Application of a New methodology for Assessing the Priorities for Abandoned Mine Water Pollution Remediation at a National Scale: Results and Implications from a Study across England and Wales

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Abstract
The results of the application of a methodology for the national-scale assessment of pollution from abandoned non-coal mines in England and Wales are presented. It is clear from this that the scale of pollution from abandoned metal mines is nationally significant. In the Northumbria River Basin District of north-east of England, for example, numerous river catchments appear to be at risk of failing to meet objectives of the Water Framework Directive, specifically due to the presence of elevated concentrations of potentially ecotoxic metals such as zinc. The difficulties of resolving these problems, in the context of potentially conflicting priorities, are discussed.

Introduction
Jarvis et al. (2007) reported on the early development of a methodology for the national-scale identification and prioritisation of abandoned non-coal mines across England and Wales. The impetus for this exercise, funded by the UK Government's Department for Environment, Food and Rural Affairs (DEFRA) and the Environment Agency of England & Wales (EA), was the need to understand the scale of pollution from abandoned non-coal mines (principally metal mines) in order to implement regional and national programmes of environmental improvements to meet the objectives of the EU Water Framework Directive (2000/60/EC) and, to a lesser extent, the EU Mining Waste Directive. A key objective of the development and implementation of the methodology was to be able to prioritise, both regionally and nationally, abandoned non-coal mine water discharges such that a phased programme of remediation measures could be instigated. Thus mine waters appearing high on the priority list (i.e. those with a high impact) could be addressed first, albeit in the wider context of river catchment improvements as a whole. This paper reports preliminary results of the full implementation of the prioritisation methodology.

Methodology
The methodology for this identification and prioritisation exercise was completed in 2007, and in the latter part of 2007 and early 2008 the methodology has been applied in 4 of the 11 River Basin Districts (RBDs) of England & Wales. An important constraint in conducting the project, which is led by Newcastle University, is that no new water quality data could be collected due to budgetary constraints. Thus, the entire 2 year project is being based on existing water quality and ecological data and local knowledge of EA staff in particular. In the first phase each water body in England & Wales (of which there are approximately 7 500) were categorised as 'At Risk', 'Probably at risk', 'Probably not at risk' and 'Not at risk' from non-coal mine water pollution. It is worth noting that this is different to the formal river basin characterisation exercise reported by Johnston and Rolley (2008), as a more comprehensive dataset is used here. This assessment was based principally on known mine sites and mine water discharges, geological strata and failures of water quality standards (Environmental Quality Standards – EQS) for 8 metals commonly associated with mine water pollution (see Table 1). With knowledge of where mine sites, mining geology, and metal EQS failures coincide it was possible to see at a glance those water bodies and districts within which mine water pollution from abandoned metal mines is a current problem or a risk (Figure 1 is an example).
However, it is widely recognised in the UK that effective management of environmental problems arising from abandoned mines is more complex than only considering water quality impacts, albeit such effects may be critical drivers for remediation. Thus, in addition to these data, key information regarding other aspects of the impacts and concerns regarding mine water discharges are also being

taken into account as part of the project (the second phase of the project). A summary of the information required to apply the prioritisation methodology is provided in Table 1. In brief, the first 4 items in Table 1 (water quality, ecological, groundwater and higher impacts) are assessed semi-quantitatively to provide a 'score' for each mine water discharge, and this information has enabled a broad prioritisation of mine waters and mine sites both regionally and nationally. The additional information in Table 1 is gathered for the benefits of implementers of remediation initiatives, since some of these factors may ultimately be important drivers for remediation (or an impediment to it).

