TIMESCALES OF NUTRIENT LOSSES FROM LAND TO SEA - A EUROPEAN PERSPECTIVE

Grimvall, A.[1], *Stålnacke, P.*[2] *and Tonderski, A.*[2]
1) Dept. of Statistics, P.O. Box 7013, Swedish University of Agricultural Sciences, SE-75013 Uppsala, Sweden; 2) Dept. of Water and Environmental Studies, Linköping University, SE-58183 Linköping, Sweden

Introduction

The export of chemically bound nitrogen from land to sea and the impact of such export on the ecosystems of the continental shelves have caused considerable concern. A goal of a 50% reduction of the nitrogen export to the North Sea and the Baltic Sea from 1987 to 1995 has been adopted by HELCOM (Helsinki Commission) and OSPARCOM (Oslo-Paris Commission), and action programmes have been initiated to reduce the emissions of nitrogen to both water and air. Now that emission data for the first half of the 1990s are becoming available, it is obvious that the goal of a 50% reduction of the nutrient loads will not be achieved. Slow implementation of proposed measures may be one important reason the goal has not been realised. However, it has also become clear that the aquatic and terrestrial systems that control the release of nutrients to the sea have an intrinsic inertia that may substantially delay and reduce the impact of implemented measures. In the present article we address and discuss empirical data that may elucidate the timescales of nutrient losses from land to sea. In particular, we examine the impact that changes in agricultural practices and point emissions of phosphorus has had and may have on the riverine loads of nutrients.

Past Increases in Riverine Loads of Nutrients

There is no doubt that significant increases in the riverine export of nutrients from land to lakes and seas had already occurred in the 19th century. Sewage emissions mounted due to urbanisation and a general population growth, and increased draining and tilling of agricultural soils favoured erosion and leaching processes. Studies of lake sediments have confirmed that the loss of phosphorus from agricultural land increased long before commercial fertilisers were used and the well-known long-term experiments at Rothamsted Experimental Station show substantial losses of nitrogen from agricultural soils in the 1800s (Jenkinson, 1991). Nevertheless, there are strong indications that the fluxes of nutrients now causing considerable concern in large parts of Europe are primarily a post-war phenomenon. At Lobith on the Rhine River, near the border between Germany and the Netherlands, the nitrate concentration more than doubled from the mid 1950s to the late 1970s and thereafter levelled out (Behrendt & Böhme, 1993). The phosphate concentration, which has now been successfully reduced, increased almost tenfold from the 1950s to 1980. Measurements in Latvia show that there was also a significant increase in both nitrate and phosphate in Eastern European rivers during the 1950s and 1960s (Tsirkunov *et al.*, 1992). Together, the available data indicate that the present nutrient fluxes may be attributed to processes that began more than a century ago and accelerated during the first decades after World War II.

Success and Failure in Reducing Phosphorus Loads

Experience of different measures to reduce riverine loads of nutrients is almost exclusively limited to interventions invoked during the past two decades, and most case studies refer to removal of point emissions of phosphorus. There were two main reasons for the focus on phosphorus. First, undesirable eutrophication was easily observed in phosphorus-limited inland waters. Second, removal of this element could easily be introduced in existing systems for wastewater treatment. The previously mentioned time series of phosphate data from the Rhine River shows how efficient such measures can be. Over little more than a decade, the phosphate concentration was reduced to the level that prevailed in the 1950s (Behrendt & Böhme, 1993). However, the experience from the Rhine is not applicable to all river basins. This is clearly demonstrated by observations downstream of Swedish wastewater treatment plants. In the 1970s, tertiary treatment was introduced nationwide in Sweden and more than 90% of the previous point emissions of phosphorus were removed. In spite of that, there was only a small reduction in the total riverine export of phosphorus to the sea. Closer examination of data revealed that the removal of point emissions was often accompanied by an equally large decrease in the retention of phosphorus in lakes and streams downstream of the point sources under consideration.

The Nonappearance of Downward Nitrogen Trends

In contrast to the phosphorus loads, which have been successfully reduced in at least some rivers, there are no indisputable cases of decreased nitrogen loads in major European rivers. The recently observed decrease in the Rhine River is still to small to allow far-reaching conclusions (Stålnacke & Grimvall, 1997), and a thorough study of nitrogen trends in Swedish rivers showed significant load decreases in only a few rivers that had previously received large point emissions of nitrogen (Stålnacke *et al.*, 1997). Studies of Eastern European rivers provide further evidence that natural variation in runoff is the main cause of interannual variation in nitrogen loads during the past two decades. The downward trends that have been reported from that part of Europe refer to small catchments and relatively short time series of data, whereas the flow-normalised loads carried by large rivers have remained practically constant (Laznik *et al.*, 1997; Tonderski *et al.*, 1997a).

The nonappearance of downward nitrogen trends in Eastern European rivers is particularly remarkable. Due to the economic changes that occurred after the fall of the Soviet Union, there has been an unprecedented decrease in the application of commercial fertilisers and a significant decrease in the application of manure in practically the whole of Eastern Europe. In the long run, such dramatic changes in agricultural practices will influence either the yields or the losses to water. However, controlled experiments on agricultural soil have shown that a pool of organic nitrogen that has built up due to extensive use of fertilisers can be responsible for more than a decade of elevated nitrogen losses to water. This pertains particularly to areas where a decreased input of nitrogen is accompanied by decreased harvests, like in the Baltic States (Löfgren *et al.*, 1997). The absence of clear downward nitrogen trends in Polish rivers requires other explanations, because despite a more than 50% decrease in the use of commercial nitrogen fertilisers, the total harvest has been maintained at almost the same level as that achieved with full nitrogen application (Tonderski *et al.*, 1997b). A special study of the Oder and Vistula

River basins indicated the following: (i) due to hydrogeological conditions that favour retention of nutrients, the losses were already low before the recent drop in fertliser application; and (ii) interannual variation in sources other than agricultural runoff may conceal a moderate reduction in the nitrogen losses from agricultural land.

The Risk of Upward Nitrogen Trends in the Near Future

The present discussion is focused on measures to reduce emissions or losses of nutrients. Notwithstanding, the risk of an increased riverine export of nutrients, in particular nitrogen, also deserves attention, since that export is controlled not only by emissions, but by retention of nutrients in terestrial and aquatic systems as well. Budget calculations for entire river basins and subasins thereof in Europe have demonstrated that up to 80% of the phosphorus and nitrogen released to water is either trapped in sediments or removed by denitrification during the transport from the source to the mouth of a river (Behrendt, 1996), and there is no guarantee that this retention can be maintained if Western European solutions and technologies are copied by Eastern Europe. Several scientists have drawn attention to the crucial role of buffer zones in river corridors (Haycock *et al.*, 1997). Other findings show the risk of handling the nitrogen and phosphorus issues separately. The retention of nitrogen in lakes and rivers may, in fact, decrease if tertiary treatment of municipal wastewater is introduced in the river basins now receiving large quantities of incompletely treated wastewater (Chesterikoff *et al.*, 1992).

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