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Annual freshwater river mass loads from Great Britain, 1975–1994: estimation algorithm, database and monitoring network issues

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Abstract

The paper presents 20-year time series (1975–1994) of annual mass loads discharged from the aggregated freshwater-monitored area of Great Britain for suspended solids, total nitrogen, orthophosphate and zinc. Corresponding time series are also given for regional groups of catchments draining towards five sea-areas recognised for monitoring UK fluvial inputs to the North-East Atlantic. A mass load computational scheme that effectively merges the national river flow and water quality databases is used to derive the mass flow time series, and their utility is considered within the context of strategic information needs and the capabilities of current national monitoring programmes. While the aggregated annual suspended solids loads presented in the paper are often severe underestimates of the actual load, because infrequent sampling tends to miss high concentrations at high flows, the loads for total nitrogen and orthophosphate, which exhibit less variability in concentration than suspended solids, are of a more acceptable quality. Mass loads for zinc, and other determinands often recorded as 'less than a limit of detection' (<LOD), can be very uncertain. Bearing in mind the uncertainties involved, the time series presented are assessed for the presence or absence of trends. Not surprisingly, annual loads exhibit correlation with annual runoff. Except for zinc, however, there is no obvious evidence for temporal patterns in the time series that are not associated with variations in annual runoff. Zinc loadings have decreased as a result of improved environmental management in industrialized catchments. Discussion of the sources of uncertainty in regional mass flows is followed by some general recommendations related to capitalising most effectively on available mass flow time series.

Keywords: River mass loads; Fluxes; Estimation algorithm; North Sea; OSPAR

1. Introduction

A rational approach to the management of our freshwater environment is based on river basins, and requires analysis of precipitation, river flow, water quality and other data from monitoring networks designed and operated with that purpose in mind. In addition to measuring the amount of water flowing in rivers it is becoming increasingly necessary to monitor the mass loads of the constituents they carry. Good-quality estimates of river mass loads (fluxes) are required for freshwater management and environmental research including: water resources assessments; hydrochemical budgets leading to

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improved understanding of nutrient (and other constituent) mobility processes in basins; hydro-ecological studies; and validating water quality computer models at a wide range of spatial and temporal scales. Research and management of water quality beyond the freshwater zone, in estuaries, coastal waters, seas and, ultimately, the oceans, also require good estimates of river mass loads.

Under the terms of the Convention for the Protection of the Marine Environment of the North-East Atlantic (1998), known as the OSPAR Convention,[1] the United Kingdom and other north-western European countries supply to the OSPAR Commission annual mass loads of prescribed hazardous substances discharged to their coastal waters by rivers. The sampling protocols and flux estimation methods recommended by the OSPAR Commission have been discussed previously by Littlewood (1995, 2003), Littlewood et al. (1998), and Jarvie et al. (1997).

The OSPAR mass loads supplied by the UK comprise two components: the aggregated mass load transported by rivers to their tidal limits; and contributions to estuaries and costal waters from other sources (principally direct point-discharges to rivers from urban and industrial centres downstream of tidal limits). The UK has supplied OSPAR with river mass loads for the years since 1990, giving indicator values for 1985 for comparison.[2] This paper is mainly concerned with time series of annual mass loads carried by rivers to their tidal limits, 1975–1994, aggregated for Great Britain, thus providing an overlapping period with UK data supplied to OSPAR and creating longer records of annual fluxes than available previously.

River constituent flux estimates are typically more uncertain than water flux estimates, and there are grounds for concern that sufficient account is not always taken of the nature and magnitude of these uncertainties when the data are used, e.g. for modelling or assessing the efficacy of environmental management actions. River loads are essentially the sum of products of flow and a constituent concentration (determinand), and are therefore generally perceived to be simple to derive. This perception has greater force for rivers draining large catchments (greater than 50,000 km^2) where flow and concentration tend not to change from day to day as much as in the smaller rivers of the UK. Total nutrient outflow from France, Germany or Spain is heavily influenced by the mass loads carried by just four or five major rivers; mass flows in the Rhine alone exceed the total outflows from the UK for most determinands (European Environment Agency, 1995). By contrast, the UK has a dense drainage network of some 200,000 km of watercourses draining to the sea through more than 100 estuaries (Kirby and Marsh, 1990) and no single river in the UK accounts for more than 4% of the total runoff. This, together with its spatial diversity in climate, topography, geology, soils, land-use and patterns of water utilisation (abstractions and discharges directly affect the flow and quality of rivers) makes the assessment of nutrient and other contaminant loads for rivers in the UK a significant challenge requiring major monitoring and database management commitments.

The nature of flow and concentration data (e.g. measurement methods, sampling frequency), and the load estimation algorithm employed, influence the accuracy and precision of flux estimates. Inaccurate or imprecise mass loads are of limited utility for environmental assessment and management, e.g. detection of trends, modelling nutrient enrichment, eutrophication, etc.

The annual fluxes presented and discussed here were derived using the National River Flow Archive (NRFA) and the Harmonised Monitoring Scheme (HMS) database, i.e. the major sources of readily available flow and concentration data respectively for surveying regional and aggregated river mass loads for Great Britain. Employing these separate sources of data, Marsh (1980) assessed mean catchment mass loads to develop a nitrate balance for England and Wales, and Rodda and Jones (1983) estimated mass loads for a selection of determinands. More recently, the NRFA and the HMS database were brought together in the same computational scheme (Watts and Littlewood, 1998) to facilitate systematic

[1] The (Oslo) Convention for the Prevention of Marine Pollution from Ships and Aircraft, 1972. The (Paris) Convention for the Prevention of Marine Pollution from Land-Based sources, 1974 (implemented 1978). The Oslo and Paris Commissions combined in 1994 (OSPAR).

[2] http://www.defra.gov.uk/ and http://www.environment-agency.gov.uk/, August 2003.