The Treatment of Pumped Minewater at Woolley Colliery, West Yorkshire

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Abstract

Woolley pumping station controls the level of underground minewater over about 100 km of abandoned coal workings in West Yorkshire. Pumping prevents the overflow of potentially contaminated minewater from many old drainage adits. On-site treatment at the adits would be difficult because of land-ownership problems, topographical constraints, and lack of capacity in adjacent watercourses. The treatment facilities at Woolley were adequate for the volume of minewater during the operational life of the colliery; however, a predicted 500% increase in volume made it essential to extend the plant if the consent standard was to be attained.

The paper describes the options which were adopted, i.e. (a) improvements to the settlement ponds and cascades, (b) the use of cloth filters, and (c) the construction of a large wetland. Further research into the use of wetlands for the reduction of amm. N is now being carried out.

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Introduction

The Woolley colliery site is situated adjacent to Junction 38 of the M1 motorway about 6 km north-east of Barnsley. Coal production at the colliery and use of the central coal-preparation plant ceased in 1991. Woolley pumping station was chosen to control the level of underground minewater over about 100 km of abandoned workings in the area to prevent the overflow of potentially contaminated minewater discharges from many old mine-drainage adits. The pumping station replaced about 15 pumping stations which controlled water at individual mines during coal production in the area. Gravitational flow of minewater is assisted through underground roadways which were built to facilitate the transportation of coal from the mine before closure.

The facilities at Woolley were adequate for treating the minewater at a rate of 40 l/s but, with the five-fold increase which was expected when used as a central pumping station, the treatment facilities had to be extended. Fig. 1 shows the developed site layout of settlement ponds and wetland.

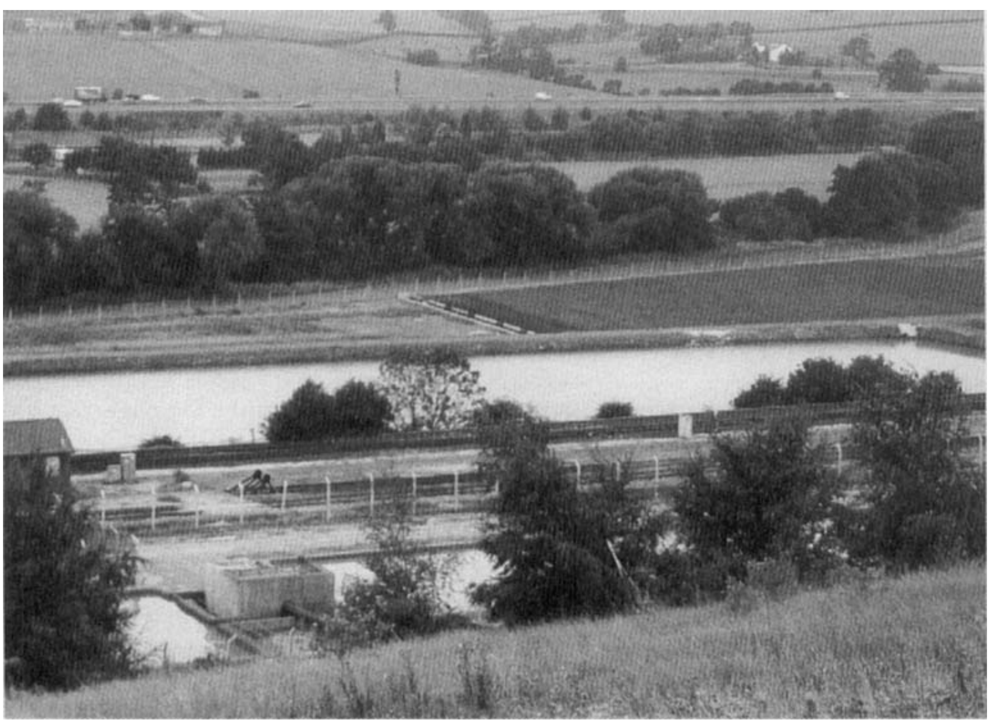

Fig. 1. General view of settlement ponds and wetland (with M1 motorway in background)

Pumping Regime

Underground water levels at Woolley shaft are maintained 101–115 m below shaft top level to prevent an increase of minewater discharges from abandoned adits in the region. Fig. 2 is a cross-section through the area, showing the adits at Hazlegreave and Gregory Springs which, at present, discharge low flows of minewater.

