Proceedings of Mine Water Solutions in Extreme Environments, 2015
April 12-15, 2015, Vancouver, Canada
Published by InfoMine © 2015 InfoMine, ISBN: 978-0-9917905-7-9

Treating high flow discharges with a modular peat-based sorption media system

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Abstract

Pilot tests were conducted at a base metal mine to determine the ability of peat-based sorption media to remove lead, zinc and cadmium from a 30,000 L/min underground mine water discharge. The pilot was designed to model both an active treatment (pressurized tank) approach and passive (biocell) approach.

The mine water had a pH around 8 and averaged 2,127 µg/L lead, 115 µg/L zinc and 0.82 µg/L cadmium. The mine water discharge was to be treated directly at a cost not to exceed 1$US per 3,785 L. In order to remove the suspended solids from the direct mine discharge, a sand filter was installed in front of the peat media. The sand filter essentially removed all of the suspended solids and suspended metals in the discharge. Periodic backwash was required, but this provided a method to directly recover and process the solids which averaged around 3% lead.

Both pilot systems removed over 99% of the lead and reduced all metals to below permit values. Due to periodic discharges of excess solids from the mine, both pilots had lead solids on the surface of the media. In an effort to remove the solids from the pressurized tank, the media was backwashed, but the backwash was not successful and the media became contaminated with lead solids that were mixed throughout the bed. Although lead removal was still around 80%, the effluent no longer met the discharge standard. The biocell was not backwashed and operated for about nine months. It met the permit limit of 11µg/L for 15,000 bed volumes. When the pilot ended over 27,000 bed volumes had been treated and Lead removal was still over 80%. Lead concentration on the media was estimated to be 0.6%.

Based on the pilot results, a full-scale treatment model was developed for the site. The treatment design included a modular unit of three horizontal tanks: a sand filter and two tanks of peat media in a standard lead/lag arrangement. Each module is capable of treating 4,500 L/min. Treatment costs were estimated to be approximately 0.43 $US per 3,785 L and capital costs were estimated to be around 5

million $US; substantially less than 10-15 million $US projected cost for a standard chemical treatment plant. The system also provided for recovery of removed materials within the treatment process. With lead values expected to approach 1% on the media, recovery of the dissolved lead might be feasible.

Introduction

Removing low levels of trace metals to meet new and lower permit limits is always challenging, particularly when flow rates are high. Traditional active treatment methods can include two-step neutralization and membrane options like nanofiltration or reverse osmosis. These technologies are effective but have high capital and operating and maintenance costs, so more cost-effective approaches are needed. A promising new technology is the use of peat sorption media. Peat has long been known for its ability to remove trace metals, and constructed treatment wetlands have been effective in removing trace metals from a variety of sources (ITRC, 2003). However, these wetlands require long residence times and large surface areas and are generally not appropriate for large flows.

American Peat Technology (APT) has developed a granulation and low temperature hardening process to convert loose peat into an engineered sorption media (APTsorb™) (Figure 1). 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.

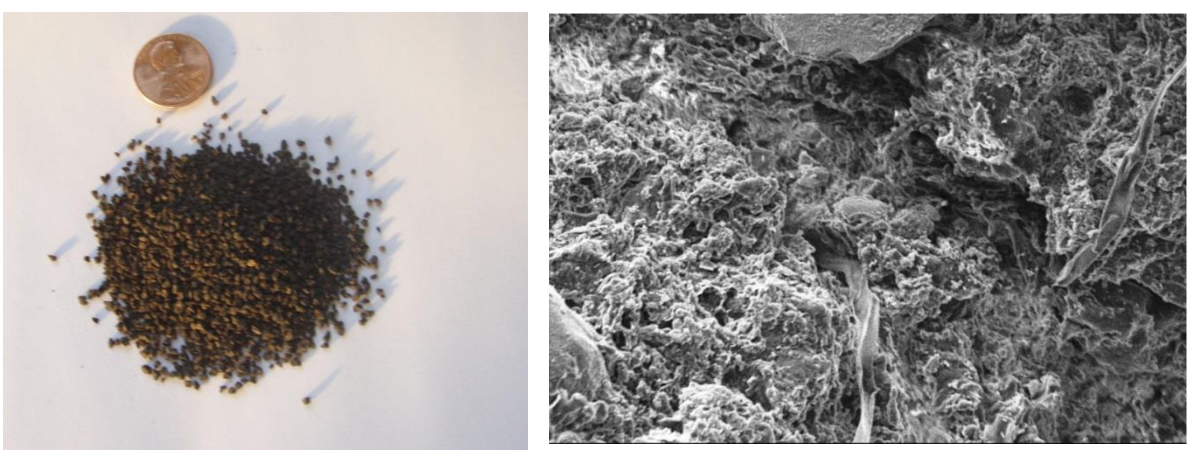


Figure 1: APTsorb granules with surface at 1,500 × magnification

Contact times needed to remove metals are relatively short, generally ranging from 5 to 10 minutes. As a result, large volumes of water can be treated in a system with a relatively small footprint.

