

Baffle Curtain Installation to Enhance Treatment Efficiency for Operational Coal Mine Water Treatment Schemes

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Abstract

Passive coal mine water treatment schemes in the United Kingdom typically incorporate settlement lagoons to precipitate iron and collect HFO (hydrous ferric oxide). Laminar flow in the lagoons enables HFO particles to settle out under gravity. Preferential flow paths through the lagoon can have a detrimental effect on treatment efficiency due to short circuiting. A field trial was undertaken at the operational Clough Foot mine water treatment scheme, Yorkshire, to assess the impact of incorporating baffles within an existing operational lagoon. Baffle curtain installation was predicted to improve lagoon hydraulics and enhance treatment performance by creating flow paths to reduce short circuiting of mine water within the lagoon.

The field trial confirmed that baffle curtains can be retrofitted into operational settlement lagoons to improve treatment performance. Concentrations of iron and aluminium at the outlet of the baffled lagoon were lower than at the outlet of the control lagoon. Baffle curtains could be used to enhance treatment scheme performance where a lagoon may be undersized or struggling to treat the mine water to the required metals concentration. Baffle curtains could also be incorporated into the design of new treatment schemes where lagoon size is constrained by the availability of suitable land. Creating vertical flow paths by changing the orientation of the open areas within each baffle curtain might yield higher removal efficiencies but may be more affected by the accumulation of HFO at the base of the lagoons. Incorporating baffle curtains into settlement lagoons offers an effective method of improving the operational efficiency of traditional passive coal mine water treatment schemes.

Key words: mine water, treatment efficiency, baffle curtains

Introduction

The Coal Authority has been treating polluted water from abandoned coal mines in the United Kingdom for the past 20 years by refining methods developed by Hedin et al. (1994) and Tarutis et al. (1999). The Coal Authority operates over 70 mine water treatment schemes and uses both passive and active treatment technologies. Typical treatment schemes use passive technologies, which allow HFO (hydrous ferric oxide) to precipitate and settle out under gravity. Passive mine water treatment schemes generally comprise of an aeration cascade, two settlement lagoons and a polishing aerobic wetland, as recommended by the PIRAMID guidelines (2003).

Land availability proves to be an ongoing problem for the Coal Authority. Passive treatment requires a substantial area of flat land for treatment to be effective. Maximising the efficiency of treatment systems is essential to achieve sufficient discharge water quality with limited land availability (Sapsford and Watson 2011).

HFO deposition is controlled by two rate-limiting steps; oxidation and settlement (Sutton et al. 2015). In conventional schemes oxidation of the mine water is achieved by passing the mine water over a cascade, aiding aeration and degassing. Precipitation commences within circumneutral pH mine waters as soon as oxidation is underway; HFO can be observed to be deposited within the cascade and the pipework. The majority of iron removal, however, occurs within settlement lagoons.

This trial proposed to optimise HFO settlement within lagoons by installing baffle curtains to determine whether improved hydraulics within a lagoon can increase the overall treatment performance of a conventional passive coal mine water treatment scheme. Baffle curtains are designed

to optimise flow paths within lagoons, thereby, enhancing the lagoon hydraulics, improving the efficiency of HFO settlement.

The objectives of the study comprise:

- To assess the iron removal performance of the treatment technology;
- To assess the reliability of the technology;
- To identify and assess any constraints on implementation.

Method

Trial Site

Trialling of the baffle curtains was undertaken at the existing Clough Foot mine water treatment scheme (MWTS) in Yorkshire, UK. Clough Foot MWTS commenced treatment in 2012 and treats between 5 and 20 L/s of mine water, utilising typical passive mine water treatment techniques.

Treatment comprises a single large cascade that splits into two short open channels, where peroxide dosing can be conducted, if required. These channels are designed to create turbulence and facilitate mixing around the dosing point after which, the flow is split into two identically sized settlement lagoons, which are operated in a parallel arrangement. After the lagoons, open channels transport the mine water into a constructed wetland for polishing before discharging through a v-notch weir into the adjacent Midgelden Brook.

