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Contaminated sediments and bioassay responses of three macroinvertebrates, the midge larva *Chironomus riparius*, the water louse *Asellus aquaticus* and the mayfly nymph *Ephoron virgo*

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Abstract

Bioassays are widely used to estimate ecological risks of contaminated sediments. We compared the results of three whole sediment bioassays, using the midge larva *Chironomus riparius*, the water louse *Asellus aquaticus*, and the mayfly nymph *Ephoron virgo*. We used sediments from sixteen locations in the Dutch Rhine-Meuse Delta that differed in level of contamination. Previously developed protocols for each bioassay were followed, which differed in sediment pretreatment, replication, and food availability. The *Chironomus* bioassay was conducted in situ, whereas the other two were conducted in the laboratory. The measured endpoints, survival and growth, were related to contaminant levels in the sediment and to food quantity in water and sediment.

Only the response of *A. aquaticus* in the bioassay was correlated with sediment contamination. Food availability in overlying water was much more important for *C. riparius* and *E. virgo*, thereby masking potential sediment contaminant effects. We conclude that growth of *A. aquaticus* was depressed by sediment contamination, whereas growth of *E. virgo* and *C. riparius* was stimulated by seston food quantity. We discuss that the trophic state of the ecosystem largely affects the ecological risks of contaminated sediments.

Keywords: Food; Sediment contamination; Survival; Growth; Whole sediment bioassay

1. Introduction

Sediment contamination is a serious problem in river sedimentation areas, such as floodplain lakes, delta areas and estuaries. Sediments in the Rhine-Meuse Delta in the Netherlands are moderately to heavily polluted with

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trace metals and organic contaminants like polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) (Den Besten et al., 1995; Reinhold-Dudok van Heel and Den Besten, 1999).

The relationship between sediment toxicity and effects on biota are studied through various approaches. These include studies into the effects of sediment contamination on in situ macroinvertebrate communities (e.g. Schlekat et al., 1994; Pinel-Alloul et al., 1996; Van Griethuysen et al., 2004), and effects on single species in situ and in laboratory bioassays (e.g. Chappie and Burton, 1997; EPA, 2000; OECD, 2001; Den Besten et al., 2003; Burton et al., 2005a). Biotic responses are usually related to total contaminant concentrations, which give good estimates of the degree of pollution, but may not be fully available to biota. Several extraction techniques, such as extraction with Tenax® beads for organic contaminants (Cornelissen et al., 2001) and the AVS/SEM method for trace metals (Di Toro et al., 1990), have been applied to estimate the pollution that is available for organisms. These concentrations are usually termed bioavailable concentrations.

Many invertebrate species are used worldwide in risk assessment procedures, and their use is described in standardized protocols (e.g. EPA, 2000; OECD, 2001). The outcome of risk assessment procedures will depend on the choice of species used in a bioassay. Several studies have shown that different species can have different responses to the same sediment contamination (e.g. Lyytikäinen et al., 2001; Ingersoll et al., 2002; Milani et al., 2003). Several criteria should be considered when selecting a species. First, the ecology of the test animal is of importance. The test animal should be a sediment dweller or feeder and should be exposed to contaminants in sediment and/or in pore water in nature (Wang et al., 2004). Second, the uptake route of the contaminant is of importance. Animals can obtain contaminants from sediments, from food, and from overlying water. The relative importance of these three routes of exposure depends on the contaminant and on the ecology of the test animal (Wang et al., 2004). Recent studies suggest that species commonly used for sediment toxicity testing do not meet the above mentioned criteria (e.g. Warren et al., 1998; Hare et al., 2003; Wang et al., 2004).

The present study compares the effect of sediment contamination on survival and growth of the midge *Chironomus riparius*, the mayfly *Ephoron virgo* and the water louse *Asellus aquaticus*.

Chironomid larvae are widely used test organisms in acute and chronic sediment toxicity tests (e.g. EPA, 2000; OECD, 2001). Larvae of *C. riparius* are opportunistic tube-dwelling deposit feeders, feeding mainly on detritus and organic matter present in the sediment (Armitage et al., 1995). *C. riparius* larvae are sensitive to food deficiency and addition of (usually artificial) food in bioassays is often necessary to exclude reduction in survival or growth due to food deficiency. However, this may mask toxic effects, especially when advantages of organic enrichment prevail against the potential adverse effects of the toxicants (e.g. Ristola et al., 1999; De Haas et al., 2002). A recent study showed that *C. riparius* selectively feeds on added food, and is therefore capable of avoiding contaminated sediments in standard bioassays (Åkerblom and Goedkoop, 2003). Studies into the different uptake routes of contaminants revealed that for *Chironomus staegeri* the main uptake route of Cd was the overlying water with associated particles (Warren et al., 1998; Hare et al., 2001).

The mayfly *E. virgo* has been used recently in (sediment) toxicity tests (Van der Geest et al., 2000; De Haas et al., 2002). The first-instar nymphs live freely on and in the sediment, feeding on fine particulate organic matter. Later instars burrow U-shaped tubes in the sediment, filtering food from the water, such as detritus and algae (Kureck and Fontes, 1996). Results from bioassays with seven different floodplain lake sediments showed that *E. virgo* seemed to be an appropriate test organism for sediment toxicity bioassays since it responded to the toxicant levels in the sediment rather than to nutritional value (De Haas et al., 2002). No information is available on the different uptake routes of contaminants for *E. virgo*.

The water louse *A. aquaticus* is proposed as a suitable species for use in sediment toxicity tests, since it is in continuous contact with the sediment (McCahon and Pascoe, 1988). It is a shredder that feeds on detritus with associated fungi, bacteria and periphyton (Marcus et al., 1978; Graça et al., 1993a,b). *A. aquaticus* is not routinely used as a test species for field sediments, but it has been used in a large number of laboratory toxicity studies (e.g. Migliore and De Nicola Giudici, 1990; Peeters et al., 2000). Comparative studies indicate that *A. aquaticus* has an intermediate sensitivity to contaminants (Van Hattum, 1995). Studies into the different uptake routes of contaminants show that both water, sediment and food are important. *A. aquaticus* could easily accumulate Cd from water and food, however that study was conducted in the absence of sediment (Van Hattum et al., 1989). Another study using stable isotope tracers showed that *A. racovitzai* accumulated Cd primarily from water (Eimers et al., 2001, 2002). In contrast, PAHs were accumulated mostly from sediments in *A. aquaticus* (Peeters et al., 2000).

These three species were used in bioassays following internal protocols developed at our laboratories. We used sediments from sixteen locations in the Dutch Rhine-Meuse Delta (Fig. 1), as part of a larger study described elsewhere (De Lange et al., 2004). The measured endpoints in the bioassays were survival and growth. These endpoints were related to contaminant levels in the sediment and to food quality parameters in water and sediment.