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Toxicological risks for small mammals in a diffusely and moderately polluted floodplain

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ABSTRACT

The ecotoxicological risk of heavy metal pollution in diffusely polluted floodplains is largely unclear, as field-based data are scarce. This study investigated cadmium (Cd) and lead (Pb) accumulation in the liver and kidneys of small mammal species (voles, mice and shrews) from a moderately polluted Dutch floodplain. The Cd and Pb concentrations were compared with effect concentrations (ECs). Reported ECs in literature varied considerably, with the lowest values frequently exceeded by our values, whereas the highest values were encountered only occasionally. Cd and Pb levels were highest in the shrew species, particularly in *Sorex araneus*. Although toxicological effects at the specimen level were present in these floodplains, effects at population level are thought to be limited, as a result of the animals' relatively short life expectancies (due to recurrent floods) and the rapid maturation of small mammals. Exceptionally high tissue metal concentrations in some specimens of all species indicated local hotspots with peaks in metal concentrations. Sanitizing such local hotspots might reduce toxicological risks.

1. Introduction

In recent decades, floodplains along the large European rivers have become polluted (Middelkoop, 2002), and it is still uncertain whether ecological rehabilitation of floodplain ecosystems is possible at the current pollutant levels (Leuven et al., 2005). The risk of heavy metals in floodplain ecosystems is largely unclear, chronic and diffuse exposure routes are unknown, and field data are lacking. Small mammals are important in floodplain food webs, and play an important role in floodplain ecosystems as they are abundant, are herbivorous and/or insectivorous, and form important preys. Earlier studies have described the distributions of small mammals in floodplains in relation to flooding (Wijnhoven et al., 2005, 2006a) and have shown spatial and temporal differences in exposure of small mammals to heavy metal pollutants

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(Wijnhoven et al., 2006b) and differences in accumulation for various species (Wijnhoven et al., 2007). The consequences of these findings in terms of risks on toxicological effects for small mammals have, however, so far not been investigated.

Most information on effect levels has come from laboratory experiments, where a certain daily intake causes toxic effects. The present study focused on critical organs, i.e. the kidneys and liver, which contain most of the accumulated metals and where toxic effects can be expected (Dodds-Smith et al., 1992). Since little was known about effect concentrations (ECs) of Zn (zinc) and Cu (copper) in small mammals, this study focused on the two other important heavy metal pollutants in western European floodplains; cadmium (Cd) and Pb. We investigated which species are most at risk, and what factors cause the highest risk, hoping to identify certain groups of animals, which are spatially or temporally related to those factors, as the most threatened species. The research questions were:

(a) Are small mammal species in diffusely polluted floodplains at risk of ecotoxicological effects from moderate heavy metal pollution levels?
(b) How do the current kidney and liver metal concentrations compare to reported ECs?
(c) Which small mammal species and specimens are most at risk of toxicological effects?

2. Materials and methods

All data were collected at the 'Afferdensche en Deestsche Waarden' (ADW floodplains), an embanked floodplain area along the river Waal, the main distributary of the Rhine in The Netherlands. Large parts of the floodplains are periodically flooded, on average once a year, predominantly in winter. The floodplains include areas with and without agricultural activities. Those without agriculture feature naturally developed vegetation and offer a wide range of habitats; detailed descriptions can be found in Wijnhoven et al. (2005, 2006a). The ADW floodplains are characterized by moderately polluted soils. Apart from Zn and Cu, Cd and Pb are the most important pollutants. Table 1 presents the average total and $CaCl_2$-extractable soil Cd and Pb concentrations calculated from the sample sites in this study, with their ranges.