Clough Foot MWTS was selected for this trial as the parallel arrangement of the settlement lagoons was identified as being ideal for enabling a comparison between the trial system and the control system. An assessment of the baseline monitoring data for the two settlement lagoons was undertaken prior to the commencement of the trial, which confirmed that there was no significant difference in performance between the two lagoons.

Baffle Design & Installation

Three baffle curtains were installed into one treatment lagoon to enhance the lagoon hydraulics and to prevent any short circuiting of the lagoon system. Installation of the plastic baffle curtains took three days to complete. These were retrofitted into the lagoon, whilst it remained fully operational.

The baffle curtains selected by the Coal Authority for this trial were designed to create defined flow paths within the settlement lagoon using a horizontal flow pathway, where the mine water zig zags through the lagoon (Figure 1). An alternative option is a vertical ‘duck and dive’ pathway design, which is likely to be more efficient as it encourages mixing on a vertical scale and eliminates potential ‘dead’ areas within the lagoon. However, the horizontal flow approach was undertaken during the trial as HFO sludge was known to be present at the bottom of the lagoon. Using a vertical flow curtain arrangement could have led to the bottom curtain openings being clogged with sludge and creating a barrier to the mine water flow. A vertical pathway design could also lead to the re-suspension of settled HFO sludge from the base of the lagoon.

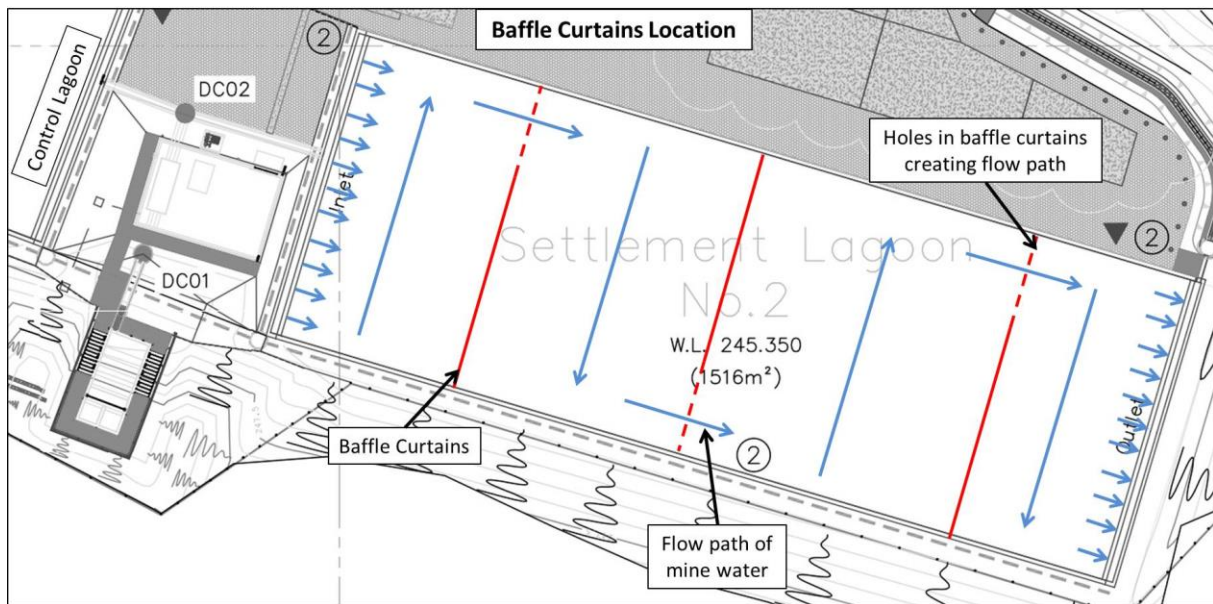


Figure 1 – Baffle curtain locations, orientations and the resultant mine water flow path through the lagoons

Power Plastics Ltd. designed, manufactured and installed the baffle curtains (Figure 2). Chains are attached to the curtains that sink down through the previously accumulated HFO sludge at the base of the lagoon, weighing the plastic baffle curtains down and keeping them in place. During installation, this chain is dragged across the base of the lagoon, which temporarily disturbs the settled HFO sludge. There was a hiatus of three weeks following the installation of the baffle curtains prior to monitoring commencing, to allow the HFO sludge, disturbed by the installation process, to re-settle within the lagoon.

