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HEAVY METALS IN THE DUTCH DELTA

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Summary

The river Rhine and to a less extent the rivers Meuse and Scheldt transport large quantities of heavy metals to the Dutch coastal area. The river Ems, on the contrary, can be regarded as relatively clean. Upstream of the rivers large proportions of the heavy metals are bound to the suspended matter. This especially holds for Cr, Pb and Cu. Elements like Zn and Ni, on the other hand, show a preferred occurrence in the dissolved state. The bond of the main part of the heavy metals to the suspended matter means that the distribution of these metals in the aquatic environment is highly determined by the hydrodynamic behaviour of the suspended matter. Furthermore, for a full understanding of the consequence of the presence of the heavy metals in the environment, the study of the geochemical behaviour and of the uptake by organisms is necessary. In this connection an integrated study is carried out in the Netherlands by the Delft Hydraulics Laboratory (hydrodynamics), the Institute for Soil Fertility, Haren, Groningen (geochemistry) and the Central Laboratory TNO, Delft (biology).

The distribution of heavy metals as components of deposited mud over the Dutch Delta has been given schematically in Fig.1. The contents of the heavy metals in the deposited material have been expressed as percentages of the contents of the relevant metals in the suspended matter upstream of the Rhine river. From this figure it is obvious that the main influence on the heavy metal composition is originating from the Rhine river.

The Rhine has still a natural pathway to the sea via the Rotterdam harbour area (Waalhaven and Europoort). Within these areas mixing processes occur of heavily polluted Rhinesediments with less polluted material coming from the North Sea. The mixing processes could be described quantatively by means of the application of the isotope geochemistry (C12/C13- and O16/O18-ratios) on several components of the sediments (carbonates, clay minerals and organic matter).

The other mouthing areas of the Rhine have been enclosed. This happened first by building the Enclosure Dike in 1932. As a consequence the IJssel (distributary of the Rhine river) was mouthing without the interaction of tidal effects into the Lake IJssel. The Ketelmeer (as a part of Lake IJssel) is now the main deposition area of the IJssel sediments. It is obvious from Fig. 1 that these deposits are from a view-point of heavy metal pollution completely equal to those of the upper Rhine river.

Another important mouthing area of the Rhine was originally the estuary via Hollands Diep and Haringvliet. The Haringvliet has been enclosed in 1970 as a part of the well-known Delta-plan. It can be seen from Fig. 1 that the deposits in the Haringvliet are more contaminated than those of the Europoort. We expect that the removal of the tidal effects in this area will give rise to the deposition of more and more contaminated sediments. In the far future a situation can be expected, which equals that of the Ketelmeer.

A similar effect can be seen in the Grevelingen area, which has been enclosed in 1972. This area, however, has no more an open connection with the Rhine river.

The Oosterschelde will be only partially enclosed in the near future. This will lead to an enhanced deposition of sediments. The degree of pollution of these sediments will mainly depend on the situation on the open sea.

A part of the suspended matter of the river Rhine will reach the Dutch Wadden Sea. Although the heavy metal contents of these sediments represent the lowest values in Fig. 1, they may not be regarded as unpolluted. For elements like Cd, Zn and Pb the values are at least twice as heigh as their base line levels.

From the above mentioned data it is obvious that large civil-engineering projects (enclosure dams) largely influence the retention of polluted sediments within the Dutch aquatic territory. The same holds for the deepening and extension of large sea-harbours. By these actions the retention of sediments is favoured. Especially from those harbours in the Rotterdam area which are located more upstream of the river (e.g. Waalhaven), large quantities of polluted sediments have to be dredged. The dredge spoils are either dumped at sea or used for land-filling. Under both conditions the material can give rise to severe environmental problems. The dredge spoils brought on land are often used for agricultural and horticultural purposes. Especially high amounts of cadmium, which are easily taken up by crops, restrict the use of these soils for plant growth.

