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Degradation of p-nitrophenol by natural microbial communities from the estuary of the river Elbe

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Abstract

The test compound p-nitrophenol during summer normally is rapidly degraded in the freshwater area of the Elbe river. In contrast, degradation of PNP is decreased significantly during periods of low temperature or low oxygen content. Thus the xenobiotic compound is carried to the North Sea. In estuarine and marine environments the degradation of PNP is diminished step by step towards the open sea and is finally ceased completely, mostly as a result of increasing salinity.

Introduction

Estuaries are characterized by a variety of gradients (e.g. salinity, quality and quantity of organic matter, inorganic salt composition, oxygen, temperature and pH) which effect the biodegradation of xenobiotic compounds. The objective of this study was to examine the effect of environmental factors on mineralization of the model compound p-nitrophenol (PNP) by mixed microbial communities from the Elbe estuary. This river was chosen as an example for an extremely polluted habitat. PNP is frequently used as a building block for pesticides, dyes and explosives. The model compound was added to water samples and $^{14}CO_2$ released from the radioactive parent compound was used as a measure of mineralization of PNP.

Results and discussion

Former investigations in different other aquatic habitats had shown, that PNP was only degraded after an acclimation period of several days or even weeks (SPAIN et al. 1980, SPAIN and van VELD 1983, AELION et al. 1987). Especially low concentrations up to 10-15 µg/l, as they are relevant for the environment, were often not mineralized at all (AELION 1987). Obviously their energy content is too low to stimulate bacterial uptake mechanisms.

In contrast in samples from a freshwater station at the Elbe river (Fig. 1) mineralization began rapidly after the addition of the test compound especially at low concentrations up to 10 µg/l. Degradation was finished for all concentrations

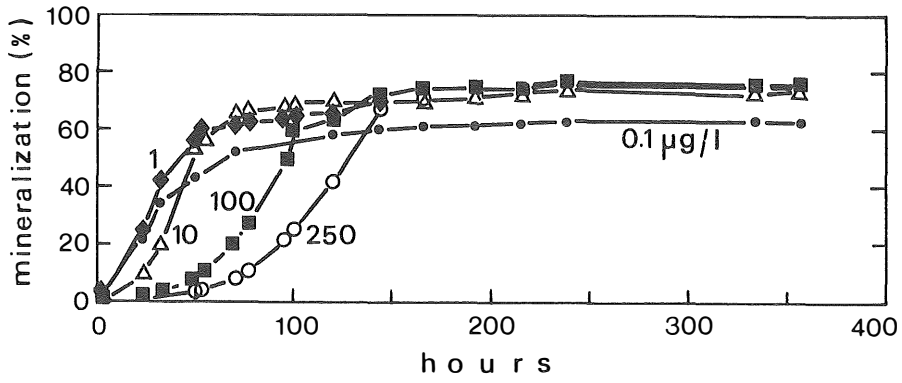

Fig. 1. Effect of different concentrations: 0.1 to 250 µg PNP/l. Incubation temperature 10 °C.

after only 150 hours, though incubation was carried out at 10 °C. The mineralization reached high values with 60 up to 75 % respiration of the test compound.

A lot of industrial waste waters containing phenols are discharged into the river Elbe and its tributaries (LEHMANN and PRESSEL 1988). The rapid mineralization of PNP even at very low concentrations indicates, that the microbial population in the river must have been exposed to PNP or a similar compound before. Thus the river contains specialized bacteria, which are already adapted to mineralize PNP.

Most of the organisms responsible for the rather complete degradation of PNP in freshwater samples are nearly identical strains of *Pseudomonas fluorescens* (MEUTER 1989). When PNP is added several times to a water sample, these organisms dominate in the microbial community. Repeated industrial discharge of PNP into the Elbe might therefore diminish the diversity of species with a degradation potential for other chemicals.

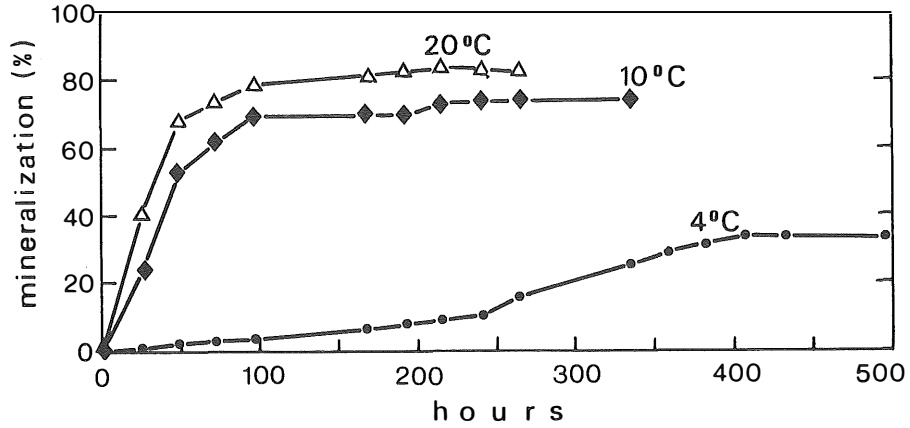

Fig. 2. Effect of temperature. PNP-concentration tested: 1 µg/l.

