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The Coal Authority Minewater Treatment Programme: an update on the performance of operational schemes

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Abstract

The performance of mine water treatment schemes, operated under the Coal Authority's national Minewater Treatment Programme, is summarised. Most schemes for which data are available perform successfully and remove over 90% iron. Mean area-adjusted iron removal rates for reedbed components of treatment schemes, range from 1.5 to 5.5 g Fe/m^2/day, with percentage iron removal rates ranging from 68% to 99%. In the majority of cases, calculated area-adjusted removal rates are limited by influent iron loadings, and the empirical sizing criterion for aerobic wetlands, based on American removal rates of 10 g Fe/m^{2}day, remains a valuable tool in the initial stages of treatment system design and estimation of land area requirements. Where a number of schemes have required modification after becoming operational, due consideration must always be given to the potential for dramatic increases in influent iron loadings, and to how the balance between performance efficiency and aesthetic appearance can best be achieved. Continual review and feedback on the performance of treatment systems, and the problems encountered during design implementation, will enhance the efficiency and effectiveness of the Minewater Treatment Programme within the UK.

Key words: aerobic wetlands, Coal Authority, mine water treatment

INTRODUCTION

In autumn 1995, the Coal Authority commissioned a series of preliminary scoping studies to investigate the potential for treating thirty discharges in England and Scotland. The studies enabled the Coal Authority, in liaison with the Environment Agency (EA) and Scottish Environment Protection Agency (SEPA), to select 14 priority sites for further study, marking the beginning of the Coal Authority's national Minewater Treatment Programme, which was implemented in 1996.

To date, there are fifteen treatment schemes in operation under the Coal Authority Programme. Brief details of these are presented in Table 1. One of the schemes, at Woolley, has been in operation since 1995, before the main implementation of the Minewater Treatment Programme. In addition to the schemes shown, scoping studies, feasibility studies, outline design and detailed design projects are in progress, or have been completed, for about another 40 discharges.

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Throughout the Coal Authority's Programme, emphasis has been placed on achieving, wherever practicable, low-cost, non-labour-intensive schemes appropriate to the locations in which the discharges are found. In general, this has usually meant a preference for constructed wetland systems. All of the treatment schemes listed in Table 1 incorporate wetlands, either as the main treatment system, or as a tertiary or 'polishing' step, following aeration and settlement. Where wetlands form the main treatment process, recent experiences have shown that, where total iron concentrations are in excess of about 10 mg/L, there may be adverse impacts on the system due to rapid accumulation of ochre in the first reed bed cell. It has also recently been demonstrated that high iron concentrations can be detrimental to growth of young reeds (Batty and Younger 2002). It has therefore now become general practice for Coal Authority schemes to avoid this by incorporating a primary settlement lagoon upstream of the wetland if necessary.

Relatively few of the operational treatment schemes established under the Coal Authority Programme are treating net acidic discharges, the main exceptions being the discharge at Old Meadows, where excess acidity is neutralised by the addition of caustic soda, the discharge at Bullhouse, though in this case no chemical neutralisation is undertaken, and a small tip discharge at Deerplay which is currently being treated using an experimental successive alkalinity producing system (SAPS). Chemical dosing is also used at Polkemmet, Monktonhall and, more recently, Acomb, to increase the rate of iron oxidation and/or precipitation and settlement. At Monktonhall, lime dosing is applied, whilst at Polkemmet and Acomb, hydrogen peroxide is used. Chemical coagulant and flocculant is also applied at Polkemmet.

Selection of the most appropriate type of treatment system for detailed design depends on a number of factors, but the deciding factors are most usually land availability, capital costs and predicted operational costs. Areas of land required and the costs of a particular design depend, ultimately, not simply on chemical quality and volumetric flow of the discharge *per se*, but also on the criteria used to size the treatment system. For most, if not all, of the currently operational schemes, treatment system designs have been based on empirical sizing criteria, such as those recommended by Hedin *et al.* (1994) for wetlands, and those recommended in the former NCB's handbook *Technical Management of Water in the Coal Mining Industry* (NCB 1982). Brown *et al.* (2002) have recently reviewed the performance of operational minewater treatment systems and presented some recommendations on sizing criteria as a result of that review.

TREATMENT SYSTEM PERFORMANCE

As Project Managers for the Coal Authority's Minewater Treatment Programme from 1996 to 2002, Scott Wilson have collated and reviewed monitoring data for operational schemes as the data has become available.

