Presence and Sources of Pollutants in the Baltic Sea

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Environmental problems of the Baltic Sea have been among the major concerns of its coastal states during the past 25 years. Practically all the threats to the Baltic environment discussed during the First UN Conference on the Human Environment in Stockholm in 1972 are still actual topics in the environmental debate and objects of environmental research. At the same time new, severe problems have been identified, not least those caused by toxic substances. There are still good reasons to be worried about the presence and effects of PCBs, DDTs and heavy metals but for most of "new" contaminants we still have to deal with first-generation estimates only. For some of these substances concentrations in, e.g., sediments or selected organisms are known (even if fragmentarily) whereas both their sources and effects are unknown or badly understood: polychlorinated benzenes, naphthalenes, paraffins and terphenyls, polycyclic aromatic hydrocarbons, chlorinated camphenes, hexachlorocyclohexanes, dibenzofurans, dibenzodioxins, etc.

A challenge for ecotoxicology

The purpose of this paper is to point out some of the difficulties in mapping the sources and monitoring the presence of pollutants in the Baltic Sea. It is a Sea of Gradients, both physical, chemical and biological (surface-bottom; east-west; entrance-innermost bays (distance about 1,500 km, latitudinally from 54° to 66°N). The surface water salinity declines from >20 0/o0 in Kattegat to <3 0/o0 in the inner parts of the Gulfs. Gradients largely modify not only the target ecosystem but also the effects of chemicals on biological systems; consequently, results from ecotoxicological studies carried out at one point along a gradient cannot, without caution, be extrapolated and applied to the whole Baltic ecosystem (see Leppäkoski and Bonsdorff 1989 for further discussion).

The usefulness of the main gradients as baselines for ecotoxicological statements is restricted due to stochastic variations in the non-living environment. The system is subjected to huge variations between seasons; some properties (e.g. ice cover, annual benthic algae, migrating birds and fish) vary from abundant presence to total absence according to season. Water movements on different scales (from mm to hundreds of km) and of varying duration (from seconds to years) tend to redistribute not only nutrients and organisms but also chemicals, and influence exposure conditions. Currents (induced chiefly by winds and water-level fluctuations), upwelling-downwelling phenomena and turbulent mixing contribute to this hydrodynamic instability, resulting in unpredictable and intermittent exposure to point-source discharges.
Gradients are easy to describe on a basin-wide scale. When the scales are reduced to levels at which local populations of organisms live, no gradient factor or exposure to chemical substances is acute or chronic; they are generally intermittent, but even so most testing is acute (Rand & Petrocelli 1984). A pollutant may be pulse-dosed into the receiving water, e.g. due to the rhythmic nature of several industrial processes. The duration of exposure to a certain discharge may thus vary from minutes to several months, with regular (or most often completely irregular) intervals, and the actual concentrations of a toxicant change, within a short period of time, from 0 to 100 per cent of the potential maximum.

It follows from the ecosystem variability (in combination with the multi-dimensional network of gradients) that exposure conditions are difficult to predict. It is necessary to limit the number of subsystems to be monitored to those which are ecologically well-known and to areas from which relevant background documentation is available. In a hazard assessment process of any particular chemical substance always three components are involved: (1) exposure-related criteria, (2) effects-related criteria, and (3) characteristics of target organisms and ecosystems; thus, "a chemical substance is considered as hazardous to the environment if it (by itself or in combination with other substances), when released to the environment and because of its exposure-related properties (partitioning, persistence, bioaccumulation potential), may cause significant damage to ecosystems or their living components" (Landner 1989).

Keeping these triplicate demands in mind, for an exposure analysis in a Baltic Sea perspective following minimum-set of exposure criteria is needed (Landner 1989): (1) annual volume used in surrounding countries, (2) fraction released into the environment, (3) initial recipient (air, water, soil, sewage works), (4) estimated environmental partitioning, (5) transformation potential, degradability, (6) bioaccumulation potential, and (7) bioavailability.

A major influx (> 300 km$^3$) into the Baltic Sea of well-oxygenated Kattegat water took place in January 1993 for the first time since 1977. During these more than 15 years of stagnation, large amounts of metals (e.g., Hg, Cd, Pb, Zn) together with other harmful substances and nutrients have been deposited in the sediments in remobilizable forms. The recent inflow may oxygenate and remobilize (not least by bioturbation, caused by mixing by bottomliving animals that rapidly recognize the formerly lifeless bottoms) remarkable amounts of chemicals in the deep basins that have been virtually anoxic covering periodically about 100,000 km$^2$, i.e., one fifth of the total bottom area of the Baltic. The highest metal concentrations were found in the centre of basins with very fine-grained material (local sites, contaminated by heavy metals from industrial sources, excluded; Hallberg 1991, Perttiä and Brügmann 1992). The contents of Zn in the uppermost sediment layer of the deepest parts of the Gotland Basin were 400 to 500 ppm, compared to values <100 ppm obtained in shallower areas. High correlation factors have been recorded between Zn and other trace metals (except Hg); therefore, Zn can be roughly used as a universal indicator of contamination of sediments by heavy metals.

This example illustrates one of the many factors that influence the spatial distribution pattern of contaminants in the Baltic Sea (Gaul 1992; Brügmann et al. 1992; modified): (1) background contamination levels (high in the Baltic due to the