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Suspended particulate matter (SPM) in the Baltic Sea—New empirical data and models

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Abstract

This work presents new data on suspended particulate matter (SPM) in the Baltic Sea (from the part called the Baltic proper). Previous reports on SPM from the Baltic Sea and other marine areas are very scarce in spite of the fact that SPM is of fundamental importance in aquatic ecology and management since it regulates the transport of pollutants and influences water clarity and phytoplankton production as well as bacterioplankton production, and hence also secondary production (of zooplankton and fish). It is, evidently, very demanding to collect data at sea during storm events and this paper presents data from 5 sites and 17 sampling occasions in 1999 and 2001 collected along gradients concerning temperature, salinity, exposure, depth and winds (also during storms). The data have been used to address problems related to the variability of SPM, and, hence also the predictive power of models for SPM. The characteristic coefficients of variation (CV = standard deviation/mean value) for SPM among and within these sites are very high, 0.69 and 0.67, respectively. Using statistical methods, the factors influencing the SPM-variability have been quantified and ranked and regressions for SPM under stratified and mixed conditions presented. The model for stratified conditions is based on the following variables (1) exposure (a measure of wind-induced wave influences), (2) number of days with wind speeds lower than 5 m/s, and (3) mean salinity. The following factors are important for the vertical SPM-variability within sites (1) water temperature and (2) distance from the bottom. SPM increases with increasing temperatures (related to increased production and stratification) and decreases with increasing water depth, wind exposure, salinity, and with the number of calm days. The reasons for this are discussed. The factors regulating the SPM-variations among and within these sites should also apply to other marine areas. Studies in other areas cannot, however, falsify these empirical results but they could clarify the boundary conditions for these models and improve our knowledge about the factors regulating SPM. This model for SPM is primarily meant to be used as a sub-model within more comprehensive models, which aim to predict key ecosystems variables, e.g., toxins in fish or production and biomass of functional groups of organisms. We have also introduced and motivated a new concept "coastal focusing" analogous to "sediment focusing" in lakes.

Keywords: Suspended particulate matter; Baltic; Empirical data; Models; Wind; Exposure; Salinity; Temperature

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1. Introduction

Suspended particulate matter (SPM) plays many important roles in aquatic systems (Håkanson and Boulion, 2002). For example, SPM regulates the two major transport pathways, the dissolved pelagic route and the particulate sedimentation and benthic route, of materials and contaminants. SPM transports all kinds of pollutants, such as organics (Clark, 1986; Axelman, 1997), nutrients (Håkanson, 1999), heavy metals and radionuclides (Wieland et al., 1991). At lower trophic levels, the carbon content of SPM is crucial as a source of energy for bacteria, phytoplankton and zooplankton (Wetzel, 1983; Jørgensen and Johnsen, 1989). SPM is also directly related to many variables used in water management as indicators of water clarity (e.g., Secchi depth and the depth of the photic zone; see Hellström, 1991; Somlyody and Konscos, 1991). Understanding the mechanisms that control the distribution of SPM in aquatic systems is an issue of both theoretical and applied concern.

Practically useful, predictive empirical/statistical models exist to for SPM-concentrations in lakes (Lindström et al., 1999) and rivers (Håkanson et al., 2005). For Baltic coastal areas (i.e., defined areas and not sampling sites), there are also validated mechanistically based dynamic models based on differential equations to handle the factors and fluxes regulating SPM-concentrations (such as tributary inflow, primary production, exchange processes between the coast and the sea, sedimentation, resuspension, burial, mineralization, etc., see Håkanson, 1999; Håkanson et al., 2004). There are many papers from other systems where SPM-concentrations are discussed, but to the best of our knowledge, there exist no practically useful models that may be run using few and readily available driving variables (*x*). One reason for this may be the difficultly that also we have faced to collect SPM-data in a coherent manner from defined sites in a gradient from calm to stormy conditions. Hopefully, the models presented here can be used as sub-models in wider ecosystem contexts where the aim may be to predict other important variables, e.g., related to toxins in fish or production and biomasses of key functional groups of organisms. For the open Baltic Sea (Fig. 1), there is very limited knowledge of SPM, its variation and the factors influencing variation among and within sites. A default value of 3 mg/l (from Pustelnikov, 1977) has often been used for SPM in the Baltic Sea. From data given by HELCOM (1998), one can note that approximately 7500×10^3 tonnes SPM per year are transported into the Baltic Sea by rivers, most coming from the former Soviet Union (USSR), Poland and Sweden.

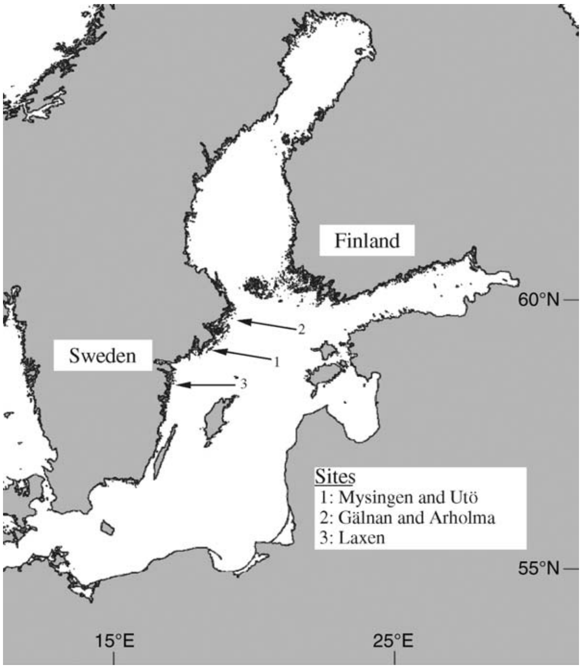

Fig. 1. Location map illustrating the geographical positions of the three investigated sites in the Baltic Sea.

Many factors are known to influence SPM-concentrations in aquatic systems (Vollenweider, 1958, 1960; Kiefer and Austin, 1974; Brezonik, 1978; Wetzel, 1983; Dubko, 1985; Ostapenia, 1989; Ostapenia et al., 1985; Boulion, 1997; Tilzer, 1988; Velimorov, 1991; Håkanson and Boulion, 2002):

(1) Autochthonous production. In the Baltic Sea, this is related to both phosphorus and nitrogen as well as climatological factors such as temperature, light and water clarity (Wallin et al., 1992; Wulff et al., 2001).
(2) Allochthonous materials, such as humic, fulvic and minerogenic substances. The inflow of allochthonous matter is especially important in estuaries.
(3) The material resuspended from the sediments via currents, wind/wave activity, slope processes, etc.