Open areas of the baffle curtains comprised laser-cut circles. This circular shape, combined with the use of a stronger material around the edges of these sections, is designed to make the open areas less prone to damage during installation and maintenance than if they were square or rectangular, which could potentially lead to weak points that might tear more readily.

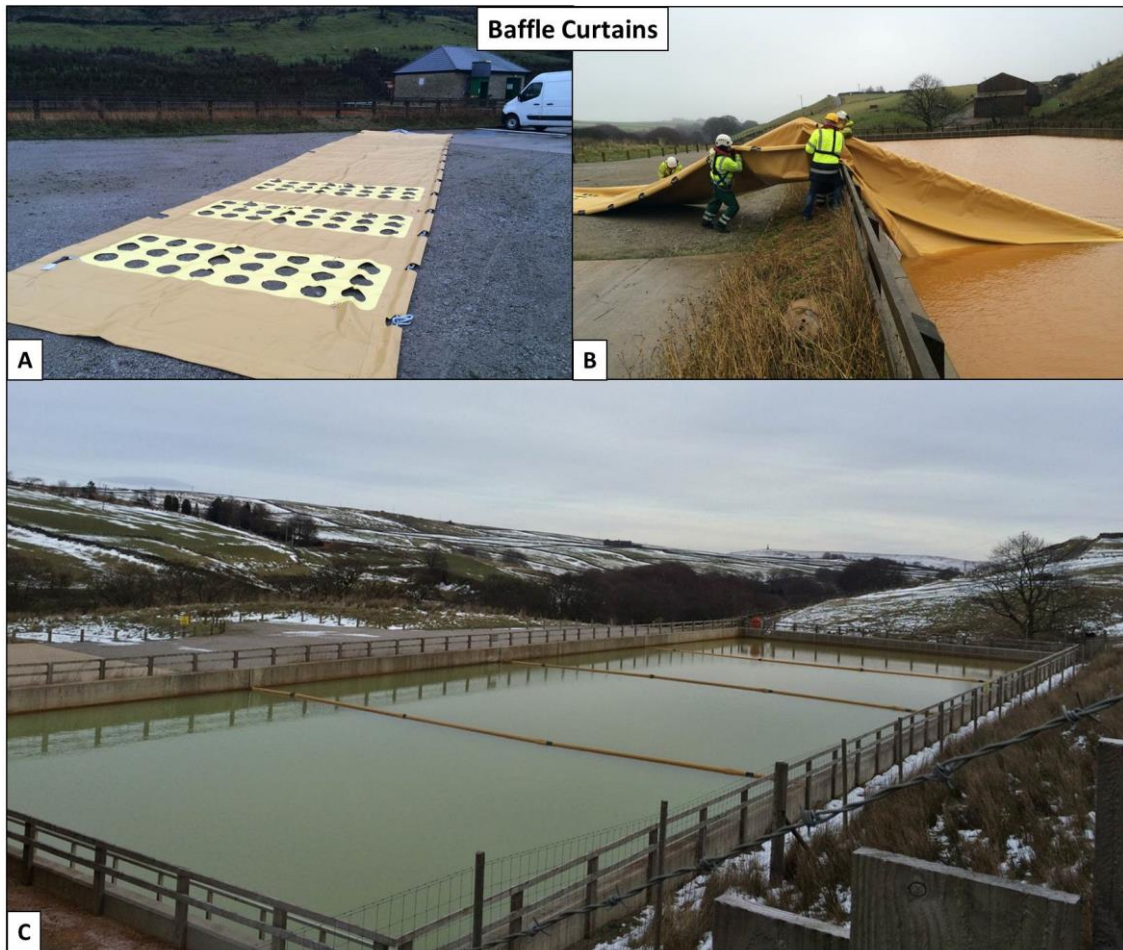


Figure 2 – Baffle Curtains; A) Baffle curtain prior to installation B) Retrofitting of the baffle curtains C) Baffle curtains after installation

