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Electro-Biochemical Treatment for Selenium and Trace Metals in Coal-Impacted Waters

Elise Hotz

Applications Engineer

In This Deck

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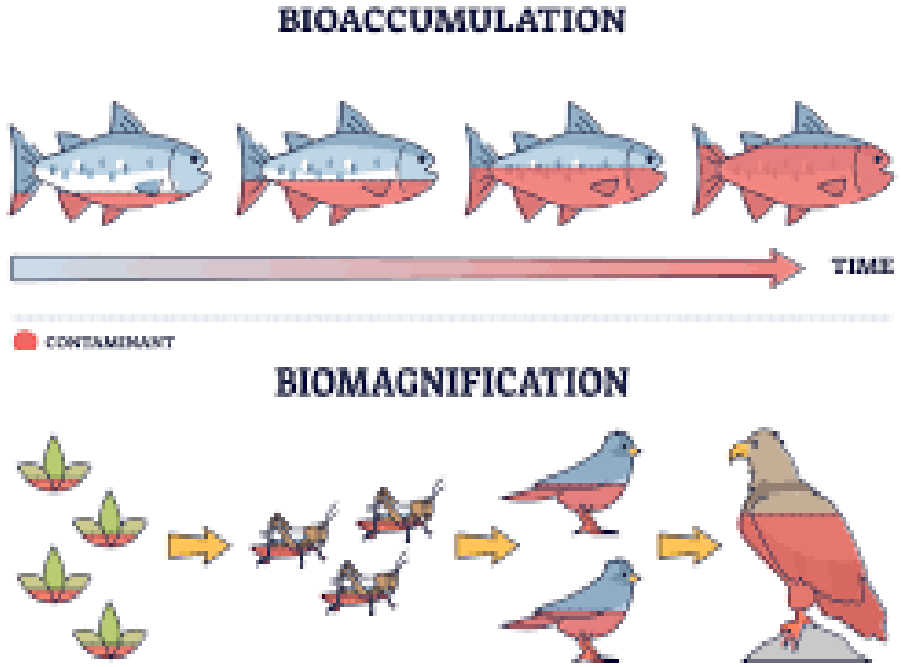
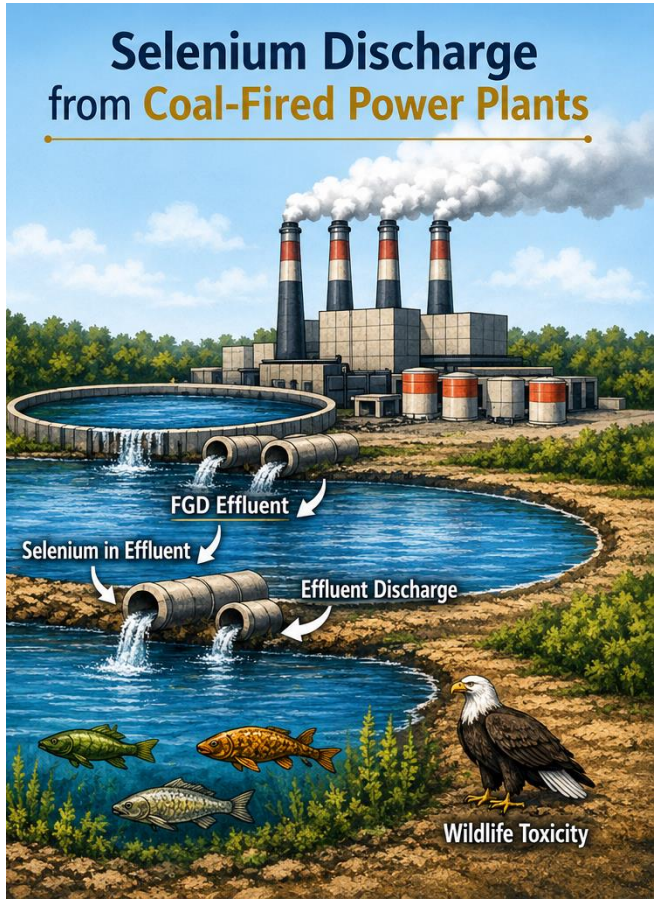
Introduction: Selenium in the Environment

