Appraisal of the potential treatment options for the Haggs Level discharge, Nentsberry

This update provides a summary of the work carried out to identify and appraise the different potential options available to treat the mine water which comes out of the Level draining the former Haggs mine system in Nentsberry.

Introduction

The Department for Environment, Food and Rural Affairs (Defra), the Environment Agency and the Coal Authority, are working together to clean up metal pollution from abandoned mines that is affecting the rivers Nent and South Tyne. One of these discharges is from the Haggs Mine, a former lead mine at Nentsberry to the south-east of Alston in Cumbria.

The Coal Authority commissioned consultants, AECOM, to identify and evaluate the treatment options as part of a wider study in 2015/16. The full report is available at: https://ea.sharefile.com/d-s099a795c590435d8

This summary explains how AECOM identified a long list of 16 potential treatment options and appraised these to draw up a short-list of four options from which compost-based ponds were selected as the best treatment technology for the proposed mine water treatment system.

What’s the problem?

The high levels of zinc and cadmium in the mine water discharging from the Haggs Mine are damaging river life in the River Nent and contributing to pollution of the River South Tyne downstream. The water and sediment quality is impacted all the way to Newcastle. Removing the metals before they enter the River Nent will improve the environment for wildlife and people and create significant economic benefits.
What are the possible management and/or treatment options?

A range of different approaches could be applied to the treatment and/or management of the mine water. A total of 16 potential options were identified on the long list, which were split into 4 groups:

<table>
<thead>
<tr>
<th>Management or treatment type</th>
<th>No. of options considered?</th>
<th>How it works</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catchment management</td>
<td>5 options</td>
<td>Physical work to either divert surface water from entering the mine workings to reduce the volume of mine water that needs treatment, and potentially using it as ‘grey water’ elsewhere; containing spoil heaps with a physical barrier to stop spoil coming into contact with water; creating a dam within the mine to contain the source underground and prevent migration into watercourses or direct discharge to a water body where natural processes will reduce the metal pollution.</td>
</tr>
<tr>
<td>Passive</td>
<td>4 options</td>
<td>Passive treatment using no chemicals or energy in the open in either reedbed wetlands or compost based treatment ponds; or in enclosed drains or tanks, where natural processes remove metals from the water.</td>
</tr>
<tr>
<td>Semi passive</td>
<td>3 options</td>
<td>Semi-passive treatment using a combination of natural processes enhanced by use of chemicals or energy where a reactant (naturally occurring or chemical) is added to captured mine water to alter the pH and precipitate out metals as a solid.</td>
</tr>
<tr>
<td>Active</td>
<td>4 options</td>
<td>Active treatment using chemicals and energy to treat captured mine water with either chemicals that react to precipitate metals out as solids, electrolysis to separate metals, or by pumping to force it through a membrane leaving soluble metals on one side and cleaner water on the other.</td>
</tr>
</tbody>
</table>

How was the treatment technology selected?

The first stage was to look at the feasibility of the 16 identified technologies: Would the treatment actually work for the situation at Haggs Mine?

Those that potentially could were then assessed to determine the:

- likelihood of reducing metal levels in the mine water to the required level
- likelihood of meeting the aspirational start date for construction
- likely initial capital cost
- likely ongoing operating cost

Short-listed management options and treatment technologies

Of the 16 potential options on the long list, 4 management and/or treatment options made it onto the short-list:

- a catchment management option of diverting surface water away from entering the abandoned mine workings thus reducing the generation of mine water and hence the volume to be treated.

- the other 3 options were all based on the ability of naturally occurring microbes to convert the sulphate in the mine water into sulphide. This sulphide then binds up the metals such as zinc, cadmium and lead to form solids that are retained within the treatment system. The treated mine water therefore contains much lower levels of metals and can be safely discharged to a river. These three treatment systems were:
  - Liquid Reactant Bioreactor (LRB) – a semi passive system comprising a tank filled with rock gravel over a layer of manure. A liquid reactant such as ethanol or ethylene glycol is added to the mine water as it enters the tank, and bacteria from the manure convert the sulphate to sulphide which binds to the metals and forms solids.
  - Sulphate Reducing Bioreactor (SRB) – a passive system in which a compost-based mixture is placed in a tank. As the mine water passes through the compost, bacteria convert the sulphate to sulphide which binds to the metals and forms solids.
  - Vertical Flow Pond (VFP) – also known as Reducing Alkalinity Producing System (RAPS) – very similar to the SRB but the compost mixture is placed in a pond rather than a tank.
Two further ‘sub-options’ were suggested for possible pilot trials but were not considered to be ready for full-scale application without further research and investigation.

These are:

- ion exchange technology; a semi passive method using minerals specifically to target the selective removal of dissolved zinc, cadmium, lead and copper by precipitation onto a highly sorptive media
- chemical sulphide precipitation; an active technology that adds sodium sulphide to mine water, causing metals to come out of solution and form a sludge that can then be removed - the requirement to store and use hydrogen sulphide means that this option was considered to have a high risk of causing odour nuisance

Further assessment of short-listed management options and treatment technologies

The short listed options were taken forward for further assessment.

