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The Ribble/Wyre observatory: Major, minor and trace elements in rivers draining from rural headwaters to the heartlands of the NW England historic industrial base

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ABSTRACT

Information on a new observatory study of the water quality of two major river basins in northwestern England (the Ribble and Wyre) is presented. It covers upland, intermediate and lowland environments of contrasting pollution history with sufficient detail to examine transitional gradients. The upland rivers drain acidic soils subjected to long-term acidic deposition. Nonetheless, the acidic runoff from the soils is largely neutralised by high alkalinity groundwaters, although the rivers retain, perhaps as colloids, elements such as Al and Fe that are mobilised under acid conditions. The lowland rivers are contaminated and have variable water quality due to variable urban/industrial point and diffuse inputs reflecting local and regional differences in historic and contemporary sources. For most determinands, pollutant concentrations are not a major cause for concern although phosphate levels remain high. Set against earlier studies for other regions, there may be a general decline in pollutant levels and this is most clearly observed for boron where effluent inputs have declined significantly due to reductions in household products that are flushed down the drain. High concentrations of sodium and chloride occurred briefly after a severe cold spell due to flushing of road salts. A major inventory for water quality within rural, urban, industrial and agricultural typologies is provided within data summary attachments for over 50 water quality determinands. Within the next year, the full dataset will be made available from the CEH website. This, with ongoing monitoring, represents a platform for water quality studies across a wide range of catchment typologies pertinent to environmental management of clean and impacted systems within the UK. The study provides a base of research "from source to sea" including extensions to the estuary and open sea for a semi-confined basin, the Irish Sea, where there are many issues of pollution inputs and contamination.

1. Introduction

There has been growing recognition of the value of earth, critical-zone and hydrologic observatories to study the chemistry and ecology of systems in flux with changing environmental constraints and feedbacks (www.czen.org; www.cuasi.org). Although much attention has focussed on more pristine areas, the need for examining our urban and industrial base is critical. For the UK, over 80% of the population live in conurbations and yet these conurbations cover only 10% of the land area (Leeks et al., 2006). Further, for many of these conurbations there is a long history of land contamination associated with the developments that started two centuries ago with the Industrial Revolution. On the applied practical front there is the strategic need to minimise environmental damage for a wide range of pollutants and develop targeted and cost effective clean up. Within the context of initiatives such as the European Water Framework Directive (WFD: CEC, 2000), where clean up is a core requirement within legislation, there is the practical need for basin wide approaches. However, there are social and economic needs that require factoring into the management options for environmental solutions and assessment of feasibility. This is particularly pertinent for the UK given the high population density, the location of many of our peri-urban and urban centres near rivers, increased pressures of water resources and changing climate (Rodda, 2007) and the current difficult economic environment. The strategic importance of population linked to rivers and economic and amenity resource comes about because most UK conurbations are located near to rivers. Historically, the rivers provided water resource, power, transportation routes and a rapid route of effluent disposal (Neal, 2001a). This provided the template for the population distribution, and the rivers continue to shape conurbation development and evolution.

The importance of researching this area has been recognised within programmes such as the UK initiative on Urban Regeneration Programme, URGENT (Leeks et al., 2006), the extensive studies in France of the Seine basin (Billen et al., 2007a), the eastern UK rivers as part of the Land Ocean Interaction Study (LOIS: Leeks and Jarvie,

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1998) and a European network of catchments (Salomons and Turner, 2005). Further, with the contemporary needs of seeing a healthy global environment, a critical component has to be to engage and engender support from the general public to change the socioeconomic outlook using the impetus generated through the needs of having pride in a local and healthy environmental community.

As part of the Centre for Ecology's remit, a new initiative has been set up to develop a basin scale observatory study within the UK in the context of a source to sea mission. A central theme for this is to provide a baseline of opportunity for promoting integrated research for catchments with rural, agricultural, urban and industrial typologies of critical environmental management concern both at the national and pan-European level. The aim is to produce a programme of the calibre of the LOIS and Seine initiatives with a more indirect route than co-ordinated high level funding initiatives. This type of study is of importance to the practical requirements of environmental management at the basin wide scale while integrating it with proactive research. It is also important for management and research purposes in extending the endeavours to estuarine and coastal areas, the end destination of many pollutants from our rivers.

The study area chosen is the basins of the Ribble and Wyre in northwest England. Both basins represent upland areas of outstanding natural beauty (Forest of Bowland and Yorkshire Dales). However, while the Wyre has a more rural typology, the upland valleys and lowland vales of the Ribble have both heritage (historic buildings, roads, culture etc) and contaminated aftermath of the Industrial Revolution and industrial and urban conurbations now in a post-industrial setting. The scars will include the impacts of mine waste and mine water pollution that characterise many UK industrialised areas (Hudson-Edwards et al., 1997; Hutchinson and Rothwell, 2008; Macklin et al., 1997; Rothwell et al., 2006, 2008; Younger, 1997). Further, there is a major imprint from atmospheric deposition of acidic oxides and heavy metals (Evans et al., 2000; Evans and Jenkins, 2000; Tipping et al., 2010). In the lowland areas of both the Ribble and Wyre, there are issues of agriculture and the significance of nutrient sources to eutrophication. This is especially of importance for phosphorus as it is often considered to be the critical limiting nutrient (Hilton et al., 2006) and is of major importance in the context of agriculture and urban/effluent sources (Bowes et al., 2008; Jarvie et al., 2006; Neal et al., 1998b, 2005a, 2010c). Indeed, nutrient levels as well as trace metals can be particularly high in the lowland rivers of much of northwest of England to which the Ribble/Wyre is a part (Rothwell et al., 2010a,b). For both the upland and lowland areas there are relatively high pressure areas in terms of anthropogenic inputs, but the two types of site differ in the nature of the pressure. Together, the Ribble and Wyre basins are important within the context of contemporary issues of pollution and cleanup, archaeology of the industrial heritage of the UK, and to environmental geochemistry and health.

