Passive treatment: A walk away solution?

During active mining and post closure, the control of water requires prudent site management to firstly minimise the generation of minewater and secondly to treat where necessary. In order to reduce associated treatment costs in the long term, artificial wetlands have gained acceptance, particularly for treating coal mine drainage. In such circumstances, where iron is often the predominant contaminant of concern, removal utilises the natural oxidation of iron II (Fe^{2+}) to iron III (Fe^{3+}) followed by hydrolysis of the iron II as shown below:

$$\text{OXIDATION}\quad Fe^{2+} + \frac{1}{4}O_2 + H^+ \Rightarrow Fe^{3^+} + \frac{1}{2}H_2O \tag{1}$$

$$\text{HYDROLYSIS}\quad Fe^{3+} + 3H_2O \Rightarrow Fe(OH)_3 + 3H^+ \tag{2}$$

As the hydrolysis process generates proton acidity (H^+), the water being treated must contain sufficient alkalinity to buffer this reaction if it is to remain 'net alkaline'. For this reason, waters with insufficient buffering capacity are termed 'net acidic' and require distinctly different treatment requirements.

NET ACID WATER TREATMENT

In order to facilitate efficient Fe removal and pH control, successful treatment of net acid water requires alkalinity supplementation. This can be achieved using a number of alkali dosing methods or as has been recently implemented at Pelenna, South Wales (UK), using a Successive Alkalinity Production System (SAPS)[1].

The SAPS works by adding alkalinity to the minewater as it vertically passes through a limestone bed beneath a layer of organic substrate, such as bark mulch or mushroom compost. As the substrate is aimed at promoting bacterial processes such as sulphate reduction and subsequent iron sulphide formation, SAPS are also referred to as RAPS or Reducing and Alkalinity Producing Systems (Figure 1).

Monitoring of the influent and effluent chemistry at the Pelenna SAPS reveals good rates of Fe removal but poor sulphate removal (Figure 2). This suggests sulphate reduction and iron sulphide formation are negligible in the system and it is more of a SAPS than a RAPS. So what processes are responsible for Fe removal?

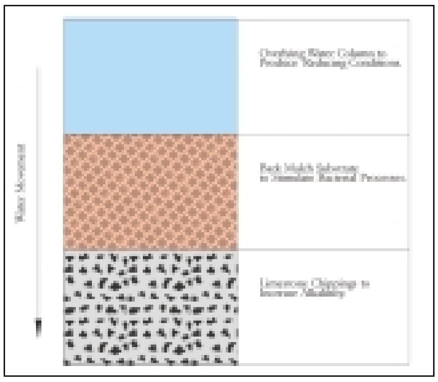


Figure 1: Cross section of a SAPS and processes thought to be occurring

IRON REMOVAL

Visual observation of the SAPS indicates Fe oxidation via equations 1 and 2 accounts for most Fe removal as significant surface ochre precipitates are evident. However, another process may occur that enhances Fe removal. This is the well documented process of autocatalytic Fe oxidation, where Fe^{2+} can be removed from solution by oxidation at the surface of previously formed ferric hydroxides[2]. In order to assess the occurrence of this process, Fe concentrations over time were recorded in two beakers of iron (II) sulphate solution, one of which also contained fresh ochre from the SAPS. The beaker containing ochre resulted in significantly lower Fe concentrations over a relatively short time period suggesting that autocatalytic iron oxidation is feasible as a method to enhance Fe removal. Further research is currently underway to assess the significance of this process.

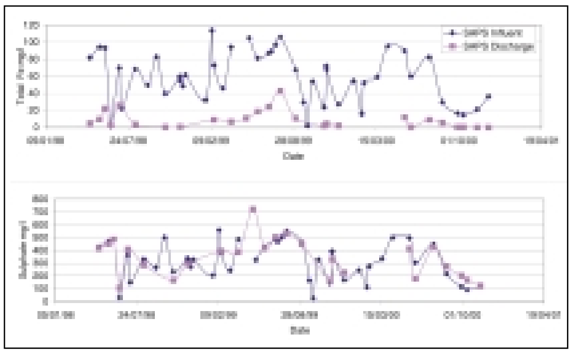


Figure 2: Iron and Sulphate removal over time in the SAPS.

