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Impact of a flood disaster on sediment toxicity in a major river system – the Elbe flood 2002 as a case study

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The extraordinary Elbe flood in August 2002 did not result in an overall increase of environmental contamination.

Abstract

The ecotoxicological implications of a flooding disaster were investigated with the exceptional Elbe flood in August 2002 as an example. Sediment samples were taken shortly after the flood at 37 sites. For toxicity assessment the midge *Chironomus riparius* (Insecta) and the mudsnail *Potamopyrgus antipodarum* (Gastropoda) were exposed to the sediment samples for 28 days. For a subset of 19 sampling sites, the contamination level and the biological response of both species were also recorded before the flood in 2000. The direct comparison of biological responses at identical sites revealed significant differences for samples taken before and immediately after the flood. After flood sediments of the river Elbe caused both higher emergence rates in the midge and higher numbers of embryos in the mudsnail. Contrary to expectations the toxicity of the sediments decreased after the flood, probably because of a dilution of toxic substances along the river Elbe and a reduction in bioavailability of pollutants as a result of increasing TOC values after the flood.

Keywords: Flood disaster; Sediment toxicity; Effect monitoring; *Chironomus riparius*; *Potamopyrgus antipodarum*

1. Introduction

Despite their ecotoxicological potential, extraordinary flood events in major river systems have not yet been explored in this regard. However, such events may cause considerable ecological damage by a flooding of industrial facilities, urban areas and smaller settlements with a discharge of toxic substances into the surface water body and into the sediment resulting in an increase in environmental pollution and a disturbance of formerly not polluted sites. As another conceivable consequence, such flooding events could lead to a dilution of toxic chemicals (Müller et al., 2003) at highly contaminated sites that will cause a decrease of pollution.

In August 2002, exceptional meteorological conditions provoked extreme rainfall in many regions of eastern Germany, Austria and the western Czech Republic. Statistical expectations for such events are one in a century. Precipitations of up to 70% of the monthly average were recorded at a single day. The precipitations were discharged mainly through the river Elbe catchment area. This resulted in a record water level of 9.40 m for the Elbe at the city of Dresden, while the normal level is 2.05 m. As the flood wave propagated

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down the Elbe, widespread damage was caused in cities such as Wittenberg, Dessau and Magdeburg. The Elbe bursted its banks more than 12 km in total at several points, flooding farmland, settlements, urban areas, sewage treatment works and industrial facilities.

The Elbe is one of the major streams in Central Europe flowing over a distance of 1091 km from its source in the Riesengebirge (Czech Republic) to its mouth at the North Sea near Cuxhaven (Germany). Numerous chemical plants are located along its banks as well as along the tributaries of the upper Elbe course in the Czech Republic. In the middle course a number of chemical plants and large industrial areas are situated with the area of Bitterfeld on the river Mulde achieving the most notoriety for excessive contaminant emission until 1990. The lower course of the Elbe is running through Hamburg, receiving a significant load of contaminants and nutrients originating from municipal and industrial sewage, especially in the international harbour. Previously, the river Elbe was one of the most polluted rivers in Central Europe as many industrial plants and cities in the Czech Republic and the former German Democratic Republic discharged their untreated wastewaters into the river. Due to technical improvements of production processes or sewage treatment the contaminant input was reduced considerably in recent years but sediment toxicities remained at a high level (Traunspurger et al., 1997; Ahlf et al., 1999; Duft et al., 2003c).

It was the main objective of the study to compare the biological effect monitoring results and chemical residue analyses before and after the flood. To this end the data of the current investigation are compared with results of two Elbe sediment toxicity investigations performed in 2000 before the flood (Schulte-Oehlmann et al., 2001b; Duft et al., 2003c). Furthermore, the present study provides an opportunity to generalise the effects of high flood events in major river systems.

2. Material and methods

2.1. Sediment sampling

Samples were obtained between 09/08/02 and 09/16/02, immediately after the flood had subsided in parts of the river where there is little flow activity such as between breakwaters, in abandoned channels or in harbours. In some cases the sampling was performed from boats. Aerobic sediment samples were collected at 37 sampling locations along the river Elbe using a Van Veen bottom grab or a spoon spatula. Fig. 1 shows the sampling sites with their respective location along the river course. The top aerobe 2 cm was removed, placed in polycarbonate containers and cooled at 4 °C. Samples were homogenized before aliquoting for toxicity testing.

2.2. Bulk-phase sediment chemical analyses

Bulk-phase sediment chemical analyses were conducted at GALAB Laboratories (Geesthacht, Germany). Polycyclic aromatic hydrocarbons ((PAH): naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benz[*a*]anthracene, chrysen/triphenylene, benzo[*b*]fluoranthene, benzo[*k*]-fluoranthene, benzo[*a*]pyrene, indeno[1,2,3-*cd*]anthracene, dibenz[*a*,*h*]anthracene, benzo[*g*,*h*,*i*]-perylene) were analysed according to DIN 38414 S23 (2002). PCBs (congeners No. 28, 52, 101, 138, 153 and 180), dichlorodiphenyl-trichloroethane (DDT) and metabolites were analysed using DIN 38414 S20 (1996). To determine the concentrations of polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans (PCDD/PCDF) DIN 38414 S24 (2000) was applied. Analytical methods for quantification of xenoestrogens (bisphenol A (BPA) and metabolites, alkylphenols, alkylphenol ethoxylates, alkylphenol carboxylates) and organotin compounds (monobutyltin (MBT), dibutyltin (DBT), tributyltin (TBT), tetrabutyltin (TeBT), monooctyltin (MOT), dioctyltin (DOT) and triphenyltin (TPT)) are described by Heemken et al. (2001) and Kuballa et al. (1995), respectively.

2.3. The 28 d-sediment toxicity tests

The non-biting midge *Chironomus riparius* (Arthropoda, Diptera) was used as one of the test organisms. This genus is widely applied for sediment characterisations (Ingersoll and Nelson, 1990; Bleeker et al., 1999; Ristola et al., 1999). The second test organism was the parthenogenetic and ovoviviparous freshwater snail *Potamopyrgus antipodarum* (Gastropoda). Duft et al. (2002, 2003a,b) established a sediment toxicity test with this species. Both species inhabit the upper layers of aquatic sediments, feeding on plants and detritus.

The brood stock of *C. riparius* was originally received from Bayer AG Leverkusen. The 28 d-sediment toxicity tests with this species were carried out according to OECD Guideline 218 (OECD, 2002) with the following modifications. The control sediment was made with quartz sand with a predominate grain size between 250 and 355 μm (Quarzwerke Frechen, Germany). For the control sediment 1.6% pulverized leaves of alder (*Alnus glutinosa*) and 0.5% pulverized leaves of stinging-nettle (*Urtica dioica*) were added as carbon sources. The content of total organic carbon (TOC) in the control sediment was 1.48%. In addition to these carbon sources, the test organisms were fed daily during exposure with TetraMin® (1 mg/individual/d). Every test vessel contained 80 g ww of field sediment and was filled up with 400 mL of reconstituted water (530 μS/cm). To ensure sufficient aerobe conditions in the sediment all samples were aerated for 21 days before