Coastal sands as biocatalytical filters (COSA)

by Markus Huettel (and others)

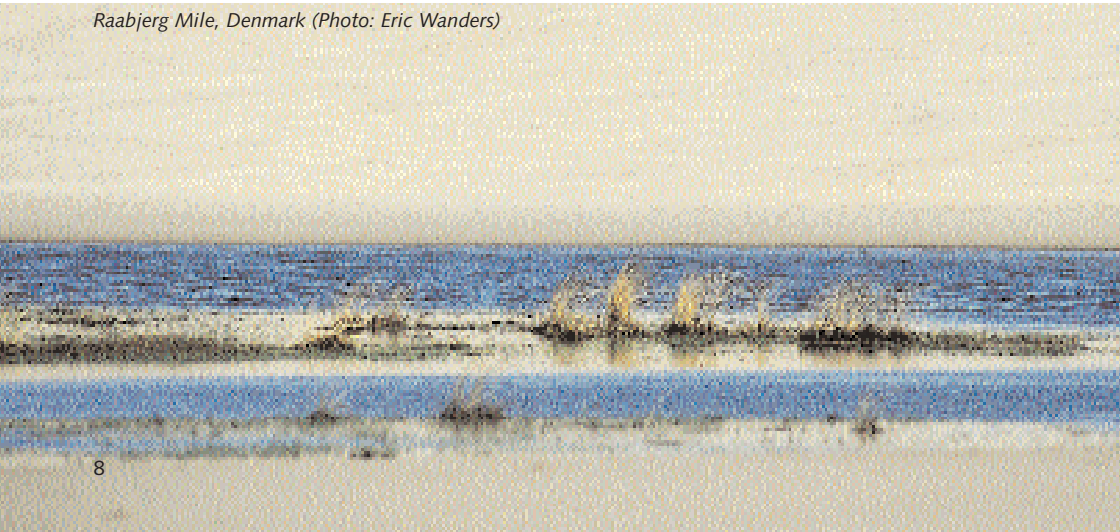
The 1st of November 2002 marked the starting date for a new RTD Project funded by the European Community: COSA – Coastal sands as biocatalytical filters. Seven institutes from four European Countries participate in this project that focuses on the ecological role and management of nearshore marine sandy sediments.

Biogeochemical activity

Sandy sediments are the dominant sediment types along the European coasts, and a closer look reveals that these deposits are of significant socio-economical value. They provide the most productive fishing grounds, are major sources for a variety of raw materials (oil, gas, water, and minerals), and form our recreational beaches. At the same time coastal zones are seriously affected by habitat destruction, water contamination and resource depletion. Despite their importance, permeable coastal sands have been poorly studied with respect to their role in the coastal cycles of matter. As their light color reveals, organic matter and nutrient pools in near-shore sands are rather low, which led to the erroneous impression among scientists and coastal managers that these sediments are biogeochemically relatively inactive. Recent investigations (by Jahnke et al., 2000, Lohse et al., 1996, Marinelli et al. 1998), however, indicated that the contribution of permeable sands in the coastal cycles of matter may be underestimated. Shelf sands may be as active as organic-rich fine-grained sediments, and fluxes of oxygen and nutrients can reach similar magnitudes, but high pore-water transport rates in these permeable sediments limit depletion of oxygen and accumulation of solutes in the pore water (Shum and Sundby, 1996, Bacon et al., 1994).

Lack of research

The belief that sands are relatively inactive may be the reason why research efforts addressing permeable sands were comparably small, investigation methods and techniques are not well developed and quantitative data on the functioning of this ecosystem are very limited (Boudreau et al. 2001). The consequence of the lack of quantitative data is that permeable sands are not well represented in coastal management concepts and that the public and policy makers are not aware of their importance.



Raabjerg Mile, Denmark (Photo: Eric Wanders)

Finally, these environments and their resources may not be sufficiently protected in relation to their socio-economical importance.
COSA is designed to address this problem by:
- assessing transport and biogeochemical reaction in permeable sediments;
- generating a model with predictive capabilities;
- transfer of knowledge and technologies concerning processes in sands;
- implementation of the scientific results into monitoring programs and recommendations for the sustainable use of coastal environments, and
- improving the awareness of the public and policy makers.

