Task 3. Treatment of Mining-Influenced Water Using Agricultural By-products to Sorb Metals

Proposed by: Freeport-McMoRan

Co-sponsored by: Brown & Caldwell

Background

Historical mine sites are sometimes characterized by surface and ground water that is impacted with metals. This is usually a result of pyrite oxidation and subsequent acid generation which can solubilize metals from the host rock. Active treatment of these waters can be difficult, costly, and challenging. For example, many of the mines are in remote locations with limited access to electrical power or other infrastructure needed to operate and support active water treatment systems. In addition, the flow rates requiring treatment may be low or seasonally variable.

Since active mining requires significant water resources to recover metals, and because the mines generally have large land holdings, they sometimes host agricultural activities on their land. Agricultural by-products may also be available from nearby farms or forest management activities.

Agricultural by-products from those activities have the potential to contribute to alternative water treatment technologies. Some of these by-products, such as plant biomass, may provide strong affinities for sorbing metals in water, with the potential of integrating these biosorbents into passive water treatment systems to remove metals.

This task is designed to challenge teams to evaluate a variety of agricultural by-products for their potential to remove metals from a synthetic mining-influenced water.

Problem Statement

Your team will identify and evaluate a minimum of three agricultural by-products for their relative performance as biosorbents for a passive system that sorbs metals in mining-influenced water. The team should select the by-product material based on a number of criteria including, but not limited to:

- Current availability or ability to produce the material in the southwestern US (New Mexico, Arizona or Colorado);
- Sufficiently large availability of the material as a result of normal crop harvesting, forest management, or animal waste-collection methods;
- Capacity of the material to sorb metals, over an extended period of time (10+ years), from waters containing low concentrations of metals;
- Sufficient permeability designed into the system to allow mine water to pass through. By-products that swell in water have the potential to plug a flow-through system and should be avoided;
- Limited leaching potential. Once the metals are sorbed into the biomass, they should not readily leach into surrounding waters from the biomass. Proper storage, disposal or reuse of metal-laden biomass is an important design consideration.

Teams will:

- conduct a literature review of the broad range of potential agricultural by-products;
- perform a desktop analysis prior to designing the system to evaluate the ability of candidate materials to meet the above criteria;
- select three candidate materials based on the desktop analysis and design a flow-through passive system to evaluate their relative performance in sorbing metals from a synthetic mining-influenced water.
- Identify a preferred sorbent.

Design Considerations

Your design for a full-scale metal sorption treatment system should be based on your bench-scale tests (see *Bench Scale Demonstration* section for more details).

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

- Monitoring water quality using standard physicochemical parameters (e.g., pH, oxidation-reduction potential, electrical conductivity, dissolved oxygen) and metal concentrations in influent and effluent water samples.
- Reduce the overall metal loading by at least 90%
- The full-scale treatment system should be designed to:
    - treat 20 gallons per minute of acidic mining-influenced water.
    - operate using gravity flow only and contain enough sorbent material in-place to last 10 years of operation.
    - prevent potential freezing during winter.
- Consider the possibility that pretreatment of the sorbent material may improve its sorption capacity and kinetics. Examples of pretreatment include composting to break down cellulose, chemical modification, or charring of the by-product. Costs for pretreating sorbent materials should be estimated for the full-scale system.
- Addition of amendments to the designed reactor, other than the sorbent material, is allowed so long as the amendment improves sorption performance rather than becoming the main reason for metal removal. An example of an approved amendment would be the addition of limestone to reduce acidity and improve metal sorption kinetics.
- Estimate capital costs (CAPEX) to construct a full-scale metal sorption-based treatment system using the preferred sorbent. This includes, but is not limited to, equipment, buildings, land use, pipes, pumps, construction costs, engineering mark-up, sorbent pretreatment, etc.
- Estimate the operating cost (OPEX) for the full-scale treatment system, specifically changing out the sorbent every 10 years and appropriate disposal of the metal-laden sorbent material.
- Document success in improving energy efficiency, pollution prevention, and/or waste minimization, as it applies to your project to qualify for the P2E2 Award. Place this in a separate section of the report.
- Discuss your plan's adherence to appropriate federal (USA), state and local laws and regulations. Attend WERC's webinar for helpful tips for addressing regulatory issues. (See website or email us for webinar info.)
- Include a Public Involvement Plan, as applicable (See Team Manual).
- Address safety aspects of handling the mining-influenced water and any final products. Safety issues should be addressed in both the written report and the Experimental Safety Plan (ESP). Be sure to attend WERC's webinar for helpful tips for addressing health and safety issues. (See website or email us for webinar info.)
- Address any intangible benefits of the selected sorbent, such as eliminating costs of by-product disposal in the agricultural setting. Also consider cost savings of a passive treatment system (e.g., staffing and electrical savings) versus an active treatment system.