- Selenium (Se) is a naturally occurring element, present in sedimentary rocks, shales, coal, and phosphate deposits and soils
- Unevenly distributed over the surface of Earth
- Se is an essential micronutrient, essential for thyroid hormone metabolism and immune system regulation
- Toxicity in humans > 400 µg/day
- Toxicity in aquatic life
  - **Bioaccumulation** – a substance builds in a living organism over time
  - **Biomagnification** – increase in substance concentration with each level of the food chain



Introduction: Coal Affected Waters

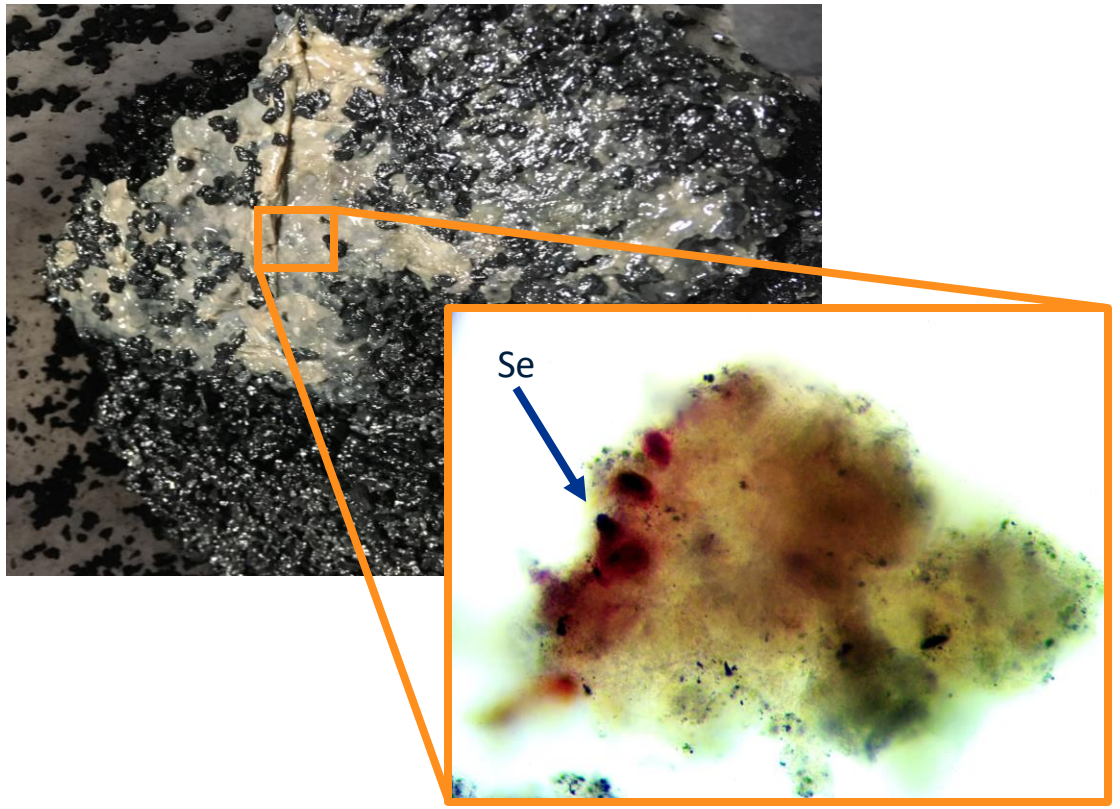
- Se contamination is a persistent challenge within the coal life cycle
- Mining
  - Historical and modern mining practices expose mineralized Se, allowing for its weathering and release into water bodies
  - Problematic in areas with naturally occurring Se in soil (Western North America and Appalachia)
- Coal-fired power plants
  - Se can be released into the environment through Flue Gas Desulfurization (FGD)
  - FGD removes metals from flue gases
  - Presence and concentration of Se depends on the coal being burned
- Biological reactors remove selenium from water by transforming dissolved Se species into stable elemental precipitate.



