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Original Research Article

Towards ecohydrological nutrient management for river basin districts

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ABSTRACT

Nitrogen and phosphorus emissions to ground- and surface waters must be drastically reduced to achieve the environmental objectives of the Water Framework Directive (WFD) in Europe. In order to reach the targets a four-step strategy must be followed by water managers. First, target nutrient concentrations for groundwater and surface water bodies must be defined. The second step is the quantification of nitrogen and phosphorus inputs to water bodies and the identification of dominant input pathways. Measures are planned and implemented during the third stage, and are most effective when they focus on nutrient emission pathways that are quantitatively important at river basin scale. Finally, the effect of measures must be evaluated using monitoring data, and if there is still a large distance to target the policy for implementing measures must be modified. In Germany, nitrogen and phosphorus emissions to ground- and surface waters arise mostly from agriculture. It is estimated that improving agricultural practice via a renewed Fertilization Ordinance will lower nitrogen emissions by 10–15%. Many agricultural measures aim to improve nutrient efficiency by using manure and biogas digestate as fertilizer, which has positive economic benefits for the farmer because it reduces the requirement for mineral fertilizers. However, it is clear that the WFD objectives cannot be achieved through agricultural measures alone. Therefore, nutrient retention must be improved by restoring rivers and wetlands. In areas where there is insufficient space for cost-effective natural solutions, ecohydrotechnical solutions such as drainage ponds, denitrification barriers or filter systems can be employed.

1. Introduction

Healthy aquatic systems can develop and exist only if their nutrient or trophic status departs no more than slightly from natural conditions. Goals for the status of aquatic systems in Europe were established by implementation of the Water Framework Directive (WFD) in December 2000 (European Union, 2000) and subsequent related policy including the Nitrates Directive (2001) and the Groundwater Directive (2006). The environmental objective of the WFD is to achieve good ecological status for all natural surface water bodies, and good ecological potential for all surface water bodies that are classified as artificial or heavily modified. In addition, all surface and groundwater bodies must reach good chemical status by 2015. It is now clear that, for most European water bodies, these targets will not be reached by the end of the first management period. The reasons for this failure are multiple (Richter et al., 2013). The timespan of the first management period is relatively short, at six years, when

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compared with the ca. 100 years of water body modification that preceded it. River deepening and straightening carried out in the past cannot be reversed in such a short period. Indeed, when any action aiming to improve hydromorphological conditions is applied, there is often a time lag before its effect on biological quality elements can be measured. However, it is also possible that the measures which have been planned and implemented to date are insufficient to remove the targeted pressures.

The main reason for failure to achieve the environmental objectives for rivers, lakes, transitional and coastal waters is that nitrogen (N) and phosphorus (P) concentrations are too high. Nitrate concentrations are also too high in many groundwater bodies in Germany (LAWA, 2014).

Effective ecohydrological nutrient management aims to reduce nutrient inputs from various pathways and includes monitoring programmes to assess its own effectiveness. The aim of this paper is to describe such a nutrient management strategy; and to illustrate its implementation with examples from Germany and, especially, the Federal State of Schleswig-Holstein.

2. Ecohydrological nutrient management

The idea of nutrient management based on ecohydrological water management principles is not entirely new (Zalewski, 2000; Moss, 2012). However, there are few examples of such management resulting in any substantial reduction of nutrient loads and concentrations in water bodies. Many European countries have drastically reduced their N and P emissions from waste water treatment plants. For the North Sea and Baltic Sea river basins in Schleswig-Holstein, N emissions from waste water were reduced by 63–83%, and P emissions from point sources were reduced by 27–49%, during the period 1991–2012 (LLUR, 2014). In Denmark, the nutrient loads discharged to the sea decreased significantly after strict rules for fertilizer management were applied alongside wetland restoration (Windolf et al., 2012).

2.1. Steps for a nutrient management strategy

An effective nutrient management strategy is structured in four steps, which are implemented sequentially and reviewed and adapted after a few years. This section introduces the four steps. They will be illustrated in more detail later.

The first step is the definition of target concentrations that must be reached to achieve good ecological status. Target concentrations should be defined for all water body categories in which nutrient availability limits the abundance of flora and fauna. For WFD purposes, target concentrations are needed for the ‘good to moderate’ and ‘high to good’ ecological status boundaries.

The second step is the quantification of N and P inputs to surface waters and the identification of dominant input pathways. This step requires monitoring of nutrient concentrations and discharges so that nutrient loads at important measuring points in a river basin district can be calculated. Also, methods and measurements for the identification of diffuse and point sources, as well as the effects of nutrient retention, are needed. Emissions from point sources such as waste water treatment plants are estimated by measuring nutrient concentrations and discharges at their outlets. Models are powerful tools for obtaining a full picture of all relevant nutrient pathways. The available models differ in their spatial and temporal resolution, in the number of input parameters required, and in their ability to calculate scenarios. The MONERIS model (Venohr et al., 2011) is used widely by European water managers; hydrologists often use SWAT (Lam et al., 2010); and the GROWA WEKU DENUZ model is employed in many German federal states because it has high spatial resolution, which is required for the identification of hotspot areas where N and P enter ground- and surface water bodies (Wendland et al., 2014).

In the third step, remedial measures are planned and implemented. In principle, measures are needed at all relevant input sources (Fig. 1). They must be planned separately for N and P because these nutrients differ in their mobility and availability in different ecosystems. Nutrient inputs in waste water from people can be avoided by connecting a high proportion of the population to public sewage systems employing best available water treatment techniques. Waste water from roads and infrastructure must also be treated if it would otherwise place significant pressure on the receiving water bodies. The best way to prevent nutrient inputs to surface water bodies from agricultural land is to adopt farming practices that balance nutrient inputs with outputs in produce. In many cases it is necessary to restore the natural retention function of the landscape either by restoring surface flow and/or groundwater flow wetlands or by developing ecohydrotechnical solutions for water treatment in agricultural areas where there is limited space for natural retention systems (Holsten et al., 2012a,b). Large additional N inputs may be received from the air. The reduction of airborne N sources was agreed in the NERC Directive (SRU, 2015) and is especially important for the protection of low-productivity ecosystems, large surface water bodies and coastal areas.

In the fourth step, the success of the measures that have been implemented is evaluated by comparing the recent ecological status of water bodies with their target states. Where actual ecological status falls substantially short of

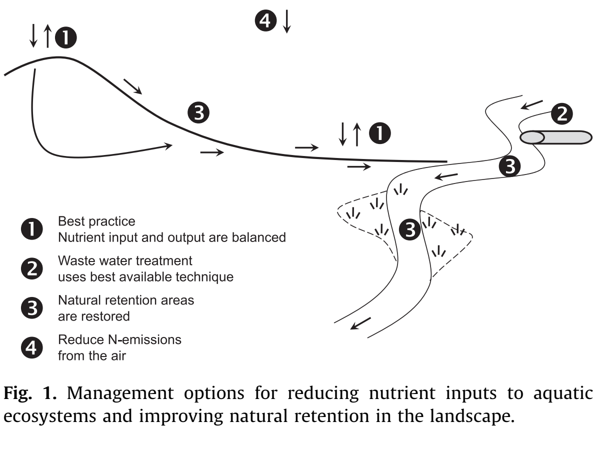

Fig. 1. Management options for reducing nutrient inputs to aquatic ecosystems and improving natural retention in the landscape.