Abandoned Mines and the Water Framework Directive in the United Kingdom

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Abstract
The Water Framework Directive is the overarching driver for water quality in Europe and its implementation in the UK is critical to how we view minewater pollution. Its basic tenet is that we achieve good chemical or ecological status in all of our water bodies. The Environment Agency, the Scottish Environment Protection Agency, and the Coal Authority work together to deal with the problem of minewater pollution and we have reviewed our work programmes to match the objectives of the directive. The Coal Authority's environment programme has been aligned with the first three river basin planning cycles and we are starting to address the problem of non-coal mines with an identification and prioritisation project that will affect river basin plans.

Introduction
The UK has a legacy of mining for coal, metal ores, and other minerals that dates back to the Bronze Age. Many thousands of mines have been abandoned and now discharge minewater containing heavy metals and other pollutants into our watercourses. Other mines, more recently closed, are still filling up with groundwater and will start discharging sometime in the future. Abandoned mines are one of the most significant pollution threats in the UK today.
The implementation of the Water Framework Directive (WFD) has become the overarching driver for water quality in Europe and its implementation in the UK is critical to how we view minewater pollution. This important piece of European legislation will fundamentally affect how we deal with pollution from abandoned mines by requiring us to achieve good status in all of our surface water and ground water bodies.
Nine percent of rivers in England and Wales, and 2% in Scotland are at risk of failing to meet their WFD targets of good chemical and ecological status because of abandoned mines. These rivers cause some of the biggest discharges of metals such as cadmium, iron, copper, and zinc to rivers and the seas around Britain. Seventy-one percent of the freshwater resources that fail to achieve the cadmium quality standard are in metal mining areas. In some areas, drinking water protected areas supplying water to many thousands of homes are polluted or threatened by plumes of sulphate and chloride-rich minewater. Eight of the twelve River Basin Districts in the UK have identified abandoned mines as a significant problem.
This paper will examine the multi-agency response to the requirements of the WFD and how programmes of measures to manage abandoned mine pollution are being integrated to comply with WFD objectives.

Abandoned Coal Mines
The Coal Authority, a government funded organisation, has an existing programme of measures to deal with pollution from abandoned coal mines that has been in place since they were established in 1994. Since its inception, an extensive programme of remedial and preventative measures has been developed, providing 46 treatment facilities in the UK, 33 to treat existing discharges and 13 to prevent new uncontrolled discharges. These facilities prevent over 1800 tonnes of iron entering rivers, streams, and aquifers every year, helping to clean up or protect over 200 km of rivers and streams.
To ensure that we comply with the requirements of the WFD, the Coal Authority has undertaken a risk-based analysis of the remaining preventative and remedial schemes with each site being assessed in terms of environmental risk and potential. These risk assessments have been performed in partnership with the environmental regulators to ensure a comprehensive and rigorous approach to the anticipated risk. The results of this risk-based approach have then been overlain onto the first three cycles of the WFD to provide a coherent strategy that complies with the legal requirements.
In the case of existing discharges, a priority list had already been established with the environmental regulators which identified and prioritised the worst existing polluting discharges. Analysis of the environmental impact of the remaining discharges provided the opportunity to define high, medium,

and low risk categories, which were then programmed into three consecutive cycles of the WFD up to 2027. This exercise has enabled all of the existing discharges to be prioritised for remediation within the WFD timescales, enabling good ecological and chemical status to be achieved whilst ensuring that the overall programme provides a cost effective solution to the problem of coal minewater.

Preventing future discharges from former collieries and coalfields is the other major element of the Authority's minewater work. Comprehensive rising minewater baseline studies were undertaken that split all of the coalfield areas into blocks of interconnected workings to establish the current level of knowledge of minewater recovery in each coalfield. The results of these coalfield studies have been analysed in terms of risk and probability and those that have the greatest risk of significant impact have been allocated a designated position within the overall programme.

Over a programme life in excess of 20 years, the variables associated with all of the above risks are subject to significant change. It is essential, therefore, that the programme be reviewed on a regular basis to ensure that the remediation priorities and the probability of prevention are properly reflected in the programme schedule.

Overall, the existing programme of measures carried out by the Authority has been updated and reviewed and now aligns with the requirements of the WFD. These revised measures have been agreed to by all of the environmental regulators and will now form the basis for the Authority's minewater work over the next 20 years. The ability to adapt the existing programme has been made possible by the programmatic structures and funding that already existed for coal mine water. The reputation and achievements of the Authority have provided the basis for the extension of an already successful programme of work into one that fully complies with its new regulatory regime.

Abandoned Non-Coal Mines

Unlike coal mines, no national body has the responsibility for dealing with the legacy of non-coal mines, and the situation is therefore less well developed. The problem, however, is just as extensive and potentially more challenging because of the variation and toxicity of the pollutants involved. The river basin characterisation exercise for WFD identified 315 surface water bodies, with 80 "at risk", and 235 "probably at risk" of failing to achieve WFD objectives because of abandoned non-coal mines. These total nearly 3000 km of river, 5% of the total. For the 80 water bodies deemed to be "at risk," the correlation between a known pollution problem and mining was well established. The characterization exercise was carried out using various datasets correlated against known geographic areas of mining (Environment Agency 2008).