In the preceding paragraphs much attention has been given to the deposited material. Heavy metals, however, can be present in

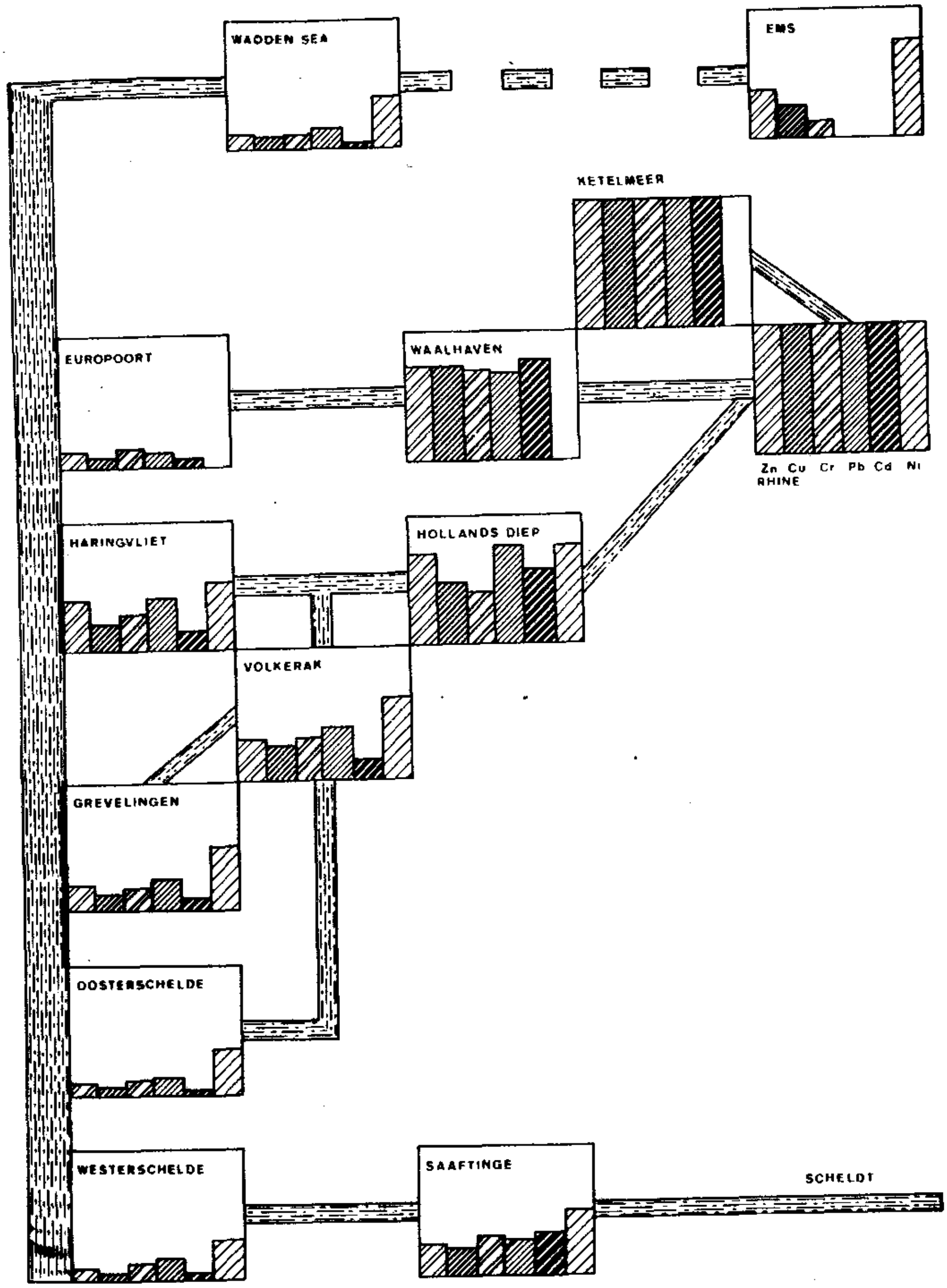

Fig. 1. Heavy metals in deposits of the Dutch Delta. Rhine = 100

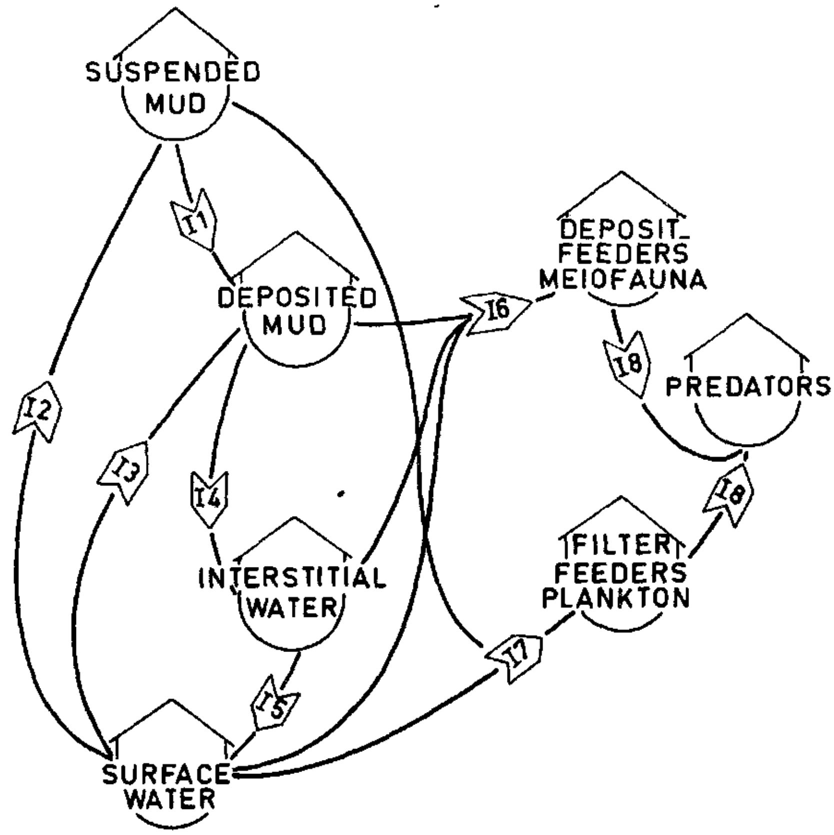

Fig. 2. Review of the role of heavy metals in an aquatic ecosystem.
I1: Sedimentation, transport, erosion.
I2: Adsorption of metals to suspended matter. Precipitation of dissolved metals.
I3: Reactions between surface water and deposited mud.
I4: Provision of the interstitial water with heavy metals.
I5: Escape of metals from the interstitial water to the surface water.
I6, I7: Uptake of metals by organisms.
I8: Accumulation in the food chain.

several reservoirs of on ecosystem. A survey of these reservoirs and their interactions (representing the integrated study as mentioned before) has been given in Fig. 2. Much of the present work is focused on the study of this system. We will restrict us in this summary to a few remarks in this respect.

As abiotic reservoirs the deposited mud, the interstitial water, the suspended material and the surface water can be distinguished. Under reduced conditions the deposited material can provide the interstitial water with rather high concentrations of heavy metals. The latter can escape to the overlying waters by means of processes of diffusion, consolidation, erosion and bioturbation. In polluted rivers there is not always an equilibrium between the metals dissolved in the water and those bound to the suspended matter. A longer residence time of the river water in a reservoir like Lake IJssel may favour the fixation of the metal to the suspended matter and subsequently give rise to more polluted deposits, as a consequence of sedimentation.

The contribution of the 4 abiotic reservoirs to the heavy metal burden of organisms depends on their way of life. In Fig. 2 some biotic reservoirs have been indicated, as they are investigated by the Central laboratory TNO.

As a representative organism for the water phase (surface water and suspended matter) e.g. the mussel (Mytilus edulis) is used in both laboratory and field experiments. As deposit feeders certain worms (e.g. Arenicola maritima) can be used. Under fresh water conditions similar organisms are available. These studies have proved that organisms which accumulate heavy metals are very useful for the characterization of the significance of heavy metals in the aquatic environment.

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