

A blue-tinted photograph of a water treatment facility. In the foreground, there are large circular tanks with mechanical components. In the background, there are industrial structures and a mountain range under a clear sky.

BQE Water

Non-Biological Removal of Selenate and Other Metalloid Oxyanions

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1

Concept of Non-biological Treatment

Why Non-Biological Treatment for Selenium?



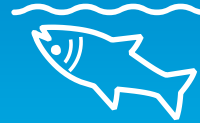
Reach end-of-pipe target
of $< 2 \mu\text{g/L}$



Avoid organo-selenium issues
& chronic effects



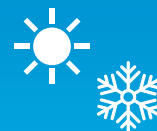
Stable refractory residue with
off-take potential



Avoid bio treatment issues:
nutrient add, COD/BOD, TSS



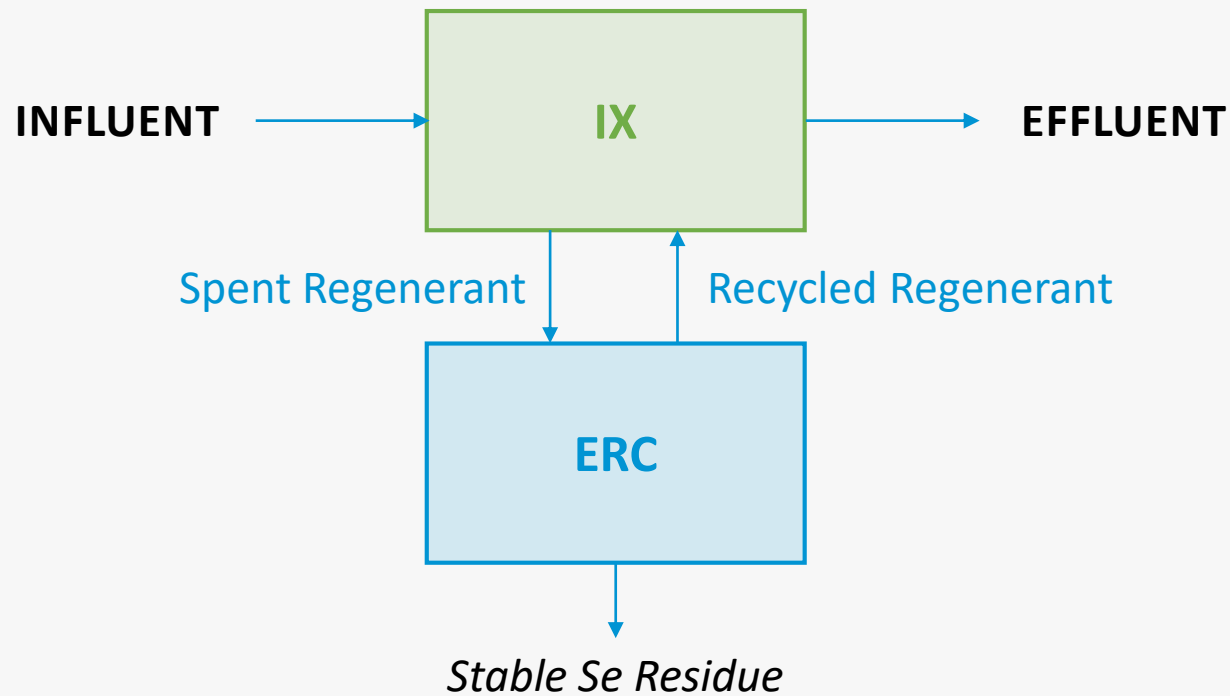
Handle large fluctuations in
flow and mass loading



Provide seasonal or
intermittent treatment

Selen-IX™ = IX + ERC for Se Removal

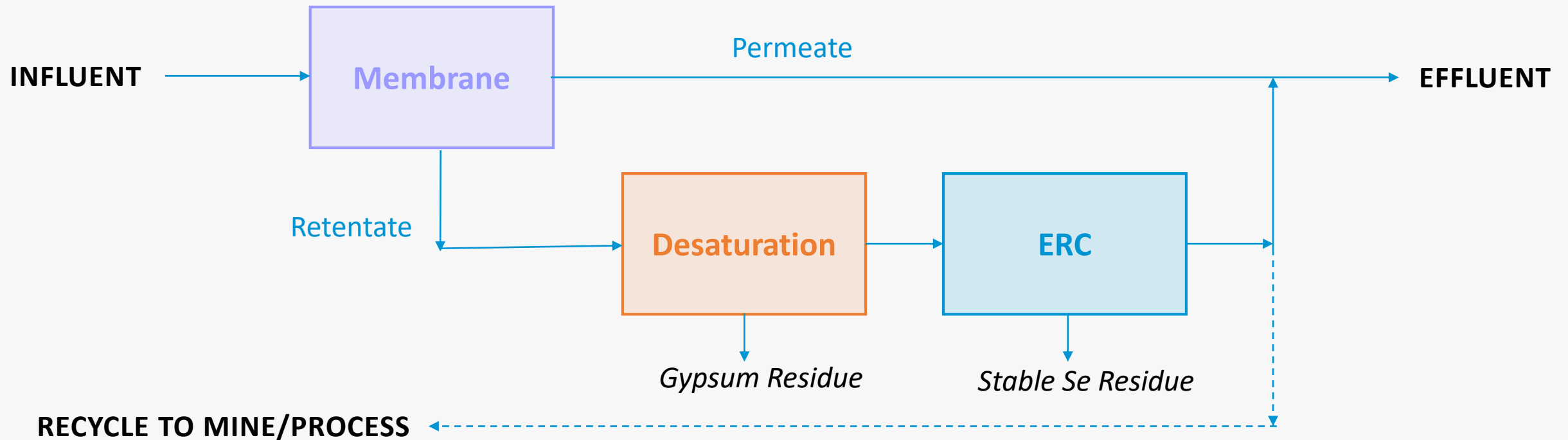
Selectively removes Se to < 1 ppb while fixing Se into small quantity of stable inorganic solid residue



