A 30-YEAR CLEAN-UP FROM INDUSTRIAL POLLUTION IN LAKE VÄNERN, SWEDEN

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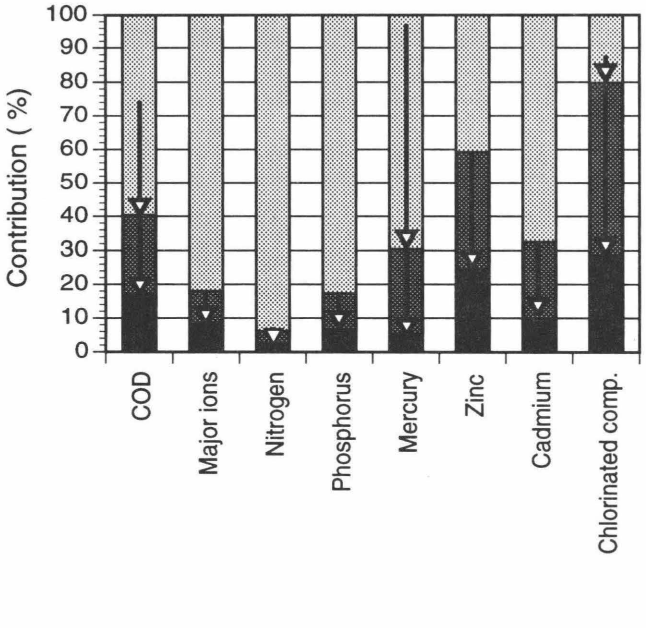
Lake Vänern is the third largest body of fresh water in Europe and the largest lake in Sweden with an areal extension of 5890 km^2, containing 153 km^3 of water with a water turnover time of 9 years. The lake has a low productivity (oligo–mesotrophic) and slightly brownish water (ca 15 mg Pt/l).

With an onset during the late 19th century the cellulose industry expanded rapidly along the watercourses draining into the lake and along the shores of the lake. A total of 63 pulp and wallboard mills were put into action during 1900–1970, of which 16 remanined open in 1970. Five paper and pulpmills and one producer of cellulose fiber ("Ryon") still remain in 1996. Effluents from these units affect the water quality of the lake.

Other inputs of substances to the lake derive from forested areas (70% of drainage area), farm land (12 % of area) and from a population of 700 000 inhabitants. Advanced municipal sewage treatment including chemical precipitation was introduced 1975–82 in major sewage works.

In 1968, a monitoring program of substance input to the lake was started in the 12 major inlets to the lake, followed by chemical and biological monitoring of the lake from 1973 onwards. Complementary inventories of point source input of substances to the lake brought forward the role of industrial pollution as compared to input from other sources.

In the figure below eight groups of pollutants derived from the cellulose industry are compared to the total input to the lake (=100%). The uppermost parts of the columns give the contribution from "other sources". The rest is the industrial contribution to the input in 1974–75. Dissolved organic substances (COD) almost doubled the input to the lake, coloured the water brown and potentially affected most parts of the ecosystem. Major ions derived from process chemicals contributed almost 20% of the salt total. Phosphorus and nitrogen contributions were low compared to other sources, of which



sewage and agricultural drainage were significant, as well as atmospheric fallout of nitrogen. Mercury was derived mainly from a plant using mercury as a catalyst for producing chlorine (and sodium hydroxide) for bleaching purposes. Huge contributions of zink and cadmium emanated from the cellulose acetate plant. In the late 80-ies a mapping of inputs of chlorinated organic compounds showed that the industrial losses from bleaching of paper and pulp had since the 60-ies dominated the input to the lake.

Reductions of inputs have to date (1994-95, black columns in the picture) reduced the industrial contributions as shown by arrows in the figure. Inputs of some substances have been possible to backcalculate to 1965 (eg. COD which then contributed 75% of the input to the lake) and additional arrows then show input reductions from that year.

The closing of mills – specifically old sulphite pulp mills – formed the basis for the clean-up of the lake. Offensive measures like better recirculation within processes, total exchange of processes (eg. abandoming of chlorine for bleaching and exchange to a non-mercury manufacturig process for chlorine) and sewage treatment made it possible to both reduce pollution and further increase production in the remaining mills.

Primarily a general concentration decrease of a number of substanses within the lake was seen. For instance, the reduced water colour raised the secci depth from 2,5–3 m to ca 5,5 m. Secondary effects include photosynthetic production which came to extend into a deeper stratum. The previously intensive photosynthesis in the surficial layer was reduced and proceeded at slower rate but to larger depth, so that total production in a water column showed small changes. Obviouly there was a regulaton of culumn production by available phosphorus whereas the light penetration allocated the production vertically.

A slight reduction in phosphorus concentration was also seen over the years while phytoplankton chlorophyll increased slightly in the 1990:ies giving a more efficient transfer of phosphorus to chlorophyll, possibly due to a reduction of biologically inactive phosphorus. Other biological effects of the reduced input of organic substances would include lowered bacterial production and food chain effects thereof, although such aspects were not monitored.

Reduced input of toxic substances correspondingly reduced the content in biota and sediment, which are the main sinks for such substances. Mercury, for example, occured in the mid 70:ies at levels up to 25 times the background concentration in deep-bottom sediments over huge areas of the lake. Sale of fish (pike) from the lake was banned due to high mercury content (>1 mg/kg ww). Fish mercury content in pike in the most polluted receiver basin adjacent to the emitting plant decreased from 1,3 to 0,8 mg/kg ww in 20 years following the onset of emission reductions. Data indicate that in ten years sediment mercury concentrations in the most exposed basin were reduced to 1/3 of the initial, whereas sediment mercury concentrations were cut to half over large areas of the deep bottoms. However, persistent compounds like mercury and chlorinated compounds still remain in elevated concentrations in fish as compared to background levels and a better understanding of crucial processes is needed. The possibility also remain that the bulk group "chlorinated organic compounds" may contain yet unknown harmful substances.

On the whole, however, the conditions in Lake Vänern vill fairly soon reach an equilibrium with present-day input in which industrial outlets have a very modest role; the rehabilitation from severe industrial pollution from ca 1945 to ca 1980 will be completed.