Odour control and abatement in metal mine water treatment schemes

March 2017

This update provides information about the works undertaken to ensure that the odour control measures designed for proposed mine water treatment schemes will not cause an odour nuisance to the local community.

1. Introduction

The project partners – the Coal Authority and Environment Agency - acknowledge that there is concern from the community that the proposed mine water treatment schemes (MWTS) could result in an odour nuisance. The project partners have received requests to provide details on our approach that will ensure that this doesn't happen and to give details of the measures we will be including within any site selection and subsequent design.

We have commissioned two respected and experienced odour mitigation consultants – AECOM¹ and WRc² to inform our approach to addressing potential odour control.

A summary of the four following reports, which shows the key conclusions and how they will be incorporated into the scheme designs, are presented within this document.

- Force Crag MWTS Air Quality Monitoring Results (April 2016)³
- Nent Haggs MWTS Odour Abatement – An Options Appraisal⁴
- An Independent Peer Review of the proposed odour abatement options⁵
- A report on odour dosing trials undertaken at Force Crag⁶

The original reports detailing the results from the air quality monitoring, options appraisal and dosing trials can be found at: https://www.gov.uk/government/publications/haggs-mine-water-treatment-scheme

¹ AECOM http://www.aecom.com/
² WRc http://www.wrcplc.co.uk/
³ AECOM_Force Crag_mine water treatment scheme air quality monitoring report_v1.0
⁴ AECOM_Haggs_mine water treatment scheme odour abatement options appraisal Report_v1.0
⁵ WRc Independent Review of proposed odour abatement for Nent Haggs mine water treatment scheme
⁶ WRc Force Crag Mine water treatment scheme odour field trials_v1.0
2. Potential for odour generation from compost-based treatment ponds

The compost-based treatment ponds such as those operating at the Force Crag mine water scheme in the Lake District rely upon bacterial sulphate reduction to remove metal pollutants. In the reactions, the bacteria reduces sulphate found naturally in the mine water to sulphide (S²⁻) which binds to the metals to produce solid metal sulphides (e.g. zinc sulphide (ZnS), lead sulphide (PbS)), which are retained within the compost. Typically, at least 70% (but often over 90%) of the metals are removed from the mine water as it passes through the compost.

The bacteria in the compost mixture typically convert more of the sulphate to sulphide than gets bound up by metals. The excess sulphide will be dissolved in the effluent and pass out of the treatment system. When this effluent reaches the open air, some of the dissolved hydrogen sulphide (H₂S) will be released as a gas, which could potentially cause an odour nuisance.

The odour monitoring undertaken at our existing compost-based treatment pond at Force Crag³ indicates that hydrogen sulphide is only detectable in the manhole chamber where the effluent emerges from under the treatment ponds, and where the water is turbulent at the entry and exit points of the very small aerobic wetland. Hydrogen sulphide has not been detected at the surface of the treatment ponds. No engineering measures were necessary to control odours (e.g. from hydrogen sulphide) at the Force Crag scheme as it is situated in a remote location with no properties nearby.

To ensure that odour from any MWTS does not cause a nuisance to local communities we must ensure that emissions are free from odour at levels likely to cause pollution outside the site boundary (this is known as the odour boundary condition⁷).

AECOM used a computer model to predict the effects of odour dispersion from a vertical flow pond (VFP) if odour control measures are not included in the proposed Haggs MWTS. The concentration at which an odour is just detectable to the “typical”⁸ human nose in the controlled conditions of an odour laboratory is called the odour detection threshold⁹. AECOM report⁴ that for hydrogen sulphide this concentration is around 0.7 µg/m³ (around 0.5 parts per billion)¹⁰.

The model predicts that without any odour control measures, concentrations of hydrogen sulphide at the site boundary would exceed this odour detection threshold. This confirmed that odour abatement measures would be required to remove hydrogen sulphide from the VFP effluent.

The modelling results for the proposed Haggs MWTS and the monitoring results at Force Crag mean that for future compost-based treatment schemes, situated in more sensitive locations the Coal Authority will need to design and implement measures to manage hydrogen sulphide to ensure that it does not cause odour nuisance.

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⁷ Environment Agency: How to Comply with your Environmental Permit: Additional Guidance H4 Odour Management H4
⁸ 50% of people on an odour panel
⁹ Defra: Odour Guidance for Local Authorities: March 2010
¹⁰ A higher concentration is usually required before the odour can be recognised in the field, i.e. it can be categorised or described by an observer.
3. Odour abatement - options appraisal

An odour abatement options appraisal report was carried out by AECOM for the project partners in 2016 to identify the most appropriate methods to deal with the risk of odour generation for the proposed MWTS in early 2016 at Nent Haggs. This was not a design report but an initial review of potential options.