- Selective sequestration of Se from impacted mine water
- Produce treated water with Se < 1 ppb
- Pre-concentrate Se by factor of 20 to 2000x

- Remove Se from pre-concentrated solution to eliminate brine from IX
- Stabilize Se into non-toxic inorganic residue suitable for re-use

NF/RO + ERC for Simultaneous Se & SO₄ Removal



- Produce treated water with Se & SO₄ complying with discharge limits
- Pre-concentrate Se & create CaSO₄ supersaturation

- Remove SO₄ by relieving CaSO₄ supersaturation
- Produce clean gypsum

- Remove Se from pre-concentrated solution to eliminate brine from membranes
- Stabilize Se into non-toxic inorganic residue suitable for re-use

2

Full-Scale Selen-IX™ Plant at Kemess Mine

Kemess Project Objective

Treat 65 L/s and remove selenate to < 2 ppb and fix it into stable residue for disposal in TSF



Interior of first full-scale Selen-IX™ plant, Northern BC

Selen-IX™ at Kemess Pilot

Ion Exchange



+

Electro-reduction

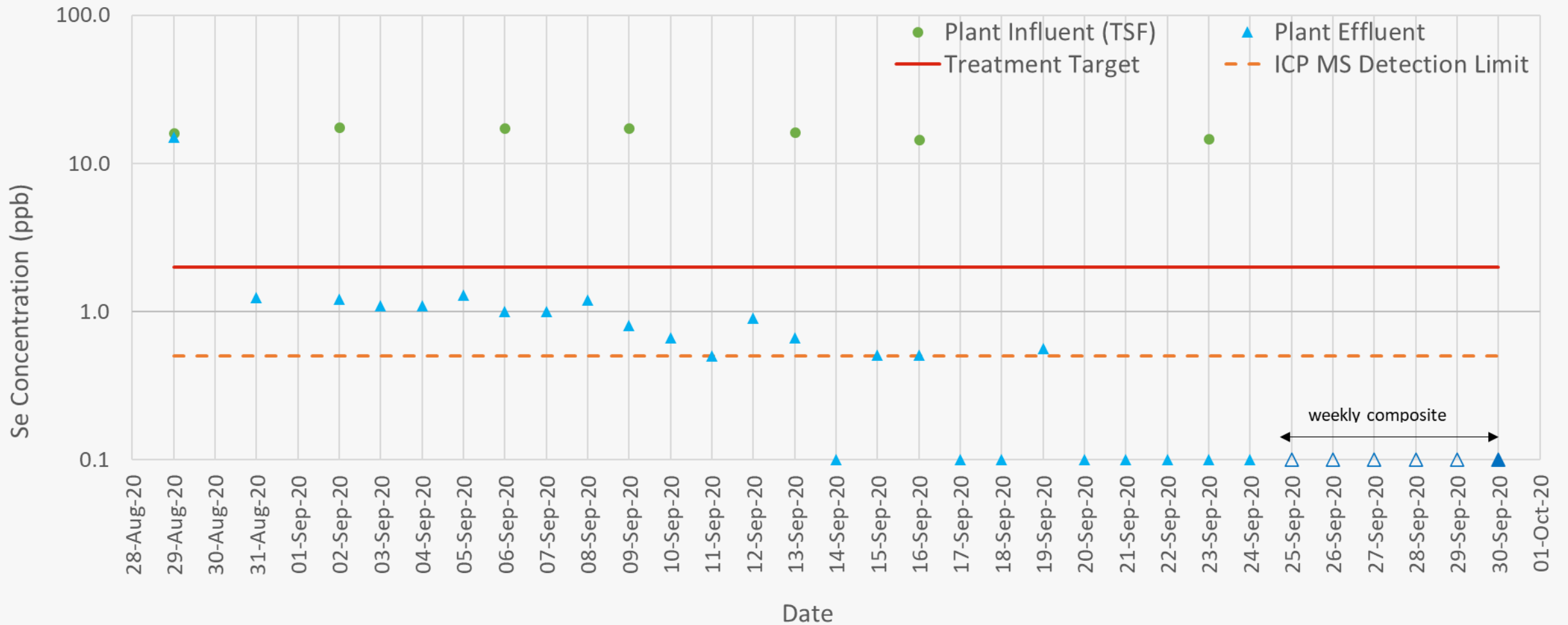


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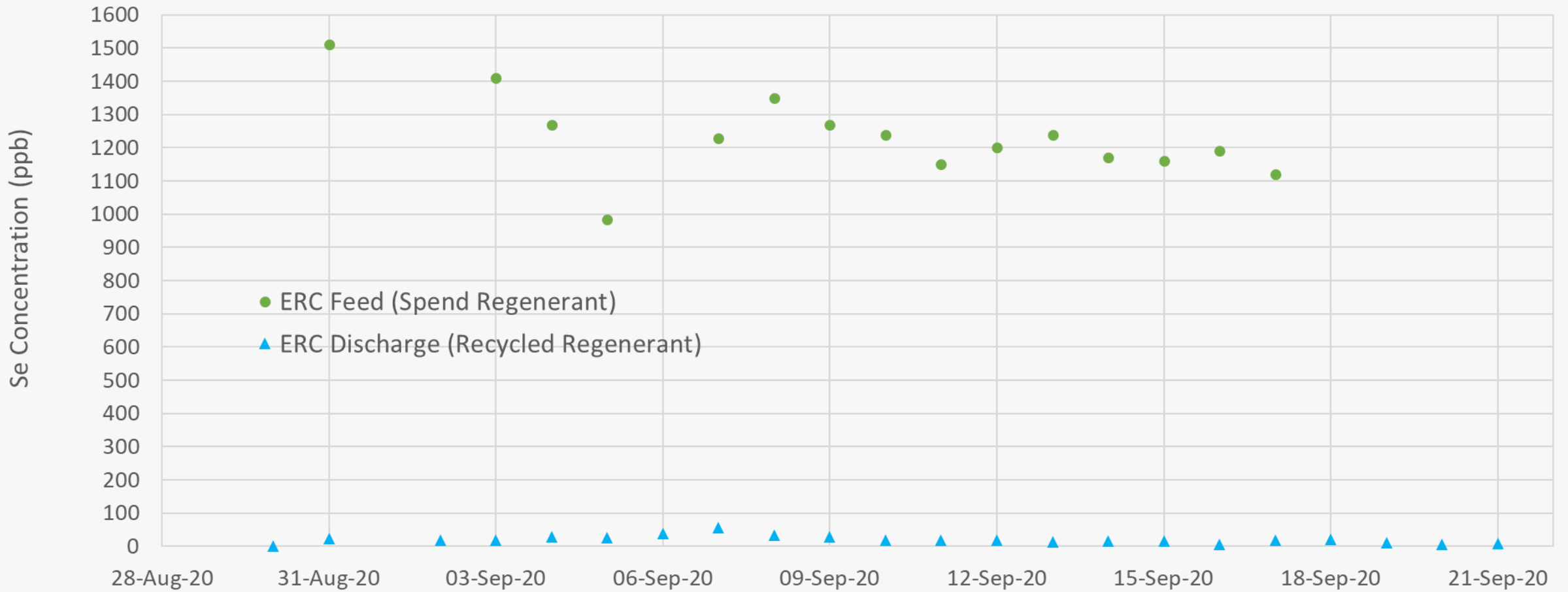
Final De-watered Residue



Se Removal from Plant Feed



ERC Performance – Se Removal into Solid Residue

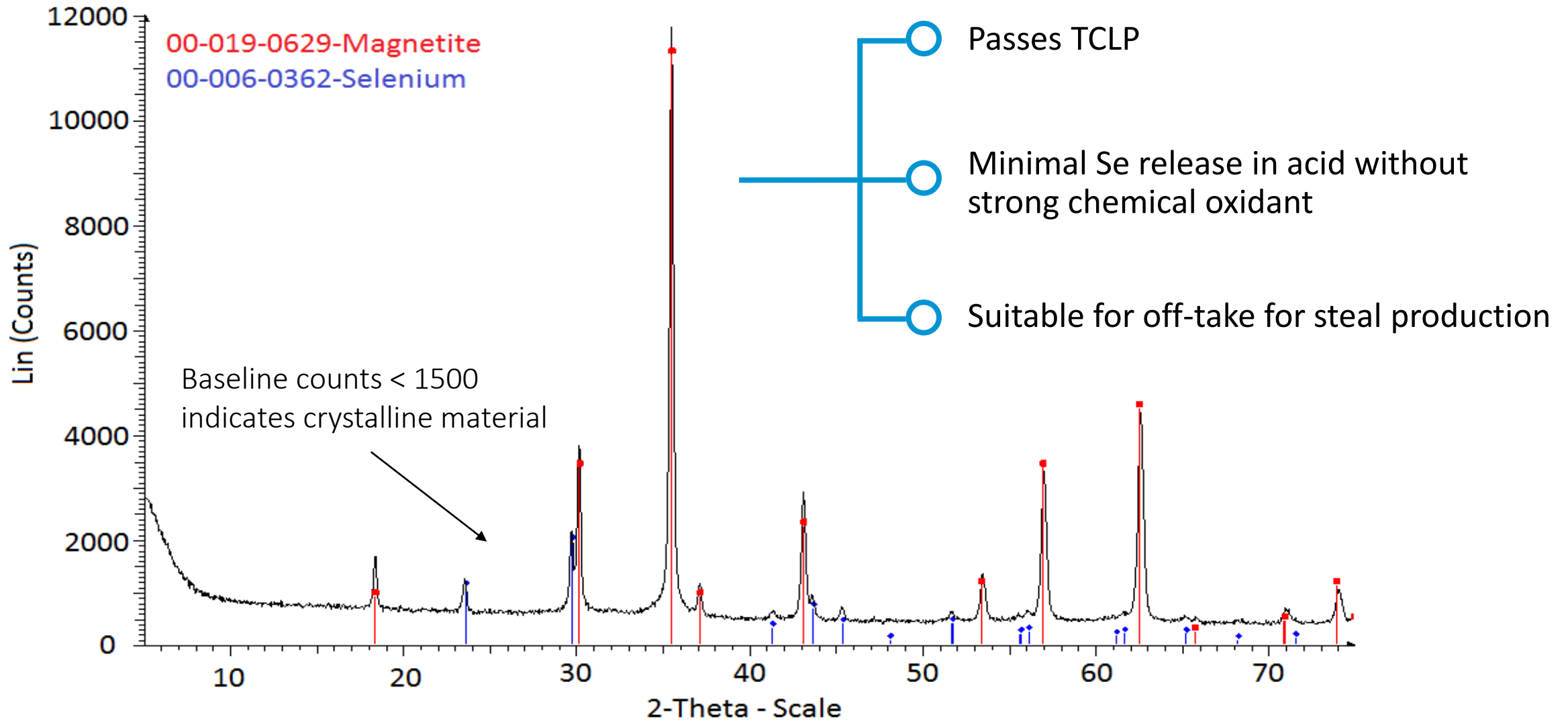


Plant Selenium Balance from 24-hour Composites

Date	Water Treated by IX (m ³ /d)	Se in Feed (ppb)	Se in Discharge (ppb)	Se Removed by IX (g/d)
Sept 2	5,609	17.6	1.1	92.5
Sept 6	5,605	17.2	1.0	90.8
Sept 9	5,617	17.2	0.8	92.1
Sept 13	5,616	16.3	0.7	87.8