Monitoring

Field monitoring was undertaken at multiple points throughout the MWTS for the duration of the trial, which was complemented by laboratory analysis of mine water samples. Key parameters analysed were pH, in conjunction with total and dissolved metals. Ideally, both hot and cold acidity would be measured in the field; however, hot acidity measurements were not undertaken during this trial due to health and safety concerns. There is currently no way to measure flow to the inlets and outlets of the lagoons, therefore flow has been assumed to have an equal split between the lagoons. This is considered a reasonable assumption based on the configuration of the lagoon inlets. The laboratory analysis was undertaken in an independent commercial laboratory using UKAS accredited procedures. Intense monitoring of three days per week was undertaken for eight weeks. After this intense monitoring period, routine operational monitoring resumed at the MWTS.

Results

Baffle curtain installation had a positive influence on iron and aluminium removal efficiency in the lagoon. During the main monitoring period for the trial, the baffled test lagoon removed on average 41% more iron (Figure 3) and 34% more aluminium (Figure 4) compared to the control lagoon. During the trial a natural acid flush event occurred. This was due to high volumes of water entering the mine workings, which flooded and scavenged minerals from previously unflooded fire clay workings. This flooding caused the mine water to have a higher than normal mineral acidity, which hindered the performance of the settlement lagoons during this time.

