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Immission targets for nutrients (N and P) in catchments and coastal zones: a North Sea assessment

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Abstract

Concern about the rising concentrations of nutrients and their adverse effects on freshwater, estuarine and marine organisms led to political action in 1970s and 1980s. Emission targets, aimed at reducing the load to the aquatic environment, were set. Also, immission targets for the concentration of different nitrogen and phosphorus compounds were set in various countries.

Immission targets are the background concentration and the quality objective of nutrients. The background concentration is defined as the concentration that could be found in the environment in the absence of any human activity. The quality objective is based on eco-physiological results and adopted by policymakers in order to minimise the risk of environmental damage.

The criteria and nomenclature for targets are ambiguous and inconsistent; different names are used for the targets.

Setting target values for nutrients in water bodies that are interconnected in a catchment area is a perilous affair. A wide range in the background concentration and quality objectives for different nitrogen and phosphorus compounds in river and sea water is found between 10 European Union countries around the North Sea. For instance for nitrate the minimum versus maximum difference for the objective is 255 fold. For the coastal waters, a method is proposed that makes it possible to calculate the target at a given salinity.

It is recommended that further development of eutrophication targets, should be based on ecological science. Links must be made between the desired ecological target (e.g. chlorophyll concentration) and the chemical target at a catchment level, taking into account that water flows across borders and flows from one place to another.

Keywords: targets; nutrients; catchment; North Sea; assessment

1. Introduction

In recent decades, nitrogen and phosphorus concentrations and loads elevated (10–20 fold) due to human activities have been found in lakes, rivers, estuaries, coastal waters and the open sea (Jickells, 1998; Billen et al., 1999; Smith, 2003). The most important phenomena resulting from this eutrophication are increased primary production, changes in algal composition (Gieskes and Kraay, 1977; Reid, 1977; Radach et al., 1990; Cadée and Hegeman, 1991; Billen et al., 1999), blooms of toxic algae (Billen et al., 1999; Conley et al., 2002), decreased oxygen concentrations (Gerlach, 1984) and a reduction in the macro benthos (e.g. in the German Bight: Rachor, 1980). These phenomena and increased loads of organic matter together give rise to "black spots" in the sediments of the Wadden Sea (Rusch et al., 1998). Increased primary production and changes in the composition of primary producers are resulting in changes in the productivity of organisms further along the food chain. In general, elevated

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nutrient concentrations boost phytoplanktonic production and turnover, and also disrupt other ecological processes in fresh water, estuarine and coastal water ecosystems.

As well as adversely affecting organisms and ecosystems, eutrophication also has economic repercussions: recently, the costs of the environmental damage resulting from freshwater eutrophication in England and Wales were calculated to be between 105 and 160 million euros per year (Pretty et al., 2003).

To properly assess the impact of human perturbations on aquatic ecosystems, the natural component (e.g. background values of nutrients, and climatic effects) must be considered carefully and the various sources of the eutrophication must be known (Conley et al., 2002). The main nutrient load to coastal waters is from rivers, which in turn accumulate the loads from their tributaries that are fed by diffusive and point sources and precipitation in the catchment. All these sources contribute to the river loads of nitrogen, phosphorus and organic matter generally. In the open sea, the contribution of atmospheric deposition of nitrogen is relatively large: 40–50% of the total load (Cornell et al., 1995). In addition to wet deposition, the dry deposition of nitrogen compounds is significant.

En route to the sea the nutrients in the river are modified significantly by different biogeochemical processes, modulated by varying residence times (e.g. lakes and dams). Some compounds are adsorbed for a while, others, such as the nutrient elements N and P, are converted several times. Some nitrogen is transferred to the atmosphere as N_2 by denitrification. Particulate matter, including N and P, may be trapped for longer periods in sediments, along the river banks, in water meadows or behind dams.

The riverine nutrients enter the coastal waters and the marine environment through estuaries, where tides and salinity gradients are important. Among the ways estuarine processes can modify riverine fluxes of nutrients to the coastal sea are adsorption and desorption, sedimentation, biological uptake and denitrification. If the natural morphological and hydrographical estuarine boundaries have been changed, the fluxes to coastal waters can alter in comparison with the natural situation. If engineering work to straighten river channels has significantly shortened the river's length, the residence time is also shortened, with the result that sorption processes and denitrification diminish, which increases the nutrient loads to coastal waters. Jickells et al. (2000) have shown that more nutrients may now be entering the sea off north-east England because 90% of the intertidal area and sedimentation accumulation capacity of the Humber has been lost as a result of reclamation.

In many countries in the West, concern about the rising concentrations of nutrients and their adverse effects on freshwater, estuarine and marine organisms led to political action in 1970s and 1980s. Ministers from countries bordering River Rhine and the North Sea agreed to reduce the load of compounds, including nutrients, by at least 50% in the period 1985–1995. The current general ecological objective is to achieve a healthy marine environment free from eutrophication by the year 2010 (OSPAR, 1998a). Within the Oslo and Paris Commission (OSPAR), problem areas, i.e. areas where the concentration of a nutrient is 50% above natural background value, have been identified (OSPAR, 2001). The European Union's Water Framework Directive (WFD) strives to achieve Good Ecological Status for all surface waters in 2015 (EU, 2000).

To assess the eutrophication status in the aquatic environment, in many countries chemical and biological (or ecological) targets for the quality of river and marine waters have been assessed scientifically and incorporated into policy by policymakers. These targets, which often have unclear regulatory and legal implications (Spaans, 2002), have different names in different countries, for instance: standards, critical concentrations, background concentrations, quality objectives, thresholds, guidelines, baseline quality, maximum permissible (or tolerable) concentrations or criteria. Problems arise when the chemical targets have to be established for the area between the river and the seaward end of the catchment, i.e. estuaries and coastal waters.

In this paper, different national targets for nutrient compounds in a catchment are compared. Special attention is given to a generic method for deriving background concentrations and target levels in estuarine and coastal waters. The results are critically discussed in terms of the applicability of targets for catchment approaches and the differentiation of targets for different water bodies.

2. Method applied

Data on targets for nutrients were gathered from the literature or from colleagues in various countries (Netherlands, Belgium, Germany, Denmark, France, Ireland, United Kingdom, Norway, Sweden, Portugal and Spain). All the data had been published in books, journals or reports.

In this study, the background concentration of nutrients has been defined as the concentration that could be found in the environment in the absence of any human activity (Chester, 1990; Stumm and Morgan, 1992; Runnels et al., 1992). A quality objective has been defined as a concentration based on eco-physiological results and adopted by policymakers in order to minimise the risk of environmental damage.