Conventional Bioreactor

Se Reduction Reaction: $SeO_4^{2-} + 6e^- + 8H^+ \rightarrow Se_0 + 4H_2O$

- Organic electron donor
- Carbon source must be metabolized to release electrons
- Biomass production
- High nutrient dosing and operating cost
- Biomass traps Se



Electro-Biochemical Reactor (EBR)

- Electrons supplied directly by current
  - <1 amp
- Low biomass production
- Lower nutrient dosing and operations costs
- More efficient contaminant reduction

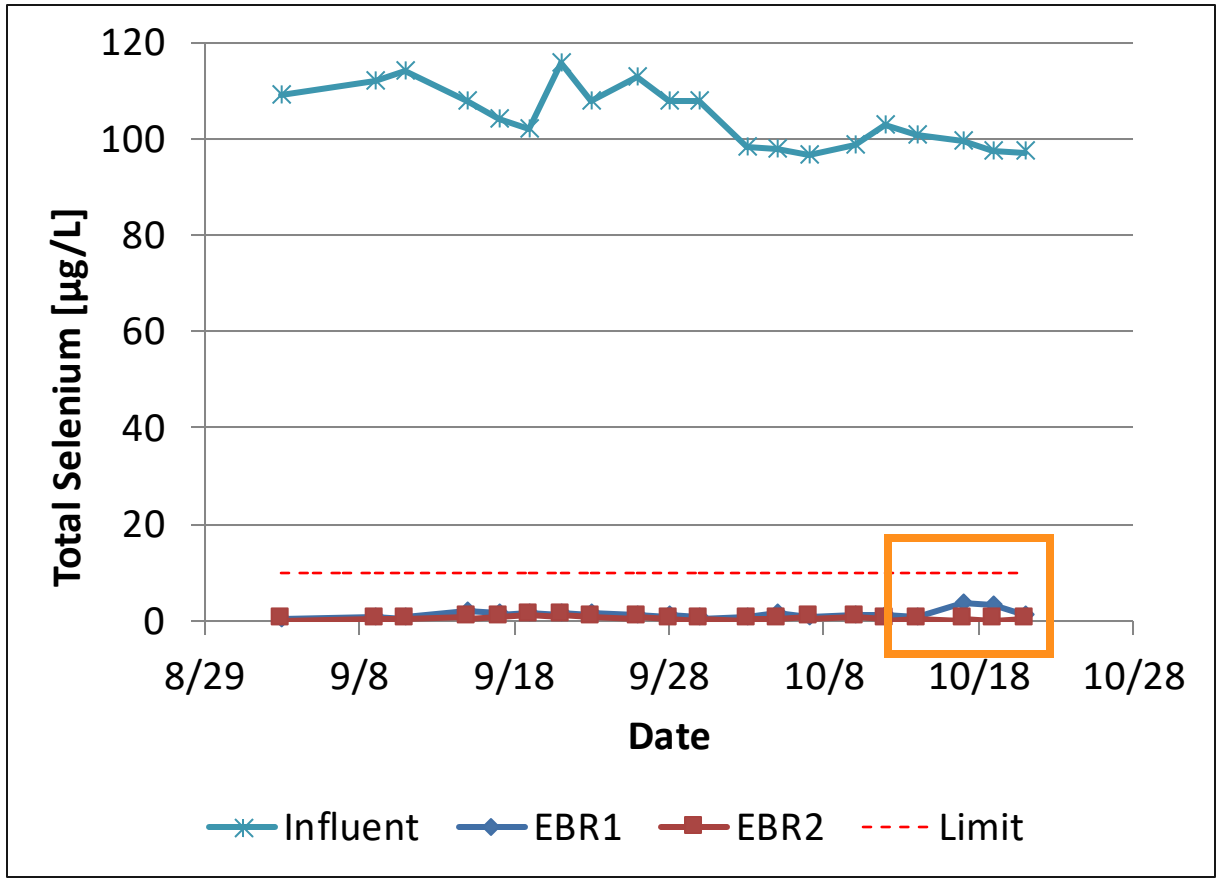
Organic electron donor
1 molecule of acetic acid = 8 electrons

Electrons supplied by current
1mA = 6.2 x 10^{15} electrons/second

Coal Mining – Seepage Waters

	Parameter	Ave. Influent	Ave. Discharge
Water A	NO_3-N [mg/L]	11.3	<1.0
	Se [µg/L]	355	1.2
Water B	NO_3-N [mg/L]	16.4	<0.1
	Se [µg/L]	35.0	1.4
Water C	NO_3-N [mg/L]	37.0	1.0
	Se [µg/L]	530	1.4
Water D	NO_3-N [mg/L]	50.0	3.1
	Se [µg/L]	105	0.5

