

TECHNOLOGY OVERVIEW

ION EXCHANGE

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Mining Waste Team**

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ION EXCHANGE

1. INTRODUCTION

Ion exchange involves the interchange (or exchange) of ions between a solid media and mining-influenced water (MIW). The solid media can be commercially produced or made from naturally occurring substances (e.g., peat or zeolites). Various resin forms are available to remove either cations or anions. Synthetic organic resins are the predominant type since their characteristics can be tailored to specific applications.

The capacity of any resin is limited and is a function of the resin, the number of available exchange sites, and the input water chemistry. Capacity is generally estimated in pounds of contaminant removed per cubic foot of resin. Once all the available sites are used, the resin must be regenerated, either on or off site. Depending on the type of water that is to be treated, selective metal recovery may be an option.

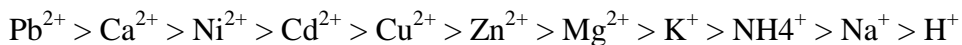
2. APPLICABILITY

Ion exchange can be applied in the following ways:

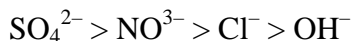
- to dissolved constituents
- to cations or anions
- to treat mine discharges with various flow rates
- as stand-alone technology or in combination with others

Ion exchange media needs to be selected based on the MIW chemistry and the specific parameters that need to be removed from solution. Tests are required to select an appropriate resin. Large flows generally require a full-scale treatment plant, but for small to intermediate flows, standard tank sizes are available that allow systems to be set up quickly.

In general, ion exchange works best for waters in the pH range of 4–8 with low suspended solids and low concentrations of Fe and Al. The more complex the mixture, the harder it is to remove all metals effectively. Resins can be designed to target specific groups (e.g., trace metals), but within these groups there is a hierarchy of removal. For example, the typical preference for cations on strong acid resins is as follows:



And the typical preference for anions on strong base resins:



At the [Soudan Mine](#) in northern Minnesota, a selective cation exchange resin was used to remove copper and cobalt from two different mine drainages. The first drainage is within the mine and had a pH of 4 with flow ranging about 1–10 gpm, copper 3–30 mg/L, and cobalt 0.1–0.3 mg/L. The second drainage is the entire discharge from the mine. This water is circumneutral with a flow rate of 150–300 gpm and copper and cobalt ranging 50–200 µg/L and 10–20 µg/L, respectively. Tests have been conducted using commercial resins and lower-cost exchange material produced from peat (Eger, Paulson, Green 2008; Eger et al. 2009).

At the Schwartzwalder Mine in Colorado, resins were used to recover uranium from mining and metallurgical processes (Zielinski et al. 2008). Other tests of ion exchange with mining influenced waters are referenced in Gusek and Figueroa (2009).

3. ADVANTAGES

Advantages of ion exchange include the following:

- temporary or permanent applications
- immediate results
- standard tank sizes available for small to intermediate flows, which allow quick installation
- minimal maintenance with standard size tank systems
- waste disposal able be handled by supplier
- capable of meeting low-level discharge permit requirements

Ion exchange resins are available in standard size tanks that can be delivered and set up on site. For these systems, a permanent shelter is not required, but the tanks must not freeze. Power is needed to pump water through the resin, but this could be supplied by a generator. Resin tanks used at Soudan range from 3.7 ft³ to 60 ft³ (Figures 3-1 and 3-2).

Once operational, the tanks can treat water until the exchange capacity is exhausted. Site-specific capacities can be developed and used to schedule tank replacement. The removed substance must be chemically stripped from the resin. In general, an acid is used to remove trace metals from the resin, and sometimes these metals can be recovered. Currently, the volume of resin from Soudan is too small to regenerate separately, so it is mixed with other resins.



