Implementation of a demonstation scale Integrated Managed Passive (IMPI) process

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Abstract An Integrated Managed Passive (IMPI) process for the sustainable reduction of sulphate and removal of sulphides from mine impacted water has been implemented on a demonstration scale at an operating coal mine in Mpumalanga, South Africa. The aim is to evaluate the technology, for long term application within the industry, from a number of perspectives, including but not limited to the confirmation of scale-up parameters, demonstration of technical efficiency and robustness over a sustained period, and determination of the actual capital and operating costs. This paper highlights some of the challenges that are associated with scale up and commissioning and illustrates some preliminary operational results which will be used to validate the application of laboratory scale data for scale-up.

Key Words IMWA 2010, sulphate reduction, integrated passive treatment, sulphide oxidation

Introduction

Conventional biological passive water treatment options for the remediation of acid mine drainage (AMD) tend to take the form of constructed wetlands or compost bioreactors and target metals removal, or sulphate reduction with biogenic sulphide and alkalinity production and subsequent metals removal respectively. Although these systems provide benefits in terms of low operational and capital costs as well as minimal input, performance of passive systems is generally variable and unpredictable (Johnson 2002). Additionally, since all reactions tend to occur in a single "bioreactor" sulphate reduction is not optimised and hence results in non-compliance with respect to meeting in-stream water quality objectives particularly in South Africa.

To mitigate some of the negative aspects associated with conventional biological passive treatment processes, a research and development programme was initiated and the Integrated Managed Passive Treatment system (IMPI process) was developed (Pulles 2003). This bacterially mediated process addresses the sustainable reduction of sulphate and the removal of sulphides as well as the concomitant removal of metals and acidity. In particular, the IMPI process differs from conventional biological passive treatment systems as the sulphate reduction and sulphide oxidation steps are performed in separate units to mitigate the impacts of sulphide inhibition on biological sulphate reduction (Pulles 2009). This ensures the optimised and enhanced operation of the passive sulphate reduction reactor itself and results in improved downstream reactor operation. Carbon which provides the electron donor is added to the Degrading Packed Bed Reactor (DPBR) as both a labile and a more recalcitrant carbon in the form of lignocellulose found in manure, grass and wood chips which are arranged in layers within the reactor (Coetser 2006). The DPBR forms the first step in the process chain and is optimised for the hydrolysis of lignocellulose but also performs a sulphate reduction and alkalinity generation function. Sulphides produced in the DPBR are oxidised in the biological sulphide oxidation reactor (BSOR) to elemental sulphur which is easily removed from the system. Sulphide inhibition is thus minimised in downstream reactors and the re-formation of sulphate is reduced. Residual sulphates not removed in the primary DPBR step are reduced in the secondary sulphate reduction reactor (SSRR) with final sulphide removal occurring in a secondary sulphide oxidation step. An oxidation cascade and a wetland provide the final polishing steps with respect to manganese and COD removal and oxygen enrichment, and uptake of nitrogen and phosphate by wetland plants.

The IMPI process is conceived as a modular technology with a maximum module size of 200 m^3/d and if a greater treatment duty is required, further modules would be constructed and operated in parallel.

Project Background

Kinetic DPBR column testwork was initiated in 2003 and the efficiency of the DPBR was tested on AMD with feed sulphate concentrations of about 1200mg/L for potential scale up on site. A target value of 60 g sulphate removed/m^3 carbon utilized/day (g/m^3/d)is required for the process to be viable and the amenability data indicated that this value was generally exceeded at least four fold for the mine water once the process reached steady state. The DPBRs removed sulphate loads at rates above 200 g/m^3/d and up to 440 g/m^3/d over the last three months of operation with sulphate concentrations of about 400 to 500mg/L remaining in the effluent (fig.1).

Sulphide production as a result of sulphate reduction was evident for all columns with average concentrations of between 200 and 250 mg/L sulphide obtained. Since sulphide concentrations are approaching inhibitory concentrations, the downstream SSRR would be required to reduce the balance of sulphate remaining in the effluent to about 200 to 250mg/L. The process is designed to reduce 1000mg/L sulphate per module taking into account the inhibitory effect of sulphide produced on the biomass. The pH was effectively elevated from feed pH levels of between 4.0 and 5.8 to a neutral pH.

