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Lead and cadmium in earthworms (Oligochaeta, Lumbricidae) in northern Finland

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Worms were collected during the summer of 1984 around the city of Oulu, northern Finland (65°N, 25°30'E) for the analysis of lead and cadmium by direct current plasma atomic emission spectrometry. The cadmium concentrations remained between 0.5 and 1.8 mg/kg/fresh weight, the average being 1.01, while lead values varied greatly (from 1.1 to 22.5 mg/kg), in the actual city area. All samples with a high lead content were situated near highways, where, however, low figures were also obtained.

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1. Introduction

Oulu, a city with a population of 96 000, is located on the coast of the Bothnian Bay, N. Finland, and characterized by a number of factories and heavy traffic (the Europe 4 highway runs through it). Thus, heavy metal pollution can be expected. The occurrence of mercury, cadmium, lead and zinc in mushrooms (Vuorela 1982, 1983, Vuorela & Ohenoja 1982), and lead and cadmium in mountain hares (*Lepus timidus*) (Pulliainen et al. 1984) has been recorded so far. The present report provides preliminary records on the occurrence of lead and cadmium in earthworms, which were chosen as study objects due to their low dispersal activity, i.e. they can be expected to give a reliable picture of the heavy metal situation in the soil in question.

2. Material and methods

The worms were collected between 6th June and 24th August 1984 at eighteen sites around the city of Oulu, Northern Finland (65°N, 25°30'E). Most of the sites were situated within a few kilometres of the centre of the city or in the neighbourhood of industrial centres (Fig. 1). The main industrial centres in Oulu are the Kemira Oy works (fertilizers and basic chemicals), the Oulu Oy works (cellulose, chloralkali industry and organic chemicals), and the Kajaani Oy cellulose works (closed 1985). In addition, Oulu has one peat-fired power plant.

The worms were kept in a clean glass jar for five days in a refrigerator in order to permit them to empty their intestines, after which they were washed and analysed as follows: The worm samples (about 2 g, whole worms) were digested in conc. HNO_3 (20 ml) using a Tecator digestion system (Höganäs, Sweden) equipped with automatic temperature control (an Autostep 1012 controller). The temperature was increased slowly from 70 to 150°C at 20° intervals in the course of about 1 hour. The solution was then evaporated to about 5 ml, after which 10 ml of a mixture of $HClO_4$ and HNO_3 (v/v=3/7) was added and the resulting solution heated to 180°C. The mixture was evaporated at 180°C until the volume was about 3 ml and white $HClO_4$ fumes appeared. The residue was removed to a 25 ml volumetric flask. The mixtures were diluted with water to the necessary volume and the emission measurements carried out. The values are given as mg/kg/fresh weight. A Spectra Span III B single-channel plasma emission instrument consisting of a direct current plasma (DCP) source, and echelle monocromator and a dynamic background compensator, was used for the measurements. The DCP-AES method is comparable to atomic absorption spectrometry (AAS). The precision of the repetitive measurements for both metals was less than 1 % (RSD).

The worms were identified down to the species level. *Lumbricus* was represented by two species: *L. terrestris* L. and *L. rubellus* Hoffm., the latter being present at all sites except Oinaansuo, where only *L. terrestris* was found. The *Aporrectodea* specimens were all *A. caliginosa* (San.).

The actual contents were calculated from the fresh weights (Table 1). In order to obtain comparable results, dry weights can be estimated by assuming the water content to be 75 % (see also Edwards & Lofty 1977).

3. Results

Cadmium (Table 1)

The cadmium content remained between 0.5 and 1.8 mg/kg, i.e. it was relatively even throughout the material, and seemed to vary randomly. An exceptionally high concentration was encountered outside the city area at Sanginkylä, some 15 kilometres southeast of Oulu, where a content of 3 mg/kg was found in *Aporrectodea*. The highest concentrations in *Lumbricus* occurred at Ainola, Huonesuo, Myllyoja and Heikinharju, while those in *Aporrectodea* were at Kuivasjärvi, Taskila, Nokela and Alppila.

Lead (Fig. 1; Table 1)

The lead content varied greatly. It was mostly low, but three clear exceptions were found. The concentrations at Ainola, Rusko and Huonesuo were markedly high, i.e. 16.4, 17.3 and 22.5 mg/kg respectively, especially in the *Lumbricus* worms. At Ainola *Aporrectodea* individuals were also found, and here they had a high lead content, too, reaching 10.4 mg/kg. At the other sampling sites the figures for lead between 1.1 and 8.0 mg/kg. The lead content were between 1.1 and 8.0 mg/kg. The lead content was in general higher than that of cadmium.

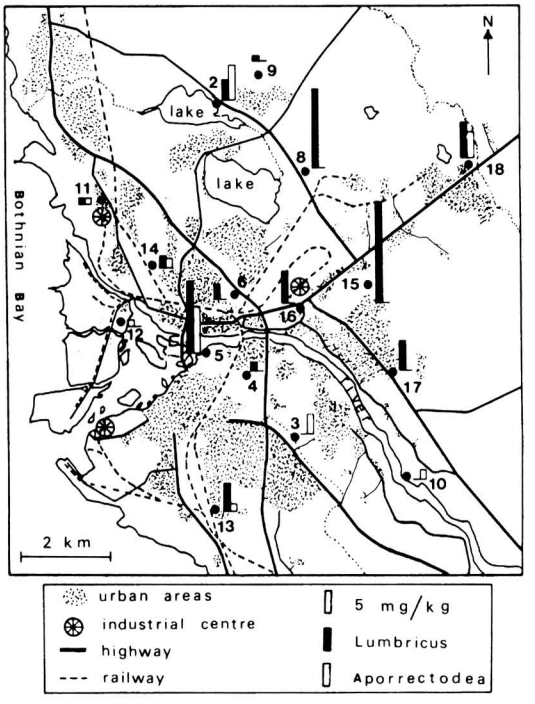

Fig. 1. Earthworm collection sites (see Table 1) and lead content at Oulu, northern Finland. Study sites 1 and 7 are located outside this area.