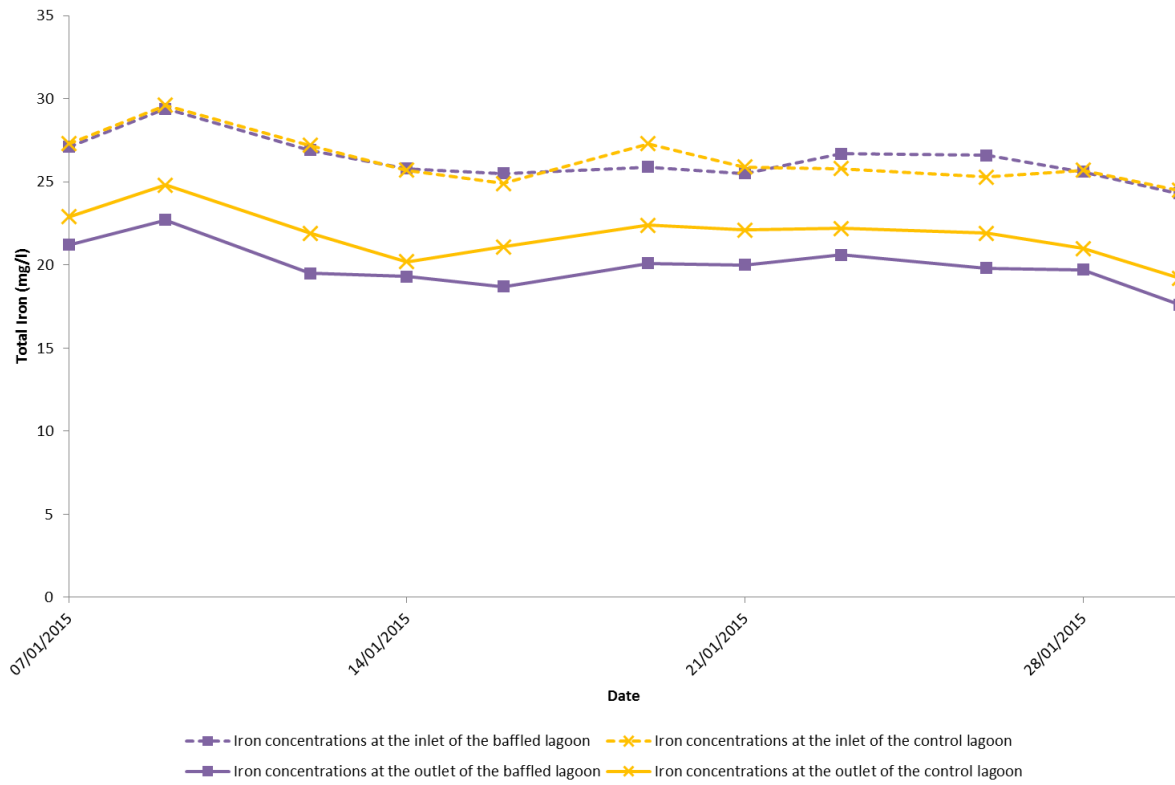


Figure 3 – Influence of baffle curtains on total iron concentrations

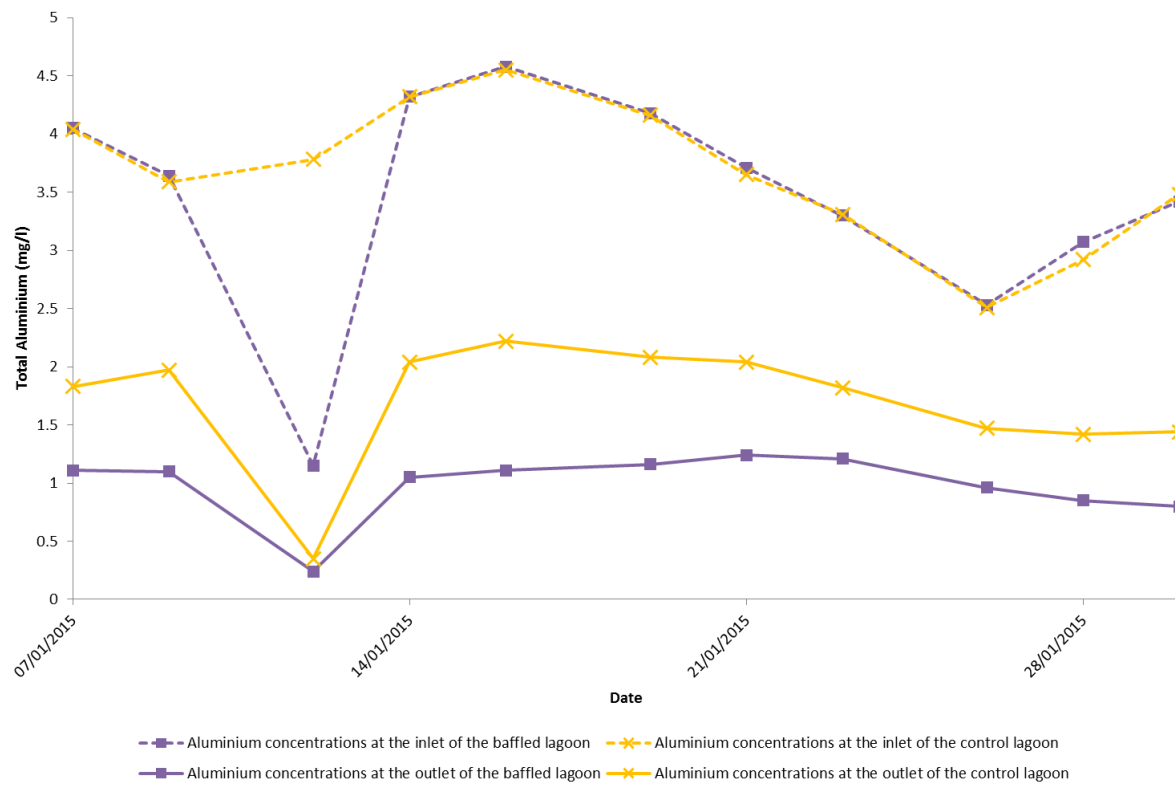


Figure 4 – Influence of baffle curtains on total aluminium concentrations

Routine monitoring data was compiled from May 2015 onwards. During this period the mine water returned to normal net-alkaline conditions. During the period May 2015 to October 2015, the test lagoon was on average 10% more efficient than the control lagoon for iron removal (Figure 5). Post-trial data indicates that the baffle curtains are continuing to enhance metal removal efficiency over the longer term, albeit by a lower amount than that observed during the main trial.