The review recommended that the following options would be effective in controlling any odours arising from a compost-based treatment pond:

System design/engineering controls:

- It is possible to design the way that the effluent flows out of the treatment ponds to limit the opportunity for hydrogen sulphide to be released into the atmosphere. These controls will minimise but not eliminate the potential for odour to be generated and need to be combined with other measures.
- These controls will need to be incorporated into the design of the treatment scheme.

Control of the hydrogen sulphide to prevent it causing nuisance odours outside the site boundary:

- The dissolved sulphide in the effluent can be converted back to sulphate before it reaches the air. Dissolved sulphate does not smell – the untreated mine water contains sulphate and has no odour.
- There are several well-established ways of converting dissolved sulphide to sulphate which involve adding an oxidant such as hydrogen peroxide (H₂O₂) or ozone (O₃) to the effluent inside a pipe or mixing chamber.
- These processes will control the hydrogen sulphide removing a sufficient concentration to prevent any odour nuisance outside the site boundary.
- Hydrogen sulphide is a problem for industries worldwide including waste water treatment, oil and gas production, chemical processing and landfill sites. As a result, considerable effort has been put into developing measures to prevent odour nuisance and so there are well-established ways of dealing with hydrogen sulphide.
- The report suggested that the preferred option for the removal of hydrogen sulphide to levels which will not cause nuisance outside the site boundary of the proposed Haggs MWTS is chemical dosing using hydrogen peroxide at appropriate ratios in the commissioning, establishment and operational phases.

4. Peer review of the options appraisal

Since preventing odour nuisance from any MWTS is such an important issue for the project partners, WRc were commissioned to carry out an independent review of the odour abatement options appraisal report.

The objectives of the review were to:

- Check that the abatement measures are fit for purpose.
- Provide confidence to stakeholders that there would no odour nuisance issues should the mine water treatment system be installed.
The review concluded that:

- The approach taken by the Coal Authority to monitor the ambient gas monitoring around the Force Crag compost-based treatment pond was reasonable and appropriate for an established treatment scheme.
- AECOM over-estimated the upper figure for the concentration of hydrogen sulphide that may be present in the treated mine water.
- The sulphate concentration in the Haggs mine water is higher (approximately 250 mg/l) than in the Force Crag mine water (30 mg/l). Although AECOM report that results from over 20 sets of experiments carried out by Newcastle University suggest that this should not make any difference (i.e. a higher mine water sulphate concentration does not appear to result in more sulphide being generated by compost-based treatment systems), the potential for a higher concentration of hydrogen sulphide in the effluent from the proposed Haggs scheme should be considered within the design.
- The assessment of potential options for removing hydrogen sulphide has been carried out thoroughly and has been well documented. Hydrogen peroxide has been used to remove hydrogen sulphide when cheaper options are not suitable. A process of dosing with both hydrogen peroxide and ozone could be assessed to see if this would reduce the amount and cost of the hydrogen peroxide required.
- The effectiveness of hydrogen peroxide in converting hydrogen sulphide dissolved in the effluent to sulphate needs to be confirmed through experimental trials. The optimum dosing rate, contact time and mixing method to achieve the required removal rate needs to be considered and included within the detailed design phase.
- The odour management plan covering the aspects expected for operating and maintaining the odour control measures is comprehensive. Consideration should be given to the inclusion of an automatic control system depending upon the location of the mine water treatment scheme(s).

Following the independent review, the project partners are confident that it will be possible to design, build in and operate measures for any proposed MWTS so that no odour nuisance is caused outside the site boundary.

5. Odour dosing trial at Force Crag

WRc was commissioned by the project partners to carry out simple trials to investigate the effectiveness of the proposed oxidant (hydrogen peroxide) for removing hydrogen sulphide from effluent at the Force Crag mine water treatment scheme. These trials were set up to demonstrate:

- This approach will convert dissolved sulphide to sulphate in the effluent from a compost-based mine water treatment scheme.
- Explore the amount of hydrogen peroxide that needs to be added.
- Clarify how long this oxidant needs to be mixed with the mine water.
The trials included simulating the effluent in a newly commissioned compost-based treatment pond by adding organic material to some samples before mixing with hydrogen peroxide. It was recognised that further experiments may be required to support the design process, and that there are differences between the chemistry of the Force Crag and Haggs mine waters.

WRc also measured the decrease in sulphate concentrations across the treatment system and compared this with the measured dissolved sulphide in the effluent.