Sulphide removal from the sulphide–rich effluent emanating from the DPBR columns was not demonstrated as part of the testwork as this research was conducted in isolation at the Environmental Biotechnology Research Unit in Grahamstown, South Africa using synthetic mine water. Data is thus not available for the case study which creates some uncertainty with respect to scale-up.

Planning Process for Scale-Up

Since the IMPI technology is an integrated process and all laboratory scale work was only conductedon the primary step of the process, the DPBR; a decision was made to evaluate the DPBR on a full scale basis (200m^3/d) whilst the sulphide oxidation step and all subsequent reactors would be assessed on a smaller scale (20m^3/d). This would still allow for the evaluation of the IMPI process as an integrated process whilst mitigating some of the risk associated with the operational uncertainty of the sulphide oxidation step. This reactor is a critical component within the process, as an inefficient or unreliable sulphide oxidation step would affect the performance of the downstream reactors as well as result in the potential re-oxidation of sulphide to sulphate thereby impacting the final water quality.

Taking into account kinetic column data, suitable carbon source inventory in the immediate vicinty and physical site information, a first order site specific conceptual design based on the descriptive IMPI process model was developed which then should form the basis for a detailed civil engineering design for a full-scale plant.

Several issues were encountered during the planning phase of the project, one of which was a change in location as the site was considered to be remote from the normal operations and safety of personnel and the increased potential for theft of plant items were identified as risks. The relocation of the plant site also meant a change in water source which at the time was not an issue as the water quality at the new site was similar to that of the old site. Changing the site also had implications with respect to the “passive” nature of the plant as the water source is currently located at the base of the plant rather than at the top and thus requires pumping of water to the holding tanks.

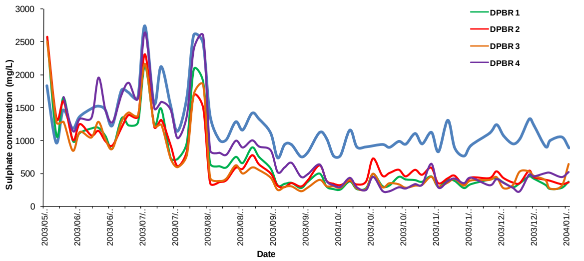

***Figure 1** Sulphate concentrations achieved for the DPBR columns relative to the influent sulphate concentration*

Construction and Commissioning

Construction was initiated on 30 July 2008 after tender adjuducation and awards were completed. The Environmental Department with the assistance of the Small Projects Department and the consultant were the responsible parties for the project. Construction was completed a year after commencement and wet commissioning of the plant began in August 2009 and progressed until October 2009. The aim was to start up the system and ensure that water flowed through the entire plant unhindered and at the required flowrate. A schematic representation of the process is given in fig. 2.

Several issues were identified during commissioning which had to be addressed. One of the most significant problems experienced was the difficulty associated with filling the DPBR with mine water. Flooding occurred during the first attempt; this was attributed to several possible reasons including (i) insufficient holes in the overhanging water distribution piping, (ii) an excessively high flowrate and/or (iii) non-ideal packing of the reactor. Several attempts were made to fill the reactor using the existing distribution system but the reactor bed was found to rise each time thereby pushing the distribution system upward and preventing water flow through the pipes. Rising of the bed was ascribed to gas formation as a result of bacterial activity and/or lack of water movement due to the presence of potentially impermeable layers within the bed. A manifold system was implemented to circumvent the installed distribution system which improved the water addition to the reactor significantly.

Problems encountered with the operation of the BSOR included leaking channels which required resealing and blocked sprayer systems were unblocked. Lack of flow to the SSRR was rectified by rerouting the effluent pipe from the BSOR to ensure sufficient gradient was available to reduce backpressure and allow unimpeded flow to the SSRR.

