Solving Mine Water Problems with Peat-Based Sorption Media

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ABSTRACT

Mine water often contains trace metals that must be removed prior to discharge. Conventional technologies exist but generally are labor intensive and expensive. Peat-based sorption material can be a less expensive alternative and is easily deployed in either "semi-active" or passive treatment designs. The media is a hardened uniform granular material produced from reed sedge peat. It has a hydraulic conductivity of around 1 cm/sec, metal removal capacities ranging from 1 - 15% dry weight and been used successfully to remove suspended and dissolved metals from the Soudan iron mine in Minnesota and base metal mines in North America.

In November 2012, a pilot test was initiated at the Soudan mine. Since startup, over 62.4 million liters (> 32,000 bed volumes) have been treated with an average removal of around 75% for suspended copper and 60% for dissolved copper. Backwash is required at about 4000 bed volumes, but with a combination of air sparging and high flow backwash, the suspended material is effectively removed from the bed. The APTsorb media produced equivalent removal to the existing system but reduced the size and complexity of the system and reduced operating costs by 50%.

In October 2013, a pilot test began at a base metal mine in North America. The pilot was designed to model both a "semi-active" (pressurized tank) and passive (biocell) treatment system approach. Lead removal in both pilot systems was generally greater than 99%. Excessive solids in the mine discharge contaminated the pressurized tank and affected treatment at 6400 bed volumes. This reduced dissolved metal removal efficiency in the media from 99% to about 85% and caused the discharge to exceed the permit limit of 11.5 ug/l lead. The biocell was not affected and it continued to meet discharge limits up to 20000 bed volumes.

Keywords: Copper, lead, zinc, cadmium, ion exchange, passive treatment, adsorption,

INTRODUCTION

Mine water often contains trace metals above regulatory limits. For many situations, lime treatment is the preferred treatment since it is effective with most mine waters. However, it is expensive, generally requires a large infrastructure and has substantial ongoing operation and maintenance costs. Commercial ion exchange resins can provide an alternative treatment approach but the media is expensive and typically cannot effectively handle water containing suspended solids.

Peat is a natural material and has long been known for its ability to remove metals from water. As a result, metal concentrations in peat have been used as a geochemical prospecting tool and peat has been tested for its ability to treat wastewater (Lapakko & Eger, 1988, Salmi, 1959, Brown et al., 2000). Up to 10% copper was measured in peat from the Tantramar Swamp in New Brunswick and copper concentrations up to 8.9 % have been reported in samples used to treat wastewater (McDonald, 1976; Premi, 1970).

Peat, although relatively inexpensive, tends to be non-uniform and somewhat difficult to handle. Although loose, fibrous peat can have hydraulic conductivities on the order of 10^{-1} cm/sec, more decomposed and compacted peat can have conductivities of 10^{-3} to 10^{-4} cm/sec. These lower conductivities reduce the overall flow rate and increase the potential for channelization.

American Peat Technology (APT) has developed a granulation and low temperature hardening process to convert loose peat into an engineered sorption media (Figures 1, 2). The granules maintain their structure when wet and can be sized to any specification, which makes them readily adaptable to a variety of treatment systems. The standard media is 0.6 to 2 mm and has an estimated hydraulic conductivity around 1 cm/sec. Metal removal capacities measured in laboratory equilibrium tests have ranged from 1 to 15% dry weight metal.

Figure 1 Peat granules

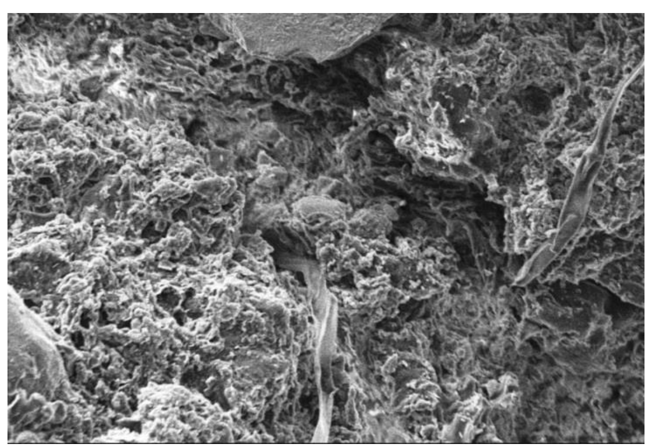

Figure 2 Sorption media surface at 1500X

APPROACH

Pilot tests were conducted at several sites to evaluate the ability of peat-based sorption media) to remove trace metals from mine drainage.