The conclusions drawn from the trials included:

**Hydrogen sulphide removal:**

- Hydrogen peroxide was effective at removing hydrogen sulphide dissolved in the mine water effluent but did not remove 100%.
- The maximum removal achieved during the trial was 82%.
- The percentage of hydrogen sulphide removed varied significantly depending on contact time and dosing rates (how much hydrogen peroxide was added to the mine water).
- The optimum dosing rate from the trial was 10g of hydrogen peroxide per 1g of sulphide with a contact time of 15 minutes; this removed 78% of the hydrogen sulphide.
- The Coal Authority and Environment Agency recognised that further dispersion modelling at potential locations for the MWTS will need to be carried out to confirm that the odour controls will remove enough hydrogen sulphide at the treatment plant to prevent any residual hydrogen sulphide from exceeding the detection threshold at the site boundary.

**Effects of higher organic material in the effluent following commissioning:**

- When the Force Crag treatment scheme was commissioned, as expected, the Chemical Oxygen Demand (COD) of the effluent was initially high since organic material and ammonia was washed out of the compost-based system, before returning to low levels after a few weeks. The high concentrations of COD during the commissioning phase would significantly reduce the effectiveness of hydrogen peroxide in removing hydrogen sulphide.
- The experiments attempted to simulate this commissioning period and found that the hydrogen sulphide removal decreased to 14%. This will need to be taken into account during the initial operating period of a compost-based treatment pond to ensure there is no short term odour nuisance.

**Decrease in sulphate concentrations across the Force Crag treatment pond:**

- The concentration of sulphate decreases as the mine water passes through the treatment ponds, since some is transformed to sulphide. By comparing this change in sulphate concentration to the change in concentrations of zinc and iron, WRc attempted to calculate how much sulphide would be dissolved in the effluent as hydrogen sulphide (“mass balance calculations”).
- Some of the sulphide generated in the treatment pond reacts with zinc and iron in the mine water and is bound up as metal sulphides within the compost. In theory, it should be possible to quantify all of the different compartments of sulphide (bound to metals, dissolved hydrogen sulphide). However, in practice this is not possible to do completely, for some of the reasons below:
The mine water takes about 80 hours to pass completely through the Force Crag treatment ponds.

The sulphate concentrations in the mine water vary depending on how much it has rained.

Measurement techniques are not precise.

Therefore, it is to be expected that these mass balance calculations will not be able to account for all of the sulphide.

Through their mass balance calculations, WRc was able to account for only approximately 38% of the measured reduction in sulphate concentration from the inlet to the outlet.

The “missing” sulphate is assumed to be unaccounted for due to inaccuracy in the measurement techniques, the delay as mine water moves through the treatment pond and/or sulphide being retained within the treatment pond in other forms (e.g. attached to the compost, bound up with lead and other metals).

Effect of influent sulphate concentrations:

- The measured sulphate concentration in the influent at Force Crag was only 10% (24 mg/l) of the sulphate concentration reported for the mine water influent from the Haggs Level (250 mg/l).
- However, the generation of hydrogen sulphide by bacteria in other waste waters has been found to be related to COD concentrations with lower COD, meaning that less hydrogen sulphide is generated. The effluent from compost-based mine water treatment ponds contains low concentrations of COD and it is possible that this may control the amount of sulphide that is generated rather than the influent sulphate concentration in the mine water.

6. Conclusion

The Coal Authority and Environment Agency have commissioned several investigations into how hydrogen sulphide is generated by compost-based treatment ponds and how the potential for odour can be controlled.

The following points summarise how the Coal Authority and Environment Agency intends to proceed based on our current understanding:

- The mine water treatment schemes proposed for the Nent catchment must not cause odour nuisance beyond the site boundary.
- The treatment system design will take into account:
  - Engineering controls to minimise the generation of hydrogen sulphide.
  - Measures to control the hydrogen sulphide that is generated before it can cause an odour nuisance.
  - Dispersion modelling to confirm that the odour controls will remove enough hydrogen sulphide at the treatment plant to prevent any residual hydrogen sulphide from exceeding the odour detection threshold at the site boundary.
  - Ways to manage the commissioning of the treatment system to minimise odours when it first starts operating.
- Odour and gas monitoring to allow rapid response to any potential odour concerns, a commitment to share technical information with the public and other stakeholders and to listen to suggestions for additional monitoring and investigations.
- A commitment to share technical information with the public and other stakeholders and to listen to suggestions for additional monitoring and investigations.

Following the Independent review, the project partners are confident that it will be possible to design, build in and operate measures for any proposed mine water treatment scheme so that no odour nuisance is caused.

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