Date	Regenerant Treated by ERC (m ³ /d)	Se in ERC Feed (ppb)	Se in ERC Discharge (ppb)	Se Fixed into Residue Solids (g/d)
Sept 4	74	1,270	29	91.3
Sept 8	74	1,350	34	96.9
Sept 10	74	1,240	18	90.1
Sept 13	74	1,240	14	90.4

Compact Stable Residue – Iron Oxide Matrix



3

New Non-Biological Selenate Projects and Applications

New Non-biological Selenate Removal Projects

Project	Se Target (µg/L)	WTP Capacity (m ³ /day)	Treatment	Regulatory Status	Project Status
US Ash Pond #1	< 7.5	5,540	Selen-IX™	Approved & Permit Issued	In construction
US Mine #1	< 1.6	660	NF + ERC	Approved & Permit Issued	In construction
US Mine #2	< 3	24,550	Selen-IX™	Approved & Permit Issued	In procurement
GW Remediation	<1	1,090	Selen-IX™	Unknown	FS

Ash Pond Clean-up Remediation

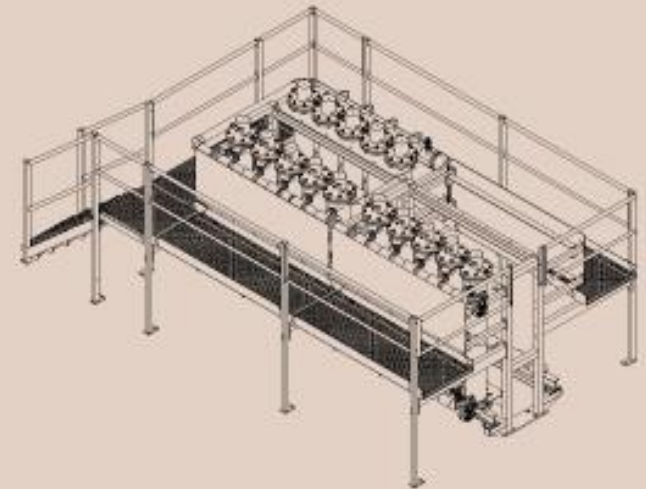
Project Schedule

2019	Bench Scale Testing
Q1/2 2020	Engineering Design
Q3/4 2020	Fabrication & Construction
Q1/2 2021	Plant Commissioning
Q3 2021	Plant Operations



Project Overview

- Up to 1,000 USGPM
- Intermittent operation with fast ramp up/down if needed to respond to rain events
- Comply with Se discharge target of $< 7 \mu\text{g/L}$
- Plant to operate 9 to 5 Mon to Fri only



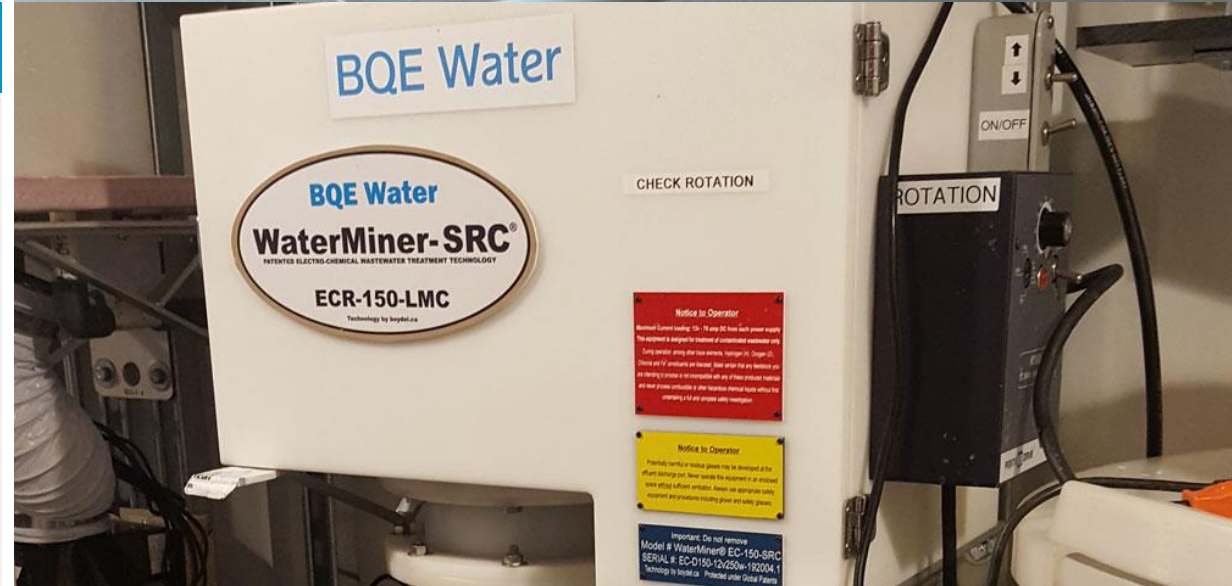
US Mine – NF + ERC under Construction

Project Overview

- Intermittent operation with fast ramp up/down if needed
- Comply with discharge limits of $< 1.6 \mu\text{g/L}$ for Se & 720 to 900 mg/L for SO_4 driven by WET chronic toxicity testing using *Ceriodaphnia dubia*

Project Schedule

Q1 2020	Treatability Assessment
Q2/3 2020	Plant Process Design & Automation
Q3/4 2020	Procurement
Q1-Q3 2021	Construction
Q4 2021	Plant Operations