Small mammals from the ADW floodplains were collected at 58 sites between 2001 and 2003, using Longworth live traps (Wijnhoven et al., 2007). For the purpose of the present study, three sessions of two three-day trapping rounds, covering all sample sites and checking the traps twice a day, were organized in August 2002 and in June and October 2003. In addition, all trapping casualties from local monitoring studies, especially specimens trapped in winter and spring, were included (Wijnhoven et al., 2005, 2006a). Since the trapping locations had originally been selected for a study to monitor recolonisation of the floodplain after flood events (Wijnhoven et al., 2005), they had been chosen on the basis of habitat characteristics (vegetation structure, soil type and management type) without prior information on levels of contamination. Trapping sites covered the whole range from non-flooding parts to flooding locations situated far from the non-flooding areas. At each of the trapping sites, the soil total (HNO_3/HCl-extraction) heavy metal concentrations and the $CaCl_2$-extractable concentrations were determined using Inductively Coupled Plasma – Atomic Emission Spectrometry (ICP- AES), as described in Wijnhoven et al. (2007). The liver and kidneys of each specimen were dissected and weighed (FW). Parts of these organs were oven-dried for 24 h at 105 °C, after which the dry weights (DWs) were measured. Heavy metal concentrations were determined after microwave extraction of approximately 0.01 to 0.25 mg DW with HNO_3 and HCl, and analysed on the ICP-AES (Wijnhoven et al., 2007).

Correlations between the liver and kidney Cd and Pb concentrations and the soil metal concentrations (total and $CaCl_2$-extractable), as well as species and specimen characteristics, trapping location characteristics and trapping season, were examined for all samples ($n=199$) by principal component analyses (PCAs) after specifying the gradient length for the organ metal datasets by detrended correspondence analyses (DCAs) using Canoco (Windows software package, version 4; Ter Braak and Smilauer, 1998). Correlations between liver and kidney Cd and Pb concentrations were calculated using the General Linear Model option in Systat 11 for Windows.

Table 1 – Soil total and $CaCl_2$-extractable concentrations of cadmium and lead in the ADW floodplains (after Wijnhoven et al., 2006b)

	Range (min–max)	Average ± sd
$[Cd]_{tot}$ (mg/kg DW)	$4.33*10^{-2}$–7.13	2.09 ± 1.96
$[Cd]_{CaCl_2}$ (mg/kg DW)	$5.75*10^{-7}$–$6.27*10^{-2}$	$2.01*10^{-2} \pm 1.54*10^{-2}$
$[Pb]_{tot}$ (mg/kg DW)	13.3–342	108.0 ± 80.3
$[Pb]_{CaCl_2}$ (mg/kg DW)	0.00–1.17	$3.65*10^{-1} \pm 3.18*10^{-1}$

3. Results

A huge variety of reported EC levels can be found in literature, ranging from 3.49 to 1000 mg Cd/kg DW in kidneys (Bremner, 1979; Hunter and Johnson, 1982; Hunter et al., 1984; Webster, 1988; Dodds-Smith et al., 1992; Shore and Douben, 1994; Hendriks et al., 1995), from 0.87 to 25 mg Cd/kg DW in livers (Hunter and Johnson, 1982; Hunter et al., 1984; Webster, 1988; Hendriks et al., 1995), and from 25 to 1506 mg Pb/kg DW in kidneys (Ma, 1989; Ma et al., 1991; Stansley and Roscoe, 1996). Specific EC values for Pb in liver tissue have not been reported. We compared the kidney and liver concentrations we measured in small mammals of the ADW with all reported levels (Fig. 1), and found a large variation in metal concentrations in kidneys and livers. For some species, certain reported metal levels were more often exceeded than for others. For Cd, higher levels in both kidney and liver tissue were found for two shrew species (*S. araneus* and *C. russula*) than for the other small mammal species. Based on the lowest reported effect concentrations for Cd, 83–100% of the specimens exceeded the 3.49 and 0.87 mg Cd/kg DW limits for kidney and liver tissue (Hendriks et al., 1995), respectively. However, compared with other reported ECs, the percentages of shrews exceeding them dropped to 35% and 0% for *C. russula*, at ECs of 105 mg Cd/kg DW (Hunter and Johnson, 1982; Hunter et al., 1984) and 25 mg Cd/kg DW (Shore and Douben, 1994) for kidney and liver tissue, respectively. Although the number of *S. araneus* specimens exceeding the EC level in