Approach

A pilot test was conducted at a base metal mine in North America to determine the ability of peat based sorption media to remove lead, zinc and cadmium from up to 30,000 L/min circumneutral mine discharge. In order for treatment to be a success, the media had to:

- treat the direct discharge from the underground mine;
- meet permit limits for all metals;
- pass chronic Whole Effluent Toxicity (WET) tests with both fathead minnows and *Ceriodaphnia*; and
- cost less than 1 $US per 3,785 L.

The typical mine water pH was around 8 and lead was the primary metal of concern with an average concentration of 2,127 µg/L (Table 1).

Table 1: Mine water discharge and permit limits. All concentrations in µg/L

	Mine water		
Parameter	Total	Dissolved	Permit limit
Lead	2,127	156	11.5
Zinc	115	70	137.3
Cadmium	0.82	0.18	0.5

Methods

Since the discharge was from an active underground mine, it could contain elevated concentrations of suspended solids depending on underground activities. A sand filter was installed to remove the bulk of the solids before the water contacted any of the peat sorption media in the pilot tests (Figure 2).

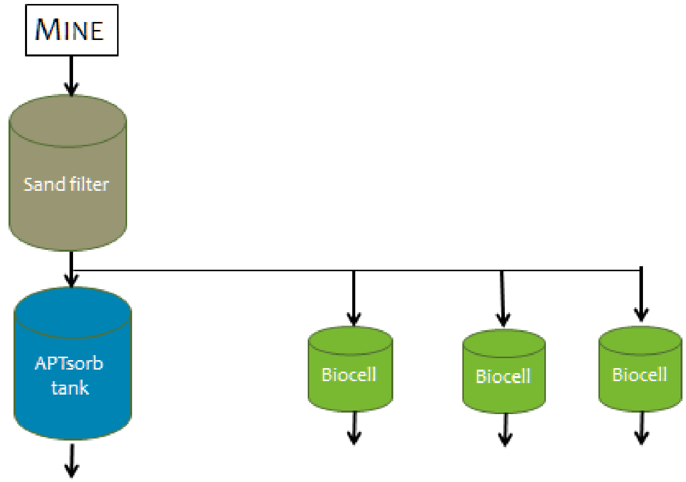


Figure 2: Layout of pilot test, schematic

The pilot had two components: a pressurized tank that required water to be pumped through the media and a series of gravity flow biocells. These pilots simulated both active and passive treatment approaches.

The pressurized tank is similar to a standard ion exchange tank, but unlike typical commercial systems, it is designed to be backwashed. The total tank capacity is around 3,800 L and contains around 1,900 L of media.

Small-scale column tests conducted prior to pilot start-up indicated that APTsorb with a particle size of less than 0.6 mm removed more suspended solids than the standard APTsorb. Since the effectiveness of the sand filter to remove all the suspended solids in the discharge was not known, the smaller size APTsorb was used in the tank. The typical flow rate during the pilot was on the order of 190 L/min, but over the course of the study, flows were varied from 95 to 380 L/min.

The biocells were constructed from 208 L plastic barrels. Each cell had a collection manifold at the bottom and contained about 132 L of media. In order to ensure sufficient hydraulic conductivity, the standard APTsorb (0.6–2 mm) was used in all the biocells. Flows for the biocell ranged from 2.3 to 9.5 L/min; corresponding hydraulic loading rates were10.2–40.8 L/min/m^2.

Water quality samples were typically collected once per week with more frequent sampling when flows were varied or when conditions in the mine discharge changed. Samples were analyzed for lead, zinc and cadmium by APT using a Perkin Elmer PinAAcle 900 graphite furnace. Periodic quality control samples were run by Pace Laboratories.