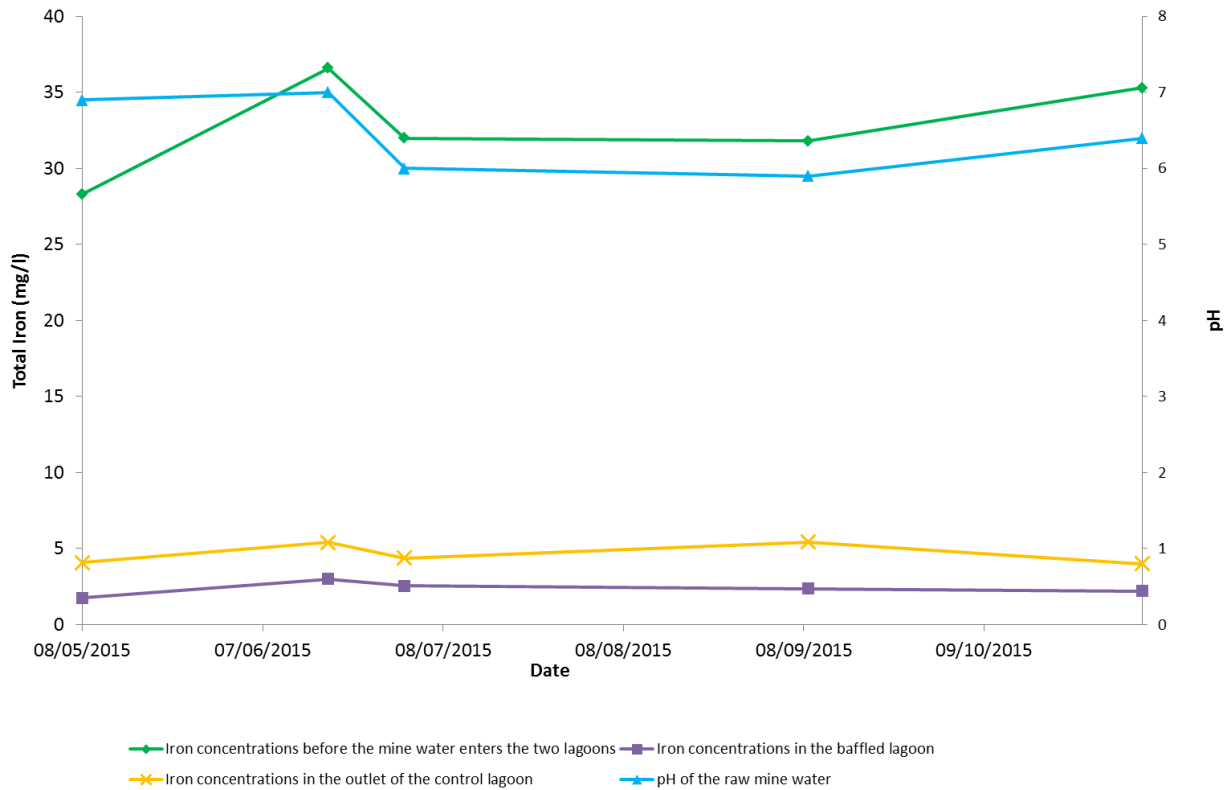


Figure 5 – Influence of baffle curtains over time

Manganese removal efficiency was not affected by the installation of the baffle curtains, however, this was expected as the settlement lagoons are not designed to remove manganese (PIRAMID 2003). Nor was there any significant difference in the concentrations of zinc or nickel observed between the test and control lagoons. An improvement in the metal removal efficiency is interpreted to relate to improved lagoon hydraulics aiding settlement of HFO particles (Kusin 2013).

