30th WERC ENVIRONMENTAL DESIGN CONTEST

2020

Task 4: Fluoride Water Treatment and Recovery

Proposed and sponsored by Freeport-McMoRan

FREEPORT-MCMORAN

Background

In this task, your team will explore technologies for fluoride removal from calcium-rich mine waters and identify opportunities for by-product reuse of the fluoride. Out-of-the-box thinking is welcome.

Some mines have high concentrations of fluoride-containing minerals that are naturally present in the ore. The fluoride concentration in mine water can further increase as fluoride dissolves from the ore during the mineral processing steps such as wet grinding of the ore and flotation of metal sulfides from the ore. Processing can lead to concentrations higher than the primary and secondary drinking water standards of 4 and 2 mg/L, respectively.

While much of the mineral processing water is recycled, mines in high rainfall areas or mines in closure may need to discharge this water. Lime (calcium oxide) treatment is commonly used to remove metals from mine waters, and it is also effective at reducing fluoride concentrations, but only to about 10 mg/L, which is the solubility limit of calcium fluoride. This level is still above the drinking water standards.

As your team addresses this task, any number of technologies may be considered, including precipitation and adsorption technologies for removal of fluoride from calcium-rich waters to below the primary or secondary drinking water standard.

Problem Statement

Your team will research, evaluate, and design a treatment system to reduce total fluoride concentrations in mine waters to below 2mg/L. The treatment goals of the designed system would be cost effectiveness, practicality, and ability to apply to large flows of 1000 to 14000 gallons per minute. Ideally, the proposed design would have the following benefits.

- The fluoride water-treatment removal process produces a waste that is easily landfilled or could be recycled for another commercial application. If a commercial application is available, provide specifics on how the fluoride will be reused, or sold as a by-product for reuse, or by-product production. Include expected sale price and expected market production.
- Treat the mine water to fluoride concentrations below the EPA secondary drinking water standard of 2 milligrams per liter.

Design Considerations

Your proposed design should provide specific details and outcomes as follows:

- Reduce total fluoride concentration in mine waters from 10 mg/L to less than 2 mg/L.
- Choose a fluoride water-treatment process that has the potential to produce a low-cost waste or reusable by-product.
- An existing water treatment technology can be chosen or a new technology can be proposed.
- Estimate the capital to construct a full-scale water treatment plant using your selected water-treatment process for a base-case plant that treats 1000 gallon per minute of mine water.
- Estimate the operating cost to treat this mine water on a yearly basis.
- The fluoride removal process should be effective in the presence of dissolved sulfate and calcium, since most mine waters containing fluoride also contain sulfate and calcium.
- Address the chemical mechanisms for removing fluoride. Provide Process Flow Diagram (PFD) for the selected treatment process.
- Address the fate or reuse of all intermediate products or wastes generated by your fluoride removal process. For example, if you choose an adsorption media to remove fluoride, address the potential of the adsorption media to be regenerated and the final fate of the fluoride residual. If the media cannot be reused, provide cost for disposal.
- Address any intangible benefits of the selected fluoride removal process, such as waste reduction, production of a salable fluoride by-product or environmental stability of the final waste fluoride product.
- Address safety aspects of handling fluoride and any final products that contain fluoride. If your process can possibly produce hydrofluoric acid, you must describe this in detail in your experimental safety plan.

Bench Scale Demonstration

Demonstrate the fluoride water-treatment removal technology on a bench-scale basis using a synthetic mine water. The bench-scale unit should be capable of removing fluoride from synthetic water (composition below), and should demonstrate a continuous process that can be scaled up to a base-case plant that treats 1000 gallon per minute of mine water.

The untreated synthetic mine water solution will be of the following composition:

Analyte	**Amount per liter synthetic solution**
Gypsum (CaSO4.2H2O)	1.7 grams
Sodium fluoride (NaF)	22.1 mg
Dilute sulfuric acid or sodium hydroxide	As needed to adjust pH of solution to 7 after other reagents are added

Each team will be provided with 18 liters (5-gallon container) of the above synthetic solution to work with during the bench-scale demonstration. At the end of the treatment process, each team will submit 100 mL of treated solution for analysis.

<u>Analytical Testing Technique(s)</u>

- Ion chromatography to determine fluoride concentration. Target: fluoride below 2 mg/L.

Written Report Requirements
The written report should demonstrate your team's insight into the full scope of the issue and include all aspects of the problem and your proposed solution. The report will be evaluated for quality of writing, organization, clarity, reasoning, and coherence. Standards for publications in technical journals apply. In addition to the listed requirements, your report must address in detail the items highlighted in the Problem Statement, Design Considerations, and Evaluation Criteria.

Evaluation Criteria
Each team is advised to read the Participation Guide for a comprehensive understanding of the contest evaluation criteria. For a copy of the Public Involvement Plan and Participation Guide and other important resources, please visit the WERC website:
(https://iee.nmsu.edu/outreach/events/international-environmental-design-contest/guidelines/).

Additionally, your proposed solution will be evaluated on the following:

- Thoroughly address the fate (reuse) of all by-products or wastes generated by your fluoride removal process.
- The quality of your treated water – the bench-scale processed water–will be evaluated for treated water volume, separation efficiency, and time to process.
- Technical fundamentals, performance, safety and other issues stated in the problem statement
- Potential for real-life implementation
- Thoroughness and quality of the economic analysis
- Originality, innovativeness, functionality, ease of use, maintainability, reliability, and affordability of the proposed technology
- How well the bench-scale represents your full-scale design concept
- Other specific evaluation criteria may be provided at a later date (watch the FAQs).

FAQs/Deadlines

- Teams are expected to watch for FAQs related to this task for any updates in the task requirements.
- The Experimental Safety Plan (ESP) is due 24 February, 2020.
- Written Report due 23 March, 2020.

Awards
Each year, the WERC Environmental Design Contest and its sponsors award more than $30,000 in cash prizes. Successful completion of every stage of the design project qualifies each team for the following awards.

1. Task awards (First, Second, Third Place; minimum amounts: $2500-$1000-$500, respectively).
2. Freeport-McMoRan Innovation in Sustainability Award ($2500)
3. WERC Resources Center Pollution Prevention/Energy Efficiency Award ($500)
4. Judges' Choice Award ($500)
5. Peer Award ($250)
6. Terry McManus Outstanding Student Award. (Minimum: $500, according to funding).

Award amounts listed are minimum amounts and may increase with available funding.
Detailed criteria for each award:
https://iee.nmsu.edu/outreach/events/international-environmental-design-contest/guidelines/