Soudan Mine; Suspended and Dissolved Copper

The Soudan Mine is an abandoned underground iron mine located in northeastern Minnesota. Mine water is discharged at an average flow rate of 227 L/min. The pH of the discharge is generally around 7 but contains low levels of copper and cobalt. Metals concentrations range from 30-50 ug/l copper and 10-15 ug/l cobalt, which exceed the permit limits of 17 and 4 respectively. About 75% of the copper is suspended but all the cobalt is dissolved. Water is currently treated with a commercial ion exchange system that employs prefiltration with bags, cartridge filters and activated carbon (Figure 3).

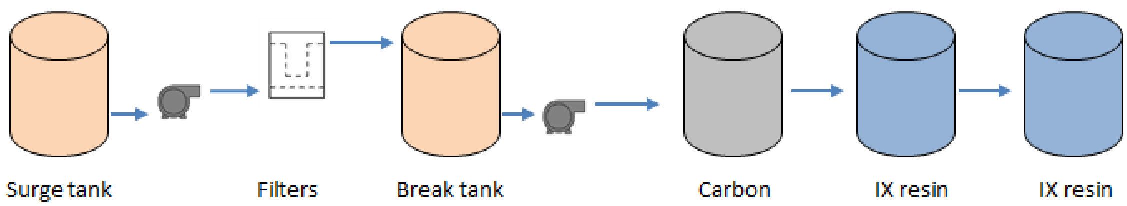

Figure 3 Existing water treatment, Soudan Underground mine

At the Soudan Mine, a pilot test was conducted to evaluate the ability of the peat-based sorption media to remove both suspended and dissolved metals from the overall mine discharge. About 1900total liters of media were installed in a 3785 liter treatment tank that was designed to be periodically backwashed (Figure 4).Typical flow rate was 189 L/min, but flow rates varied over the course of the pilot from 114 to 378 L/min.

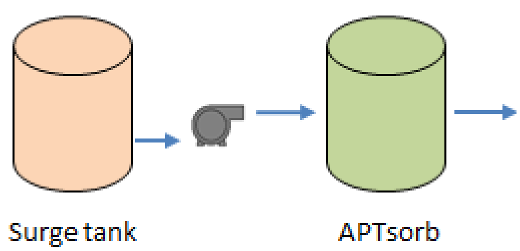

Figure 4 Pilot test, Soudan Underground Mine

Water quality samples were taken roughly on a weekly basis and analyzed by APT using a Perkin Elmer PinAAcle 900 graphite furnace. Periodic quality control samples were run by Pace Laboratories.

RESULTS

During the initial testing, samples were collected from before and after the media tank as well as after each component in the existing system. During this time, total copper in the mine discharge generally varied from 20 to 40 ug/l and dissolved ranged from 5 to 10 ug/l. A total of about 17 million liters was treated by the peat based sorption media system during the comparative test.