Flow through the pressurized tank was monitored continuously with a GF George Signet 9900 flow meter. GPI flow meters were used to record the lower flows in the biocells. All the meters provided instantaneous readings and also recorded the total flow through each of the pilot systems. Flows, ambient temperature and pressure at various points in the system were relayed through the use of an Onset Hobo U30 GSM telemetry equipment, which allowed remote monitoring of the entire system.

The pilot began in October of 2103 and ran until August of 2014.

Results

Mine Discharge

Although the concentrations of dissolved metals were relatively constant, the amount of suspended solids varied substantially during the study. This variation affected the total metals concentration, particularly lead. While the average dissolved concentration for lead was 154 µg/L, the total concentration was over an order of magnitude higher at 2127 µg/L (Table 2).

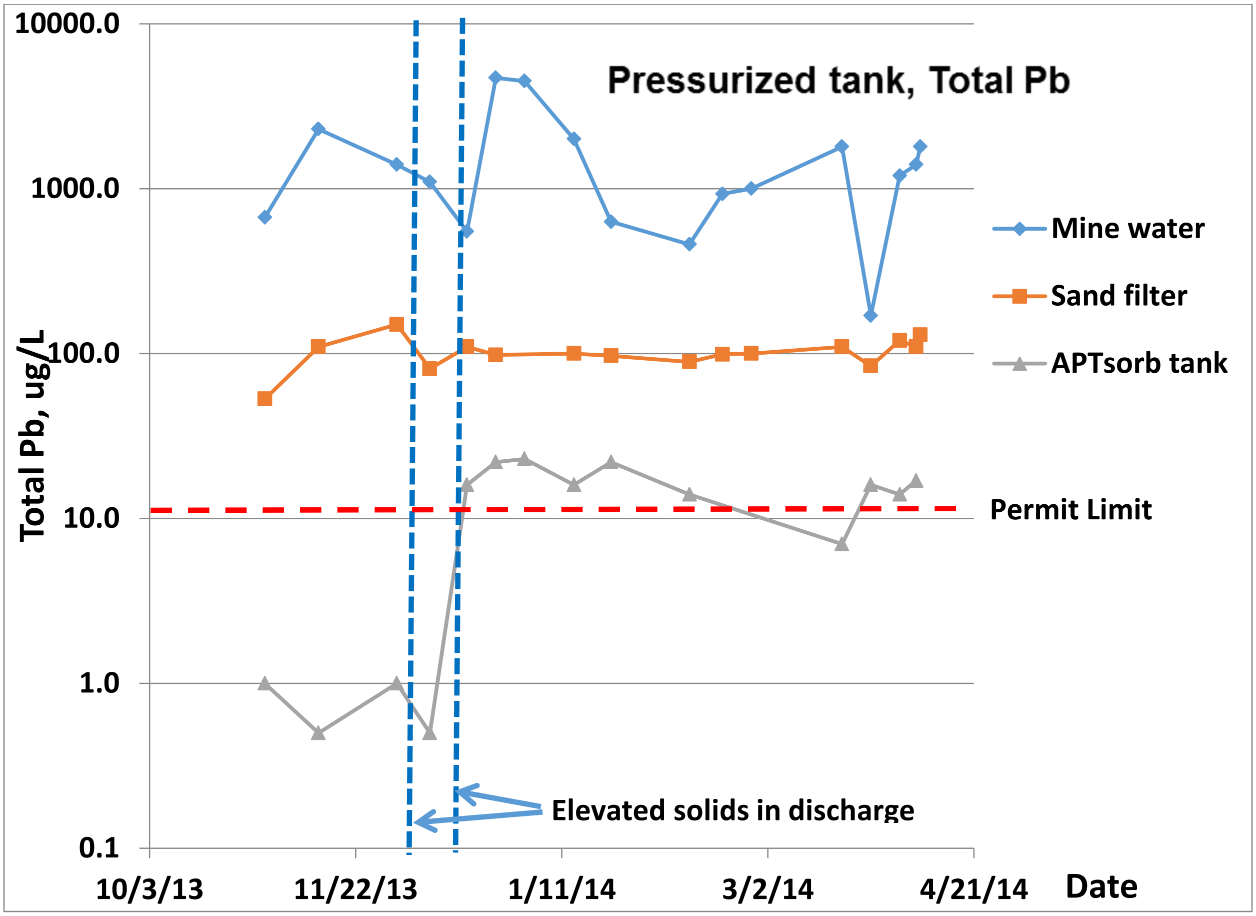


Figure 3: Pressurized tank results

Sand filter

The sand filter generally removed about 98% of the suspended lead in the discharge (Table 2). However, during the high solids discharge events, the sand filter plugged in less than an hour and some fine solids were forced through the filter (Figure 3).

