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Cross sector contributions to river pollution in England and Wales: Updating waterbody scale information to support policy delivery for the Water Framework Directive

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ABSTRACT

Diffuse water pollution represents a major environmental issue for the European Union. Attempts to provide a coordinated approach to the management of the freshwater environment require appropriate tools for macro-scale spatial analysis to deliver the evidence base for informing targeted decision making and interventions. In this context, this paper reports the development of a new national multiple pollutant (nutrients and sediment)-source apportionment screening framework for England and Wales. SEPARATE (SEctor Pollutant AppoRtionment for the AquaTic Environment) includes emissions to the aquatic environment from both diffuse (agriculture, urban, river channel banks, atmospheric) and point (sewage treatment works (STWs), septic tanks, combined sewer overflows (CSOs), storm tanks) sources and summarises the source apportionment on the basis of Water Framework Directive cycle 2 waterbodies. National scale source proportions (with waterbody ranges) for total nitrogen (TN) were estimated to be in the order; agriculture (81%, 1–100%) > STWs (14%, 0–95%) > CSOs (1.5%, 0–73%) > direct atmospheric deposition (1.3%, 0–93%) >diffuse urban and storm tanks (both 1%, 0–80% and 0–93%) >septic tanks (0.2%, 0–30%) >river channel banks (~0%, 0–1%). The corresponding estimates for total phosphorus (TP) were; STWs (47%, 0–100%) > agriculture (31%, 0–100%) > CSOs (9%, 0–94%) > storm tanks (6%, 0–100%) > diffuse urban/septic tanks/river channel banks (all 2%, 0–100%, 0–70%, 0–71%) > direct atmospheric deposition (1%, 0–65%). For sediment, the estimates were in the order; agriculture (72%, 0–100%) > river channel banks (22%, 0–96%) > diffuse urban (5%, 0–100%) > STWs (1%, 0–91%). Without the inclusion of groundwater sources, agricultural contributions dominate water pollution by TN in 93%

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(130,384 km^2) of waterbodies across England Wales, compared to 58% (68,434 km^2) in the case of TP and 76% (104,434 km^2) for sediment. In combination, agricultural contributions of all three of these pollutants are dominant in 53% (63,030 km^2) of waterbodies.

1. Introduction

Pollution of the aquatic environment, including rivers and lakes, remains a persistent and widespread problem in many parts of the world (UN-Water, 2011; Patterson et al., 2013). Freshwater ecosystems deliver services crucial to human survival and wellbeing and yet globally, their degradation has outstripped the success of remedial programmes (Ormerod et al., 2010). More specifically, agricultural pollution has been widely recognised as one of the key contributors to the degradation of river water quality and aquatic biodiversity (Carpenter et al., 1998; Smith, 2003; Berkes et al., 2003; Poole et al., 2013). Agricultural emissions of various pollutants contribute to environmental problems including those resulting from excessive loss of sediment (Collins et al., 2011) and nutrients (Hilton et al., 2006) to freshwaters. The need to tackle pollutant emissions to freshwater habitats has resulted in the introduction of significant water policy instruments including the Water Framework Directive (WFD) in Europe (European and Commission, 2000).

In England and Wales, a number of mechanisms are being used to help deliver the WFD, through improved management of the agricultural sector and its pollutant emissions (McGonigle et al., 2012). These include baseline regulations for farmers such as those in Cross Compliance or Action Programmes for Nitrate Vulnerable Zones, targeted advice or training such as Catchment Sensitive Farming or the Campaign for the Farmed Environment (CFE, 2011) and incentives delivered by agri-environment or payments for ecosystem services schemes. Balanced approaches are required for the management of freshwater environments to help achieve multiple goals (McGonigle et al., 2012). A key challenge facing the agricultural sector is the need to increase productivity to feed a growing population in the context of minimising environmental burden (Foresight, 2011).

Attempts to provide a coordinated approach to environmental management such as the WFD, require appropriate tools for spatial analysis and informing decision making (Giupponi and Vladimirova, 2006). Computational methodologies for characterising and assessing pollution pressures on the aquatic environment differ profoundly in terms of data requirements, process or pathway representation and complexity. The use of modelling has gained momentum and these approaches range from simple export coefficient frameworks (Beaulac and Reckhow, 1982; Johnes, 1996; Shaffner et al., 2009; Ma et al., 2011) to regression models (Alexander et al., 2002) to more complex deterministic tools for individual or multiple pollutants (Horn et al., 2004; Rao et al., 2009; Coffey et al., 2010; Rivers et al., 2013; Parajuli et al., 2013).

Pollutant source decomposition has been undertaken using empirical load apportionment modelling founded on the fundamental contrast in the timing of point (e.g. water treatment discharges) and diffuse (e.g. agricultural) emissions and corresponding associations with flow (Bowes et al., 2008; Howden et al., 2009; Greene et al., 2011). Source apportionment screening tools are, however, more appropriate for national or macro-scale analyses and for guiding targeted decision making (Navulur and Engel, 1996; McLay et al., 2001; Margane, 2003; Collins and Anthony, 2008; Collins et al., 2009a,b; OECD, 2012; Comber et al., 2011, 2013). These screening tools in their most rudimentary format represent a simplification of the DPSIR (Driving force–Pressure–State–Response) conceptual framework (EEA, 1999) by focussing on the key pollutant pressures on the aquatic environment. Previous additional examples include Brouwer and Van Pelt (2002), Giupponi and Vladimirova (2006), Anthony et al. (2006) and Brouwer and De Blois (2008). Since macro-scale pollutant screening tools can be used to appraise primary sources of emissions to the aquatic environment, they are ideally placed to ensure that no individual sector is unduly burdened with abatement costs in the context of the 'polluter pays' principle.

Evidence for significant and sustained improvements in river water quality and aquatic ecology in response to diffuse source mitigation programmes remains scant due to a number of confounding factors. These include, amongst others, failure to take sufficient account of cross sector or multiple source contributions to pollutant loadings (Collins et al., 2014) and the need for substantial reductions in pollutant pressures before ecological responses are observed (Bowes et al., 2011). On-farm interventions including those in agri-environment schemes across England and Wales have been used to help reduce the detrimental impacts of agricultural pollutant emissions (Natural and England, 2012), but since such schemes are funded by public tax revenue, it is important that they are optimised spatially to help maximise the delivery of multiple outcomes (Poole et al., 2013). Against this background and the desire to demonstrate best value for the expenditure of public money on agricultural diffuse pollution mitigation, a new collaborative science project was commissioned by the UK Department for Environment and Rural Affairs (Defra) to develop a national scale framework for targeting on-farm interventions for water pollution management. One key component of this project was the development of a novel national river water pollution screening tool for multiple pollutants to identify those WFD waterbodies where agricultural emissions are dominant compared to those from alternative sectors or sources. The following sections detail the fundamental components of this new screening tool which has been given the acronym SEPARATE (SEctor Pollutant AppoRtionment for the AquaTic Environment).