site bulletin

CL:AIRE site bulletins provide a source of background information on sites which have been used within the scope of CL:AIRE technology demonstration and research projects. This bulletin describes the CoSTaR research facility.

Coal Mine Sites for Targeted Remediation Research: - The CoSTaR Initiative

1. INTRODUCTION

The purpose of this bulletin is to describe each of the six sites that comprise the Coal Mine Sites for Targeted Remediation Research (CoSTaR) facility in northeast England. CoSTaR was established in 2002 by the Hydrogeochemical Engineering Research & Outreach (HERO) Group at University of Newcastle, the Coal Authority, Durham and Northumberland Councils and CL:AIRE.

2. THE PROBLEM

Mine water pollution is a consequence of mining activity where the excavation of mineral deposits (metal bearing or coal), below the natural groundwater level, exposes sulphur containing compounds to oxygen and water. Mine water pollution is caused by the oxidation and dissolution of sulphide minerals exposed during mining, a process which is catalysed by bacterial activity. The most prolific contaminant in the UK is iron, with manganese, aluminium and sulphates all adding to increase the acidity of the water. Mine water pollution is a problem because the vast majority of natural life is designed to live and survive at, or near, pH 7 (neutral). The drainage acidifies the local watercourses and so either kills or limits the growth of the river ecology. There is also a problem because of the metals contained in the drainage. As most mines in the UK extracted coal rather than metalliferous minerals the main metal of concern is iron.

Mine water pollution events are more harmful than incidents involving nitrate and oil because the pollutant will not be broken down to carbon dioxide and water, the metal pollutants will remain in the environment in one form or another.

3. THE SOLUTION

There has been a long history of mine site restoration in the UK, however until the early 1990's virtually all efforts in this regard were focused on re-shaping and re-vegetating bodies of spoil and backfill. Since 1994 there have been advances in so called "passive treatment" systems for the long-term clean up of polluted mine site drainage, including leachates from spoils or backfills and also waters emerging from flooded underground mine workings.

The EU's PIRAMID project (Contract EVK1-CT-1999-000021) defines passive treatment as (www.minewater.net):

"… constructed (or appropriated, natural) gravity-flow systems, in which all treatment processes use only naturally-available energy sources (such as topographical gradient, microbial metabolic energy, photosynthesis and chemical energy), and which require only infrequent (albeit regular) maintenance to operate successfully over their design lives …"

The UK currently enjoys a leading position in Europe in the development of passive treatment systems for mine waters, with more full-scale systems in place than in any other European country.

Although passive treatment systems have operated with a high rate of success to date, the fact remains that the design of such units is empirically- rather than process-based. A more precise understanding of the process mechanics and rates in passive systems will give far greater confidence in treatment performance, and allow optimisation of system design and longevity.

Figure 1: Location of the six CoSTaR sites in northeast England.

4. THE CoSTaR INITIATIVE

Building upon the highly successful mine water research programme which has been operating at Newcastle University since 1992 (the University was awarded a Queen's Anniversary Prize for Higher and Further Education in 2005 in recognition of the work of this programme) and drawing also upon the major achievements of the Coal Authority's national rolling programme of mine water remediation, the CoSTaR research facility has been established in the heart of the once-great Northern Coalfield.

CoSTaR comprises a 'constellation' of six established mine water remediation sites (see map), which have been selected to provide at least one example of each of the principal types of passive systems currently used to treat polluted mine waters at numerous sites in North America and Europe:

Aerobic reed beds treating non-acidic waters with high iron contents: St Helen Auckland, Whittle and Acomb sites
Compost wetlands treating acidic waters: Quaking Houses site
Reducing and Alkalinity Producing System (RAPS), i.e. vertical flow compost / limestone bioreactors: Bowden Close site
Permeable reactive barrier: Shilbottle site
Hybrid active / passive system: Acomb site

Nowhere else in the world is such a complete array of passive treatment systems available within such a small geographical area: all six constituent sites of CoSTaR lie within 30 miles of central Newcastle.

Key issues in the longevity of such systems relate to the rate at which carbon, and other key elements, are cycled, and to the rate at which (metalliferous) sediment accumulates within passive units. CoSTaR is ideally suited to unravelling the nature and rates of the controlling processes. The concept is to ensure baseline performance data are collected for all six systems, so that researchers undertaking specific investigations and experiments on the sites are able to place their findings within the overall context of treatment efficiency, thus ensuring the practical relevance of the research.