Coal Mining – Seepage Waters



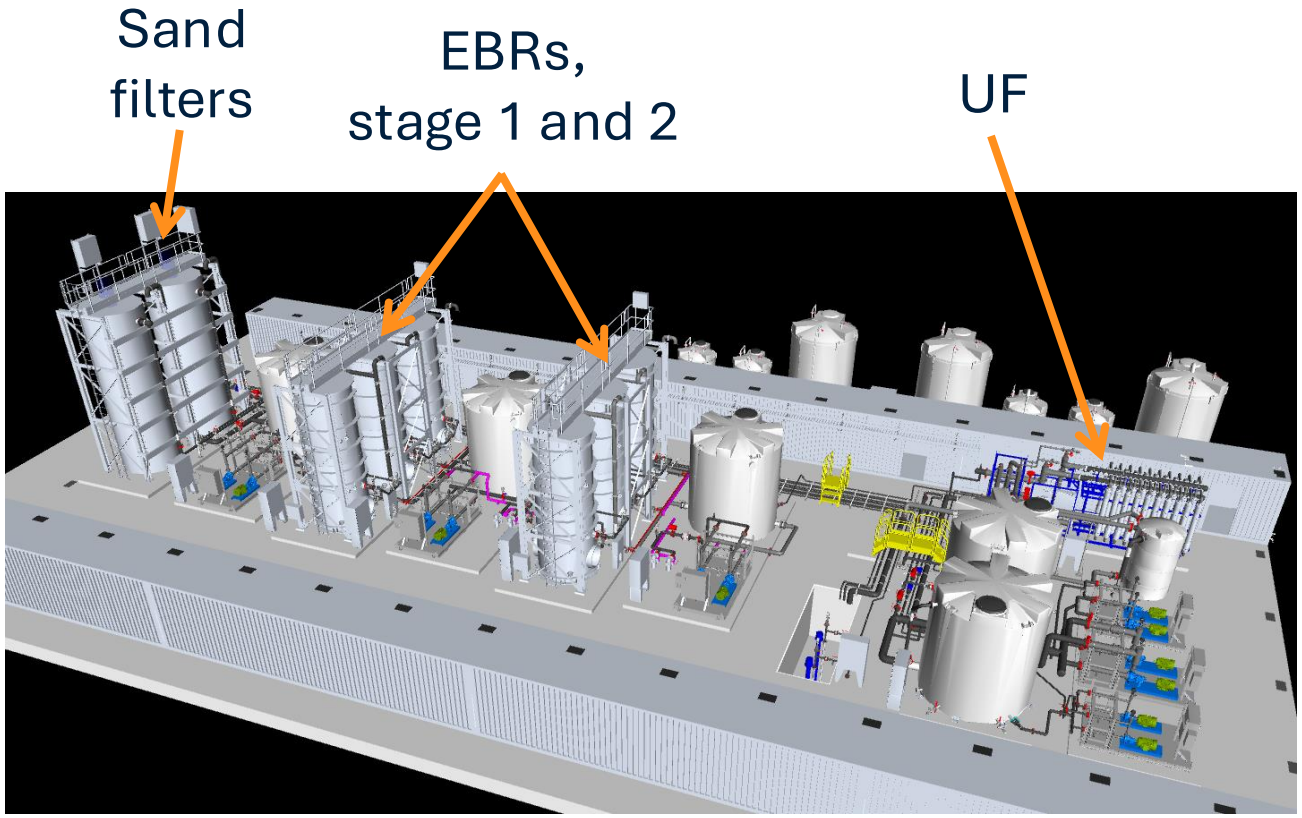
- Targeted design

Parameter	Ave. Influent	Ave. Discharge
NO_3-N [mg/L]	50	3.1
Se_{-tot} [µg/L]	105	0.5