The sand filter was backwashed about every two weeks or when the pressure drop reached 103-138 KPa. Initially water that had been treated by the peat media was stored in an on-site holding tank and used for backwashing. Later untreated mine water was used directly. Backwash flow rates were generally around 1890 to 2,140 L/min and the backwash could be completed in 10-15 minutes. Solids were always effectively removed from the bed and the pressure drop after backwash returned to the original observed value of 0.2 to 0.3 KPa.

Peat sorption media

Pressurized tank

The peat media was successful in removing any residual suspended metals and the dissolved metals from the mine discharge. Removal rates were highest for lead with over 99% of the lead being removed in the initial part of the test (Figure 3). Zinc and cadmium were also removed and the treated water met permit limits (Table 2). In addition, there was no toxicity or any effect on reproduction during the WET testing.

After the second discharge of elevated solids, a layer of solids was visible on top of the peat media. The peat media was backwashed in an attempt to remove the solids. However, the media fluidized at a flow rate on the order of 510 L/min and media was forced out of the tank. In order to avoid losing more media, the backwash was stopped after only a few minutes. Immediately after the backwash, lead concentrations increased sharply from around 1 μg/L to 17 μg/L. Although the media continued to remove about 80% of the lead, concentrations generally exceeded the permit limit (Table 2, Figure 3). The pressurized tank was stopped in April 2014 after about 15,400 bed volumes had been treated.

Table 2: Pressurized tank results, before and after backwash, all concentrations in μg/L

	Mine Water		After sand filter		After APTsorb		
Before APTsorb backwash							
Parameter	Dissolved	Total	Dissolved	Total	Dissolved	Total	Permit Limit
Lead	114	2,577	83	128	1	1	11.5
Zinc	54	88	45	40	17	8	137.3
Cadmium	0.13	0.70	0.13	0.15	<0.1	<0.1	0.5
After APTsorb backwash							
	Dissolved	Total	Dissolved	Total	Dissolved	Total	Permit Limit
Lead	209	1,545	88	142	17	20	11.5
Zinc	53	139	38	52	23	28	137.3
Cadmium	0.23	1.05	0.19	0.25	0.06	0.10	0.5

