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A review of sediment contamination by trace metals in the Humber catchment and estuary, and the implications for future estuary water quality

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Abstract

This paper reviews what is presently known about sediment contamination in the macro-tidal Humber estuary on the east coast of the UK, with particular reference to the trace elements arsenic, copper, lead and zinc. The Humber is a post-industrial estuary, with an industrial and mining legacy of contaminated sediments throughout the river catchment. Surface and near-surface sediments in the estuary also show significant contamination of trace metals over background values. Inputs of dissolved and particulate trace elements to the estuary from the rivers are reviewed, and atmospheric deposition to the catchment and estuary calculated as a potential additional source of contamination. The necessity of maintaining the sediment balance within the estuary means that contaminated sediments dredged from the estuary harbours are deposited to other sites within the estuary, rather than being removed. Trace metal concentrations in recent dredged sediments, and sediments from the period of peak contamination in the 1970s, are compared with background values. Current inputs to the estuary from point sources, and trends over the last decade are considered. Our calculation of the current depositional fluxes of trace metals to the estuary intertidal sediments, and comparison with the inputs, reveals that the estuary sediments are today capable of storing 55–97% of the input load of As, 15–27% of the Cu, 17–50% of the Pb and 11–12% of the Zn annually.

Sediment quality in the estuary is currently far from its 'background' state with respect to trace metals. This has implications for the future water and sediment quality of the Humber under the terms of the EU Water Framework Directive. One management option being considered to improve sea defences in the estuary, managed realignment, may also act to dilute contaminated sediments in the estuary, and thereby to improve future water quality. We look at the effect on sediment contaminant storage of three possible future managed realignment scenarios.

Keywords: fluxes; managed realignment; arsenic; lead; copper; zinc; Water Framework Directive; North Sea

1. Introduction

The European Union Water Framework Directive (2000/60/EC), which came into force in December 2000, has been the impetus for a number of national and international initiatives aimed at specifying the current state of groundwater, surface waters and coastal waters of the EU. The ultimate aim of the Directive, as outlined in Article 1, is to achieve "*concentrations in the marine environment near background values for naturally occurring substances and close to zero for man-made synthetic substances*". One important compartment of the marine environment is the sediment, which acts as both a source and a sink for many contaminants, and supports a wide range of flora and fauna, which are important components of the aquatic food chain. This paper is concerned with the current state of sediments in the Humber

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estuary, one of eight catchment–coastal areas being studied under the EU-funded EUROCAT project (EVK1/2000/00510). The Humber is a good example of an estuary in its post-industrial phase.

In this review we consider four trace elements – arsenic, copper, lead and zinc. These are all List II substances under the EC Dangerous Substances Directive (76/464/EEC), while lead is also a priority substance under the Water Framework Directive. All four elements have a large anthropogenic component in the Humber, due to the history of mining, industrial activity and urbanisation in the catchment. Lead and zinc also have high natural levels in some parts of the catchment due to the underlying geology (Jarvie et al., 1997).

The Humber catchment is one of the largest in the UK, draining 24,240 km^2, about one fifth of England (Fig. 1), with a population of 10.5 million (based on census data for 2001 from the UK Office of National Statistics). The two principal river systems, the Trent and the Ouse, drain into the Humber estuary on the east coast of the UK, and from there into the North Sea. The estuary is macro-tidal, shallow and well-mixed, 63 km long and with a surface area of some 265 km^2. The average freshwater flow from the catchment is 236 $m^3\ s^{-1}$ (Neal and Davies, 2003). Data collected and analysed during the UK Land–Ocean Interaction Study (LOIS – Leeks and Jarvie, 1998 – see Appendix A for details) yielded well-constrained estimates of fluxes for a range of dissolved and particulate trace metals from the catchments of the Trent and Ouse rivers into the Humber estuary during the 1990s (Neal and Davies, 2003). These rivers drain former coal and metal-mining areas, as well as large industrial, urban and agricultural areas. Heavy industry in the catchment, principally metal-working and textiles which expanded rapidly during the Industrial Revolution in the 19th century, began to decline in the 1920s, being replaced by lighter industry such as pharmaceuticals, and service industries. Heavy industry and mining however have left a legacy of contamination throughout the catchment in the form of spoil heaps, abandoned mines and contaminated floodplain sediments (Macklin et al., 1997). The area surrounding the Humber estuary itself has also been heavily industrialised, with pollution estimated to have reached its peak from 1950 to 1970 (Lee and Cundy, 2001). The estuary hosts several major ports (Fig. 2) and is continually dredged to maintain shipping channels. The estuary is also a major landing and refining point