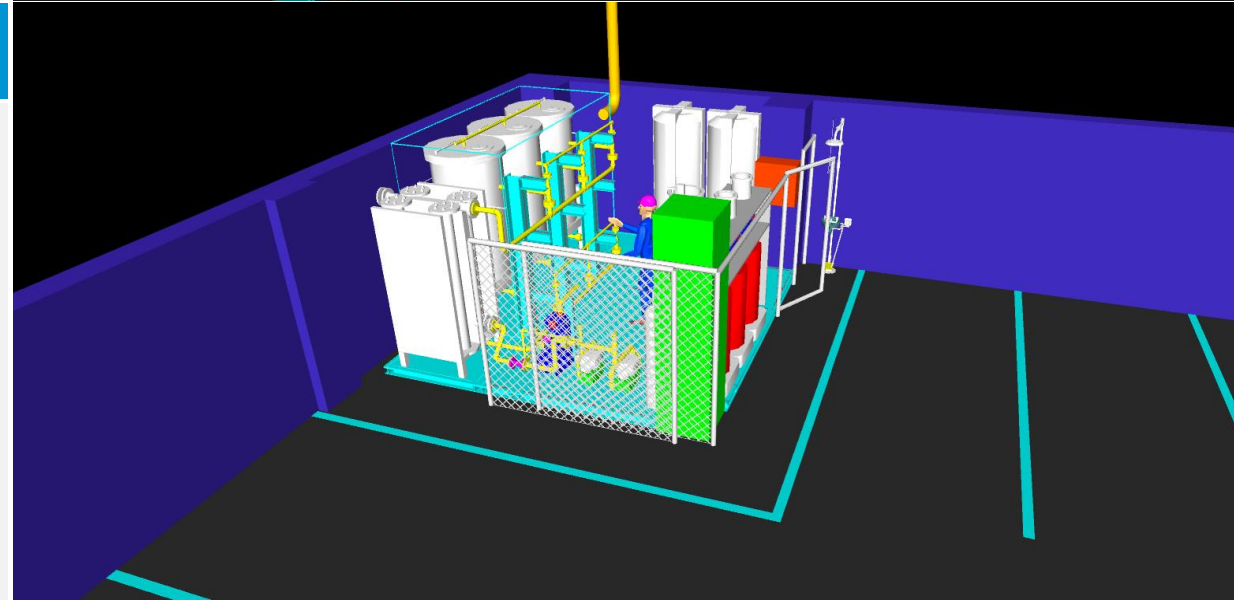
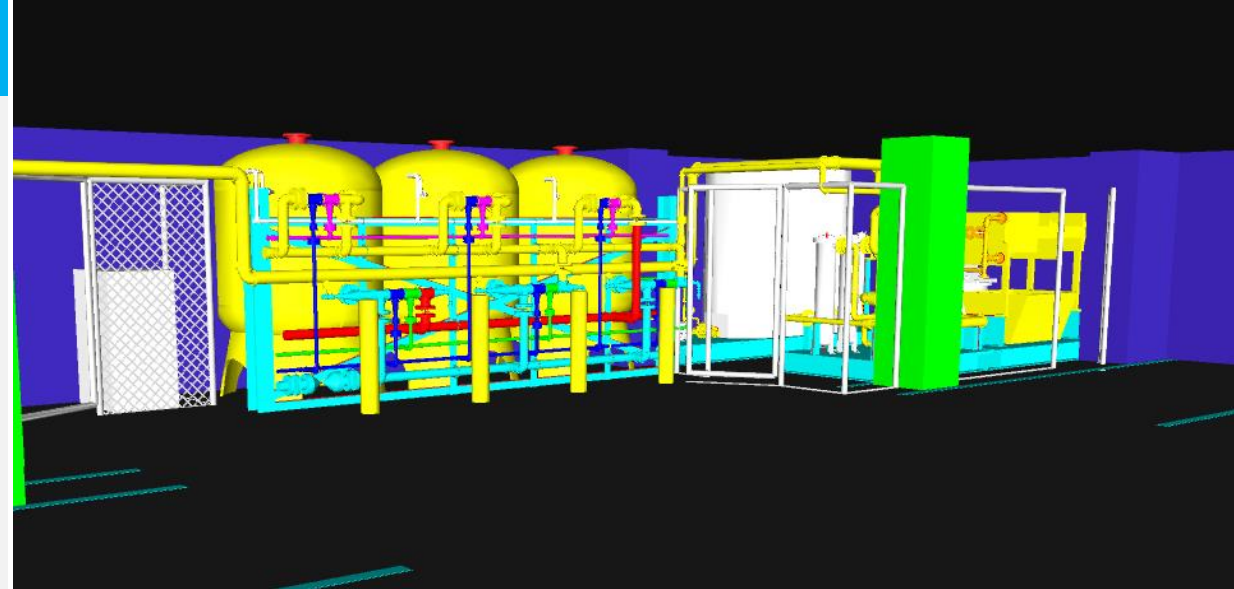
Office Building Parkade IX-ERC for Se Removal in USA

Project Overview

- Groundwater seepage (200 GPM) into commercial building requires Se removal prior to discharge to city's sewer
- Discharge limits of $< 1.0 \mu\text{g/L}$ for Se
- Total footprint of treatment less than 4 standard parking stalls in underground parkade