Table 1 *Data required to implement prioritisation methodology*

Data	**Details**	**Source**
Water quality impacts	Concentrations for As, Cd, Cu, Fe, Mn, Ni, Pb, Zn	EA Environmental Quality Standard (EQS) failure data held by EA
Ecological impacts	Ecological quality e.g. benthic macroinvertebrate abundance and diversity data	EA General Quality Assessment (GQA) records and fisheries / biological surveys
Groundwater impacts	Degradation of groundwater quality in mining districts	EA groundwater monitoring network data
Higher impacts	e.g. impacts on water resources, recreational value	Questionnaire completed by EA personnel
Stakeholder concerns	e.g. conservation and heritage concerns, public complaints	Questionnaire completed by EA personnel
Visual impact	Principally arising due to elevated Fe	Questionnaire completed by EA
Diffuse mine water pollution	Principally subjective assessment, but implications for remediation	Questionnaire completed by EA personnel
Airborne pollution risk	From mine waste dumps	Questionnaire completed by EA and local authority
Mine water outbreak risk	From flooded workings	Questionnaire completed by EA
Stability concerns	Principally due to mine waste dumps	Questionnaire completed by EA and local authority personnel

Results

Table 2 illustrates the number of water bodies in each of the RBDs across England and Wales that fall into the four risk categories, and illustrates that nationally some 8.5% of all water bodies are at risk or probably at risk of failing to meet WFD objectives due to abandoned non-coal mining pollution. In the RBDs that have been a particular focus of historic mining these figures are higher than this national average: 16% in Northumbria, 9% in South West and 10% in Western Wales. Those water bodies that are categorised as at risk or probably at risk all have at least one metal EQS failure, either in the water body itself or in the water body immediately downstream of it. 40% of all of these EQS failures are due to zinc, 14% due to cadmium and 18% due to lead. It is worth noting that less than 5% of all failures are due to iron, which is typically the main contaminant associated with coal mine water pollution (note that the impacts of coal mine water discharges should not register as risks here as coal strata were not included as 'mining geology' for this exercise, since pollution from abandoned coal mines is already well characterised).

The greatest density of water bodies at risk or probably at risk is in the Northumbria RBD in north-east England. Figure 1 shows the locations of the at risk and probably at risk water bodies in the RBD, together with the known mine sites and the major rivers in the region (from north to south, the River Tyne, River Wear and River Tees). Most of the problems arise from the former mining district in the

Pennine hills in the west of the region, which was principally mined between the 17th and 19th centuries for a variety of minerals, but especially lead and zinc.

Table 2 *Summary statistics showing initial categorisation of water bodies across England and Wales*

River Basin District	At risk	Probably at risk	Probably not at risk	Not at risk	Total
Anglian	1	30	146	929	1106
Dee	7	10	10	84	111
Humber	15	56	111	761	943
North West	15	28	63	469	575
Northumbria	23	43	41	302	409
Severn	37	38	82	639	796
South East	0	47	61	403	511
South West	59	73	419	887	1438
Thames	0	65	81	509	655
Western Wales	70	36	190	783	1079
Grand Total	**227**	**426**	**1204**	**5766**	**7623**

Concentrations of Zn, Cd and Pb in streams and rivers of Northumbria are as high as 2 400 μg/L, 8.4 μg/L and 119 μg/L respectively, which is an order of magnitude higher than current quality standards in all cases (see Johnston and Rolley (2008) for further discussion).

