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

Proposed by: Freeport-McMoRan

Co-sponsored by: Brown & Caldwell

This desktop study is identical to the full version of Task 3, but omits all aspects related to building or testing of the bench-scale apparatus. The key technical element in this desktop study is the process flow diagram and may benefit from computer simulations. The virtual competition will include an oral Zoom presentation and a follow-up Zoom Brochure Discussion.

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.

Steps:

- Use Table 1 for the starting chemistry of the mining-influenced water. Assume all constituents to be sulfate-based salts, as is typical of mining-influenced waters.
- Conduct a literature review of the broad range of potential agricultural by-products;
- Perform a desktop analysis to evaluate the ability of candidate materials to meet the criteria listed in the Problem Statement;
- Select three candidate materials based on the desktop analysis and further develop these through construction of a process-flow diagram for each design;
- Analyze the pros and cons of each candidate material and identify one preferred sorbent (or a combination of sorbents used in tandem). Develop a sorption system based on your sorbent selection.

Design Considerations

For your preferred sorption system, propose a design that provides these specific details and outcomes:

- Goal: reduce the overall metal loading by at least 90%. Address the effects of the sorbent on each constituent: Al, As, Cd, Cu, Fe, Pb, Mn, Ni and Zn.
- Provide a detailed and accurate Process Flow Diagram (PFD). This is the key feature of your design. The PFD should include all selected treatment processes and sorbents and must include mass and energy balances (input and output rates, reactants, and reaction rates, etc., as applicable). See the 2021 Team manual for an example of an acceptable PFD.
- Your analysis may include a computer simulation, but it must be based on the PFD.
- The full-scale treatment system should be designed to treat 20 gallons per minute of acidic mining-influenced water. It should operate using gravity flow only, contain enough sorbent material in place to last 10 years of operation, and be designed to 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.
- 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.
- List all equipment, materials, and chemicals that would be needed, and indicate all efforts to reduce costs.
- List all vendor sources, and report and reference all performance data for each piece of equipment or materials.
- Estimate capital costs (CAPEX) to construct a full-scale metal sorption-based treatment system using the preferred sorbent(s). 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, including pre-treatments, changing out the sorbent every 10 years, and appropriate disposal of the metal-laden sorbent material.
- 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 mining water of the chemistry shown in Table 1 and any final products. Attend WERC's webinar for 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.
- To qualify for the P2E2 award, in a separate section of the report, document success in improving energy efficiency, pollution prevention, and/or waste minimization, as it applies to your project.

Table 1. Starting chemistry of mining-influenced water.

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

**Assume the final sulfate concentration would be adjusted with sulfuric acid addition or sodium sulfate, if needed.*

Technical Report Requirements

The 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 writing quality, organization, clarity, reasoning, and coherence. Standards for publication in technical journals apply.

The report must address in detail the items highlighted in the Problem Statement, Task Requirements, Evaluation Criteria, and the 2021 Team Manual.

This desktop-study technical report should total no more than 16 pages, including title page, executive summary, and references. Note that this is shorter than the full-contest entry, because virtual contest entries do not include discussion of bench-scale results. The required page formatting has changed this year—check the 2021 Team Manual for more information.

Technical Report Checklist:

- Title Page
- Executive Summary
- Body
  - Background Research
  - Detailed Process Flow Diagram quantifying all mass/energy balances
  - Materials List and performance
  - CAPEX
  - OPEX
  - Public Involvement Plan (no more than 1.5 pages)
  - Regulatory Discussion (no more than 1.5 pages)
  - Health and Safety issues associated with full-scale treatment (no more than 1.5 pages)
- References
- Audits (not included in page count)

Evaluation Criteria
Refer to the 2021 Team Manual for a comprehensive explanation of the evaluation criteria. For a copy of the Team Manual, Public Involvement Plan, and other important resources, visit the WERC website: https://iee.nmsu.edu/outreach/events/international-environmental-design-contest/guidelines/.

Evaluation of your solution will be based on the items highlighted in the Problem Statement, Design Considerations, and 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.
- Other specific evaluation criteria may be provided at a later date.

FAQs/Deadlines

- Teams are responsible for all task updates posted in the FAQs online (wercdesigncontest.nmsu.edu)
- Due 29 March 2021: Technical 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. Full 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/