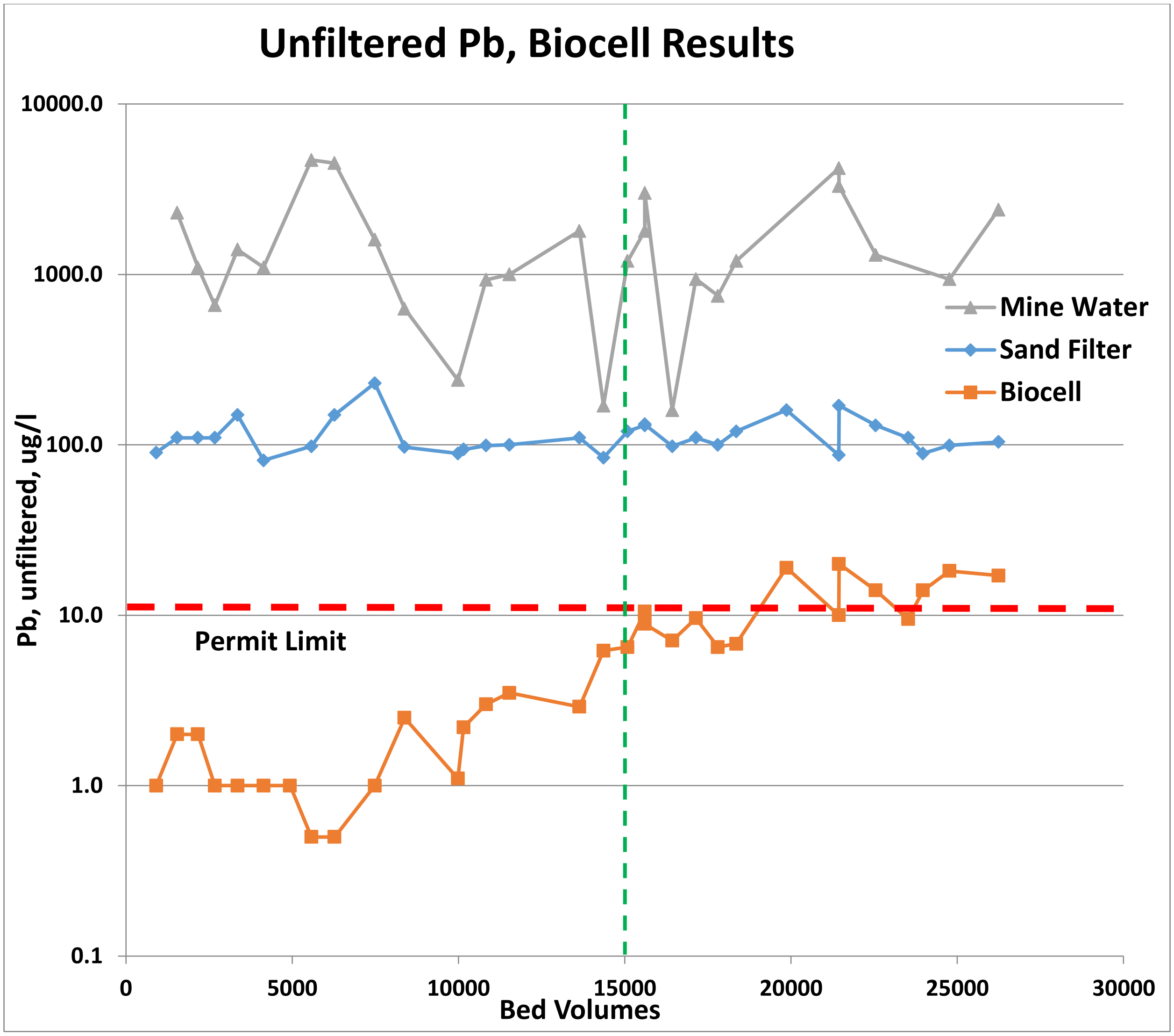
Note: Before backwash: 10/31/13 to 12/19/13; after backwash: 12/19/13 until the pressurized tank was shut down on 4/8/14. Anomalies: dissolved zinc was greater than total zinc in several samples.

Biocells

All biocells removed lead, zinc and cadmium, but only the results from the biocell with the highest hydraulic loading are presented since it treated the most water during the pilot test.

Initially over 99% of the lead was removed and concentrations remained below the permit limit for over 15,000 bed volumes (Figure 4). After 20,000 bed volumes the lead concentration exceeded the permit limit but the biocell continued to remove over 80% of the lead until the pilot was ended and over 27,000 bed volumes had been treated (Figure 4). Zinc and cadmium were below the permit limits after the sand filter, but the biocell further reduced average concentrations by an additional 40%. Average total zinc dropped from 90 to 54 µg/L, while cadmium was reduced from 0.29 to 0.16 µg/L.

Figure 4: Biocell results



Solids also accumulated on the surface of the biocell. Although the accumulation of solids did not appear to effect overall treatment, they did cause a decrease in hydraulic conductivity. Initially, the pressure drop over the biocell was about two centimeters but increased to about 68 cm when the pilot was ended. Despite the solids buildup, the flow rate was maintained throughout the pilot.

When the pilot was ended the biocell was visually examined and the majority of the solids had been trapped at the surface of the media. Small particles were observed in deeper levels but the bulk of the particles were confined to the upper few centimeters of media.

Discussion

Peat sorption media successfully removed lead, zinc and cadmium from the mine discharge. A variety of removal mechanisms, including adsorption, ion exchange, complexation and chelation, account for this removal (Brown et al., 2000). Typically effluent concentrations increase slowly as the removal sites are filled but performance abruptly changed in the pressurized tank after the media backwash. Although the standard media (0.6–2 mm) had been successfully backwashed, this was the first time the 0.6 mm minus material had been used for this type of application (Eger et al., 2014). The smaller size fluidized much more quickly than the standard size media and was easily forced out of the tank with the backwash water. At this location the suspended solids in the mine discharge were generally fine ore particles and had a specific gravity of at least three times that of the peat media. As a result, the peat media was transported out of the tank more easily than the heavier mineral fragments which were mixed throughout the media. When the media was removed, fine mine solids could be found mixed throughout the media. This distribution of mine solids (which contain about 3% lead) is believed to be responsible for the sudden and dramatic spike in effluent concentrations following the backwash.