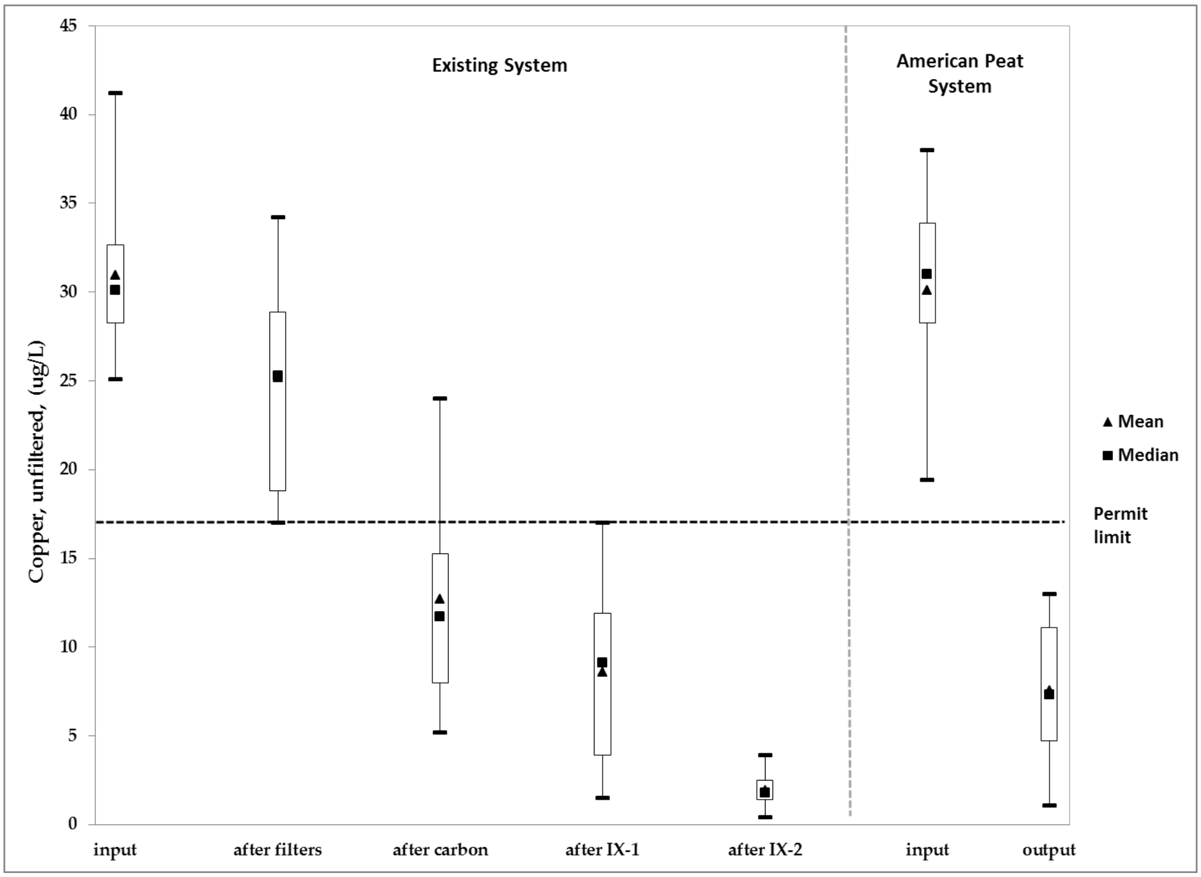

Figure 5 Comparison of existing system and APTsorb, November 2012 – April 2013

In the existing system, total copper concentrations decreased after each component, and were less than 5 ug/l after the last ion exchange tank. (Figure 5). After the peat media tank, total copper ranged from 4 to 13 ug/l and was always less than the permit limit of 17 ug/l.

Starting in May 2013, there were problems with an in-mine treatment system that pre-treated a small but concentrated flow, and the copper concentrations in the overall mine discharge began to increase. It reached a maximum of 364 ug/l in July. The problems with the in-mine system were corrected by October, and concentrations returned to the typical range of 30 – 50 ug/l (Figure 6).