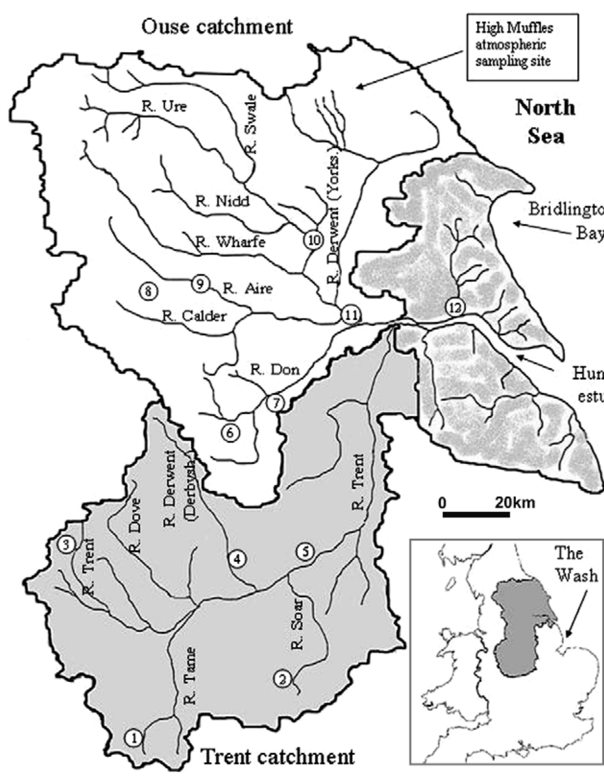

Fig. 1. The Humber catchment, showing the Ouse catchment (white) and Trent catchment (grey). The river Hull on the north side of the estuary and the river Ancholme on the south side, also contribute small amounts of fresh water to the Humber estuary (catchments in pale grey). Numbers refer to major cities in the catchment: 1—Birmingham, 2—Leicester, 3—Stoke-on-Trent, 4—Derby, 5—Nottingham, 6—Sheffield, 7—Doncaster, 8—Bradford, 9—Leeds, 10—York, 11—Goole, and 12—Kinston-upon-Hull.

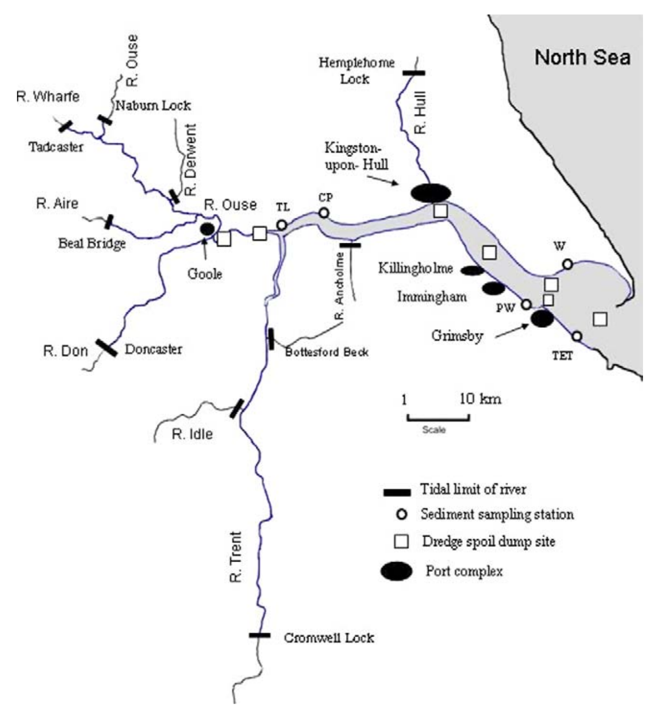

Fig. 2. The Humber estuary and tidal rivers. Tidal limits are indicated by black bars. The rivers all have weirs or locks at their tidal limits, which retard the movement of river sediment downstream into the tidal rivers and estuary. Sediment sampling stations in the estuary are TL (Thornton Lands), CP (Capper Pass), W (Welwick marsh), PW (Pyewipe) and TET (Tetney marsh), sampled as part of the Land–Ocean Interaction Study (LOIS, Leeks and Jarvie, 1998).