The SSRR presented the next major problem as filling of the reactor resulted in water daylighting from the inlet pipe which is positioned at the base of the SSRR. Excavation of the soil next to the reactor down to a depth of 3m was required to determine the extent of the problem. A breach in the wall due to erosion of the cement at the inlet pipe was noted which resulted in leakage from the reactor. The problem was solved by removing all the carbon material from the reactor to allow for the wall to be repaired using a flange system. Reactor carbon material was replaced with fresh carbon material as the old material was compromised and partially degraded.Additional problems that had to be resolved included the re-engineering of the oxidation cascade which did not allow for sufficient aeration through the system.

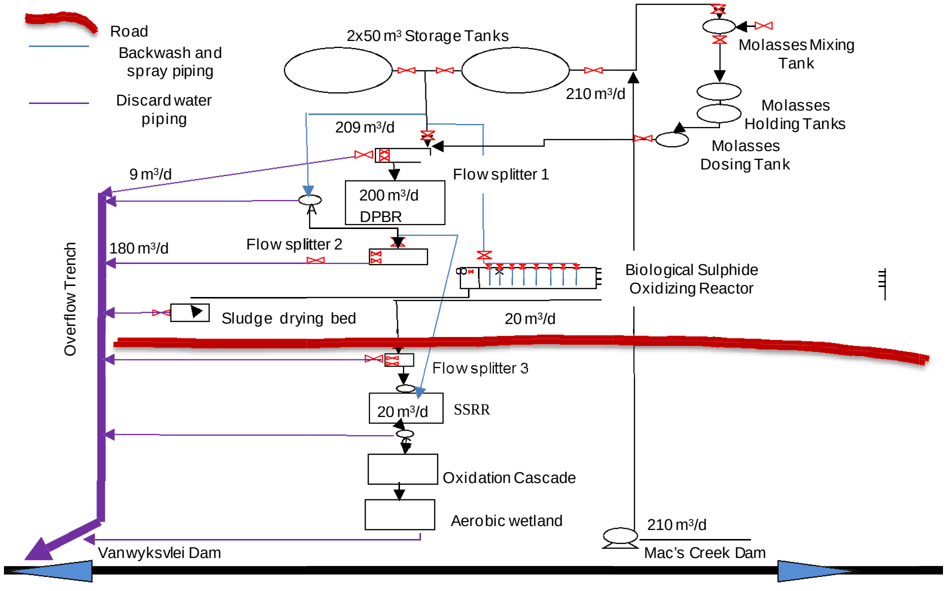

***Figure 2** Schematic representation of the IMPI process*

Figure 3 *Elemental sulphur formation in a. the BSOR, b. the DPBR and c. the splitterbox*

Results to date show almost complete sulphate removal in the DPBR, although it must be noted that influent sulphate levels are also considerably lower than anticipated. Feed concentrations are on average about 350mg/L compared to the expected 1200mg/L and this is attributed to seasonal fluctuations in the dam sulphate levels which is expected particularly when excessive rainfall periods are experienced as has been the case in 2009/2010. The sulphate was reduced to on average about 90mg/L sulphide. Sulphide oxidation has been achieved in the BSOR where elemental sulphur biofilm formation has been observed (fig. 3a) as well as in unexpected areas such as the surface of the DPBR (fig. 3b) and the splitterbox (fig. 3c) when mine water flow was terminated. Sulphur accumulation in these areas however ceased when flow resumed.

Conclusions

Although the project suffered from numerous issues during construction and commissiong, the process principles have been demonstrated and sulphate reduction and sulphide oxidation to elemental sulphur can be achieved. What needs to be demonstrated now is that this can be achieved consistently over the long term in addition to meeting required water quality objectives for discharge. The evaluation of this process in terms of sustained technical efficiency and sharing of learnings regarding scale-up and cost implications will provide valuable information to the mining industry with respect to adding a further tool to the AMD treatment toolbox. One of the most critical aspects with respect to this project is the ownership and commitment that is required by all involved to ensure the successful completion of any project. Research and development projects which are generally not considered to be core business, may not always be suitable for testing on an operational site as often the necessary commitment, in-depth technical know-how and time are not available to deal with issues that arise. Close supervision, which will minimise commissioning problems, is not always possible during construction as operational issues will always take precedence at operating sites and needs to be accepted as such.

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