In contrast the biocell, which was never backwashed, had effluent concentrations increase slowly and a much higher volume of water was treated before the permit limit was exceeded.

Costs

Since there is a fixed cost for the media, the cost per liter decreases as the volume of water treated increases. Based on the biocell, the cost per 3,785 L was on the order of 0.43 $US, well below the target cost of $US1 (Figure 5).

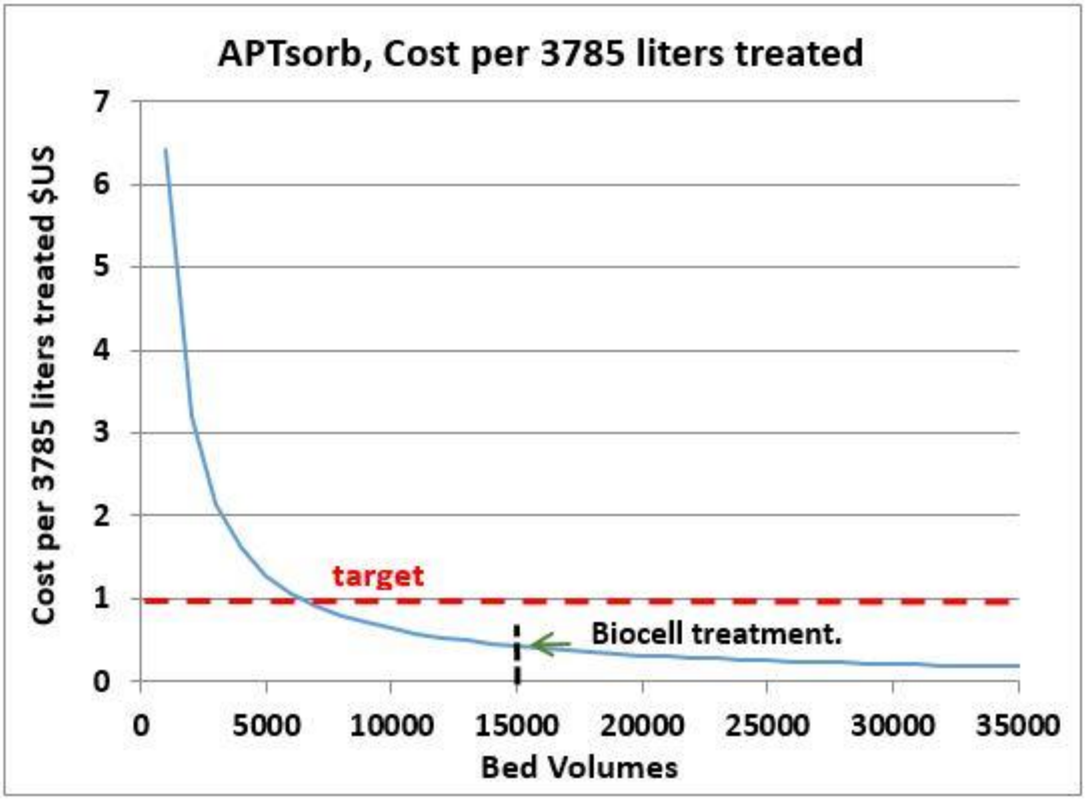


Figure 5: Treatment costs

Proposed treatment

In order to handle up to 30,000 L/min, a modular system was developed. Each module would contain three tanks: an initial sand filter and two tanks of APTsorb in a standard lead/lag configuration (Figure 6). Each module would be capable of treating 4,540 L/min, so a total of seven modules would be needed to treat the entire mine drainage. Since each tank is 2.44 m in diameter and 13.1 m long, the total footprint would be on the order of one quarter of a hectare.