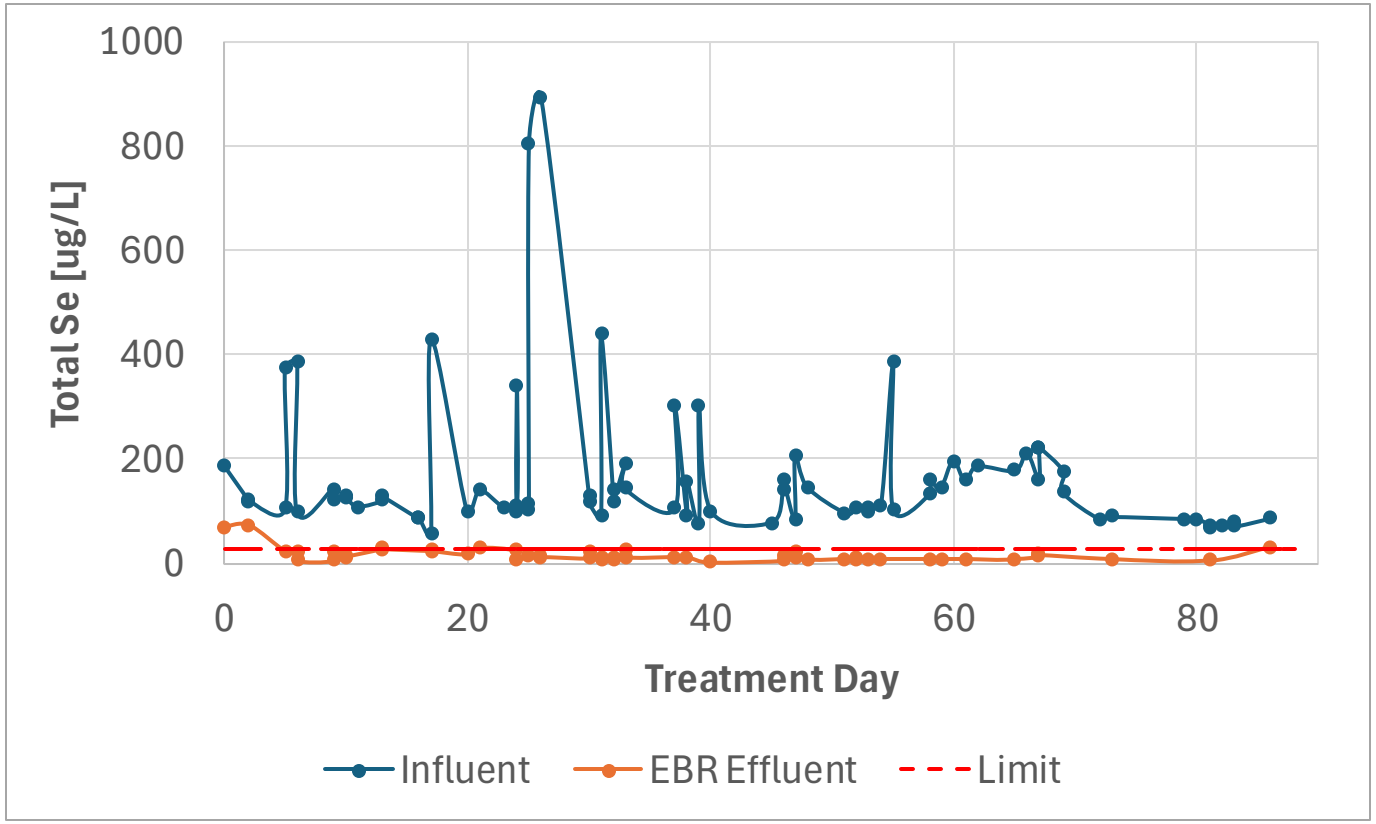
- Cold weather performance
- Fast start-up
- Secondary Contaminant Removal

Parameter	Ave. Influent	Ave. Discharge
Sb_{-tot} [µg/L]	2.7	<0.3
Ni_{-tot} [µg/L]	113	<10
U_{-tot} [µg/L]	18.4	0.07
Zn_{-tot} [µg/L]	64	<6

