

Final Report

Project WFD85

**An Improved Understanding of Phosphorus Origin, Fate and
Transport within Groundwater and the Significance for
Associated Receptors**

July 2008



© SNIFFER [2008]

All rights reserved. No part of this document may be reproduced, stored in a retrieval system or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise without the prior permission of SNIFFER.

The views expressed in this document are not necessarily those of SNIFFER. Its members, servants or agents accept no liability whatsoever for any loss or damage arising from the interpretation or use of the information, or reliance upon views contained herein.

Dissemination status

Unrestricted

Project funders

Scotland & Northern Ireland Forum for Environmental Research (SNIFFER)
Scottish Environment Protection Agency (SEPA)
Environmental Protection Agency (EPA)
Environment Agency of England and Wales (EA)
Environment and Heritage Service (EHS)

Whilst this document is considered to represent the best available scientific information and expert opinion available at the stage of completion of the report, it does not necessarily represent the final or policy positions of the project funders.

Research contractor

This document was produced by:

Ian Holman, Nicholas Howden, Mick Whelan, Patricia Bellamy and Monica Rivas-Casado (Natural Resources Department, Cranfield University)
Nigel Willby (School of Biological and Environmental Sciences, University of Stirling)

Natural Resources Department,
Cranfield University
Cranfield
Bedfordshire MK43 0AL
United Kingdom

SNIFFER's project manager

SNIFFER's project manager for this contract is:

Peter McConvey, Environment and Heritage Service, Northern Ireland

SNIFFER's project steering group members are:

Tim Besien, Environment Agency
Sean Burke, Environment Agency
Deborah Ballantine (part), Scottish Environment Protection Agency
Garrett Kilroy, Environmental Protection Agency
Rebecca Kelly, Scotland & Northern Ireland Forum for Environmental Research

SNIFFER

First Floor, Greenside House
25 Greenside Place
EDINBURGH EH1 3AA
Scotland
UK

Company No: SC149513
Scottish Charity: SCO22375
www.sniffer.org.uk

EXECUTIVE SUMMARY

WFD85: An Improved Understanding of Phosphorus Origin, Fate and Transport within Groundwater and the Significance for Associated Receptors (April, 2008)

Project funders/partners: Scotland & Northern Ireland Forum for Environmental Research (SNIFFER), Scottish Environment Protection Agency (SEPA), Environment Agency, Environment and Heritage Service, Environmental Protection Agency (EPA).

Background to the research

The United Kingdom Technical Advisory Group Groundwater Task Team have identified limitations in knowledge relating to understanding the origin (natural and anthropogenic), fate and transport of phosphorus within the sub-surface and in groundwater, with particular regard to the potential impact on dependent surface waters and terrestrial ecosystems.

Objectives of the research

The purpose of this study was to develop an improved understanding of the origin (natural and anthropogenic), fate and transport of phosphorus as it moves through the soil, unsaturated zone, saturated zone and hyporheic zone to discharge in rivers, lakes or wetlands. The report aims to answer a number of key questions:

1. Are observed phosphorus concentrations in groundwater a cause for concern in the context of achieving the status objectives for receiving surface waters and groundwater dependent terrestrial ecosystems?
2. Is there evidence that observed phosphorus concentrations in groundwater are elevated above concentrations which would be expected to occur naturally?
3. Where groundwater P concentrations are elevated, is there sufficient certainty in our understanding to justify restoration measures?
4. What further research or monitoring are likely to be appropriate to develop the necessary understanding for delivery of WFD objectives?