Conclusions

Baffle curtains have had a positive effect on both metal (iron and aluminum) removal and improving lagoon hydraulics. However, even though the residence time and hydraulic efficiency is almost tripled, only 10% betterment is observed when it comes to the removal of metals.

Benefits of improving lagoon hydraulics, in terms of treatment performance, may be constrained by oxidation rates. Column testing undertaken at Clough Foot MWTS using the methodology described in Sutton’s paper (2015), indicated that oxidation rates were the rate limiting factor affecting this particular site. This explains why increasing the residence time at Clough Foot MWTS only achieved relatively minor improvements in metal removal efficiency.

Column testing has been undertaken at numerous Coal Authority sites by Cardiff University (Sutton et al. 2015). Where settlement rate is determined to be the rate limiting factor, increasing residence time within the lagoon and improving the lagoons hydraulic efficiency by adding baffle curtains is expected to result in a greater improvement in metal removal efficiency than was observed during the trial at Clough Foot MWTS.

To increase the hydraulic efficiency of the lagoons, more baffle curtains should be installed. Increasing the number of flow paths will help to decrease ‘dead’ zones within the lagoons. Adding baffle curtains might improve the hydraulic efficiency, however, from a cost perspective, it is better to minimize the number of curtains required to achieve the optimal treatment for the site.

Creating a vertical flow pattern using the baffles may be more efficient as it encourages mixing on a vertical scale, decreasing dead spots, that may be missed using horizontal flow paths. However, the effectiveness of vertical flow pattern baffles may be more influenced by the build-up of HFO sludge at the base of the lagoon. Vertical flow paths are likely to disrupt the build-up of HFO, which can lead to re-suspension of the sludge. Overall, this could lead to a decrease in baffle curtain performance.

Land availability is a key issue for the construction of MWTS’s and often settlement lagoons are undersized for the concentrations of metals that are needed to be removed. Installing baffle curtains at MWTS that are currently undersized and/or that are not performing adequately may provide benefit. Future mine water treatment schemes in areas without sufficient land availability for traditional lagoons may become feasible as smaller lagoons with baffle curtains may be sufficient to achieve the required level of treatment. However, this would need to be reviewed on a case by case basis.

Capturing HFO within settlement lagoons is advantageous when considering whole life costs for mine water treatment. HFO that has been captured within settlement lagoons is likely to be more suitable for re-use or metal recovery than HFO that is captured within an aerobic wetland, which can contain a significant amount of organic matter. Baffle curtains could be used to encourage HFO precipitation in settlement lagoons where there is less potential for contamination, allowing the HFO to be more easily developed into salable products. Aerobic wetland refurbishment is a complex and costly process; once an aerobic wetland has reached its operational capacity it often requires replacing. Reducing the metal loadings reaching the constructed wetlands used for polishing is also considered to be beneficial; by reducing maintenance requirements and extending the operational life before an aerobic wetland desludging is necessary.

Recommendations

Tracer testing should be conducted on the site to confirm that the lagoon hydraulics in the baffled lagoon have an increased hydraulic efficiency. When prioritizing sites for retrofitting curtains, Cardiff University’s column testing methodology (Sutton et al. 2015) should be used and baffles should be installed where HFO settlement is the rate limiting factor. Column testing at Clough Foot MWTS indicated that oxidation was the rate limiting factor; installing baffle curtains into a system where settlement is the rate limiting factor should improve the iron removal rates significantly. For future MWTS designs, the ability to measure flow at both the inlets and outlets of the lagoons should be incorporated.

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