Broader Applicability

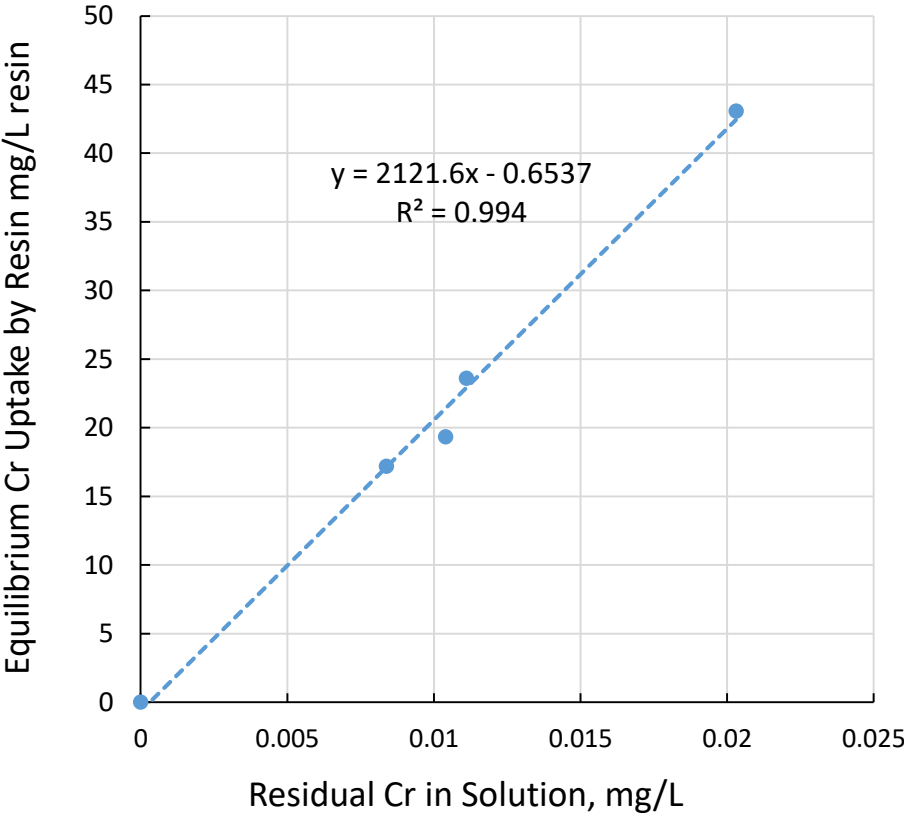
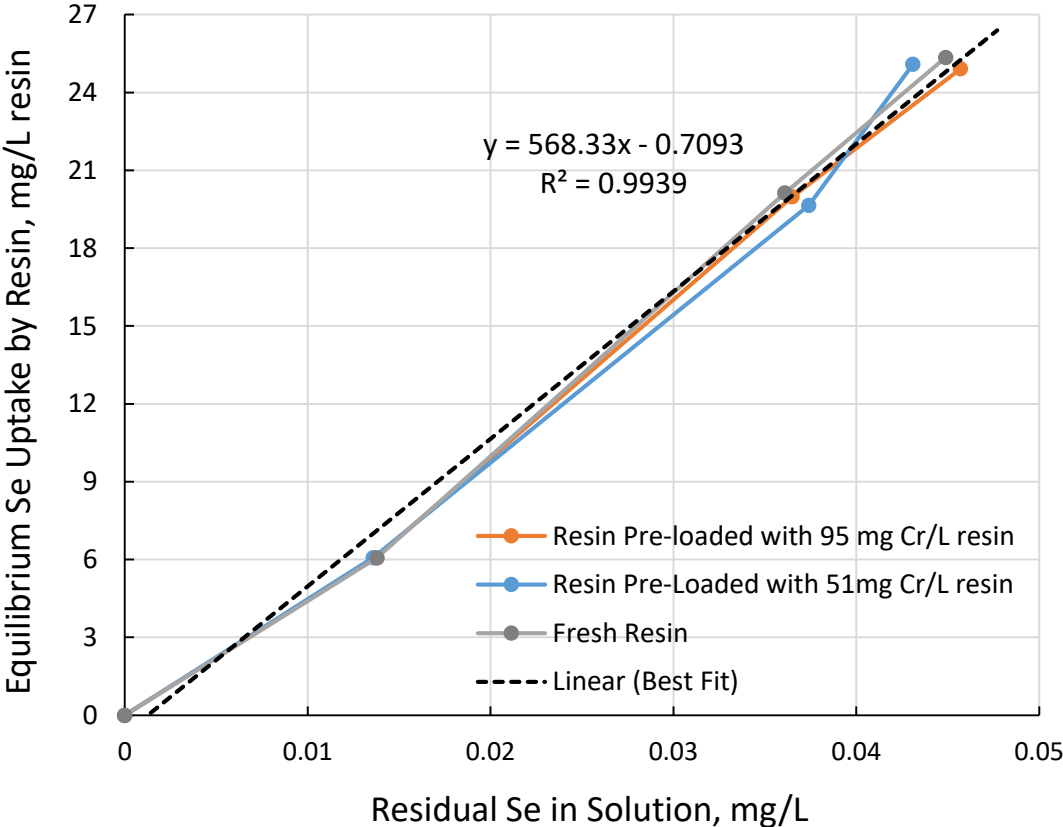
- Important in situation when groundwater Se levels are naturally elevated
- Potable water treatment by RO produces a reject that cannot be directed to sewer