ACOMB

LOCATION
The Coal Authority's Acomb Minewater Treatment System can be located 1 mile north northwest of Hexham in Northumberland; Ordnance Survey, Landranger series, map 87, OL43, at the coordinates NY 927 663.

HISTORY
Prior to closure in 1952, two coal seams had been mined at Acomb during the 19th and 20th centuries. Polluted mine waters discharge into the Red Burn at Acomb, to the east of the Acomb Drift, via an old pipe which is known to have been present prior to reclamation of the colliery area. This discharge occurs approximately 1000m above the Red Burn's confluence with the River Tyne, causing severe contamination which was highly visible in the village.

THE PROBLEM
The minewater at Acomb is net alkaline with a total iron concentration in the region of 25 to 40mg/l. There had been reports of high levels of lead, copper, nickel and zinc and these levels may indicate connections with local metal mines. The average flow of the discharge is 10l/s with a pH value of 6.6.

THE SOLUTION
This is a hybrid treatment system with some pumping and hydrogen peroxide dosing upstream of settlement lagoons and an aerobic reed-bed wetland. The passive treatment element at Acomb consists of aeration, settlement lagoons and aerobic wetlands to remove the iron from solution. Construction work commenced in August 2001. The minewater is pumped from the top of the drift into an aeration tower. Once the water is aerated it is dosed with a small volume of hydrogen peroxide before passing into two irregular shaped lagoons, which operate in parallel. These are approximately 3.0 m deep and have a total area of 750 m^2. These lagoons have some peripheral planting to improve the aesthetics of the scheme. The water then passes into two reed beds in sequence, with a combined area of 1200 m^2, which are planted with a variety of reeds including *Typha latifolia*, *Phragmites australis*.

Figure 2: Settlement lagoons (top) and aerobic wetland (bottom) at the Acomb CoSTaR site.

Figure 3: Aluminium hydroxide deposition from one of the acidic discharges at Bowden Close, prior to remediation.

BOWDEN CLOSE

LOCATION
The Bowden Close Passive Treatment System is located in County Durham and can be found on the Ordnance Survey, Landranger series, map 92, at the coordinates NZ 181 356. The system was designed by Newcastle University, and is owned and operated by Durham County Council.

HISTORY
The colliery and cokeworks were abandoned in the 1960s, and it it wasn't until the 1970s that restoration of the derelict site was undertaken by Durham County Council. Reclamation consisted of demolition of buildings, reshaping of spoil heaps, and application of topsoil over made ground. There were no efforts made to intercept or reduce subsurface flow through heaps or made ground.

THE PROBLEM
During 1998/99 three spoil heap discharges were identified as being highly acidic (pH3-4), with high concentrations of metals, in particular Fe, Al, and Mn. These leachates caused severe contamination of the local water course, the Willington Burn (see Fig.3).

THE SOLUTION
Two subsurface flow Reducing and Alkalinity Producing Systems (RAPS) and an aerobic "polishing" reedbed were designed. RAPS 1 is fitted with an HDPE artificial liner; RAPS 2 is unlined, but has been excavated into low permeability glacial till. The substrate for both RAPS is a well mixed combination of horse manure plus straw, and limestone clasts. The areas of RAPS 1, RAPS 2, and the reedbed are 1511 m^2 , 1124 m^2 , and 990 m^2 respectively. There are three discharges, discharges 1 and 2 are treated in RAPS 1 while the third, and most polluted discharge feeds into RAPS 2. The effluents of both RAPS drain into the aerobic wetland.

Further details of the Bowden Close will be given in the forthcoming CL:AIRE Technology Demonstration Report (TDP5), which will be available in April 2006.

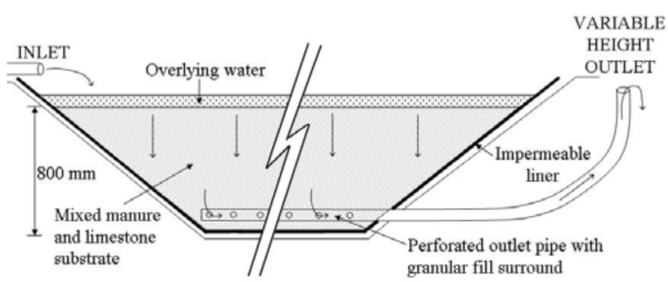

Figure 4: Bowden Close - Schematic of the Reducing and Alkalinity Producing System.