Figure 3-1. In-mine ion exchange treatment, Soudan Mine. (3.7 ft³ tanks)

Recovered metals at the Soudan treatment site are used as a granular additive for cement. In general, depending on metal concentration, form, and the solidification process, additional treatment or disposal options will need to be considered for the extracted metal waste product.



Figure 3-2. Ion exchange resin tanks (60 ft³), Soudan Mine.

4. LIMITATIONS

Limitations of ion exchange include the following:

- chemical characteristics of the influent mine water
- generally not effective for low pH
- generally not effective for high concentrations Fe, Mn, Al
- generally not effective for complex mixtures of metals
- suspended solids need to be removed prior to treatment
- resin regeneration
- resin fouling
- ongoing operational cost

Prefiltration is generally recommended prior to treatment through the resin and pH may need to be adjusted. The presence of iron and aluminum complicates treatment since they can form precipitates and plug or coat (armor) the resin. High concentrations of aluminum within the Soudan Mine caused plugging of the in-mine resin tanks and required a bank of prefilter units. These prefilters need to be changed at least twice per week.

The overall Soudan discharge is currently filtered with bag and cartridge filters to a nominal 1 μm size to avoid plugging the large resin tanks with fine suspended iron. Filter maintenance and replacement in addition to tank rental and resin regeneration have significant costs.

5. PERFORMANCE

At the Soudan Mine, once startup problems were resolved, the ion exchange system has been effective in removing metals from the level within the mine for four years. Removal efficiencies are generally over 95% and often exceed 99%. Startup problems were the result of an unexpected aluminum precipitate, which plugged the resin tanks (Eger 2007). Removal efficiency decreases as the capacity of the resin is approached or the resin becomes totally saturated.

Data for treatment of the entire discharge are more limited. During the pilot test input, total copper ranged about 60–70 $\mu\text{g/L}$, filtered copper was around 10 $\mu\text{g/L}$, and total and filtered cobalt was on the order of 7–8 $\mu\text{g/L}$. Essentially all dissolved copper and cobalt were removed to less than the detection limit of 2 $\mu\text{g/L}$. The outflow did contain some suspended copper, but the total concentrations were below the permit limit of 17 $\mu\text{g/L}$ (Eger et al. 2009).

A full-scale system was installed to treat the entire flow of 150 gpm from the mine. Preliminary data suggest that the resin tanks are removing some of the finely suspended copper as well as dissolved copper and cobalt. Initial samples met the required limits of 17 $\mu\text{g/L}$ for total copper and 4 $\mu\text{g/L}$ for total cobalt. Dissolved metals in subsequent samples continued to be below permit standards, but some samples contained small amounts of suspended copper, which caused the total value to exceed 17 $\mu\text{g/L}$.

6. COSTS

Ion exchange can be an expensive treatment option. Estimated annual costs for the Soudan Mine discharge (average flow 60 gal/min) is around \$150,000.

7. REGULATORY CONSIDERATIONS

Ion exchange requires approvals and/or permits from one or more regulatory authorities (federal, state, and/or local), depending on the applications being proposed. It should also be noted that if any surface water is being impacted, a National Pollutant Discharge Elimination System (NPDES) permit may be required at the final point of discharge. Treatment of the Soudan mine discharge was required by an NPDES permit under the Clean Water Act and managed by the Minnesota Pollution Control Agency.

8. STAKEHOLDER CONSIDERATIONS

Ion exchange is a well-accepted standard treatment technology capable of meeting low-level discharge permit requirements. The ability to regenerate resin and recover metals provides a potential additional benefit of this approach.

9. LESSONS LEARNED

Prevention of plugging of the resin by either chemical precipitates or suspended solids is critical to maintain treatment. Since every water is different, testing must be done to adequately select an appropriate resin. The available resin capacity must be monitored carefully to ensure that adequate exchange sites remain to provide treatment. A program to replace exhausted tanks is critical to maintain continual performance.

10. CASE STUDIES

Table 10-1. Case study using ion exchange

[Soudan State Park, MN](#)

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