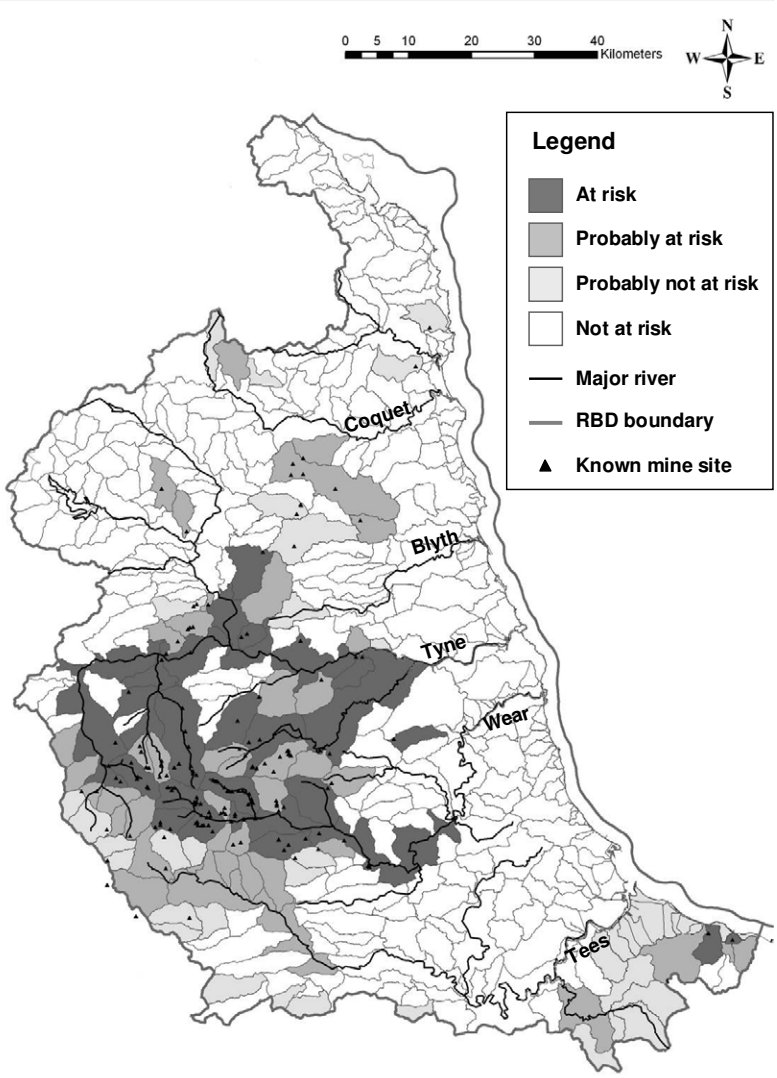
Conclusions

This paper briefly outlines the implementation and results of a national-scale assessment and prioritisation of the impacts of abandoned non-coal mines on the freshwater environment. The results indicate that nearly 10% of all water bodies across England & Wales are at risk or probably at risk of failing to meet EU Water Framework Directive objectives, and in the most heavily mined River Basin Districts this figure is greater than 15%. In the Northumbria River Basin District the metal concentrations exceed standards by at least an order of magnitude in some cases. The nature of metal mine water pollution, and its extent, has important implications for future management of environmental problems arising from former mining activity, particularly with respect to meeting the objectives of the Water Framework Directive. Taking the Northumbria River Basin District as an example, these include:

- Establishing exactly what the contribution of former metal mining is to the overall metal loading of major rivers, particularly given that in the lower reaches (i.e. below the tidal limit) of some of these rivers river sediment contamination with metals is recognised as an important environmental problem. Therefore establishing what the major sources of these metals are is an important precursor to instigating any improvements
- Diffuse metal mining pollution has recently been highlighted as a potentially major source of metals to the aquatic environment (Mayes et al, 2008). Indeed, in storm events the vast majority of metal loading in some mining catchment rivers is <u>not</u> due to identifiable sources of mining pollution such as mine entrances
- Remediation of such metal mine waters is highly challenging, in part because of the high mobility of metals such as zinc and cadmium which makes passive treatment very difficult, but also because of the diffuse nature of mining pollution in at least some of these river catchments

Further research needs to be conducted to begin to find resolutions to some of these problems, but such initiatives may well need to focus on the dynamics of metals in river catchments as a whole, not just specifically on mine water pollution issues within them.

Figure 1 *Water bodies at risk of failing to meet WFD objectives in the Northumbria River Basin District (This map is reproduced from Ordnance Survey material with the permission of Ordnance Survey on behalf of the Controller of Her Majesty's Stationery Office © Crown copyright. Unauthorised reproduction infringes Crown copyright and may lead to prosecution or civil proceedings. Environment Agency, 100026380, 2008)*



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