QUAKING HOUSES

LOCATION
The village of Quaking Houses can be located on Ordinance Survey map, Landranger series 88, Tyneside and Co. Durham area, at grid reference NZ 185 506; whilst the Quaking House wetland is situated at grid reference NZ 179 509.

HISTORY
Quaking Houses was born out of the coal mining industry early in the 19th century. A number of pits opened and closed in the vicinity over the next 200 years. The area reached the peak of its prosperity around the first quarter of the 20th century, but by 1947 coal mining was already in decline. The last shift to be worked at the Morrison Busty Pit, the only remaining deep mine in the area of Quaking Houses, was on October 5th 1974.

THE PROBLEM
A large spoil heap (35 hectare) associated with the Morrison Busty Pit was bisected during the construction of a major road. This led to the creation and subsequent disturbance of a perched aquifer within the spoil. Oxidative dissolution of pyritiferous spoil created a leachate rich in sulphate, metals, and depressed pH. This leachate drained into a local water course, the Stanley Burn, where it caused significant pollution.

THE SOLUTION
Following a pilot study, a dual-celled, surface-flow wetland was constructed to treat the leachate. The substrate consisted of a 30:40:30 mix of cow, and horse manure, and municipal composted waste to a depth of 0.3-0.5m. A limestone berm was situated close to the system effluent to give a final boost of alkalinity to the exiting waters. The total substrate surface area is 440m^2.

Further details of the Quaking Houses wetland are given in CL:AIRE Case Study Bulletin CSB2.

Figure 5: Quaking Houses - Pollution of the Stanley Burn with iron and aluminium oxyhydroxides.

Figure 6: Quaking Houses - Compost wetland treating acidic spoil leachate.

SHILBOTTLE

LOCATION
The Tyelaw Burn and Shilbottle spoil heap lie in the catchment of the River Coquet in Northumberland. The southern toe of the spoil heap can be located at NY 220 078.

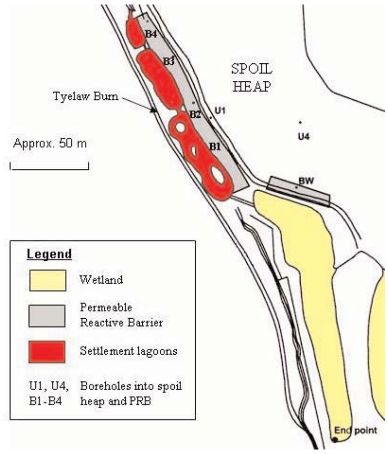

Figure 7: Shilbottle - Schematic of the PRB.

HISTORY
There are records of mining activity from 1882, but it was not until 1914 when The Cooperative Society took over the mine, that production started to increase. All the coal produced from this colliery was classed as household coal. Mining continued after Nationalisation in 1947, up until October 1982 when the pit was closed.

THE PROBLEM
A single seam of coal was worked at Shilbottle Colliery. Due to the situation of this seam within the Carboniferous Limestone Series (Dinantian), where the immediate roof bed consisted of highly pyritic shale, the spoil from this colliery is the major source of acidic, metalliferous leachate. The waters of the flooded mine workings are buffered by the limestone which overlies the shale, but the spoil does not contain any limestone and is devoid of alkalinity. In fact the leachate from this spoil is possibly the most contaminated spoil leachate yet documented in this country. This contamination has led to severe pollution of the Tyelaw Burn in the form of ochres, aluminium hydroxysulphate foams, and localized patches of black manganese 'wad'.

THE SOLUTION
The leachate represents a severe pollution hazard which, left untreated would have the following characteristics; pH ~ 3.5, mineral acidity ~ 6000 mg/L, Fe ~ 1100 mg/L, Mn ~ 300 mg/L, Al ~ 700 mg/L, and SO_4^{2-} ~ 15000 mg/L. This leachate is conveyed to the Tyelaw Burn chiefly as subsurface seeps. To intercept these seepages for treatment, a Permeable Reactive Barrier (PRB) was designed. The barrier comprises a trench ~ 180 m in length by 2-3 m width and depth, and is filled with a mixed substrate of 25% composted horse manure, 25% green waste compost, and 50% limestone gravel. The treated leachate exits the barrier through a permeable face lined with brick rubble, and into a series of three settlement ponds for polishing. From the third pond the water enters a reedbed for a final polishing before entering the Tyelaw Burn.