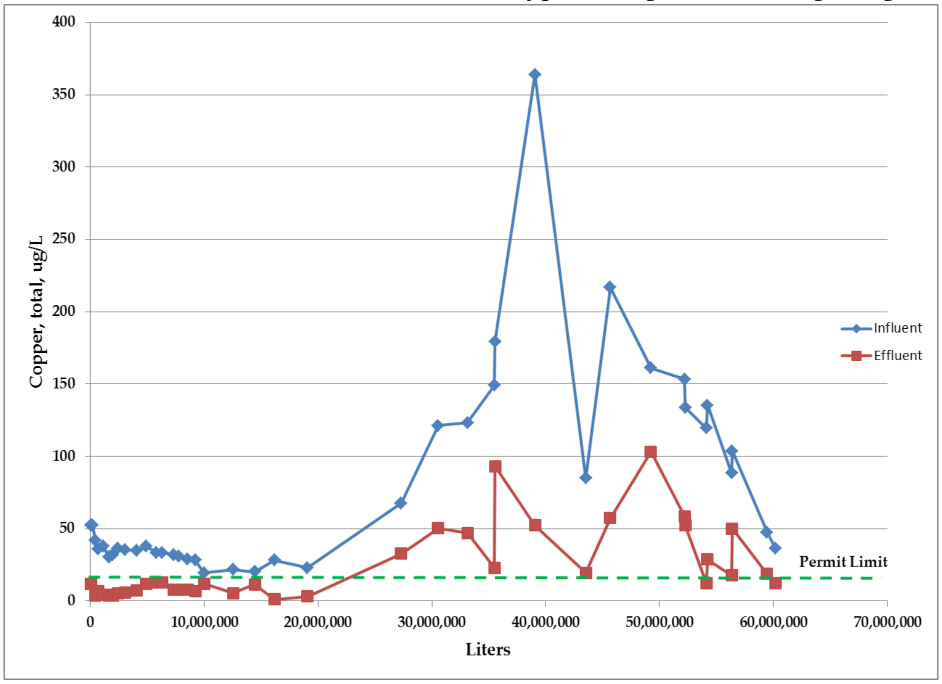

Figure 6 Total copper removal at the Soudan Mine, November 2012-2013

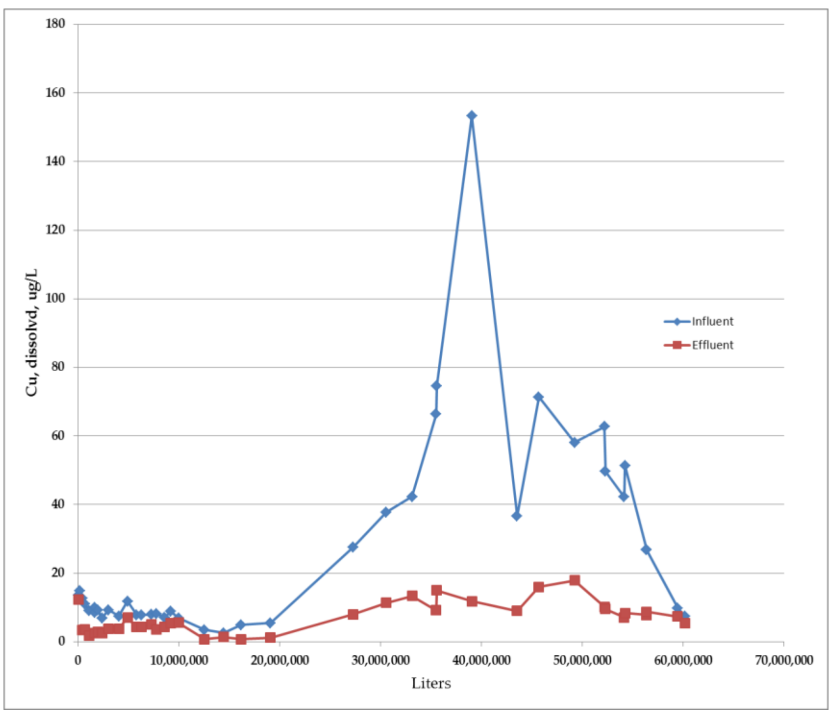

Figure 7 Dissolved copper removal at the Soudan Mine, November 2012-2013

When concentrations in the mine water increased, the peat media continued to remove both total and dissolved copper, but concentrations exceeded the permit limit of 17 ug/l. (Figures 6, 7). When the influent copper concentrations decreased in the fall, the effluent concentrations also decreased and the discharge met the permit limit. Dissolved copper was removed continuously throughout the study despite an order of magnitude variation in input concentration. Treatment continued until November 2013 when the system had to be shut down and moved to a new treatment location. During the treatment period, about 62.4 million liters of water had been treated.