Here, an overview is made of the first two years of water quality data across the rural, urban and post-industrial typologies within the Ribble and Wyre basins. Within a fortnightly to monthly programme, major, minor and trace elements, nutrients, dissolved organic carbon (DOC) and suspended sediments (SS, including their chemistry) have been assayed. The paper provides the first wide ranging analysis based on detailed and high sensitive methodologies to provide a key riverine resource of examining the pollution to an important semi-contained and polluted coastal system, the Irish Sea, where there are many environmental concerns (Allen et al., 1998; Ridgeway and Shimmield, 2002; Williams et al., 1998). Indeed, the Irish Sea is being researched as part of the development of a coastal observatory (Proctor and Howarth, 2003, 2008) that complements well with our Ribble/Wyre rivers observatory. Further, the paper provides an important base for making the data fully available to the research community that will follow (March 2012 at the latest). The data also provides information of regional and national value for specific elements of environmental concern such as mercury and titanium (Rowland et al., 2010; Neal et al., in press). The source to sea study puts greater emphasis on having a distributed network of sites that cover, upland, intermediate and lowland typologies, rather than with conventional research monitoring programmes that deal upland acidification and environmental management that deals with lowland pollution. The work increases the range of determinands, with improved detection levels and in the case of the uplands illustrates an unusual typology with an acidic upland area with streams that have been partially neutralised by base rich groundwater but retain "acidic character" with regard to elements such as Al, Fe and Ti. The data complements regulatory monitoring data collected by authorities such as the Environmental Protection Agency of England and Wales (EA) and the Scottish Environmental Protection Agency (SEPA).

Use is made of the Journal's attachment facility to allow a compendium of statistics, time series and spatial distribution information for all the water quality determinands. This would normally be prohibitive with standard journal format and the attachment provides a reference point and facilitates comparison with other regions of the UK (Neal and Robson, 2000) and within the European Union in the context of the urban wastewater treatment and WFD (CEC, 1991, 2000), as well as for global rivers (Horowitz, 2008; Livingstone, 1963; Hirsch, 2001; Martin and Meybeck, 1979; Meybeck, 2003; Tardy et al., 2005).

The work links with the growing themes of GIS on water quality and pollution apportionment studies (Davies and Neal, 2007; Keller et al., 2006; Rothwell et al., 2010a,b) and linkages to socioeconomic frameworks with issues such as the WFD and the changing European Union Common Agricultural Plan (Bateman et al., 2006).

1.1. The Ribble and Wyre Basins

The Ribble (inc. Douglas and Darwen) and Wyre provide two of the main basins in northwest England (Fig. 1), with basin areas of 1133, 231, 136 and 314 km^2, for the Ribble, Douglas, Darwen and Wyre respectively. Both rivers flow southwards then westward to the Irish Sea, draining upland areas of outstanding natural beauty (part of the Yorkshire Dales and the Trough of Bowland). In its lower part, the Ribble includes some of the urban/industrial heartlands of Lancashire (Accrington, Blackburn, Burnley and Wigan). Correspondingly, the Wyre basin is much more rural in nature with only one notable market town (Garstang). The upper part of both basins comprises acid moorland, while the vales have a vegetation cover that includes grassland with sheep and intensive dairy farming. Correspondingly, the soils are predominantly deep loams (40% of the total area), with 14% comprising of peat, and 20% deep peaty loams, the rest being mainly silty sandy loams. Details of vegetation and soils for individual sub-catchments are provided in attached files: here we use the term catchment to denote tributary drainage areas within each basin. The geology is predominantly carboniferous rocks (Fig. 2), while for the lower Wyre and the western edge of the Ribble basin there are Triassic age sandstones with relatively thin strata of Permian mudstones between. In the upper half of the Ribble, including its main tributary, the Hodder, the catchment is rural apart from market towns such as Settle and Clitheroe. However, in the southern parts of the basin and river, there are the urban/industrial conurbations for the tributary Calder, Darwen and Douglas catchments. The Hodder and Calder enter the Ribble within the non-tidal river, while the Darwen and Douglas directly enter the estuary.

1.2. Monitoring

After an initial basin wide assessment using field surveys and GIS information on geology, relief, agriculture, point source inputs (septic tank and sewage treatment works) and population, 26 sites were chosen for monitoring (Fig. 2: see also attachments for details). Catchment areas and mean altitude statistics were estimated using