Key findings and recommendations

1. There are over 49,000 measurements of groundwater P concentrations available to this project in England and Wales, Scotland, Northern Ireland and Republic of Ireland, of which about 25,000 are above the Limit of Detection (LOD). They are generally measured as orthophosphate, as P (dissolved inorganic P), or Total dissolved phosphorus (dissolved organic and inorganic P).
2. Significant areas of the countries have no groundwater P data- 14% , 37% and 49% by area of groundwater bodies have no groundwater P observations in England & Wales, Republic of Ireland and Scotland, respectively.
3. Of the 49,000 measurements of groundwater P, only about 0.15% (76 samples) exceed the Drinking Water Standard (2200 µg P /l), of which all but 5 samples are in England and Wales.
4. In all countries, a significant proportion of samples have concentrations above important ecologically-based P thresholds for river and lakes under the WFD. For example, more than 24 % of samples in each of the countries' datasets (assuming any samples below the Limit of Detection are at half the LOD) have Orthophosphate concentrations (as P) in excess of 30 µg P /l (Chapters 1 and 3). Expressed as a percentage of the area of groundwater bodies with groundwater P data, 15%, 28% and 9% have median groundwater P observations in excess of 30 µg P /l in England & Wales, Republic of Ireland and Scotland, respectively. Only 5%, 0.2% and 1 % of the area of groundwater bodies with groundwater P data have median groundwater P observations in excess of 60 µg P /l in England & Wales, Republic of Ireland and Scotland, respectively.

5. Literature review (Chapter 2) suggests that anthropogenic sources which may potentially pose phosphorus leaching risks to groundwater include (1) Accumulation of soil P levels as a consequence of long-term over-fertilization of arable and grassland; (2) Manure heaps and unlined slurry storage facilities; (3) Leaking mains water pipes; (4) Leaking sewers and (5) Septic tank discharges.
6. Many factors can influence the likelihood of anthropogenic impacts on groundwater P concentrations to the extent that they result in ecological impairments in associated receptor systems. These factors have been synthesised in a generic conceptual Source-Pathway-Receptor model.
7. The sensitivity of the Receptor to groundwater P (Chapter 2) will depend on many factors, especially trophic status, flow regime, residence time and synchronicity between groundwater P delivery and biological demand. Season-specific features associated with many impact responses means that aspects other than just the total P load should be taken into consideration. The timing of P transfers in relation to biological demands is an important factor determining the significance of different sources.
8. A comparison of routine monitoring data and BASELINE data from England and Wales (Chapter 3 and 5) demonstrated the difficulty of defining natural background concentrations from an analysis of monitoring data alone.
9. Significant correlations between measured groundwater P concentrations and land use (Chapter 3) and between measured data and predicted P concentrations arriving at the water table, based on soil P and groundwater vulnerability (Chapter 4) provide some evidence that anthropogenic activities may have had an impact on groundwater in England and Wales. The lack of a significant relationship in Scotland (Chapter 6) and generally lower concentrations (Chapter 3) suggests that groundwater concentrations in Scotland are more likely to reflect natural background levels than diffuse-source transfers resulting from agricultural activity. The high proportion of samples below high LODs in Northern Ireland hinders useful interpretation. For the Republic of Ireland, undertaking a correlation was not possible due to the unavailability of national datasets such as the diffuse pollution screening tool or similar.
10. On the basis of the evidence presented in this report it is considered that groundwater P may be a problem for a limited number of surface water and GWDTE receptors. However, considerable uncertainties exist over, in particular: defining background levels; groundwater P concentrations in the many unmonitored groundwater bodies; the effect of the hyporheic zone in attenuating or mobilizing P; and the sensitivity of receptors to P delivery from groundwater.
11. Significant uncertainty remains in defining natural background concentrations of phosphorus in groundwater, given the limitations of the available data on groundwater quality, aquifer properties (especially mineralogy) and P sources. This has important implications for setting threshold values and alternative objectives.
12. Recommendations about monitoring, data collation and remediation are made (Chapter 8) where these are considered relevant to the delivery of WFD objectives. However, in support of a pragmatic approach to characterising natural and anthropogenic contributions to groundwater-P, particularly from a regulatory perspective, a more detailed knowledge of anthropogenic P sources and pathways is a major need.

Key words: Phosphorus, Groundwater, Risk, Receptors, Thresholds, Baseline