Base Metal Mine; Lead, zinc, cadmium

The second site is an active underground base metal mine in North America. The suspended solids in the mine water vary substantially but average around 30 mg/l. The water is circumneutral with average total metal concentrations of 2100 ug/l lead, 115 ug/l zinc and 0.8 ug/l cadmium; average dissolved concentrations were 150 ug/l lead, 70 ug/l zinc and 0.2 ug/l cadmium. Typical discharge is around 18,900 L/min. Water is currently discharged to a clarification basin.

Two pilots were constructed; one using a pressurized tank similar to the Soudan mine and the second a gravity flow system to simulate a passive treatment approach (biocell). Since the media has a high hydraulic conductivity, hydraulic loading rates of 40.8 L/min/m^2 are possible with minimal head pressure. The pressurized flow tank typically treated 189 L/min, but flow rates up to 378 L/min were tested. The biocells were operated at loading rates of 10.2, 20.4 and 40.8 L/min/m^2 (2.3 to 9.5 L/min). Since the discharge was directly from an active underground mine a sand filter was installed prior to both pilots to avoid excessive solids loading.

Pressurized tank

Treatment began in October of 2013. Lead concentrations in the input water were typically around 1000 ug/l, but spiked as high as 40,000 μg/l in December (Figure 8). The sand filter essentially removed all the suspended lead, although it plugged quickly during the high solids discharge. The peat media removed about 99% of the remaining lead with effluent concentrations well below the current permit limit of 11.5 ug/l (Figure 8).

Although the sand filter removed most of the suspended material, an excessive solids load plugged the sand filter within 30 minutes and solids were pushed into the media tank. In an effort to remove these solids, the peat media was backwashed.

The backwash did not effectively remove the solids but instead distributed them throughout the bed and contaminated the media. After the backwash, Lead concentrations immediately jumped to around 20 ug/l.

Biocell

Only the results from the biocell with the highest loading are presented. Treatment was similar in all biocells; those with lower flows just treated less volume.

The biocell removed about 99% of the lead for the first 10 weeks of the study (Figure 9). Concentrations increased gradually and reached the permit limit at about 30 weeks. Although suspended solids did enter the biocell, they were retained in the upper layer of the media.