Bench-Scale Demonstration

Once your team has selected the three candidate materials to test, develop an experimental design for a bench-scale study. The table below shows the chemistry of the synthetic mining-influenced water to be used in the bench-scale study. All constituents of a synthetic solution shall be sulfate-based salts, as is typical of mining-influenced waters. All chemicals must be identified in the experimental safety plan and every precaution taken to ensure that no one is injured during this evaluation.

Your reactor should be capable of operating unattended for as long as possible during the competition time frame (9:00 am Monday through 2:00 pm Tuesday, or until the team has run through all provided synthetic water). This will allow your team to demonstrate the sorption kinetics and potential longevity of the material in the reactor.

Each team will be provided with 36 liters of synthetic mining-influenced water to work with during the bench-scale demonstration. This should be more than you need to run the experiment. At the end of the treatment process, each team will submit three 100 mL samples of treated solution for analysis.

Analyte	**Amount salt per liter synthetic solution**
Aluminum, as $Al_2(SO_4)_3 \bullet 16H_2O$	197.07 milligrams
Arsenic, as As_2O_3	0.26 milligrams
Cadmium, as $CdSO_4 \bullet 5H_2O$	0.37 milligrams
Copper, as $CuSO_4 \bullet 5H_2O$	5.89 milligrams
Iron, as $FeSO_4 \bullet 7H_2O$	547.18 milligrams
Lead, as $PbSO_4$	0.15 milligrams
Manganese, as $MnSO_4 \bullet 4H_2O$	252.27 milligrams
Nickel, as $NiSO_4 \bullet 6H_2O$	0.09 milligrams
Zinc, as $ZnSO_4 \bullet 7H_2O$	228.57 milligrams
Sulfate, final concentration needed*	850 mg/L
pH, adjusted with H_2SO_4 or NaOH as needed	2.60

*Final sulfate concentration will be adjusted with sulfuric acid addition or sodium sulfate, if needed.

For the on-site team demonstration, teams will set up one reactor with their preferred sorbent and flow synthetic mining-influenced water through the on-site reactor. It is preferred the team relocate one of their existing bench-scale reactors, so that the reactor has already been in operation for an extended period of time. After 2:00 pm on Tuesday, a sample of the reactor effluent will be collected and analyzed by ICP-MS for the metals: Al, As, Cd, Cu, Fe, Pb, Mn, Ni and Zn.

Technical 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, logic, organization, clarity, reason, 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, Evaluation Criteria, and 2021 Team Manual. The required page formatting has changed this year—check the 2021 Team Manual for more information.

Evaluation Criteria

Refer to the 2021 Team Manual for a comprehensive explanation of the evaluation criteria.

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

- 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 system represents your full-scale design concept.
- The quality of your treated water – the bench-scale treated water will be evaluated for treated water volume, separation efficiency, and time to process.
- Other specific evaluation criteria may be provided at a later date.

FAQs/Deadlines

- Teams are expected to watch for FAQs online for any updates in the task requirements. (wercdesigncontest.nmsu.edu)
- Due 1 February 2021: Experimental Safety Plan (ESP).
- Due 29 March 2021: Written Report.

Awards

Each year, the WERC Environmental Design Contest and its sponsors award more than $25,000 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. Virtual Desktop Study Awards (awarded independently of the full bench-scale designs). Amounts TBA.
3. WERC Resources Center Pollution Prevention/Energy Efficiency Award (P2E2) ($500)
4. Judges' Choice Award ($500)
5. Peer Award ($250)
6. Terry McManus Outstanding Student Award. ($500-$1000, according to funding).

Additional awards may be announced at a later date.

Award amounts listed are minimum amounts and may increase with available funding.
Detailed criteria for each award are listed in the 2021 Team Manual:
https://iee.nmsu.edu/outreach/events/international-environmental-design-contest/guidelines/