THE SOIL ENVIRONMENT OF THE INTERTIDAL AREA IN THE WESTERSCHELDE

OENE OENEMA, ROB STENEKER and JAAP REYNDERS

KEYWORDS: estuary; intertidal area; soil environment; biogeochemical processes; heavy metal contamination.

ABSTRACT

Hydrodynamic forces and sediment discharges determine the sedimentary environment and surface morphology of the intertidal area in the Westerschelde estuary in the S.W. Netherlands. Sandflats (clay content < 8%) are found in the central part, mudflats (> 8% clay) and especially salt marshes (>15% clay) occur in sheltered places.

The semi-terrestrial soil of the intertidal area is a complex environment where hydrosphere, biosphere, lithosphere, and atmosphere interact. Surface morphology and the semi-diurnal tide may significantly modify this interaction pattern. Organic matter and constituents of the clay-size fraction are the most reactive compounds in the soil.

The pathway and rate of organic matter decomposition determines the nature of many biogeochemical processes. Sulfur transformations are dominant processes in the sulfidic grey-black coloured horizons underneath the generally thin yellow-brown surface layer. The sulfur geochemistry also affects the sorption-behaviour of metals. Oxygen intrusion by diffusion, burrowing fauna and plant roots cause a local and sometimes temporary oxidation of reduced inorganic compounds. Thus, in the surface layers, and in and around tubes and roots at greater depth in the soil, a dynamic cycling occurs of redox active compounds, which affects the sorption mechanism of e.g. metals-ions.

INTRODUCTION

In the lower estuary of the Schelde river, the Westerschelde in the S.W. Netherlands (Fig. 1), extensive intertidal flats and salt marshes (11000 ha) are found. These areas have a typical landscape-morphology; they are important for biota. Below the surface, interaction occurs between the lithosphere, hydrosphere, biosphere and atmosphere; the product of these interactions is called the semi-terrestrial soil. Following PONNAPERUMA's (1972) discussion, semi-terrestrial (sub-aquatic) soil also applies to a sediment and therefore we use the term semi-terrestrial soil. A soil is defined here as the three dimensional space below the surface; it comprises all inorganic and dead-organic compounds in solid, aqueous and gaseous phase. It houses a biological community and exhibits a clear biological and micro-biological activity. A semi-terrestrial soil is subject to semi-diurnal flooding.

The Schelde estuary has main functions for navigation and for drainage of the Schelde river, carrying the discharge of industrial and densely populated area's in its catchment. Significant changes occur as regards dissolved and particulate compounds in the water-compartment and most studies deal with this compartment. It seems, however, that the soil-environment has been overlooked.

The soil in an estuarine ecosystem has three main functions: - source and sink function for e.g. sand, mud, organic matter, nutrients, and contaminants; - regulation function:
it acts as a biological waste-treatment and several biogeochemical processes adjust and transform both the solid and dissolved constituents; - carrying function: the soil is the habitat of vegetation and zoobenthos and the fundament of several human activities. Moreover the soil gives site-specific information on environmental processes in a historic perspective.

In the following paragraphs some characteristic features of the soils of the intertidal area in the Westerschelde are discussed. The multi-functional character of the soil and its complexity are to some degree illustrated by the discussions about the effect of sedimentation processes and surface morphology on the soil. Human influences are among other things reflected in heavy metal contamination.

This work is based on field studies in the Westerschelde since 1984 and on experiences obtained elsewhere.

SEDIMENTATION OF SOLID MATERIAL

Sedimentation of solid material on the intertidal area has two important consequences: - accretion of the surface in order to keep pace with or even exceed the relative sea-level rise; a steady supply of new, reactive materials which activate the biogeochemical processes occurring during early diagenesis in the semi-terrestrial soils.

The relative sea-level rise in the Westerschelde at Vlissingen is 0.22 cm y\(^{-1}\), but the rise in mean high water level approaches 0.4 cm y\(^{-1}\) during the last century (DE RONDE, 1983). This faster rise results from embankments, and thus from the subsequent decrease in basin storage capacity, and from dredging in tidal channels, causing an increase in tidal volume. The sediment supply in the Westerschelde exceeds 4 - 8 times the demand of approximately 0.2 - 0.4 \(10^6\) m\(^3\) y\(^{-1}\) of the intertidal area required to keep pace with the relative sea-level rise. High accretion rates of 2 - 4 cm y\(^{-1}\) have been found in the marshes at Saettinge during the last few decades (pers. comm. Frank Steyaart). Several major mud sources can be distinguished (e.g. VAN MALDIGEM, 1987): - discharges by the Schelde river (0.7 - 1 \(10^6\) ton y\(^{-1}\)); - internal sources (primary...