2019 WERC Design Contest
TASK 3
Selenium Water Treatment and Recovery

Background

Selenium is a naturally occurring element that is toxic at low levels. It is also an essential micronutrient for many plants and animals, but at very low concentrations. In addition, selenium has commercial uses as a glass colorant, semiconductor, food supplements and may have potential uses in new generation batteries for electric vehicles.

Many industrial waters have the potential to be impacted by selenium, including waters from coal mines, power plants, smelters and gold mines. Recent rule changes by the EPA has led to lower selenium limits for water discharged into the environment, with the new standard at 5 micrograms per liter. Some jurisdictions have even lower standards depending on the receiving water. One result of these lower standards has been a proliferation of new technologies to remove selenium from water to very low levels. These technologies are wide-ranging and include:

- Biological reduction
- Ion exchange
- Adsorption
- Reduction with reduced iron species
- Co-precipitation with ferric

Most of these technologies concentrate selenium into some form or another with the goal of producing a selenium containing sludge that can be safely landfilled. The reason for the wide range of technologies is that selenium may be present in multiple oxidation states in the water complicating treatment. In addition, some technologies are limited by the presence of sulfate in the water.

Problem Statement

The problems statement has two goals.

Goal 1) The first goal of this project is to select and demonstrate a selenium water-treatment removal technology that is capable of removing selenium from a synthetic water containing two forms of dissolved selenium: selenite and selenate. Most industrial waters contain both of these forms of selenium. The selenium removal technology will be demonstrated on a bench scale as described below.

Goal 2) The second goal of the project is to propose a selenium recovery process that uses the selenium containing sludge from your selected selenium removal technology to make a salable selenium product. This second selenium recovery process will not be demonstrated on a bench scale due to safety concerns with handling selenium and this process will only be conceptual on paper.

Ideally, the proposed solutions would have the following benefits.

- Selenium water-treatment removal process produces a selenium waste product that can be readily processed for selenium recovery.
- Treat water to below the new EPA target concentration of 5 micrograms per liter.

- Reduce the amount of selenium reporting to a landfill
- Recover some of the costs of recovery by sale of selenium
- While the proposed selenium recovery process may not produce economic selenium for one particular water, the process could potentially treat sludges from multiple sites utilizing economies of scale.

Design Considerations

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

Goal 1

- Choose a selenium water-treatment process that has the potential to concentrate selenium.
- An existing water treatment technology can be chosen or a new technology can be proposed.
- Estimate the capital cost to construct a full-scale water treatment plant using your selected water-treatment process for a plant that treats 1000 gallon per minute of industrial water. The plant should reduce the total selenium concentration from 100 micrograms per liter to less than 5 micrograms per liter.
- Estimate the operating cost to treat this water on a yearly basis.
- The selenium removal process should be effective in the presence of sulfate. Most industrial selenium containing water also contain sulfate.
- Address the chemical mechanisms for removing both selenite and selenate from water.

Goal 2

- The conceptual selenium recovery process should convert the impure water treatment residual to produce elemental selenium as salable amorphous red-brick powder or as the commercially available black vitreous beads.
- Estimate the cost of the selected technology for the conceptual selenium recovery process with focus on the cost of recovery on a dollar per pound selenium produced basis.
- Evaluate if selenium recovery can be economically performed at the proposed 1000 gpm water-treatment plant of goal 1 or if it makes more economic sense to processing sludges/by products from multiple water treatment plants.

Combined benefits of Goal 1 and Goal 2

- Address the intangible benefits of the combined process, such prevention of landfill of selenium sludges and sustainability of process.
- Address other potential waste products from the conceptual selenium recovery process (e.g. what happen to the iron if processing an iron selenium sludge)
- Address safety aspects of handling and processing a toxic substance such as selenium.

Bench Scale Demonstration

Demonstrate the selenium water-treatment removal technology on a bench-scale basis for Goal 1. Goal 2 will be a paper study only. The demonstration unit should be capable of removing selenium in the form of

both selenite and selenate. The demonstration unit should operate continuously at least 20 ml/min treating the synthetic feed solution of the following recipe:

Ingredient	Quantity per liter synthetic solution
Sodium Selenate (Na_2SeO_4)	0.12 milligrams
Sodium Selenite (Na_2SeO_3)	0.11 milligrams
Sodium Sulfate (Na_2SO_4)	2.21 grams
Distilled water	1 liter
Dilute $NaCO_2$ or H_2SO_4 solution	As necessary to adjust pH to 7

Your team will be provided with 2 liters of the synthetic water for treatment.

The selenium will be measured using an ICP-MS to verify that selenium has been reduced to below 5 micrograms per liter.

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, 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, and Evaluation Criteria.

Evaluation Criteria

Each team is advised to read the Participation Guide for a comprehensive understanding of the contest evaluation criteria. Please visit the WERC website: https://iee.nmsu.edu/outreach/events/international-environmental-design-contest/guidelines/ for a copy of the Public Involvement Plan and Participation Guide and other important resources. 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 represents your full scale design concept
- The quality of your treated water – the bench-scale processed 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.