Filtering capacity of marine sands

In contrast to fine-grained, cohesive sediments, where the main transport mechanism is molecular diffusion, pore water can flow through the interstices of permeable marine sands causing advectional transport of solutes and particles (Fig. 1). The velocity of this advective transport can exceed that of molecular diffusion by orders of magnitude emphasizing the importance of this process for sediment-water exchange of matter. Coastal sands are subjected to different pore water flow regimes, such as net flow through the whole sand body, a mosaic of local inflow and outflow, and groundwater flow. These regimes are controlled by tidal amplitudes, the sediment roughness, hydrodynamics of the overlaying water and wave action.

Pressure gradients that develop at the sediment water interface when bottom currents interact with small surface topography (e.g. ripples, mounds, funnels generated by benthos fauna) force water and its suspended particulate matter into the sediment and pore water out of the bed (Huettel and Rusch 2000). The porous coastal sand beds act in this way as expansive filter systems. Mass fluxes through such beds are a function of the volumetric exchange and concentrations in the inflowing and outflowing stream. The interfacial water flows provide substrates and electron acceptors for sedimentary microbial decomposition processes. More than 90% of the bacteria that live in the surface layers of permeable marine sands are attached to the sand grains, and these organisms process and degrade the substances that are filtered through the bed converting the sands into biocatalytical filters.

Main goal

The Fifth and Sixth Environmental Action Programmes initiated a European-wide action to improve the sustainable use of the coastal environments. Discharge of rivers, run off from land, precipitation and groundwater carry large amounts of nutrients and pollutants into the sea. In the shallow coastal zone, these materials are rapidly mixed down to the sea floor highlighting the potential importance of the biocatalytical filtration in permeable sand beds but also the high risk of contamination for these sediments.

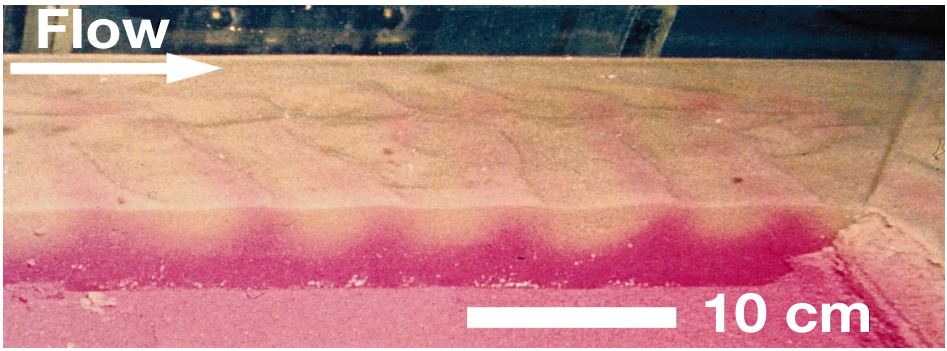


Fig. 1 Advective pore water transport in permeable sediment. Permeable sands exchange fluid and particles with the overlying water through advective pore water flows. In a laboratory experiment, red tracer dye shows the flushing of pore water from the sediment due to the advective pore water flows caused by unidirectional bottom flow (Photo by: M. Huettel).

The main goal of COSA is the improvement of the sustainable use of sandy coastal environments in Europe. This can only be achieved by generating a solid base of knowledge. Without a thorough mechanistic understanding of the system the formulation of recommendations and management concepts would be neither possible nor convincing.

The participants

In order to achieve this goal a wide array of investigations ranging from the analysis of historical data to physical, chemical and biological measurements is necessary. This is accomplished by the interdisciplinary combination of complementary expertise provided by the participants of COSA (Fig. 2).

Project field sites

Research in COSA will investigate processes in sand sediments at two field sites located on the Polish and German coasts that represent typical sandy environments of the North Sea and Baltic (Fig. 3). Due to their shallow water depths, densely populated coasts and high input of nutrient-rich polluted water from rivers, terrestrial run-off and atmosphere, the North Sea and Baltic are among the most vulnerable European seas.