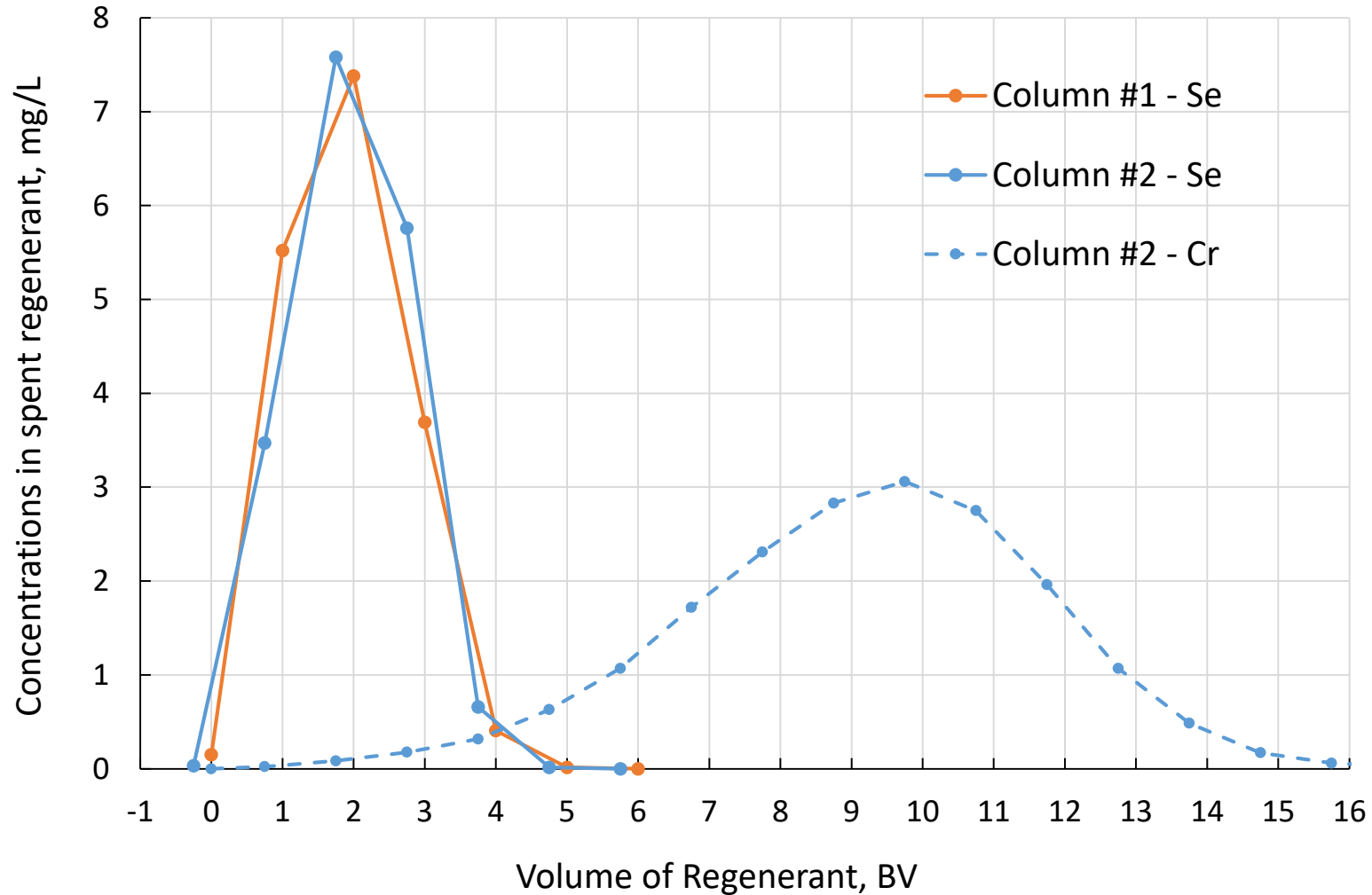
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Removal of Metalloid Oxyanions Other than Selenate

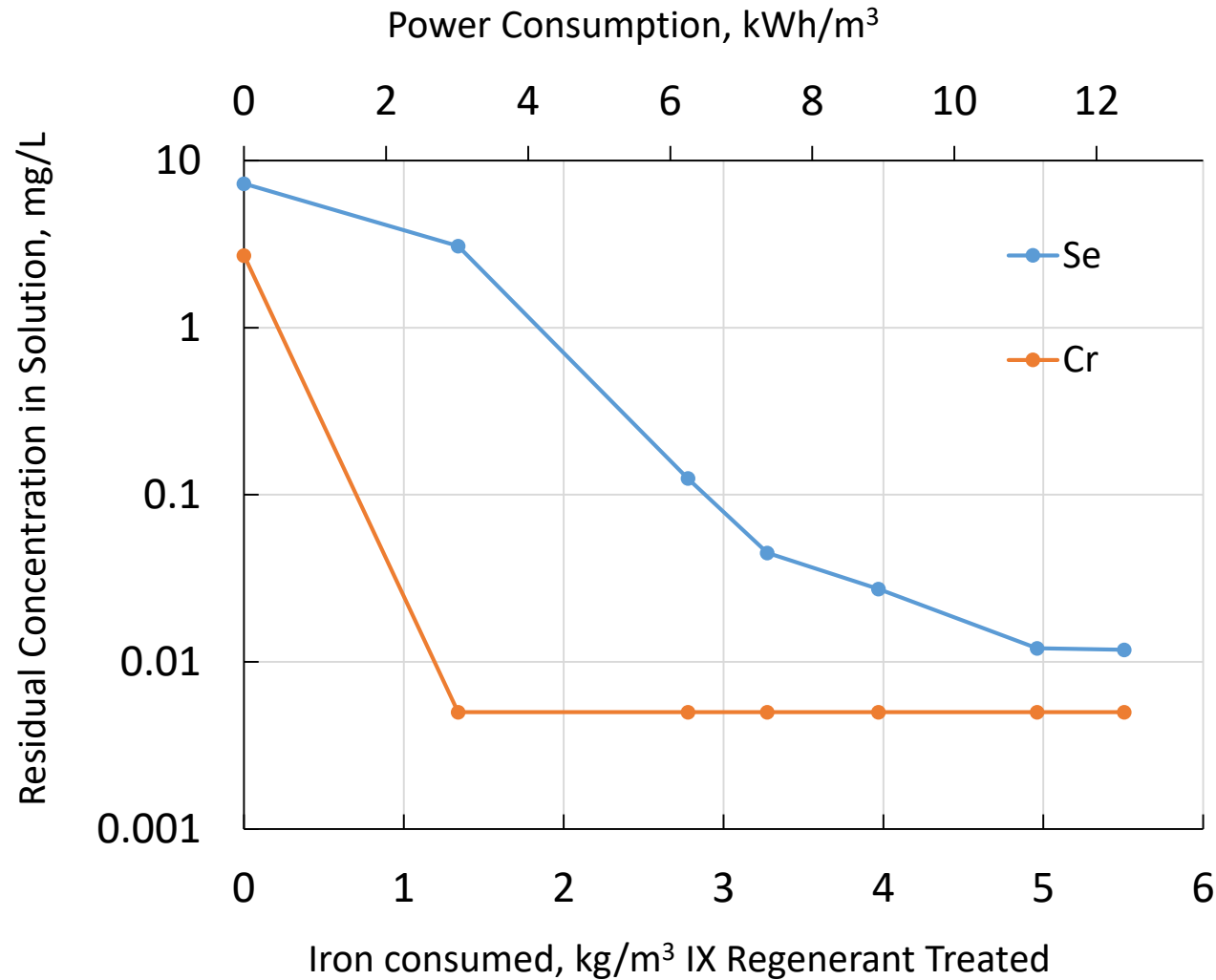
Co-removal of Hexavalent Chromium by Selen-IX