4. Discussion

The review of the heavy metal content of earthworms by Martin & Coughtrey (1982) quotes for cadmium and lead minimum and maximum amounts of 0.18 and 144, and 0.31 and 7593 mg/kg dry weight respectively. The figures for both elements in Oulu are relatively low by comparison. Even the highest figures obtained for lead would not represent alarming figures in the case of human beings.

Firstly, it is worth noting that all the sites with excessive amount of lead are situated near highways, although low figures were also recorded in similar surroundings. The lead intake of worms is influenced by the pH and calcium content of the particular soil (Ireland 1975), which may have some effect here, too. In city areas soil is also commonly moved to parks and similar places, so that the earth in which the worms are living may have accumulated earlier in some other place, perhaps further away from roads and highways. In any case a significant correlation has been demonstrated between the lead and cadmium content of worms and the soil (Williamson & Evans 1972, Martin & Coughtrey 1982). At least at the three sites where a high lead content was found the earth must be more contaminated than at the other sites. The keeping of worms for 24 hours without food does not entirely empty their intestines (Andersen 1979), and here when the worms were kept for five days without food some food still remained in the gut. Thus, the contents of the gut have probably decreased the relative proportion of metals due to the increase in fresh weights. On the other hand, all the worms were treated similarly in a cool room.

The age of worms also plays some role with respect to their heavy metal content, older individuals having higher concentrations than younger ones (Andersen & Laursen 1982). In the present case the age was not determined, but the worms were analyzed collectively.

According to Vuorela (1983), the cadmium content of mushrooms in the city and sur-

Table 1. Cadmium and lead content of earthworms in the area of Oulu, northern Finland. Values are mg/kg/fresh weight. Dry weight values can be calculated assuming a 75 % water content. Lrub = *Lumbricus rubellus*, Acal = *Aporrectodea caliginosa*.

Date	Site	Cadmium		Lead	
		Lrub	Acal	Lrub	Acal
06.06.84	1 Sanginkylä	0.9	3.0	–	–
25.06.84	2 Kuivasjärvi (E-end)	0.6	1.3	4.6	7.8
26.06.84	3 Kontinkangas	–	1.2	–	4.3
26.06.84	4 Intiö (graveland)	1.1	–	2.0	–
26.06.84	5 Ainola	1.3	0.8	16.4	10.4
27.06.84	6 Castren	0.4	–	3.1	–
26.06.84	7 Kempele	0.7	–	1.7	–
12.07.84	8 Rusko	1.2	–	17.3	–
13.07.84	9 Oinaansuo	1.0	–	1.7	–
17.07.84	10 Saarelan saari	–	1.0	–	1.9
09.08.84	11 Taskila	1.1	1.4	1.6	1.6
09.08.84	12 Hietasaari	0.5	–	1.1	–
10.08.84	13 Nokela	1.0	1.8	6.2	1.8
10.08.84	14 Alppila	1.0	1.7	2.7	2.1
22.08.84	15 Huonesuo	1.7	–	22.5	–
24.08.84	16 Hintta	0.7	–	7.2	–
24.08.84	17 Myllyoja	1.4	–	6.6	–
24.08.84	18 Heikinharju	1.6	0.6	8.0	5.5

roundings of Oulu varies significantly (from 0.04 to 83.8 mg/kg) with respect to sites and species, being on average 3.2 mg/kg dry weight. Similar findings were made in the case of lead. The average lead content of the mushrooms was 1.68 mg/kg dry weight, varying from 0.03 to 74.00 mg/kg. The present cadmium concentrations found in worms were thus significantly lower than in mushrooms, whereas the average lead content of worms was higher, even if the present results are compared with Vuorela's values recorded in the actual city. There is a faint discrepancy here, since Martin & Coughtrey (1982) consider earthworms as being good indicators of cadmium, which according to Vuorela (1982a, b) occurs in large amounts in mushrooms in the centre of Oulu. The concentrations in the earthworms were nevertheless not high. This may be correlated with the fact that the fallout in the Oulu area is in general very low, the monthly maxima for cadmium varying from 0 to 0.067 g/100m^2 and the means from 0 to 0.017 g/100m^2 (P. Vuononvirta, pers. comm.). Vuononvirta's figures are from the years 1980–81, but as far as we can see no obvious change has taken place. The maxima do no seem to coincide with the high concentrations in the worms. Mushrooms thus seem to be better at extracting cadmium from the ground than worms.

The highest lead concentrations in the present material noticeably occur near highways. In the case of lead our worms seem to confirm the statement made by Martin & Coughtrey (1982) that earthworms can be used as good bioindicators for this metal. Several questions were left open in the present study. An attempt is being made to answer at least some of these in a new study started in 1986 in the same area, both in the field and in the laboratory.

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