The pumping installation comprises two pumps having a total capacity of 250 l/s compared to the consented limit of 200 l/s. One pump operates continuously and is normally adequate to control the minewater within the pumping band, with the second pump on standby. Pumps, which normally perform alternate duty, require regular changing because of the build-up of 'ochre' within the units and in the shaft ranges. Each pump has a separate shaft range along with breather valves, stop-cocks and stop-valves. The pump motors operate at 3300 V and consume 42 amps. During the year 1995–96, 4 million m^3 of minewater were discharged to the River Dearne.

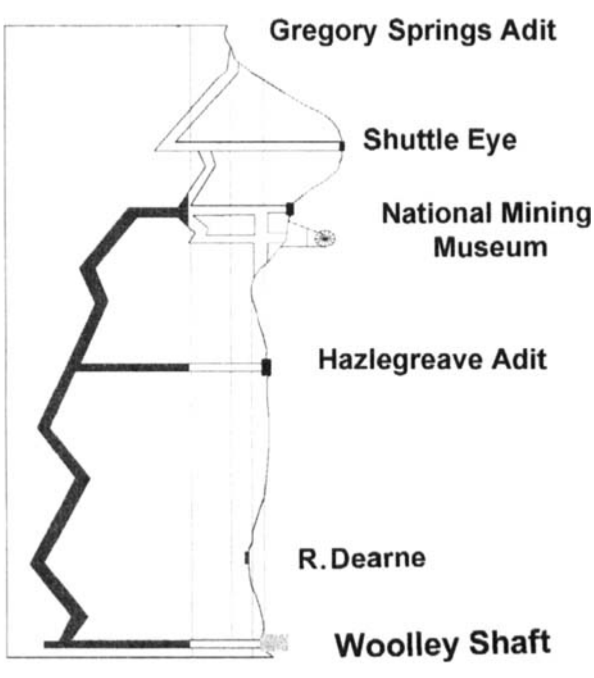

Fig. 2. Schematic underground section

Minewater Quality

The minewater raised at Woolley colliery contains ferrous bicarbonate. The dissolved-iron concentration has reached 100 mg/l, the chloride concentration is less than 2000 mg/l, the pH is about 6.5, and the concentration of amm. N averages 3.5 mg/l. Because of the excess alkalinity, treatment procedures have only required simple aeration because the conversion from ferrous to ferric iron is rapid.

Since the transfer of the site from British Coal to the Coal Authority, a gradual decline in the total iron concentration (from about 80 mg/l to 50 mg/l) has been observed. This diminution appears somewhat more rapid than at the other minewater pumping stations in the area; for example, at one station it has taken twenty years for the total iron concentration to decrease from 160 mg/l to 50 mg/l. The total iron concentration in the mine water during the mine's working life was about 15 mg/l, and it is envisaged that this value will not be re-established for many years. It is therefore likely that treatment of the Woolley pumping facility will have to continue for the foreseeable future.

When other pumping stations in the region ceased to operate, the minewater flowed underground to Woolley and the rate of discharge to the River Dearne increased from 40 l/s to 200 l/s. The treatment facilities which were then available resulted in an unacceptable impact on the River Dearne, with a pronounced ochre plume visual impact evident for a considerable distance downstream.

Discharge Consent

A consent to discharge minewater and surface drainage, which was issued in 1987 to British Coal, limited the discharge to the following maximum values:

Suspended solids: 80 mg/l
Rate: 750 m^3/h (208 l/s)
Volume: 17 000 m^3/d
Total iron: 15 mg/l until April 1995
5 mg/l from May 1995 to April 1996
3 mg/l from May 1996

Improvement Works

Substantial improvements to the treatment facilities were urgently required to enable compliance with the revised discharge consent, as follows:

Improvement to Cascades

Simple concrete step-aeration cascades were constructed to give a minimum 2 m free fall with splashing of water to allow oxidation of the ferrous iron with atmospheric oxygen. The alteration of flow through the ponds (from series to parallel) allowed better aeration to be accomplished together with improved settlement of ochre because of the reduction in flow velocity.