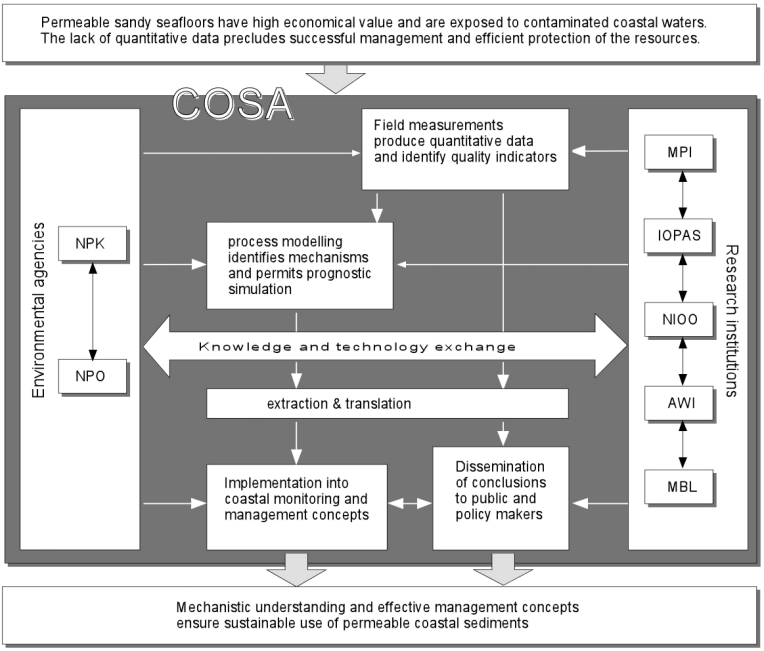


Fig. 2 The concept of COSA and the participants of the project.
The Nadmorski Park Krajobrazowy on the Polish Coast (NPK) and the Nationalpark Schleswig-Holsteinisches Wattenmeer (NPO) have accumulated a wealth of information on the two representative field sites that will be investigated within COSA. The Institute of Oceanology, the Polish Academy of Sciences (IOPAS) and the Alfred-Wegener Institute (AWI) did scientific research at these field sites over the last five decades and will integrate this knowledge into COSA. The Institute of Oceanology, the Netherlands Institute of Ecology (NIOO), the University of Copenhagen Marine Biology Laboratory (MBL) and the Max Planck Institute for Marine Microbiology (MPI) are active in the fields of benthic processes, diagenetic modeling, sedimentological processes, microbial ecology and pore water transport. Bringing together this knowledge and expertise will have a multiplicative effect and facilitate an in-depth assessment of the processes governing coastal sands.

Because in the shallow water the majority of suspended particles can settle to the sea floor, North Sea and Baltic sediments are important sites for processing and storage of organic matter, and they function as sinks and sources for nutrients and contaminants. The project field sites were chosen not only for their respective importance to the local environments and their link to environmental agencies, but also because they represent "type" environments that will allow for the broadest, practical range of study within the context of this project.

Concept of COSA

COSA has a two-pronged concept combining scientific research and implementation of the results by end-users participating in the project. This combination ensures efficient conversion of the scientific results into community environmental objectives. The research tasks include intensive field campaigns and time series measurements of key parameters. Special attention will be given to the filtration processes and fluxes of dissolved and particulate matter, and the impact of animals, plants and microorganisms on biogeochemical reactions. The data on filtration and mineralization rates in permeable coastal sands provide crucial information for nutrient, contaminant and waste management. The investigations will produce quantitative data of transport, geochemical and microbial processes for development and validation of a transport-reaction model. Such models are important tools that coastal management agencies employ to evaluate impacts of nutrient and carbon loading on the marine environment and the establishment of monitoring regimes. The participating local environmental agencies add the broad data basis and historical data that are essential for the interpretation of the results and successful modelling, and implement the research conclusions and model results into their coastal management concepts.

The results

COSA will quantitatively show how sandy sediments react on changes in the water column composition. The project results will indicate where the limitations of sandy ecosystems are reached and thereby provide essential information necessary for the preservation of this environment and its important resources. As integral part of ELOISE (European Land-Ocean Interactions in the Coastal Zone), COSA will contribute to the international resarch on coastal zone processes. COSA supports the goals of the SCOR Group "transport and reaction in permeable sediment" that aims at a better understanding of the mechanisms governing biogeochemical processes in sandy sea beds. A better understanding of the sandy coastal seafloors will not only help to preserve a healthy coastal ecosystem but also ensure the quality of life, health and safety in the coastal zone and human population.