Two main indicators are used by the Coal Authority to assess the performance of their operational schemes. These are:

- the percentage total iron removal achieved between influent and effluent waters sampled simultaneously; and
- whether the treated discharge meets the quality agreed with the EA or SEPA.

To date, discharge consents applicable to the treated mine waters have tended to require one of the following:

- that the discharge does not result in the EQS for dissolved iron (1 mg/L) being exceeded in the receiving water; or

Table 1. Operational minewater treatment schemes implemented by the Coal Authority by August 2002

Discharge/treatment scheme	Discharge type	Main features of treatment scheme
Acomb (England)	Net alkaline, pumped adit discharge	Hydrogen peroxide dosing, aeration, primary settlement, aerobic reedbeds
Blaenavon (Wales)	Net alkaline, adit discharges	Aeration, settlement, aerobic reedbeds
Bullhouse (England)	Net acidic, gravity flow	Aeration, settlement, small aerobic polishing reedbed
Deerplay (England)	Net alkaline, pumped borehole discharge, net acidic tip discharge	Aeration, settlement, aerobic reedbed; experimental SAPS system treating tip discharge
Edmondsley (England)	Net alkaline, drift discharge	Aerobic reedbeds
Fender (England)	Net alkaline, drift discharge	Aerobic reedbeds
Gwynfi (Wales)	Net alkaline, gravity flow, drift discharge	Aerobic reedbeds
Kames (Scotland)	Net alkaline, shaft overflow	Aeration, primary settlement, aerobic reedbeds
Minto (Scotland)	Net alkaline, deep mine shaft overflow	Aerobic reedbeds
Monktonhall (Scotland)	Net alkaline, deep mine, pumped discharge	Lime dosing, settlement, aerobic reedbeds
Old Meadows (England)	Net acidic, adit discharge	Aeration, alkali dosing, settlement, polishing in small aerobic reedbed
Polkemmet (Scotland)	Net alkaline, pumped shaft discharge	Aeration, hydrogen peroxide dosing, coagulation and flocculant dosing, settlement, polishing in aerobic reedbed
Silkstone (England)	Net alkaline, gravity discharge	Settlement, aerobic reedbeds
Taff Merthyr (Wales)	Net alkaline, gravity discharge from shaft	Primary settlement, aerobic reedbeds
Woolley (England)	Net alkaline, pumped deep shaft discharge	Aeration, settlement, aerobic reedbed

Table 2. Performance of operational minewater treatment schemes implemented by the Coal Authority

Site	Monitoring period	Flow (L/s)	Raw minewater, mean total iron (mg/L)	Treated minewater, mean total iron (mg/L)	% reduction in mean total iron
Acomb	December 2001	nd	33.1 (1)	18.3 (1)	44.7 (1)
Blaenavon [a]	Oct 2001–Mar 2002	nd	10.7 (6)	3.91 (6)	63.3 (6)
Bullhouse	Jan 2000–Jan 2001	79.5[c]	49.0 (12)	2.34 (12)	91.0 (12)
Edmondsley	Sept 1999–Feb 2002	4.3 (7)	15.2 (21)	0.10 (21)	99.6 (21)
Fender	Sept 2000–Nov 2001	25 [c]	8.79 (11)	1.21 (11)	86.4 (11)
Gwynfi	Mar 2000–Mar 2002	7.5	4.6 (17)	0.45 (17)	90.3 (17)
Kames	May–May 2002	11.4 (5)	12.7 (7)	0.19 (7)	95.4 (7)
Minto	Sept 1998–Sept 2001	37.8 (1)	11.8 (27)	3.76 (27)	68.1 (27)
Monktonhall	June 2001–Feb 2002	98.3[c]	46.8 (18)	1.88 (18)	94.1 (18)
Old Meadows	June 1999–June 2001	46.3 (109)	29.1 (261)	1.28 (259)	95.5 (259)
Polkemmet	Nov 2000–Feb 2002	100 [c]	57.7 (82)	0.31 (251)	99.6 (81)
Taff Merthyr	Dec 2001–Mar 2002	77.4 (22)	7.6 (4)	0.16 (4)	97.8 (47)
Woolley	April 1995–Feb 1998	125 (1)	59.1 (185)	1.56 (185)	99.2 (185)
	April 1998–Nov 2001	152 (3)	13.8 (34)	0.21 (34)	98.5

[a] scheme newly operational autumn 2001; reedbeds not fully established; [b] number in brackets is number of results on which mean is based; [c] assumed; nd no data

- that the discharge does not contain matter which may be injurious to fish, spawning grounds or other ecology in the receiving waters; or
- that the discharge does not contain any iron floc or silt such as to cause visible discoloration of the receiving watercourse.