As Fig. 2 demonstrates, PNP can be easily degraded in the freshwater area of the Elbe at temperatures between 10 °C and 20 °C. In contrast in winter, when temperatures of the water are around 4 °C, the test compound can only be mineralized up to 34 %. Additionally the time for degradation is prolonged to about 17 days (Fig. 2).

Suboptimal conditions do also occur in summer when the oxygen content of the Elbe river is usually very low (sometimes around 1 mg/l). Then again the biodegradation potential is decreased significantly. In freshwater samples with an oxygen content of 1.8 mg/l PNP (in a concentration of 1 µg/l) could only be mineralized to 25-30 % within 30 days.

When PNP cannot be degraded in the freshwater area of the Elbe because of unfavourable conditions, the chemical will be carried by currents to the North Sea. In samples taken at four different sites (Hamburg, Cuxhaven, Lightship Elbe I and Helgoland) representing a gradient from freshwater to estuarine and further to marine systems, mineralization of PNP slows down step by step towards the open sea (Fig. 3). Degradation is also decreased in brackish water and seawater areas. Microorganisms from a sampling site near Helgoland did not adapt to degrade PNP within 50 days.

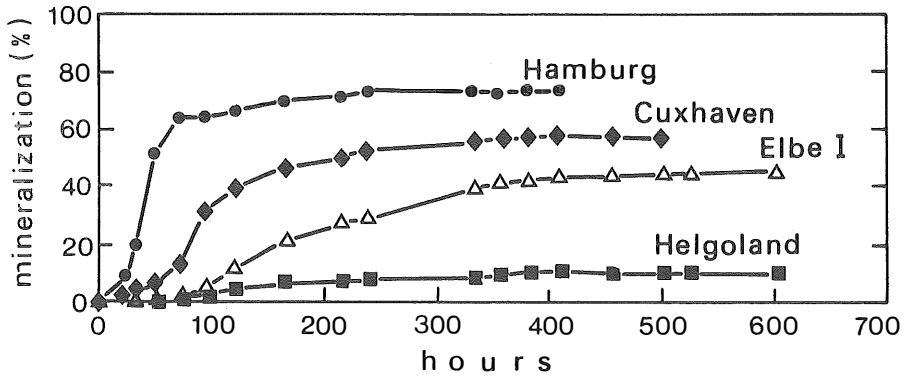

Fig. 3. Effect of different sampling sites. PNP-concentration tested: 1 µg/l.

The main factor for the decrease of mineralization is obviously the increasing salinity (Fig. 4): when freshwater samples were adjusted to specific salinities (18 or 32 ‰) by an artificial salt mixture, degradation was reduced in a very similar way as in the samples taken at the four different sampling sites (Fig. 3). With increasing salinity total bacterial numbers and also species diversity often decrease (HUNTER et al. 1986). Own degradation experiments with *Pseudomonas* strains isolated from freshwater habitats in artificial seawater indicated that these organisms needed longer periods of time for the mineralization of PNP or lost this ability completely. These results suggest, that for freshwater bacteria also a metabolic inhibition of the degradative pathway for PNP occurs at the higher salinities. Therefore marine microorganisms would have to adapt to degradation of this xenobiotic compound in marine environments.

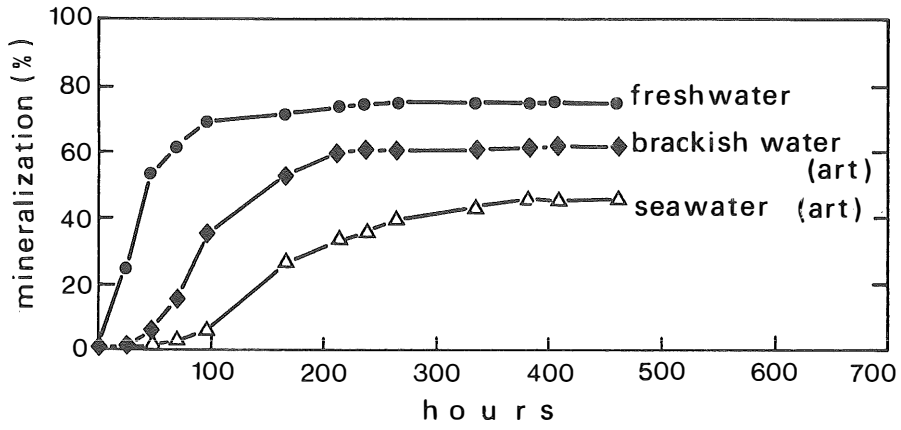

Fig. 4. Effect of salinity. PNP-concentration tested: 1 µg/l.

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