Geophysical Research Abstracts, Vol. 8, 05578, 2006
SRef-ID: 1607-7962/gra/EGU06-A-05578

Sustainable planning of underwater sand mining and beach protection in vulnerable semi-enclosed sea areas under heavy anthropogenic pressure

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Large mining and nourishment projects in the neighbourhood ot Tallinn Bay

During the latter decade the intensity of various development activities at the shores of Estonia has explosively increased. This small country with extremely long coastal line (about 3800 km) lies in the north-eastern part of the Baltic Sea, which is treated as a particularly sensitive sea area since 2005. A major part of the construction works has been concentrated in the vicinity of Tallinn, the capital of Estonia. This area is specifically under anthropogenic pressure which besides includes intense construction works at the coasts, release of large amount of waste water, which is properly pre-treated but still carries components favourable to eutrophication with it [1], and unique level of long-wave hydrodynamic activity due to wake waves from fast ferries [2].

A large part of activities is connected with development of ports in the area in question. Their eventual extension towards the sea requires a vast volume of landfill material. Approximately 3 mio m^3 of landfill material was required for the construction of a coal terminal of Muuga Harbor located in a bay neighbouring Tallinn Bay. In the future, construction of major breakwaters is planned, which requires even larger volumes of filling material. Large amount of sand is also necessary for nourishment of the major recreation area in the Tallinn region, the sand beach at Pirita [3].

From both economical and environmental points of view, mainland sources of landfill, which are quite limited in the area in question [4], have been left aside, and the material

has been, and apparently will be, taken from coastal sea areas in the vicinity of Tallinn.

We report the results of several specific studies and precautionary activities, which were undertaken additionally to the standard procedure of environment impact assessment, and were targeted to mitigation of the influence of both underwater mining and beach nourishment to the local ecosystem and the adjacent coasts [5].

Studies of potential changes of wave, current and suspended matter transport regime

Since the mining areas are located relatively close to sensitive beaches, a thorough study of the local wave climate and its potential changes was undertaken [5]. The main concern was that bathymetric changes may change the downwind wave regime and cause enhanced coastal erosion [6]. The use of a fast method for assessment of wave properties specifically developed for semi-enclosed sea areas [7] allowed making high-resolution wave climate simulations covering a few decades for both the original and after-mining bathymetry within reasonable computing time. For specific patterns of sand removing the wave climate at the coasts located leeward from the mining area will be even milder than the existing one. This occurs due to specific combination of the geometry of the Gulf of Finland and the directional distribution of dominating winds. In certain perspective mining areas the potential influence of long waves from fast ferries has been shown to play a role as well.

Despite of extensive studies of wave regime and its potential alteration, and encouraging results of these, problems arose in the neighbourhood of one of the sand mining areas [8]. A sandy headland underwent substantial erosion after the mining was completed. However, the probable reason of the enhanced erosion was a combination of extremely heavy wave conditions in a storm after the mining [9] and apparent ignoring the requirements formulated in the environment impact assessment [10]. According to reports in daily newspawers, at places several meters of a thicker layer was probably mined and a part of mining was evidently performed in a restricted area [11].

Another major study was performed to understand the consequences of the release of suspended matter into marine environment [5]. Since the models of currents and suspended sediment transport are not perfect yet, forecasting the sedimentation areas of suspended matter (both intermediate and final deposition) is a problematic issue today. The basic hope is that most of the material is fine–grained and therefore it finally it will be deposited in a deeper sea area where the benthic communities are either absent or poorly represented. The intermediate sedimentation may cause certain substantial problems but it apparently has no crucial effect on a long-term balance of benthos in shallow sea. To mitigate the short-term adverse impact of increased (re)sedimentation of suspended matter, underwater mining the mineral resources has been forbidden

during the spawning period of fish [5,11].

Influence of anthropogenic waves on beach nourishment projects

The presence of long ship wakes creates a specific concern in beach nourishment projects in the vicinity of Tallinn Bay. The dimensions of such a project at Pirita beach as well as sections of coastline with increased seaward and landward sediment transport were identified based on *in situ* measured profiles, numerical estimates of wind wave conditions, and theory of equilibrium beach profiles [3]. The largest impact of wake wash from intense high-speed traffic on the bottom of certain non-tidal areas occurs on considerably larger depths than the impact of storm waves [2]. Although the presence of ship wakes formally does not change the closure depth in inner parts of Tallinn Bay, it still may add a substantial component to near-bottom sediment transport, the amount of which has to be quantified in order to correctly desing the whole project. Another feature of potential importance of this nourishment project is the asymmetry of wakes from inbound and outbound traffic, which may modify the estimates of longshore sediment transport obtained from simulations of wind waves.

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