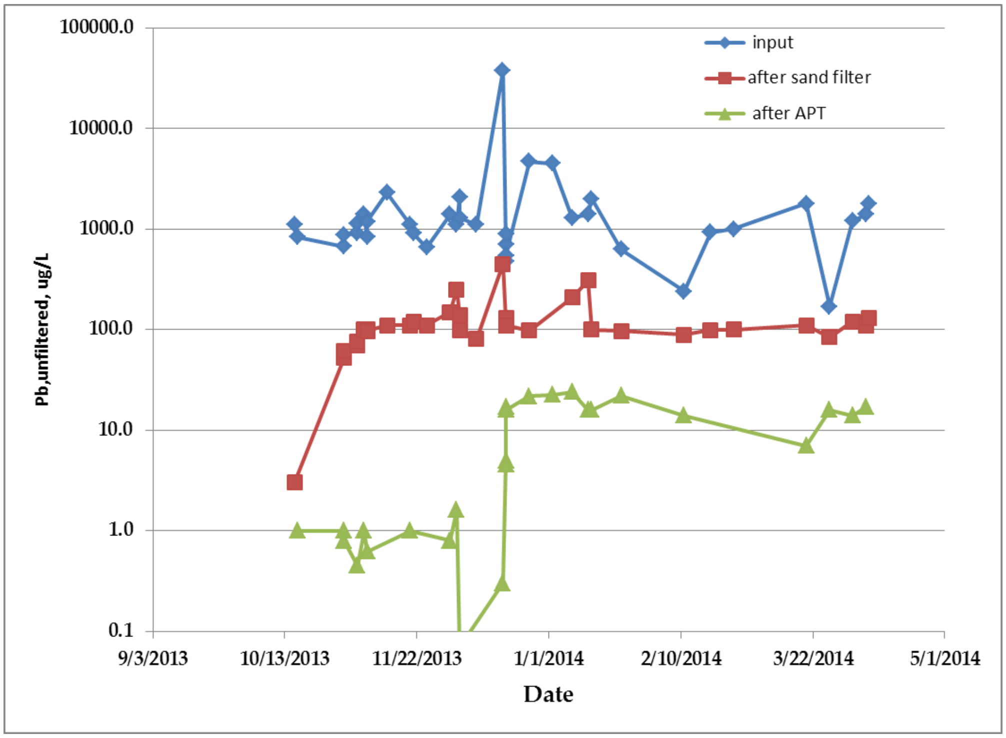

Figure 8 Lead removal, pressurized tank, October 2013-February 2014

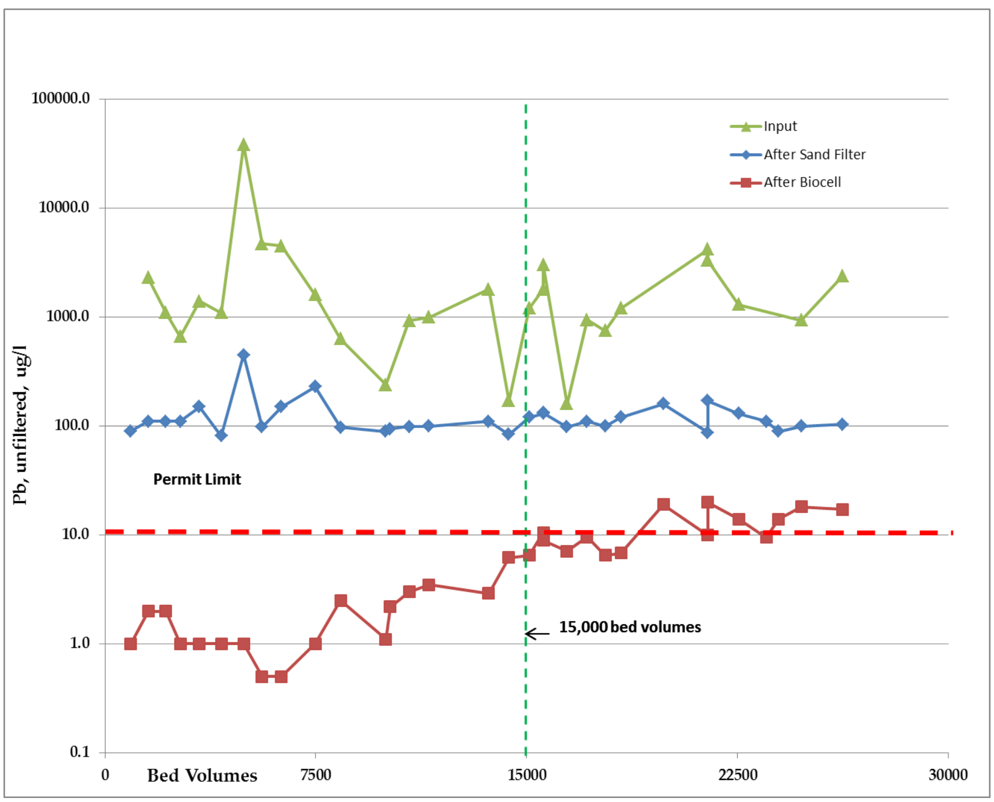

Figure 9 Lead removal, biocell October 2013 – August 2014

This caused a slight increase in head but the flow rate remained constant. No backwash was conducted on the biocell and the system continued to treat water until the test was terminated in August 2014. At the end of the experiment, Lead removal was still greater than 80%.