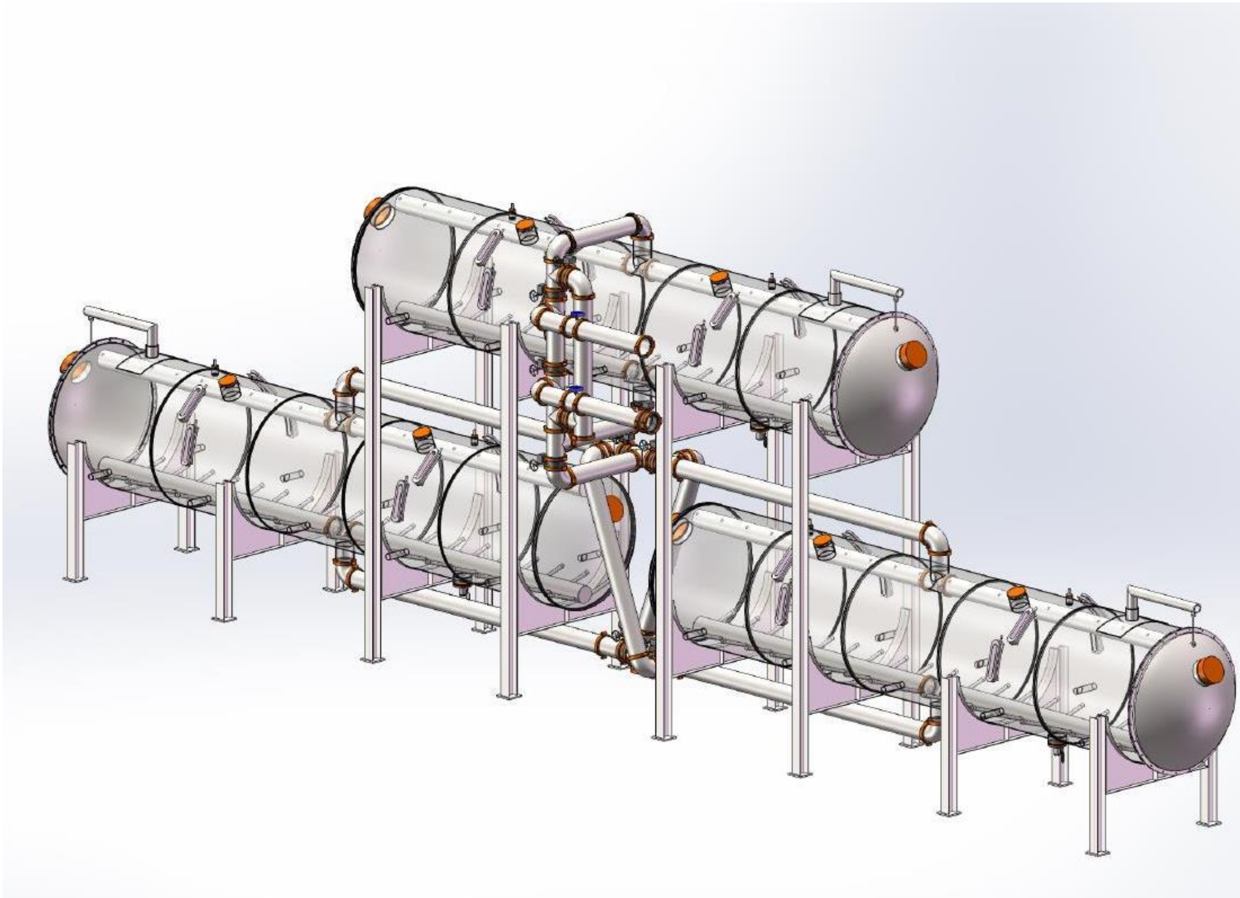


Figure 6: Proposed treatment module

The complete installed cost is about 700,000 $US per module, so the total estimated cost of the system would be on the order of 5 million $US which is less than half the estimated cost for a chemical treatment plant. Operation and maintenance costs were estimated to be about 50% less than a chemical plant (Table 3).

Table 3: Projected treatment costs

Costs	Chemical precipitation	APTSorb
Capital cost million $US	10–15	5
Treatment cost ($US /3,785 L)	1	0.5
Annual cost million $US	2.6	1.3

Metal recovery

In addition to lower projected capital and operation and maintenance costs, the system provides opportunities to recover both the suspended and dissolved metals from the discharge. Since the solids are finely ground ore, the sand filter backwash can go directly back into the processing circuit. The lead concentration on the biocell media was estimated to be on the order of 0.6% when the pilot ended but was projected to reach around 1% when the media was fully utilized. Based on model projections, the estimated total bed volumes would exceed 40,000, which would reduce the treatment cost to less than 0.20 $US per 3,785 L. When metals reach the percent range, reprocessing may be economically favorable and should be considered.

Conclusions

Peat sorption media is a cost effective alternative to more traditional active treatment approaches and can treat high flow discharges. The media can be deployed in either active or passive systems and offers the added benefit of complete metal recovery from the mine discharge.

References

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