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Within-river nutrient processing in Chalk streams: The Pang and Lambourn, UK

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Summary This work examines baseflow nutrient concentrations and loads along two rural Chalk streams, the Pang and Lambourn. Soluble reactive phosphorus (SRP) and boron (B) concentrations in these streams were heavily influenced by point-source inputs and the effects of downstream flow accretion and dilution. Unlike B (which is chemically conservative), SRP loads were also strongly influenced by in-stream processing resulting in uptake of SRP, particularly immediately downstream of sewage effluent discharges, where rates of SRP uptake were highest. For the upper River Pang, up to 80% of SRP loads were lost within 4 km downstream of Compton sewage treatment works (STW) and on the River Lambourn up to 55% of SRP loads were lost within 1.6 km downstream of East Shefford STW. In contrast, nitrate (NO_3) concentrations at sites along the Pang and Lambourn were largely controlled by groundwater inputs and plant uptake during periods of high photosynthetic activity in spring and summer and silicon (Si) by diatom uptake in April/May. There were net gains in NO_3 loads along the river reaches, as a result of volumetric increases in groundwater discharge, and, compared with SRP, the role of in-stream processing of NO_3 appeared low.

Examination of SRP exchange by bed sediment and uptake of SRP into algal biofilms indicated that biofilms accounted for only a very small percentage of in-stream P-uptake, but that bed

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sediment SRP-exchanges had a more important control on baseflow SRP concentrations and loads. Point source P remediation at East Shefford STW, by removal of P from final effluent (P-stripping), resulted in 70–90% reductions in river-water SRP loads. After introduction of P-stripping at East Shefford STW, bed sediments immediately downstream of the STW switched from being net sinks to net sources of SRP. Our results show that, in the immediate aftermath of P-stripping, bed sediment SRP-release was responsible for a 30 μg-P l^{-1} rise in river-water SRP along this reach. While this increase in SRP concentration, as a result of bed sediment SRP release, is potentially ecologically significant, it is small in relation to the increase in SRP concentrations from effluent prior to P-stripping, which resulted in increases in SRP concentration of up to 500 μg-P l^{-1}. There was a six-month lag between the introduction of P-stripping at East Shefford STW and bed sediment EPC_0 recovering to equilibrium levels with the overlying river water (and thus negligible SRP release). Recovery of bed sediments to equilibrium levels is likely to have occurred as a result of winnowing and removal of high-EPC_0 sediment and delivery of lower EPC_0 sediment from upstream. Under higher/more variable flow conditions and greater rates of in-channel sediment erosion/delivery, more rapid recovery of bed sediment EPC_0 levels following P-stripping might be expected.

Introduction

This paper examines in-stream processing of nutrients (predominantly nitrogen and phosphorus) in the Rivers Pang and Lambourn, two lowland Cretaceous Chalk streams in south-east England. Cretaceous Chalk (termed Chalk in the rest of the paper) is the dominant geology across large areas of lowland Britain, especially in southern and eastern England and is a major water supply aquifer. Chalk streams are susceptible to multiple pressures, including increasing population, especially in south-east England, and resultant increased demands for abstraction for public supply and sewage disposal (Evans et al., 2003). These pressures are compounded by climate variability, particularly summer drought, with low summer baseflow volumes resulting in reduced capacity for effluent dilution and enhanced river nutrient concentrations. Furthermore, Chalk catchments represent a key typology for the rural and agricultural areas of the lowlands of England (Neal et al., 2002b, 2004a,b). Many of the Chalk streams are intensively farmed and there are also concerns about nutrient leaching (particularly nitrate) to groundwater (Burt and Trudgill, 1993; Limbrick, 2003) and diffuse inputs of N and P and sediment to the stream channel (Bowes et al., 2005; Evans and Johnes, 2004; Evans et al., 2004). Chalk streams are species-rich and the dominant aquatic macrophyte (*Ranunculus spp.*) is of high ecological significance and scheduled as a priority habitat under the EC Habitats Directive (Council of European Communities, 1992). However, 'Chalk Stream Malaise' (Defra, 2003), a growing problem in the rivers and streams of southern England, is threatening an aquatic environment of high conservation value (Jarvie et al., 2002b, 2004, 2005b). Chalk Stream Malaise is the term used to describe the general deterioration in the classic Chalk stream habitat, linked to loss of key macrophytes, such as *Ranunculus spp.*, excessive growth of benthic and filamentous algae and increased turbidity and siltation of gravel beds. These changes have been linked to a decline in salmonid and coarse fish species and invertebrates (Defra, 2003). The low gradient, low energy groundwater-fed shallow Chalk stream environments, with high water residence times, make them particularly sensitive to nutrient inputs and eutrophication associated with benthic and epiphytic plant growth (Environment Agency, 2002; Jarvie et al., 2004).

This research deals with nutrient functioning for two Chalk rivers which are strategically important, in terms of both environmental science and management: the Pang and the Lambourn, within the upper Thames basin of south-eastern England. The studies are strategic for three reasons. Firstly, they form a major focus for permeable catchment research as part of a UK community research programme, the Lowland Catchment Research programme (LOCAR, Wheater and Peach, 2004). LOCAR is forwarding new interdisciplinary science and modelling tools for integrated management of lowland permeable catchments, in terms of water resources, water quality and surface water ecology. Secondly, the upper Thames Basin is a major UK Basin of important environmental and socio-economic concern in relation to ecological health, amenity value, population redistribution and agricultural change (Neal et al., 2002b). Thirdly, the upper Thames represents a focus for nutrient studies within both permeable and impermeable catchments (Neal et al., 2002b, 2004a,b, 2005a,b, 2006a,b).

In this study, we use detailed water quality monitoring surveys and in-stream process studies, to:

(1) Assess spatial variability in nutrients (and other water quality determinands) and identify the effects of point-source discharges under baseflow conditions.
(2) Provide monthly 'snapshots' of nutrient fluxes along the river continuum to provide estimates of within-river nutrient flux transformations.
(3) Assess fluctuations in baseflow nutrient concentrations, fluxes and in-stream processing linked to changes in groundwater discharge and in-stream biological activity.
(4) Examine the role of in-stream phosphorus processing by interaction with bed sediments and algal biofilms.
(5) Provide a 'spatial dimension', to complement companion research on water quality functioning (Neal et al., 2004a,b) and a base for within-river nutrient