Coal–Fired Power Plant – FGD



Coal–Fired Power Plant – FGD



Influent Se (ug/L)	Effluent Se (ug/L)	Target Effluent Se (ug/L)
200	< 15	29

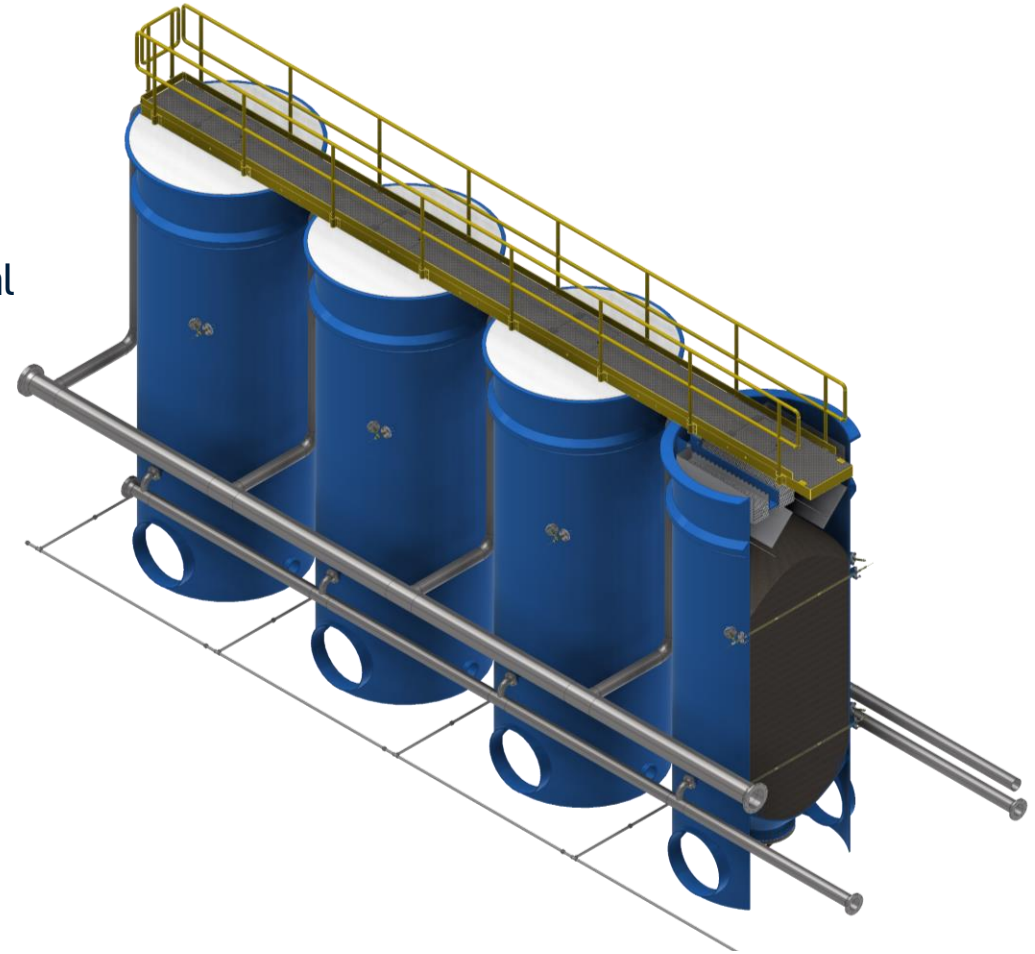
- Polishes arsenic and mercury aiding with meeting the compliance of the entire treatment system
- Fast start-up – achieving the design flow and effluent quality within 10 days
- Low nutrient requirement
  - Reducing operating expenses and limiting the excess biogrowth production
- The final system design produces no liquid waste streams

Design Considerations

	Coal mine seepage	Coal fired FGD waters
Typical Se_{tot}	10 – 500 µg/L	100 – 5,000 µg/L
Typical Nitrate-N	10 – 50 mg/L	1 – 100 mg/L
TSS	50 – 500 mg/L	10,000 – 60,000 mg/L
Bio-process inhibitors	None	Chloride (5,000 – 15,000 mg/L) Hardness (10,000 – 30,000 mg/L)
Pretreatment needed	TSS settling or media filtration	Phys-chem for TSS removal and metals control
EBR design HRT	10 – 30 min	20 – 120 min

Key Takeaways

- **Se contamination is a persistent challenge** in coal mining regions and from coal-fired power plant FGD discharges
- **EBR decouples electron delivery from carbon:** using a direct current instead of organic carbon to drive Se and nitrate removal
- **Proven Se removal across water types:** treating influent concentration between 50-530µg/L from mine seepage waters and >800 µg/L from FGD wastewater
- **Multi-contaminant treatment:**
  - Removes Se, nitrate, and nitrite
  - Polishes arsenic, mercury, antimony, nickel, uranium, and zinc in a single process, simplifying post treatment and reducing cost
- **Operationally efficient:** fast 10-day start-up, low nutrient requirements and no liquid waste streams



Elise Hotz

Application Engineer

ehotz@westechwater.com

(801) 290-1472

Ola Opara, PhD

Product Portfolio Manager

oopara@westechwater.com

(801) 290-1485

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