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Original Research Article

Comparison of mineral and organic phosphorus forms in regulated and restored section of a small lowland river (NE Poland)

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ABSTRACT

A two-year study on water quality changes with particular concern about forms of phosphorus in two sections (regulated and restored) of a small lowland river in north-eastern Poland, was carried out. Analyses were performed 7 years after restoration treatment. A clear, significant differences in water quality between the two investigated sections were observed. In the case of different phosphorus (P) forms: soluble reactive phosphorus (SRP), dissolved hydrolysable phosphorus (DHP), total dissolved phosphorus (TDP) and total phosphorus (TP), concentrations were by about 40% lower within restored than in regulated river section. There has been a significant influence of hydro-meteorological conditions on P concentrations in the river. Contrary to the assumptions, concentrations of all P forms, with the exception of DHP, were lower in more humid period than in year characterized by smaller precipitation sum, and minor differences between two compared sections of the river were noted. These decreases of P forms concentrations were not only induced by dilution effect. Better catchment hydration (even degraded/regulated one) prevents rapid transport of P to the surface waters. Numerous relationships between P concentrations and other water quality parameters were found (e.g. with Cl^-, NO_2^-, NO_3^-, NH_4^+, Na^+ and K^+). The comparative study on the regulated and restored river sections confirms that the preservation or construction of riparian land/water buffer zones can be recommended to reduce P forms concentrations in lowland rivers. Even small-scale restoration efforts in the estuary sections of rivers may be important factor improving the quality of water leaving degraded catchment.

1. Introduction

Freshwater ecosystems have long been affected by numerous types of human interventions that have a negative impact on their water quality and ecological state (Søndergaard and Jeppesen, 2007). Most changes in a catchment on agricultural areas were land reclamations and regulation of small rivers carried out on a large scale (especially in the 60s and 70s in Poland). As a consequence, these treatments significantly changed hydromorphological features of rivers by reducing their ecological status (Zieliński et al., 2012a,b). Hydromorphological degradation of rivers and streams is one of the most severe limitations to improving the water quality in many parts of the world (Søndergaard and Jeppesen, 2007; Schirmer et al., 2014). However, in recent years, there has been a lot of efforts to improve the condition of many types of water, especially running waters, due to restoration projects. A number of

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studies on the effectiveness of restoration focused on the improvement of the ecological status taking into account aquatic invertebrates (Jenkins and Boulton, 2007), macrophytes (Pedersen et al., 2007), fish (Grift et al., 2001), and birds (Poudevigne et al., 2002), while issues related to water quality were undertaken to a lesser extent (Meyer et al., 2013; Zieliński and Jekatierynczuk-Rudczyk, 2014). This issue is very important from the point of view of the Water Framework Directive (WFD), that is defined to gain at least a good ecological status of surface water by 2015. Of the major plant nutrients, phosphorus (P) is typically in shortest supply in rivers and other freshwaters so generally has the greatest potential to limit plant growth. P is derived to the river system from a range of sources, varying in its bioavailability from source to source (Mainstone and Parr, 2002). The total load of P to the river can be broadly divided into point source inputs and diffuse inputs. Most watersheds have a range of P sources, with varying composition of timing of P delivery, from highly episodic event-driven P delivery (diffuse sources), to near-continuous P inputs (point sources) (Stamm et al., 2013). Catchment export of P is a function of land use, population densities, agricultural practices and urban development (Carpenter et al., 1998). The other important factors influencing P export, retention and transformation in river catchment are hydrology and hydro-meteorology. The travel time of water in streams governs the time of exposure of stream P to key transformation sites, the sedimentation rate of organic and inorganic particulates, hyporheic flow, oxidation at the soil and sediment water interface and diffusion into interstitial waters (Boström et al., 1988; Kerr et al., 2011). Riverine buffer zones efficiently reduce P content occurring as a result of diffuse pollution through several mechanisms e.g. assimilation of inorganic forms by microbiological activity (Parn et al., 2012) or building-up the P into the biomass. River restoration projects and restoration of degraded buffer zones comprise one of the most effective management measures for non-point source pollution control according to Ecohydrology principles (Zalewski, 2000; Izydorczyk et al., 2013). Analyses of P forms in rivers, its spatial and seasonal variability, were investigated repeatedly by scientists (Carpenter et al., 1998; Jarvie et al., 2005; Royer et al., 2006; Fink and Mitsch, 2007; Jarvie et al., 2013; Meyer et al., 2013; Stamm et al., 2013). However, there is no comprehensive analysis of different P forms in the river subjected to restoration treatment in the context of the effectiveness of these measures particularly in relation to the watershed hydration. Considering the current state of knowledge, we hypothesize that better hydration of catchment accelerates restoration effects, improving water quality including the decrease of reactive P forms in restored river.