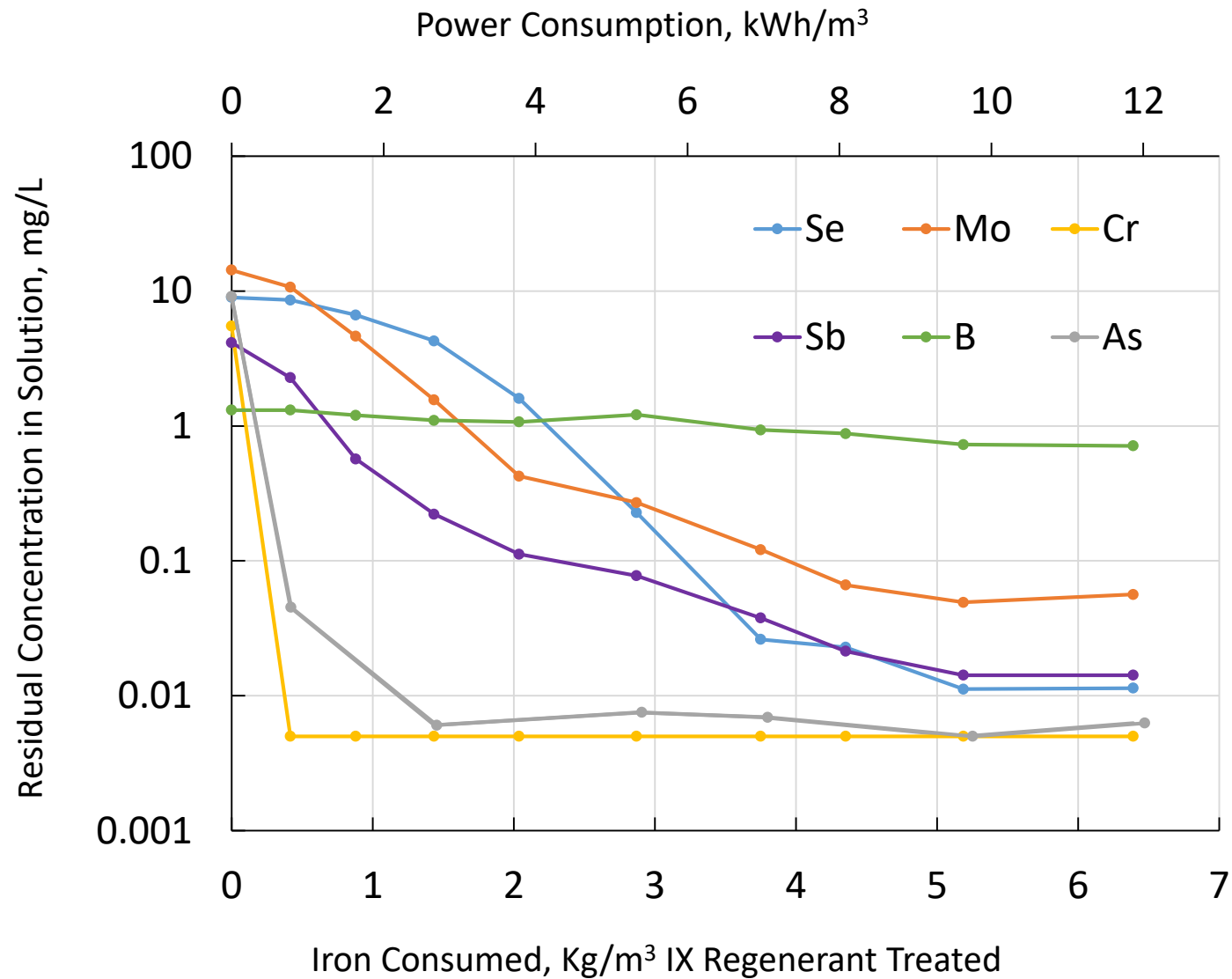
Co-removal of Hexavalent Chromium by Selen-IX



Co-removal of Hexavalent Chromium by Selen-IX



Metalloid Oxyanion Removal by ERC



Summary

- IX-ERC and NF-ERC provide step change in selenium control
- Modular system suitable for mobile deployment for remediation
- Broadly applicable to removing metalloid oxyanions to ultralow levels without waste brine generation