Removal of Redundant Pond Banks

Earth ponds on the site were approximately square, and the hydraulic flow was in series through the system. A significant loss in effectiveness was occurring due to 'dead' corners in the ponds and the constant funnelling through discharge pipes. The removal of dividing banks gave an increased surface area of about 15% and a better shape where the length/width ratio was about 3:1. The initial ponds were made to operate in series to halve the flow velocity and improve sedimentation characteristics.

Fabric Filtration Systems

The original concrete ponds in the system proved to be effective in reducing the concentration of suspended solids to relatively low values. However, in the final earth ponds, the small particle size of the residual solids made them difficult to settle. A positive-filtration system, rather than additional settlement, was proposed to remove these fine suspended solids and to gain rapid improvement in discharge quality within two months, to meet consent conditions.

Two fabric filter-wall units were constructed to strain the fine suspended solids from the minewater in its passage through the earth ponds. Each unit consists of three individual fabric walls through which the minewater is made to pass, thereby retaining fine suspended solids. The filters require regular changing because they quickly become coated with ochre, the rate being dependent upon the iron concentration. This labour-intensive feature was viewed as a short-term expedient until the wetland became adequately mature.

A number of filter materials were considered; for example (a) fine geo-textile materials were found to be highly effective in straining suspended solids but they rapidly became impermeable due to ochre coating, and (b) Copra mats (which comprise coconut fibres) proved to be too permeable and ineffective in removing suspended iron particles, and were therefore unsuitable. The material which was selected for long-term use comprised waste wool materials from local industry, which proved to be economical in cost with a life of 3–4 days between replacement. The filter walls achieved a rapid and effective improvement in the quality of the discharge to within the consent standard.

The development of the wetland to maturity, together with plans for an additional treatment lagoon in the system, will improve treatment capability to the extent that use of the filter system has now been discontinued, although the structures will be retained for use during maintenance periods.

Construction of Wetland

In order to achieve compliance with the discharge consent from May 1996, a wetland (Fig. 3) was constructed between the colliery site and the River Dearne.

A key parameter in the design was a 110-m minimum width which needed to be maintained throughout the length of the wetland; this restricted the size of the wetland to 1.4 ha. Surveys showed that minimum grading was necessary to achieve the required land profile which reduced earth-moving costs and, more importantly, helped to preserve a good soil structure in which to plant reeds.

In order to minimize costs and maintain visual amenity, the wetland was designed with earth berms seeded with a stabilizing low-maintenance mix as the main water-containing structure. Concrete was only used for the outlet to the discharge ditch, and six adjustable weirs allow the water level to be adjusted. The objective was to construct a natural feature which would blend into the environment and provide a wildlife habitat, whilst performing its principal function of minewater treatment.

A simple pipe-distribution system was devised to spread the flow evenly over the entire wetland. This comprised 300-mm plastic pipes carrying water into four distribution zones incorporating 'Tee' fittings. If changes in flow pattern are required, this system is easily adjustable and readily dismantled and reconnected. The plants have been set directly into the existing soil so that the passage of water through the wetland can result in the retention of solids on plant stems and leaf litter. The system requires little maintenance or supervision other than regular monitoring of the growth of the plants and possible addition of fertilizers, although this has not yet proved necessary because of the high concentration of nutrients remaining in the soil.

Construction commenced in May 1995 and planting was completed within two months. Plants were mainly pot-grown but bare-rooted stock were used in some areas to contrast the rates of growth of each type

Fig. 3. Wetland area and discharge weir

and, despite extremely high temperatures during planting, few plants failed to establish. The following species were selected because of the knowledge that they naturally become established at colliery sites.