In order to classify water bodies into good or poor status, we have researched our water quality database to identify where water bodies fail to achieve the proposed environmental quality standards for potentially hazardous contaminants and other specific polluting substances, as outlined in annexes 8 and 10 of the WFD (European Parliament 2006). Significant failures have been determined to be those where we have greater than 95% confidence that the standard has been exceeded. When the significant failures are mapped in a geographical information system (GIS) against known metal mining areas, it is clear that many are likely associated with abandoned metal mines. In the case of cadmium, 71% of significant failures are in areas of historic metal mining. We are obliged to cease or phase out discharges of priority hazardous substances but it is not clear how this will be implemented for historic unregulated discharges.

Note 1: There is duplication between Cadmium MAC (maximum allowable concentration) and annual mean results; of mean results, a small number are not reflected as MAC failures; all cadmium failures is therefore the number of MAC fails plus the number of mean failures not duplicated.

Note 2: Significant failure is a failure with >95% confidence that the EQS is exceeded

Note 3: Range of EQS dependent on water hardness. (UKTAG 2007, European Parliament 2006)

Data source: Annex 8&10 failure database December 2006.

These data indicate that we will be unable to achieve good status in these water bodies without dealing with the historic mining legacy. In some areas, it is clear that although the chemical standard for metals is exceeded, there is a viable ecology.

Table 1 *WFD Annex 8 & 10 failures for metals attributed to metal mining catchments*

	Cadmium	Lead	Nickel	Copper	Zinc
Environmental quality standard, ug/L	0.45-1.5[3] (MAC) 0.08-0.25[3] (annual mean)	7.2	20	1-28[3]	8-125[3]
All significant failures[2]	133	69	85	234	470
Significant failures in metal mining	95	65	32	115	141
Percentage significant failures in metal mining areas	71	94	38	49	30

Though there has undoubtedly been local adaptation to the conditions, it may be that not all of the metals discharged are bioavailable. We are investigating the use of biotic ligand models to determine the proportion of metals that are biologically available so that we can determine which exceedances represent the most significant likelihood of ecological impact (Peters 2007).

In England and Wales, the Environment Agency has started a project in collaboration with the Department of the Environment, Food and Rural Affairs (Defra), and the Welsh Assembly Government (WAG) to identify and prioritise abandoned non-coal mines causing pollution (Jarvis 2008). SEPA is carrying out a parallel process in Scotland. The projects build on a strategy developed in Wales (Johnston 2007) and uses a catchment-based approach to identify the water quality problems caused by non-coal mines, from which sources are prioritised using local knowledge. In the first phase of the project, we used water quality data to identify rivers with high concentrations of eight metals commonly discharged from abandoned mines: cadmium, lead, nickel, zinc, copper, iron, manganese, and arsenic.

Using GIS, we compared the rivers containing high metal concentrations with the locations of abandoned mines or mining geology. This allowed us to make decisions about the likelihood of reported water quality problems being due to mining, and to prioritise the water bodies affected by abandoned non-coal mines.

The second phase of the project has taken this information and tested it with a questionnaire aimed at the Environment Agency and local authority staff with expert local knowledge of the rivers and mine sites. The final outcome of the projects, in 2009, will be national priority lists of the water bodies polluted by abandoned non-coal mines in England, Wales, and Scotland and the sources of that pollution.

Despite the lack of a national strategy, efforts to deal with the pollution from non-coal mines have been made by us and other organisations in many areas. Most projects have used a civil engineering approach to control leaching and dust generation from spoil heaps, usually because of concerns over human health. In some instances, such as at the Bwlch and Cwmsymlog lead mines in mid-Wales, water quality has not been improved because previously undisturbed spoil has been exposed to oxygen, causing metals to be more easily dissolved by percolating rainwater. At other sites, such as the Cwmbrwyno lead mine (Robinson 2001), Greenside lead mine (Potter et al 2004), and Parys Mountain, a civil engineering approach has been more successful in reducing loadings of metals downstream.

Only one full-scale minewater treatment plant has been built at an abandoned non-coal mine in Britain, at the Wheal Jane tin mine in Cornwall, which was abandoned in 1992. It prevents 150 tonnes of zinc and 670 tonnes of iron from entering the environment every year. Pilot-scale plants to assess the feasibility of treatment by different methods have been built at a few sites in Wales, Cornwall, and the North Pennines.

The lack of a proven sustainable method to treat discharges from non-coal mines remains a significant issue and its development will be a priority measure in the first round of river basin planning.

Conclusions

Abandoned mines are a significant threat to good status in our river basins. A programme to deal with the most significant abandoned coal mine discharges is already being implemented by the Coal Authority and will continue over three rounds of river basin planning. We do not have a similar national strategy for non-coal mines, though a start has been made in identifying and prioritising mine

sites that are causing water bodies to have a poor status. Water quality in UK mining-impacted catchments would benefit if the collaborative approach developed for coal mines was extended to non-coal mines.

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