Terrestrial isopods: useful biological indicators of urban metal pollution

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Summary. Environmental pollution by toxic metals is widespread in urban areas. In contrast to many industrialized sites, however, metal pollution in most urban regions occurs at low or moderately elevated levels. Reliable criteria of environmental quality have therefore to be established, with the consequence that there is an increasing need for sensitive monitoring of pollution. In this present study, the isopod species *Porcellio scaber* was used as a bioindicator of lead and cadmium pollution in Innsbruck, Austria. During May 1988, isopods were collected at 356 points over the whole city area; lead and cadmium in whole animals were measured using flame atomic absorption spectrophotometry. Lead and cadmium contamination of urban districts were correlated with traffic density, the only exception being higher cadmium contamination of one district in which several factories are situated. Concentrations of lead, but not of cadmium, increased along the main arterial roads with increasing traffic density and with decreasing distance from the city centre. On a large scale, concentrations of lead and cadmium increased in the direction of the prevailing wind, from south-west to north-east. On a small scale, the variability of metal concentrations can be explained by the irregular distribution of active business centres, by different degrees of contamination between exposed and non-exposed sites, and by contamination gradients depending on wind direction. Compared to highly polluted sites around industrial factories and metal smelting works, lead contamination in Innsbruck can be considered as moderately elevated, whereas cadmium contamination is low.

Key words: Biomonitoring – *Porcellio scaber* – Lead – Cadmium – Environmental pollution

Because of its health effects, environmental pollution of urban areas has become a subject of increasing interest (Jermann et al. 1989; Seinfeld 1989). Among different pollutants, some toxic metals, such as lead and cadmium, play an important role. Although the proportion of leaded petrol is decreasing in all European countries, considerable amounts of lead are still emitted by traffic exhausts (Moore 1986; Ward 1990). In addition, cadmium is released by automobile traffic as well as by the burning of refuse and of fossil energy (Hiatt and Huff 1975; Stöppler 1984; Barratt 1988). Many attempts have been made to estimate the effects of urban metal pollution on human health (Pirkle et al. 1985; Gilli et al. 1988) and on ecosystems (Kratz and Weigmann 1987). It has been reported, for instance, that children are particularly affected by urban lead emissions (Marecek et al. 1983; Needleman 1983; Fulton et al. 1987; Lyngbye et al. 1988).

One of the most serious problems in this respect is the fact that metal exposure of humans and of ecosystems in urban areas occurs at relatively low doses over extended periods, possibly causing long-term toxicity effects (Friberg et al. 1979; Moore 1980). In Tyrol it has been shown that the milk of breast-feeding mothers living in Innsbruck and other cities is already contaminated with lead, metal concentrations of the mother's milk being 7-fold higher compared with those of women from regions with little traffic (Lechner et al. 1988). Under such circumstances there is an increasing need for sensitive monitoring of environmental quality, the use of biological indicators being a valuable approach (Anderson and Gustafsson 1989).

Several biological indicator systems have been proposed for monitoring urban metal pollution. Most of these studies were based on quantitative relations between environmental exposure and tissue concentrations of humans, animals or vegetation. It has been shown, for instance, that lead exposure of inhabitants is reflected by elevated levels of the metal in the blood (Sinn 1980; Snee 1981). Birds, such as urban pigeons (Ohi 1974; Hutton 1980a, b; Drasch et al. 1987), mammals (Wren 1986), and tree foliage (Valerio et al. 1989), have also been used as biological indicators of urban metal pollution.
Some time ago, Wieser and coworkers showed that copper concentrations of terrestrial isopods reflect the degree of environmental soil and litter contamination (Wieser et al. 1976; Wieser et al. 1977). This group of animals has also been used successfully for biomonitoring of zinc, cadmium, lead, and copper pollution around smelting works in Bristol (Hopkin et al. 1986) and for zinc biomonitoring in the area of Reading (Hopkin et al. 1989). In these cases, however, due to industrial contamination, metal concentrations in isopods reached extremely high levels.