Scirpus lacustris (true bull rush)
Typha latifolia (bull rush)
Typha angustifolia (lesser bull rush)
Phragmites austraulis (common reed)
Iris pseudacorous (flag iris)
Phalaris arundinacea (reed canary grass)
Juncus efflisus (soft rush)

A review of the success of each species has been undertaken and supplementary planting has been carried out with the most prolific species. It is now two years since the wetland was planted, and results are encouraging. As the plants continue to mature, it is expected that the performance of the wetland will show further improvement, resulting in cost-effective minewater treatment. It is also hoped that long-term performance will be maintained from the natural productivity of the site, with the need for only minimal imported plant nutrients.

The Woolley scheme has therefore been created by exploiting, sympathetically, the existing landform and natural resources of the site to provide a low-cost minewater treatment system with good visual amenity and diverse wildlife habitats. Planting directly into a prepared field surface without importing sub-strata materials has resulted in a low-cost (but successful) element of the treatment, which has reduced the concentration of iron in the discharge to less than 1 mg/l. The overall cost of the complete construction of the wetland (including inlet and outlet arrangements) was less than £5/m^2, which makes the use of well-designed wetland an attractive option.

Reduction in ammoniacal N

The concentration of amm. N in the raw minewater is about 3.5 mg/l, and there is little change in this value during its passage through the treatment system; it was anticipated that the wetland would effect a reduction but this has not been realized. It is thought that, because the wetland plants are located in what was highly productive agricultural land, sufficient nutrients are available to them to make the reduction of the amm. N (by plants) unnecessary.

Although amm. N is not a consented parameter, the Coal Authority is looking to the future when reductions may be required at sites for which they are responsible. The Authority has accepted a proposal to carry out research into the effectiveness of wetlands in reducing amm. N. The scheme is to insert plants, into a gravel substrate, separated from underlying soils by an impermeable seal to ensure that other sources of nutrient are not available to plants, making the amm. N the only source of nutrient available. Composting of the surface of some beds will provide a slow-release carbon source to the plants so that any increase in efficiency can be determined.

The trial wetland is located after the main wetland. The available area of less than 0.5 ha will not allow treatment of the total flow, although it does allow the loading/unit area to be varied and the resulting reduction recorded. The construction and planting of the wetland is complete, and monitoring commenced during June 1998. Initial findings appear to confirm a significant reduction in the concentration of amm. N, principally through algal growths – mainly of filamentous green alga *Mougeotia* and boat-shaped diatoms.

Sludge Management

Ochre sludge, which is produced as part of a minewater treatment system, is a waste from 'a mine or quarry' and is therefore not a controlled waste. The sludge at Woolley colliery is removed from the settlement ponds using suction tankers and is discharged to 'on-site' drying beds. The beds are constructed using burnt and unburnt colliery spoil to achieve controlled drainage along with natural evaporation of water from the ochre which thickens from 5% DS to 25% DS reasonably quickly. The long-term disposal of this thickened sludge is being considered, and options such as disposal off-site or engineered disposal on-site are being evaluated.

Utilization of the sludge as a useful product has been researched, although no firm solution has yet been identified. Its use as (i) a dye in the brick/pipemaking industries, (ii) a flocculating agent in water treatment, (iii) jewellers rouge, and (iv) in road-marking thermoplastics have all been considered. Chemical conditioning of the ochre to produce high-quality pigments has also been discussed, but considerable capital investment would be necessary to establish this option.

Conclusions

The treatment system has achieved compliance with consent conditions by engineering cost-effective schemes which make best use of the existing facilities and materials available on the colliery site, i.e.

(i) Improvements to the aeration system were low cost and significantly improved the transfer of dissolved iron into suspension;
(ii) The filter fabric walls proved to be a novel method of providing an instant improvement in discharge quality;
(iii) The development of the wetland has provided long-term, low-maintenance tertiary treatment for the retention of fine iron particles;
(iv) The development of on-site sludge facilities will result in considerable cost savings; and
(v) Data from the wetland will help to design future treatment schemes which are intended to reduce the concentration of amm. N.

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