SAPS LONGEVITY

The continuous accumulation of ochre on the surface of the SAPS could have significant implications for long term SAPS performance if it is not managed. In order to assess this effect, a full scale cross section of the SAPS was reconstructed in the laboratories of the Division of Materials and Minerals at Cardiff University (Figure 3).

Using fresh ochre collected from the SAPS, it became clear that as ochre thickness increased, vertical permeability decreased (Figure 4). Based on these observations, it is anticipated that with time the bed permeability will decrease and the SAPS will become impermeable leading to over-spill unless maintenance is made. Since operation in early 1998, approximately 0.2 m of surface ochre has accumulated. Based on the experimental relationship derived in Figure 4 this observation can be used to predict the longevity of the SAPS.

As shown in Figure 5, problems with vertical permeability are predicated to occur ~ five years after commissioning, although no account of ochre ageing is included in this prediction. A further complication at Pelenna is that during the period February to May 2000 minewater did not enter the system due to blockage of the minewater distribution network. Therefore, previously deposited ochre may have compacted, thereby potentially creating different sub-surface conditions which may affect long term permeability. However, the short term saving grace of the Pelenna system may be the ~1 m of freeboard available and the wet Welsh weather. Combined, these factors may provide sufficient head to allow flow to continue, albeit at a reduced rate for a longer period of time before remediation engineering is required or the system over-spills.

TREATMENT ALTERNATIVES

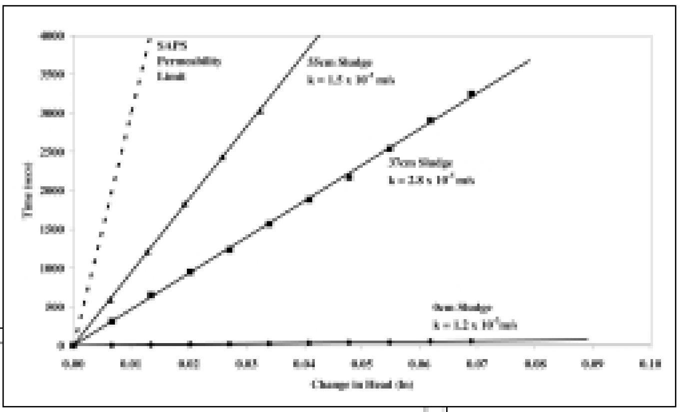
A number of SAPS have been installed worldwide and it is considered likely that the observations and predictions made are applicable to these other systems where surface ochre is accumulating.

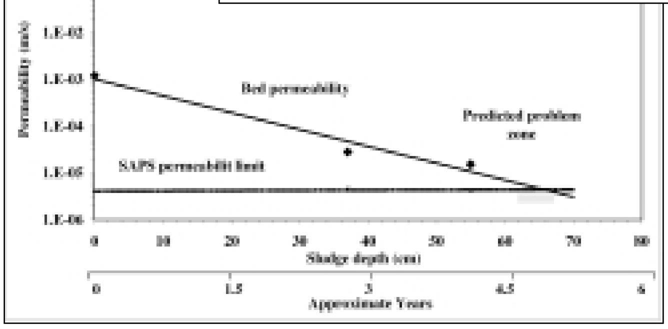
Successful treatment of net acidic minewater requires separation of the alkalinity supplementation and Fe removal stages. The alkalinity should be added in an anaerobic environment and then the water exposed to

Figure 3: Laboratory reconstruction of the Pelenna SAPS

Figure 4: Variation in SAPS permeability with ochre depth

Figure 5: Prediction of SAPS longevity





oxygen to enable efficient Fe oxidation. Long term treatment of net acidic minewater is possible, provided the water chemistry is first fully characterised, the treatment design is based on geochemical understanding and it is recognised that the system requires on-going maintenance which will incur operational costs.

Treatment options available include:

- a modified SAPS system;
- anoxic limestone drains;
- bacterial remediation; and
- anaerobic reactive barriers inside workings.

The latter treatment option is particularly attractive and has recently been implemented at Aznalcóllar, in Spain, and at Renishaw Park, in the UK[3]. As the system relies on treating the minewater prior to discharge from the mine it is essential that mine planning is proactive and preparations are initiated prior to abandonment of a mining area.

Successful long-term treatment using systems such as wetlands and SAPS requires ongoing management and they should not be considered a walk-away option.

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