The aim of this study was to compare the concentrations of different P forms in two sections (regulated (RG) and restored (RS)) of small, lowland river. Another analyzed aspect was the influence of the hydration status of the catchment and different hydro-meteorological conditions (dry and wet period) on the concentrations of P forms in both: regulated and restored parts of the investigated river.

2. Materials and methods

2.1. Study area

The Rudnia River is a right tributary of the Narew River which is main and the largest lotic system in north-eastern Poland. The Rudnia River has a total length of 23.2 km and its catchment covers the area of 88.6 km^2. The catchment inclination is very low (1.2‰), being typical of this region. Mean flow in the river mouth profile during the study period was 0.2 m^3 s^{-1}, which contributes to a low specific discharge (about 2.4 dm^3 s^{-1} km^{-2}). In the 1970s the Rudnia River was intensively regulated, mainly in the upper and middle sections. In the ending part of Rudnia River, the natural channel (going parallel to Narew River) was shortened by 250 m long artificial canal leading water directly to Narew River (Fig. 1). A cut-off, 4 km long, river channel fragment has been remained for over 25 years, and held role as an oxbow lake. In 1998–1999, the North-Podlasie Association for Birds Protection (N-PABP) commissioned a project designed to restore the cut-off river section of Rudnia River. As a result of this project, the natural course of lower river section was restored by damming the artificial canal built in the 70s and unblocking overgrown old river bed. The Rudnia River catchment is dominated by agriculturally used lands in 70%. More than a half of this areas are covered with arable lands (58%), meadows and pastures (41%) and orchards (1%). The afforestation coefficient within the catchment reaches 21%. The fallow lands cover 9% of the Rudnia River catchment with domination dense and dispersed rural areas as well as urban development–Zabłudów town. The type of agricultural management can be described as extensive. Significant source of the pollutions for investigated river is Zabłudów town with less than 2500 inhabitants. Rudnia River catchment soils are developed from fluvioglacial formations of Warta glaciation (sand, gravel, clay). In the river valley, especially in the restored part, the soil cover was formed on Holocene peat. Regulated part of the Rudnia River represents intensively canalized river with fascine bundles and small weirs. Most of the bends were straightened out and branches cut off from the main stream. This part of the river built and farming in the floodplain area were intensified. This has brought a degradation of the natural freshwater habitats. The restored part of the river kept its more natural character with meandering riverbed, oxbow lakes and wetlands in the floodplain. In this part of Rudnia River ecotone wetlands are broad and play an important role as buffer zones.

2.2. Hydrological features of Rudnia River in 2006–2007

During the study period, the average flow rate within the estuary section of Rudnia River was 0.54 m^3 s^{-1}, and at the measurement point Trześcianka (site no. 4) 0.52 m^3 s^{-1} (Fig. 2). The flow rate of the Rudnia River in Trześcianka profile changed during the study period from 0.012 m^3 s^{-1} in August 2006 to 8.80 m^3 s^{-1} in March 2007. Minimum flow rates in 2006 were recorded in summer amounting to 0.01–0.03 m^3 s^{-1}, while in 2007 to 0.07 m^3 s^{-1}, which occurred in July. In contrast to 2006, there were high water