To date it has been rare for the discharge consenting authorities to set quantitative requirements on the discharge itself; however, a discharge consent was set for Six Bells which specified no more than 3 mg/L total iron and no more than 50 mg/L suspended solids. Whether or not discharge consents will become more prescriptive in the future, both with regard to iron and to other metal ions such as aluminium, manganese, cobalt, copper and zinc, remains to be seen.

Table 2 summarises the performance of operational schemes under the Coal Authority Programme, in terms of percentage reduction in total iron concentrations.

The data in Table 2 indicate, that, for the monitoring periods to which the data relate, the majority of the schemes were achieving in excess of 90% removal of total iron. Notable exceptions to this are Blaenavon, where reedbeds were still becoming established, and Minto, which was affected by severe reed die-back for a period. The latest available data indicate that iron removal rates at Minto in September 2001 were around 96%. It has been suggested that initial poor iron removal rates at Acomb may, in part, have been associated with the non-rectilinear design of the primary settlement lagoon, which was designed with aesthetic appearance in mind. This is likely to be an issue for further discussion in the future. Performance of the Acomb scheme has subsequently been improved by the use of hydrogen peroxide dosing.

In general terms, the operational schemes appear to be performing successfully. Hopefully this will be further reflected as new data are received for these schemes.

Whether or not the systems are performing optimally, however, is a separate issue. For those schemes incorporating reedbeds, percentage iron removals within the reedbeds have ranged from 68 to 99%, with mean area-adjusted iron removal rates of 1.5 to 5.5 g iron/m^2/day. Although these area-adjusted iron removal rates are generally lower than those recommended by Hedin *et al.* (1994), for use in sizing of wetlands (10 g/m^2/day for aerobic wetlands), mean effluent iron concentrations in these UK systems are, in most cases, less than 1 mg/L. It is evident that, in many cases, calculated removal rates are limited by the influent iron loadings relative to actual constructed wetland areas, and hence do not reflect the performance of these systems if subjected to greater iron loadings.

Several schemes have required modification after initial construction, due to poor performance, generally associated with a failure to achieve efficient precipitation and settlement of iron within the treatment system. In some cases, such as Polkemmet, this has been exacerbated by iron concentrations which increased dramatically after the scheme became operational, whilst in others, such as at Acomb, design efficiency may have been of secondary importance to aesthetic appearance. In both of these cases, the problems have been solved by dosing with hydrogen peroxide. Whilst each scheme is unique in terms of the combination of iron concentrations, flows and site setting, we can expect to encounter similar problems in the future, but through experience will gradually learn what will work. The Coal Authority has now produced a Design Guidance for Minewater Treatment Schemes which encompasses many of the engineering and environmental issues that have been raised during the design and development of schemes to date.

CONCLUSIONS

Percentage iron removal, used by the Coal Authority as a Key Performance Indicator benchmark for its operational schemes under the Minewater Treatment programme, indicates that, to date, operational schemes are generally successful in removing in excess of 90% of the iron present in raw minewater.

Although data remain relatively limited, the indications are that reedbeds which form either the whole or part of operational schemes, also achieve in excess of 90% iron removal.

Although calculated area-adjusted iron removal rates in the operational reedbeds are significantly smaller than those recommended by Hedin *et al*. for the sizing of aerobic wetlands, this criterion remains invaluable as a basis for preliminary wetland design and estimates of land area requirements.

Where a number of schemes have required modifications after becoming operational, due consideration should always be given to the potential for dramatic increases in influent iron loadings, and to how the balance between performance efficiency and aesthetic appearance can best be achieved.

Continual review and feedback on the performance of treatment systems, and the problems encountered during design implementation, will enhance the efficiency and effectiveness of the Minewater Treatment Programme within the UK. The Coal Authority's Design Guidance for Minewater Remediation Schemes reflects experience gained during the course of the Minewater Treatment Programme to date. It is anticipated that, in the future, the design guidance may be added to and/or modified as further schemes are implemented in the UK.

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