Further details of the Shilbottle PRB will be given in the forthcoming CL:AIRE Technology Demonstration Report (TDP13), which will be available in May 2006.

Figure 8: Shilbottle - PRB and ponds.

ST. HELEN AUCKLAND

LOCATION
Approximately 11 miles south southwest of Durham city, the wetland is situated in St. Helen Auckland, and can be located at the coordinates NZ198 269.

HISTORY
The St. Helen Auckland Colliery opened in 1831 with the sinking of the Engine Pit. This was followed by Emma and Catherine Pits. Coal was extracted for coking and manufacturing; from 1923 coal was extracted for household use, coking, and the production of steam. Following the General Strike of 1926, during which time the mine pumps were switched off, the St. Helen Auckland Colliery remained closed due to partial flooding.

THE PROBLEM
Severe flooding of a formerly productive hay meadow with polluted mine waters. This was caused by the release of ground water from flooded mine workings of the former St.Helen's Engine Shaft; the water burst through the long-forgotten shaft, flooding the building which had been constructed over it. The decision was made to divert the water to the nearest drain; the drain chosen debouched into a small ditch which ran through the hay meadow. The flow of water (approaching 2000 m^3/d) was far more than the ditch could accommodate, resulting in widespread flooding of the meadow.

Figure 9: St Helen Auckland - an aerobic reed-bed treating net-alkaline mine water.

THE SOLUTION
Following chemical analysis of the water, an aerobic reed-bed was proposed as the best option for treatment. The design of the reed-bed incorporated an existing natural reed-bed area called Stivvy's Swamp. The swamp was surrounded with a clay bund to prevent water seepage, and to retain a greater depth of water within the wetland. Pipe work to distribute the influent water, and collect the effluent water was installed. The water was diverted into the 'new' wetland on 28/08/99, some 20 years after the initial flooding.

WHITTLE

LOCATION
The Coal Authority's Whittle Passive Treatment System can be located on the Ordnance Survey, Landranger series, map 81, at the coordinates NU 217 085.

HISTORY
After nearly a century of activity Whittle Colliery ceased mining operations in March, 1997. Dewatering of the underground workings also came to an end at this time. Groundwater rebound of the workings was measured and found to be 5cm/day. Flooding of the mine voids resulted in the production of mine drainage rich in iron and manganese.

THE PROBLEM
The rising contaminated groundwater gave cause for concern, as any uncontrolled release into the Hazon Burn would have resulted in a major pollution event for this water course. The Hazon Burn is a tributary of the River Coquet, itself one of the 27 river Sites of Special Scientific Interest (SSSIs) in Britain. A pollution event in the Burn would have impacted adversely on the River Coquet.

THE SOLUTION
The scheme at Whittle is a preventative scheme and therefore the water was prevented from reaching the surface naturally. The water is pumped via a purpose drilled borehole that stretches 70m into the Whittle Colliery drift, with the water initially entering into the aeration cascade at the head of the treatment scheme. After aeration, the water simultaneously flows through two parallel settling ponds. These have an area of 800 m^2 where the ochre precipitation takes place. The water then enters into three surface flow aerobic wetlands in series. The wetlands each have an area of 3000m^2. Wetlands 1 and 3 are planted with *Typha Latifolia*, with wetland 2 planted with *Phragmites*. The purpose of the planting was to distribute the flow of the water and polish the final discharge into the Hazon Burn. The treatment system has demonstrated an overall removal rate for iron of 97%.

For further information visit the CoSTaR website at www.minewater.net/CoSTaR

Figure 10: Whittle - parallel settling ponds.

COMMUNITY ENGAGEMENT AND THE CoSTaR FACILITY
The CoSTaR facility is an important focus for the HERO Group's outreach dimension, which aims to initiate, maintain and enhance community participation as a way to encourage involvement of non-specialist public in areas of science and engineering that are of importance to them. Particular emphasis is placed on enabling young, disadvantaged and vulnerable people to get their voices heard. Recognising the essential role that communities play in improving sustainability, voluntary and community sector projects are encouraged, in order to develop understanding of real environmental issues to a level far beyond traditional classroom delivery.

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