This included preliminary estimates of:

- the number of years the intervention (management option or treatment system) would last
- the indicative lifetime cost over 25 and 40 years, the lifetime costs are based on:
  - Capital Expenditure to design and construct the plant (CAPEX)
  - Operational Expenditure (OPEX) to operate and maintain the plant

The costs were based on a review carried out for the Coal Authority in 2014\(^1\). These costs are indicative for comparison purposes and have not been discounted to give a Net Present Value (see separate Benefit Summary for an explanation of economic assessments):

\(^1\) Metal Mine Water Treatment Review, October 2014 (Ref 47068625/MARP001)
<table>
<thead>
<tr>
<th>Management or treatment type</th>
<th>Estimated CAPEX in £M</th>
<th>Estimated OPEX in £M/yr</th>
<th>Estimated lifespan of technology in yrs</th>
<th>Estimated lifetime costs over 25yrs in £M</th>
<th>Estimated lifetime costs over 40yrs in £M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface water diversion / leat</td>
<td>&gt;£0.1</td>
<td>-</td>
<td>25</td>
<td>2.5</td>
<td>4</td>
</tr>
<tr>
<td>Liquid reactant bioreactor (LRB)</td>
<td>1.5</td>
<td>0.2</td>
<td>7.5</td>
<td>10</td>
<td>16</td>
</tr>
<tr>
<td>Sulphate reducing bioreactor (SRB)</td>
<td>2</td>
<td>0.1</td>
<td>7.5</td>
<td>9.2</td>
<td>14.7</td>
</tr>
<tr>
<td>Vertical flow ponds (VFP)</td>
<td>2</td>
<td>0.1</td>
<td>7.5</td>
<td>9.2</td>
<td>14.7</td>
</tr>
<tr>
<td>Ion exchange technology</td>
<td>1.5</td>
<td>0.4</td>
<td>25</td>
<td>11.5</td>
<td>18.4</td>
</tr>
<tr>
<td>Chemical sulphide precipitation</td>
<td>2</td>
<td>1</td>
<td>25</td>
<td>27</td>
<td>43.2</td>
</tr>
</tbody>
</table>

Note: These costs have not been discounted to give a “Net Present Value” and so are higher than those reported by the Coal Authority and Environment Agency elsewhere.

Which management options and treatment technologies did AECOM and the project partners identify as the best options?

Surface water diversion at specific locations was identified as a reasonably low cost option for reducing the amount of water entering the Haggs mine system. This would need further detailed mine drainage and hydrogeology assessment to identify the potential benefits this would have in reducing the amount of mine water needing to be treated. This option will be investigated by the Coal Authority and Environment Agency.

For the treatment options VFP or SRB were considered the most cost-effective option over an operating period of 25 years (indicative £9.2m cost), even assuming that the performance in the treatment ponds or tanks deteriorates over time, and the compost-based material needs renewing periodically.
Whilst SRB is a tank based system and thus needs a smaller amount of land compared to VFP, the consultants proposed that where land is available then VFP could be considered in preference to SRB because:

- It’s well established and proven in the UK, with metals removal ranging from 60% to more than 90%.
- It’s a passive treatment whereas SRB is a semi-passive one (that is, it requires the use of energy and chemicals), and
- The treatment ponds would merge more readily into the landscape of the Nent Valley than SRB treatment tanks.

SRB or LRB could be used where less space is available, and where the “industrial looking” tanks could be screened. SRB technology is better established than LRB and has been proven as a mine water treatment over a longer period than LRB. Conversion from SRB to LRB would also be relatively straightforward and could be carried out in a single stage (that is, during a major refurbishment) or over a period of years.

Of the sub options, the consultants concluded that chemical sulphide precipitation would cost a lot more than VFP, SRB or LRB and so could be held in reserve and used only where absolutely necessary while ion exchange technology would need a field scale pilot trial to prove it is suitable and cost effective in relation to VFP, SRB or LRB.

Irrespective of the treatment technology chosen, the consultants recommended that monitoring be carried out upstream before the discharge from the treatment plant and further downstream along the River Nent or River South Tyne to fully assess the improvements.

What does the proposed technology involve?

Vertical Flow Ponds contain deep beds of a combination of compost (or similar) and a material such as limestone or crushed shells that will make the water alkaline. Untreated mine water feeds into the surface of the pond and the treated water drains from its base via a network of pipes. This arrangement gives a vertical flow pathway through the compost and alkaline generating material, and minimises the introduction of oxygen.
Clogging of the system is managed by choosing the right composition for the compost-based material and designing the pipework and size to best suit the expected flow rate and pollutant levels.

This system has been trialled and installed at various USA/UK locations and can demonstrate 60 to >90% metals removal.