DISCUSSION

Lifetime

Treatment lifetime is often measured by the number of bed volumes treated. One bed volume is equal to the volume of the media; which in the pressurized tank is about 1890 liters. At the Soudan Mine, over 32,000 bed volumes have been treated, while the biocell at the base metal mine treated over 26,000 bed volumes (Figure 10). In both cases, the media was still removing substantial amounts of metal when the pilot ended.

At the base metal mine, the media treated 15,000 bed volumes before effluent concentrations approached the permit limit. The first sample that actually exceeded the permit limit of 11.5 ug/l was at 20,000 bed volumes. The standard procedure in media treatment is to employ a two-tank (lead/lag) design. The first tank would treat the first 15,000 bed volumes then a second or lag tank would be added to polish the effluent from the first tank to reduce the concentration below the permit limit. This extends the life of the media in the first tank. Although lead exceeded the permit limit in the biocell, the overall lead removal was still over 80% and the rate of increase in the lead concentration in the effluent was gradual, which suggests that breakthrough would be manageable and allow for methodical replacement of media.

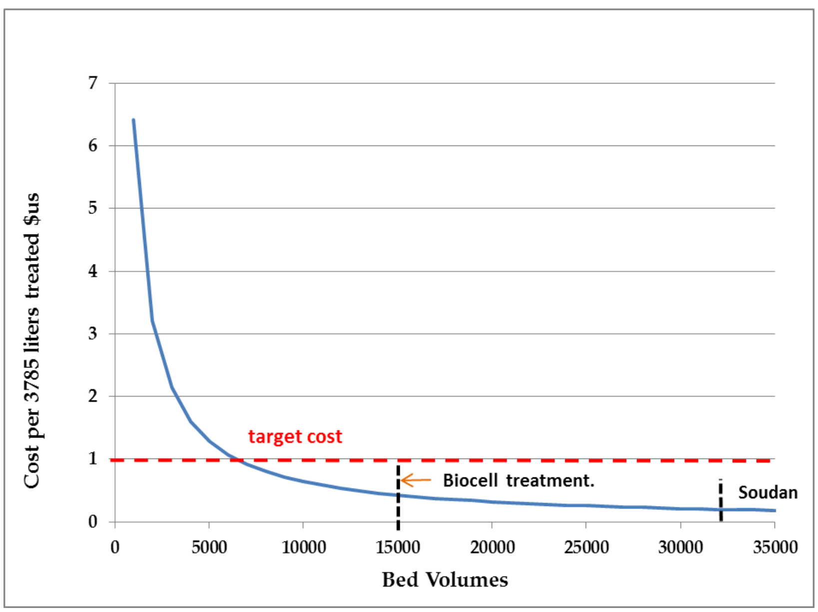

Figure 10 Treatment cost

Costs

As the number of bed volumes treated increases, the treatment cost (cost per liter treated) decreases (Figure 10). For copper treatment at Soudan the operating cost is on the order of 0.25 US$ per 3785 liters. For lead, the treatment cost using a single bed of media would be 0.43 US$ per 3785 liters.

At the Soudan Mine, a single tank of peat based sorption media provided equivalent (or better) copper treatment than the first four components of the existing system. Reducing the complexity of the system also reduced the overall cost associated with treatment. The estimated annual operating cost for the existing system was around 163,000 US$; this could be reduced to around 70,000 US$ by replacing the first part of the system with a tank of peat media.