In the present study it is shown that the terrestrial woodlouse Porcellio scaber can also be used as a bioindicator for lead and cadmium pollution in less industrialized urban areas. This approach is relevant because in most cases metal pollution in cities occurs at low or moderately elevated levels. Thus less spectacular, but by no means negligible, effects in terms of metal contents in biota or toxicological consequences are to be expected. Moreover, the present study shows that the method used also allows metal contamination to be detected on a fine-grained regional scale.

Material and methods

Study area and sampling of isopods and substrate

Innsbruck (Tyrol, Austria), a city with a population of 120000, is one of the most important traffic junctions of the alpine region. Most of the 356 sampling points were situated within the centre of Innsbruck, but suburbs and important surroundings were also included (Fig. 1). Isopods were collected during May 1988. Most of the animals were found to inhabit moist places under stones, decaying leaf litter or wood piles within gardens or at sites near the main roads. At each sampling point, 5-10 individuals of Porcellio scaber were placed in a numbered, screw-capped polypropylene tube (Greiner, Austria). In order to avoid size-dependent differences in metal concentrations, individuals of the same weight class were chosen, the mean weight per animal being 0.016 ± 0.004 g (dry weight). At 22 sampling points small samples of substrate consisting of a mixture of soil particles and decaying organic matter were also collected from the upper soil horizon and stored in small plastic bags.

Preparation of samples and metal analyses

All samples were oven dried at 60°C for several days. After determination of dry weight, 2 ml of a mixture (1:1) of distilled water and concentrated nitric acid (suprapure grade, Merck, FRG) were added to the polypropylene tubes containing the carcases of sampled isopods. Digestion was carried out in a heated aluminium block (75°C) for several days.

The remaining solutions were oxidized with a few drops of hydrogen peroxide and made up to a volume of 10 ml with distilled water. Lobster hepatopancreas (TORT1, NRC, Canada) was used as a standard reference material and digested in the same way. Some time ago, Wieser and coworkers showed that copper concentrations of terrestrial isopods reflect the degree of environmental soil and litter contamination (Wieser et al. 1976; Wieser et al. 1977). This group of animals has also been used successfully for biomonitoring of zinc, cadmium, lead, and copper pollution around smelting works in Bristol (Hopkin et al. 1986) and for zinc biomonitoring in the area of Reading (Hopkin et al. 1989). In these cases, however, due to industrial contamination, metal concentrations in isopods reached extremely high levels.

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Concentrations of lead and cadmium were measured by flame atomic absorption spectrophotometry (Perkin Elmer, model 2380) using an air-acetylene fuel mixture. Metal concentrations of standard reference material samples were found to be within the expected range of reproducibility.

Evaluation and statistical analysis

For statistical analysis, commonly purchasable programs were used and run on an MS-DOS compatible personal computer (AT). The city area was subdivided into 15 different zones corresponding to the most important urban districts or surrounding villages. Names of districts or villages belonging to these zones are given in Table 1. Also shown are the rivers Inn and Sill (bold lines) as well as the motorways A12 and A13 (dashed lines). Dotted line: transect from southwest (SW) to northeast (NE) of Innsbruck along which are the sampling points included to illustrate metal concentrations depending on the wind direction, as shown in Fig. 6. Coordinate grids expressed in km

Metal pollution of different urban zones

For both lead and cadmium, statistically significant correlations were found between the concentrations in Porcellio scaber tissue and in the substrate of the 22 sites from which substrate samples were taken (Fig. 2).

Metal contamination of isopods was determined in 15 zones of Innsbruck, based on 356 sampling points (see Fig. 1). The correlations of the means and standard deviations of lead and cadmium concentrations in isopods with traffic densities of some districts (Table 1) were significant for both metals (Fig. 3), the only exception being represented by zone 7 (not included in correlation