



Swedish Metals & Minerals

impact innovation

U-REM: Development of treatment technology for uranium separation from mine drainage

- State-of-the-Art
- Project P2025-03622
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Project background

- Uranium (U) may be present in process water or mine drainage at elevated concentrations due to the dissolution of minerals and release of U into these waters.
- Once released, U may pose a threat to both human health and the environment if concentrations are sufficiently high.
- Mining companies may need to remove U from process water and mine drainage prior to discharge to surface water recipients.
- Drinking water limit of 30 µg/L U.
- Under the EU Water Framework Directive, environmental quality standard (EQS) for good status is 0.17 µg/L U (annual average) and 8.6 µg/L U (maximum allowable concentration).
- Adjustments to these standards are allowed based on background concentrations of U.

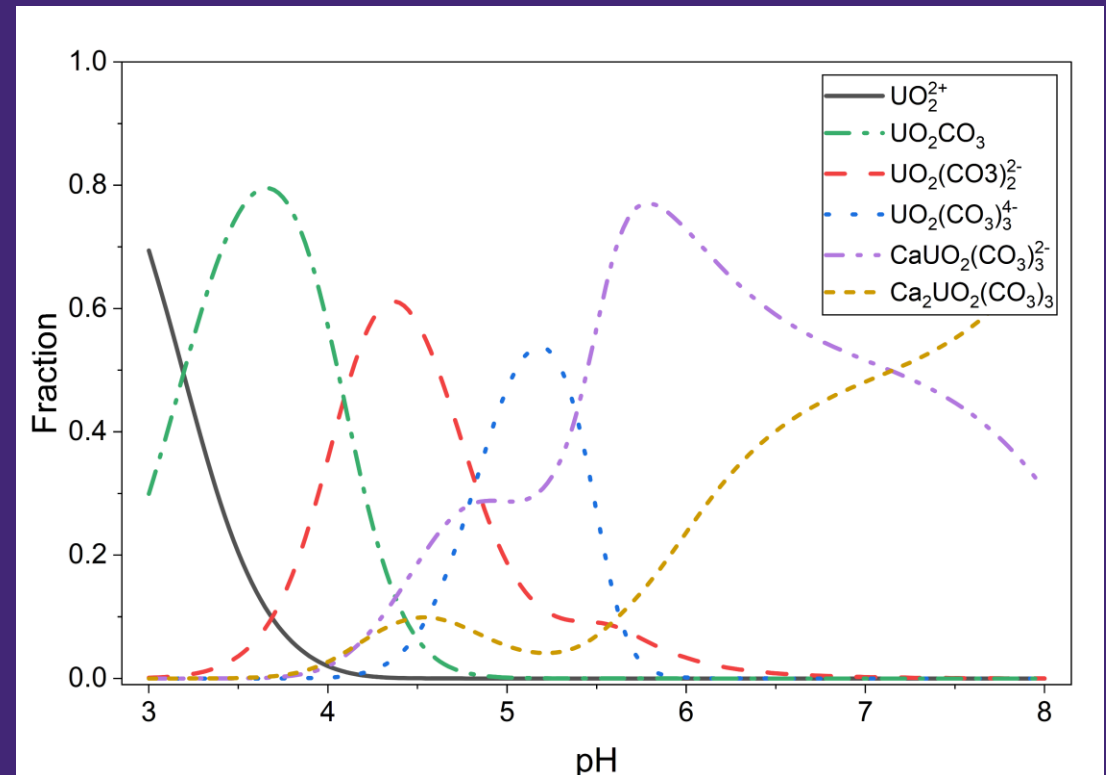
Project objective

- To develop a method for uranium removal from mine drainage, with focus on one solution: the filtration of mine water through a porous zero-valent iron matrix, promoting U removal.
- In the SOA study, a general presentation of three BAT methods is provided.
- Considering the aim of the U-REM project, SOA will also consider U removal by flow through zerovalent iron (ZVI).



Chemical forms of U in natural systems

- The chemical form (i.e. speciation) of U in water is highly relevant for the mobility and bioavailability of U in the environment, as well as for the removal of U in water treatment processes.
- Species charge, and therefore its tendency to sorb to surfaces, is pH dependent.
- Two oxidation states common: U(VI) and U(IV).



Theoretical speciation of U(VI) in water as a function of pH. Conditions: 100 $\mu\text{g/L}$ U, 132 mg/L HCO_3^- , 40 mg/L Ca.

State-of-the-art on U removal



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- SOA consists of mature and well-tested technologies that can often achieve >95% removal.
- Best demonstrated available technologies for uranium removal (US EPA, 2007):
 - ion exchange
 - chemical precipitation
 - membrane processes

SOA Ion exchange

- Industrial-scale water treatment by ion exchange employs synthetic resins with charged functional groups that are selective for either anions or cations.
- Divalent uranyl should be removed with an acidic cation exchange resin, while negatively-charged carbonate species require a basic anion exchange resin.
- There are large number of ion exchange resins available on the market, and most of the major manufacturers supply resins suitable for U removal.
- High selectivity to U required, since competition with other ions can be significant, e.g. Ca^{2+} competes with UO_2^{2+} and SO_4^{2-} competes with $\text{UO}_2(\text{CO}_3)_2^{2-}$.