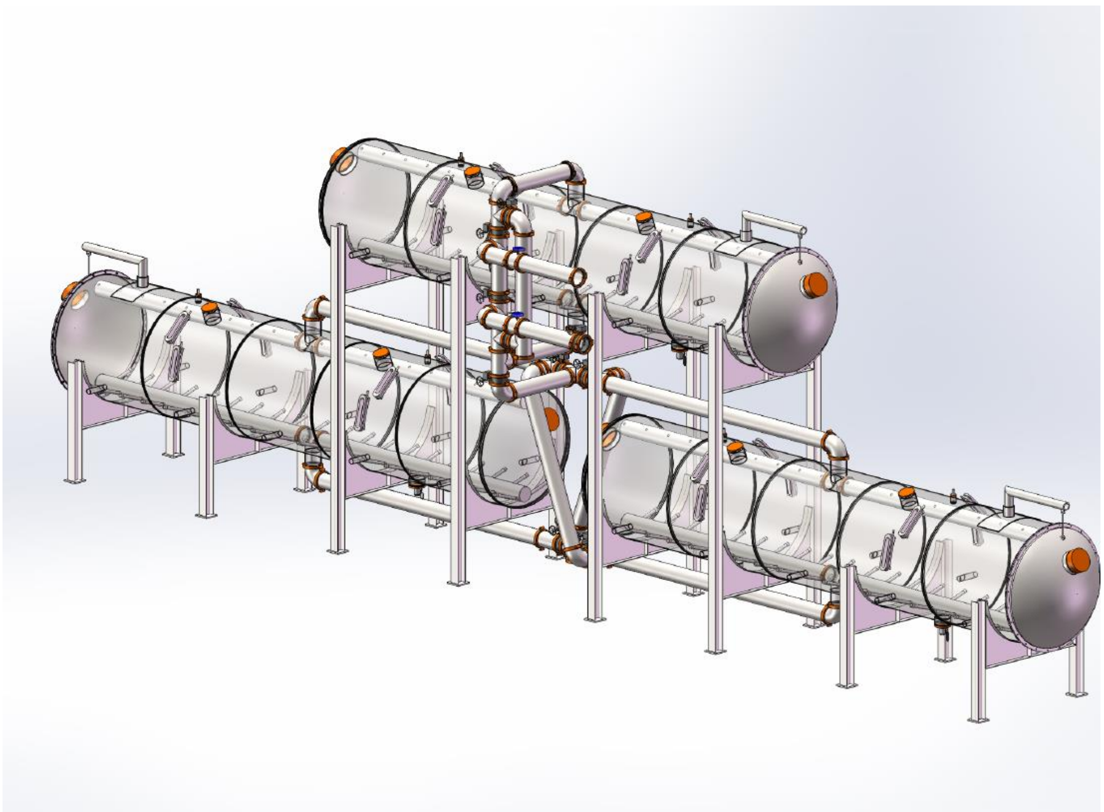

Figure 11 Three -tank module

At the base metal mine, a conceptual treatment approach was developed using a three tank modular system, containing a sand filter, and two tanks of media in a lead/lag configuration (Figure 11). Each module would be capable of treating up to 4540 L/min. The projected capital cost for the system was less than half that of a chemical treatment plant and the projected operating cost of 0.43 US$ per 3785 liters was significantly less than the company's target cost of 1 US$ per 3785 liters.

CONCLUSIONS

A variety of metal removal mechanisms occur in peat and include adsorption, ion exchange, complexation and chelation (Brown et al., 2000). This variety of mechanisms makes peat a very effective natural treatment media with the ability to cost-effectively remove a wide range of trace metals.

Peat resources are plentiful in Minnesota and the northern portion of the state still retains over 90% of its presettlement wetlands. Peat used to produce the media is harvested from an area that was drained in the early 1900's when there was a major effort to develop agriculture in northern Minnesota. The use of peat as a water remediation media is an example of using a resource in a sustainable, thoughtful way to maximize its best use potential.

Technically and politically, peat is described as a slowly-renewable resource and given the large area of wetlands in northern Minnesota overall accumulation exceeds the small extractive use. Peat accumulation rates are very slow but American Peat Technology is currently investigating methods to increase the rate of accumulation as part of its reclamation program.

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