The Authors: Markus Huettel, Max Planck Institute for Marine Microbiology (MPI)
Jan-Marcin Weslawski, Institute of Oceanology Polish Academy of Sciences (IOPAS)
Stanislaw Massel, Institute of Oceanology Polish Academy of Sciences (IOPAS)
Jack Middelburg, Netherlands Institute of Ecology (NIOO)
Justus van Beusekom, Alfred Wegener Institut für Polar- und Meeresforschung (AWI)
Ronnie Glud, University of Copenhagen (MBL) Jaroslaw Jaszewski, Nadmorski Park Krajobrazowy (NPK)
Adolf Kellermann, Nationalpark Schleswig-Holsteinisches Wattenmeer (NPO)

Further information can be obtained from the co-ordinator Markus Huettel (mhuettel@mpi-bremen.be)

The article (including references) is available at www.coastalguide.org/denmark/index.html

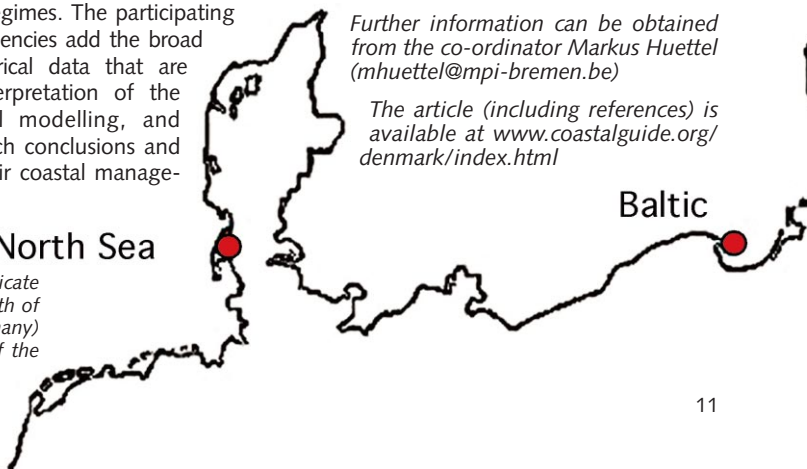


Fig. 3 The red circles indicate the field sites in the North of the Island of Sylt (Germany) and on the East coast of the Hel peninsula (Poland)

References

Bacon, M. P., Belastock, R. A. & Bothner, M. H. (1994) 210Pb balance and implications for particle transport on the continental shelf, U.S. Middle Atlantic Bight. *Deep Sea Research Part II Topical Studies in Oceanography*, **41**(2-3), 511-535.

Boudreau, B. P., Huettel, M., Froster, S., Jahnke, R. A., McLachlan, A., Middelburg, J. J., Nielsen, P., Sansone, F., Taghon, G., Van Raaphorst, W., Webster, I., Weslawski, J. M., Wiberg, P. & Sundby, B. (2001) Permeable marine sediments: overturning an old paradigm. *EOS*, **82**, 133-136.

Huettel, M. & Rusch, A. (2000) Transport and degradation of phytoplankton in permeable sediment. *Limnology & Oceanography*, **45**(3), 534-549.

Jahnke, R. A., Nelson, J. R., Marinelli, R. L. & Eckman, J. E. (2000) Benthic flux of biogenic elements on the Southeastern US continental shelf: influence of pore water advective transport and benthic microalgae. *Continental Shelf Research*, **20**(1), 109-127.

Lohse, L., Epping, E. H. G., Helder, W. & Vanraaphorst, W. (1996) Oxygen Pore Water Profiles In Continental Shelf Sediments Of the North Sea - Turbulent Versus Molecular Diffusion. *Marine Ecology Progress Series*, **145**(1-3), 63-75.

Marinelli, R. L., Jahnke, R. A., Craven, D. B. & Eckman, J. E. (1997) Benthic microalgal production and sediment nutrient inventories on the south atlantic bight (sab) shelf: the relative importance of nutrient regeneration, uptake, bioirrigation and advection. In: *Aquatic Sciences Meeting, , February 10-14, 1997*, pp. 232. ASLO, Santa Fe, New Mexico.

Shum, K. T. & Sundby, B. (1996) Organic matter processing in continental shelf sediments - The subtidal pump revisited. *Mar Chem*, **53**(1-2), 81-87.

Wallmann, K., Linke, P., Suess, E., Bohrmann, G., Sahling, H., Schluter, M., Dahlmann, A., Lammers, S., Greinert, J. & Vonmirbach, N. (1997) Quantifying Fluid Flow, Solute Mixing, and Biogeochemical Turnover At Cold Vents Of the Eastern Aleutian Subduction Zone. *Geochimica et Cosmochimica Acta*, **61**(24), 5209-5219.