SOA Chemical precipitation and membrane processes

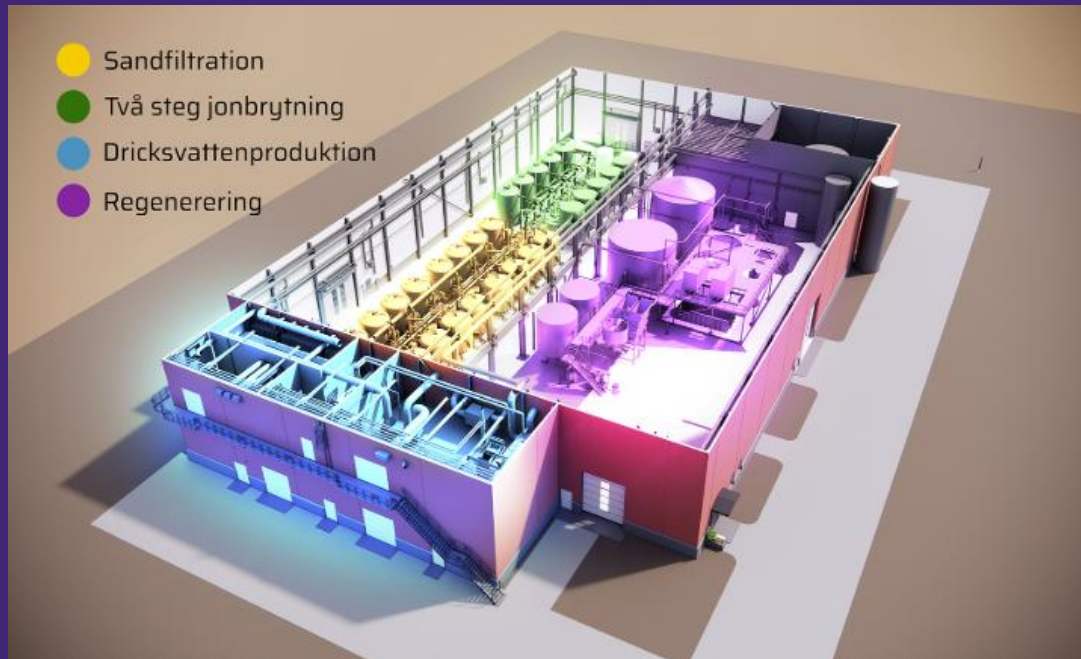
• Chemical precipitation

- Mature technology that has been employed in the mining industry for decades.
- Often involves pH adjustment and/or addition of coagulant
- Can result in production of large volumes of sludge that require disposal.

• Membrane processes

- Removal with nanofiltration (~1 nm pore size) or reverse osmosis (~0.1 nm) membranes
- Both membranes are effective for U removal since molecule is charged and relatively large.
- Technically complicated with issues related to high pressures, fouling and scaling.

The latest in mine water treatment - Viscaria



<https://www.viscaria.com/sv/hallbarhet/vattenrening/>

- In October 2025, Viscaria commissioned Sweden's first mine water treatment plant especially designed for high-level sulfate and uranium removal.
- Considered a state-of-the-art plant, designed for a maximum flow of 1000 m³/h
- Cation and anion exchange resins are used. Nanofiltration for drinking water production.

"SOA" for zerovalent iron (ZVI) treatment

- The reaction:



- Initial applications in the 1990s used millimeter-scale ZVI particles
- U-REM uses micrometer-scale particles in filter, through which water flows.
- Recent advances involve nano-scale particles (nZVI). Highly reactive.
- Too fine-grained to be used as filter. Need to be applied in reactor or injected into the subsurface.
- Surface modification techniques have been investigated in the laboratory, including nitridation (i.e. incorporating nitrogen on the surface of nZVI) and synthesis of nZVI composites (e.g. with metals, graphite, organics) that reduce the reactivity and agglomeration of particles.

Industrial challenges

- Rulings from Land and Environmental Court of Appeal
 - Limiting U discharges in order to obtain / renew environmental permits
- Bioavailable concentrations of U
 - Total U concentrations don't reflect bioavailability
 - Biological ligand model needed for establishing bioavailable concentrations
- Practical aspects of water treatment
 - Treatment of process water typically involves very large daily flows
 - Discharges from waste rock piles much lower
 - Mine drainage water quality
 - High ionic strength
 - High Ca and SO₄ concentrations
 - Waste disposal of U-rich residues / reject water