauritii*. The study clearly indicates that earthworms have efficient potentials for bioaccumulation of metals in their tissues which can be used as an ecological indicator of soil contaminations. A species-specific metal accumulation pattern was observed in studied earthworms. Comparatively, endogeic showed the higher metal contents in their tissues than anecic (t-test: $P < 0.05$); collected form different habitats studied. Data suggested that species-specific feeding behaviour, earthworm niche structure, ecological category of inhabiting earthworm and even horizontal distribution of contaminants in soil layers are some major determinant for metal accumulation patterns in soil dwelling earthworms. The difference in burrowing patterns can influence the patterns of metal bioaccumulations between endogeic and anecic, although other factors are also contributory. Further more detailed study is still required to elaborate the proposed hypothesis.

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doi:10.1016/j.ecoleng.2007.10.003

1. Introduction

The impact of earthworms on soil properties and plant growth has been widely documented during the last two decades. From these studies abundant evidence has emerged that earthworms are powerful regulators of soil processes, participating in the maintenance of soil structure and regulation of soil organic matter dynamics (Lavelle et al., 1997). Furthermore, these detrivorous animals are relatively efficient accumulators of certain essential and non-essential metals (Morgan and Morgan, 1999; Sample et al., 1999; Janssen et al., 1997). Earthworms are, either directly or indirectly, potentially important agents modulating the transfer of inorganic and organic toxicants by virtue of their habitation in a site's contaminated soils (Cooke et al., 1992), and for many years they have been considered an interesting biological indicator of many metals in soils (Gish and Christensen, 1973; Lee, 1985). Van Hook (1974) claimed that earthworms could serve as useful biological indicators of contamination because of the fairly consistent relationships between the concentrations of certain contaminants in earthworms and soils. It is interesting that the tissues accumulation of metals by these detritivorous organisms can, in principle, damage soil processes and local biodiversity indirectly if their activities and demographics are compromised, and directly if the residues are transferred via earthworms to organisms occupying different trophic levels (Morgan et al., 2001). Because the potential impacts of chemicals on the structure of earthworm communities are of concern with respect to soil fertility, these macroinvertebrates play a key role in terrestrial ecotoxicological risk assessment (Spurgeon et al., 2003).

Since the metal accumulated within earthworm tissues is partly dependent on the absolute concentration of the metal within given soil, it is strongly codetermined by physiochemical edaphic interactions, including factors such as pH, Ca concentration, organic matter content C-to-N ratio and cation-exchange-capacity (Ma, 1982; Beyer et al., 1987; Morgan and Morgan, 1999; Kizilkaya, 2005). Moreover, it is suggested that inter-specific differences in dietary metal intakes and physiological utilization also affects the metal accumulation patterns in earthworm tissues (Anderson and Laursen, 1982; Morgan and Morgan, 1992). The variability of metals in worm tissues may vary in respect to degree of contamination, species type, ecological category of earthworm species, distribution of contaminants in soil layers, worm age, season and several other factors. Morgan and Morgan (1999) suggested that the difference in dietary intakes of metals is an important factor in contributing the differences in metal bioaccumulation between earthworms of two physiologically contrasting species (*Lumbricus rubellus* and *Aporrectodea caliginosa*). The relationship between the ecological strategies of earthworm species and exposure had received attention during last decades. Although differences in sensitivity between representatives of the litter dwelling (epigeic), horizontally burrowing mineral soil feeder (endogeic) and vertically burrowing surface feeder (anecic) earthworm species have been reported (Ireland and Richars, 1977; Ash and Lee, 1980; Morgan and Morgan, 1999), little is known about the consequences of their behaviour for exposure and effect in field (Spurgeon et al., 2003). Therefore, field studies of earthworm ecotoxicology are more important because these are the sites with a non-homogeneous vertical distribution of pollution and there may be significant differences in exposure for soil dwelling earthworms (Spurgeon et al., 2003).

The aim of this study was to evaluate the differences in concentrations of metals in casts and body tissues of earthworms belonging to two different ecological categories: endogeic (*Metaphire posthuma* (Vaillant)) and anecic (*Lampito mauritii* Kinberg), collected from same habitats e.g. sewage soil, garden soil, and agriculture lands. We selected three different habitats having distinct pedo-ecological structure, land-use pattern and contamination history. *L. mauritii* and *M. posthuma* are commonly distributed in soils of this region (Suthar, 2002) and probably they can provide good information about metal bioavailability in soils of this region.

2. Experimental

2.1. Study site

Mature (clitellated) specimens of two earthworm species, *L. mauritii* Kinberg and *M. posthuma* (Vaillant), which represent the earthworms of two different eco-physiological groups (Bouché, 1977): anecic and endogeic, respectively, were collected from three different habitats (cultivated land, urban garden and sewage soil) in September–November, 2005. However, in the Indian subtropical climate especially in plains, abundance of earthworm populations is found during the rainy season leading to maximum densities in September–October and least density in hot summer (May–June) (Gates, 1961; Chauhan, 1980). Moreover, during this period burrowing earthworms (endogeic and anecic) can be found mainly in topsoil layers (Suthar, 2002). Individuals of both species were collected from the same site of three habitats studied, i.e. sewage, domestic garden, and agriculture land. The earthworms were identified to species level with the help of monographic work of Julka (1988). The study of two habitats, namely sewage and grassland (dominated by the Bermuda grass *Cynodon dactylon*), was conducted in some sites situated in campus of Maharshi Dayanand (PG) College, Sri Ganganagar, India. Agricultural land with *Citrus reticulata* plantation as standing crop, situated in Northeastern part of the college campus, was selected as the third study site to conduct present experiments. Geographically, the site is located between 28°42′ to 30°11′N and 72°38′ and 74°17′E. The soils of study sites are of Torripsamments (P) subgroups. The climate of this region is semi-arid with extreme temperature conditions in summer (up to 45 °C) and winter (up to 1.0 °C). The site is influenced by the Indian southwest or summer monsoon (June–September) and during winter (December–February) by Siberian anticyclones. The main rainy season is during July and August which receives approximately 80% of the annual rainfall. The annual mean rainfall has been recorded as 286 mm.

2.2. Earthworm sampling

Sampling was done in same duration in selected sites by digging soil (0.5 m × 0.5 m × 0.5 m). Earthworms (*L. mauritii* and