# SELENIUM MANAGEMENT IN MINING AND METALLURGICAL PROCESSING USING ELECTRO-REDUCTION

*COM 2024, Halifax*

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BQE Water

# Why is Selenium an Issue?

# Why is Selenium an Issue?

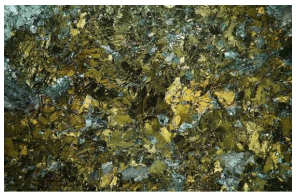
BQE Water

| 16 VIA 6A |
|---|
| 8 15.999 O Oxygen Nonmetal |
| 16 32.07 S Sulfur Nonmetal |
| 34 78.97 Se Selenium Nonmetal |
| 52 127.6 Te Tellurium Metalloid |
| 84 208.98... Po Polonium Metalloid |
| 116 293.2... Lv Livermorium Post-Transition M... |

- Selenium is a ubiquitous trace element present in many mineral deposits across the commodity spectrum

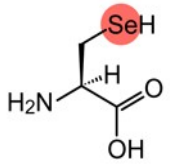
| | |
|---|---|
| Chlacopyrite-CuFeS2 | Eskebornite – CuFeSe2 |
| Pyrite – FeS2 | Dzharkenite - FeSe2 |
| Thiosulphate | Selenosulphate |
| Thiocyanate | Selenocyanate |
| Cysteine | Selenocysteine |
| Methionine | Selenomethionine |

*Eskebornite – CuFeSe2 mineral*

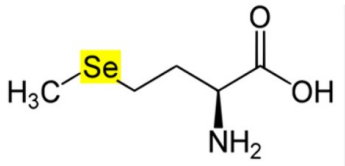


*Dzharkenite –FeSe2 mineral*

*Selenocysteine*

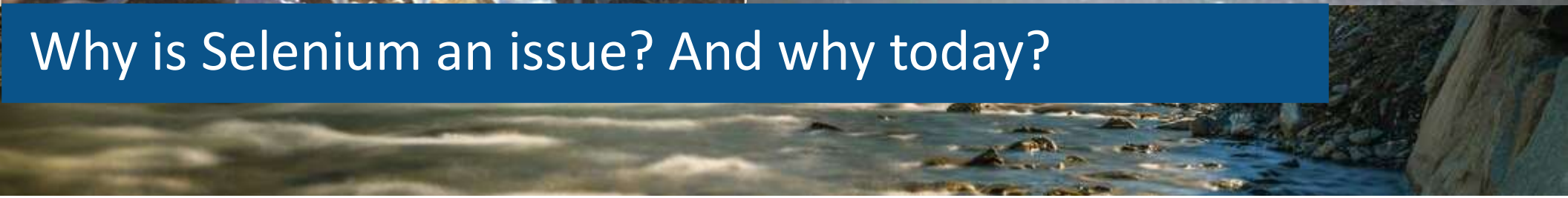



*Selenomethionine*



BQE Water

# Why is Selenium an issue? And why today?



# Selenium Regulation – Aquatic Life

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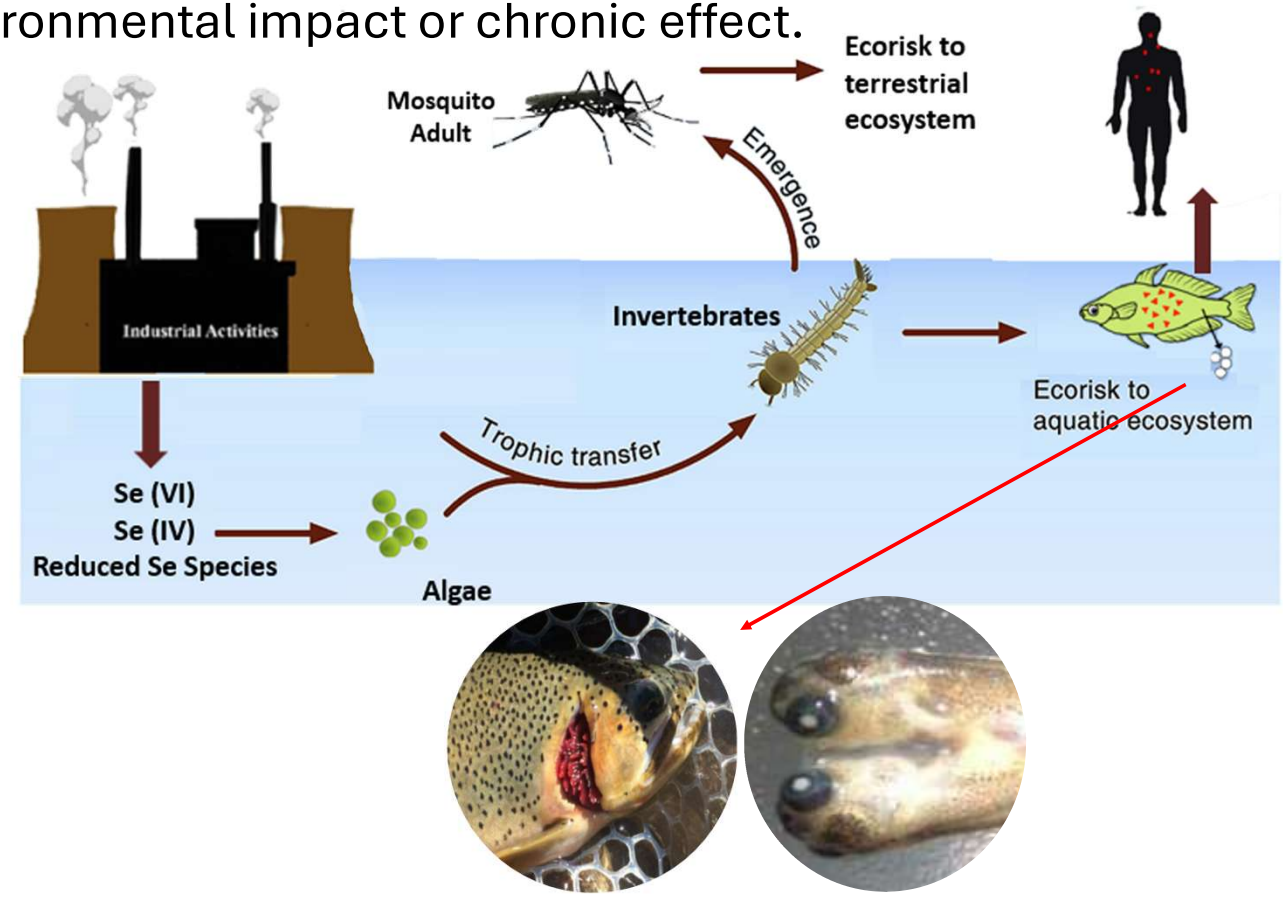
- Selenium regulations have recently advanced to understand the actual toxicology of selenium and its true environmental impact or chronic effect.

| 2014: BC WQG<br>2018: Alberta | 2016: US EPA |
|---|---|
| Water Quality < 2 ppb<br>Alert Conc. <1 ppb | Water Quality (Lentic) < 1.5 ppb<br>Water Quality (Lotic) < 3.1 ppb |
| eggs/ovary < 11µg/g<br>whole-body <4 µg/g<br>Muscle < 4 µg/g | eggs/ovary < 15.1 µg/g<br>whole-body <8.5 µg/g<br>Muscle < 4 µg/g dwb |



# Selenium Regulation – Drinking Water

BQE Water

- People are a lot less sensitive to Se than fish and the regulation for drinking water is orders of magnitude higher for the fish.

**Health Canada Drinking Water and US US National Primary Drinking Regulations (NPDWR)**

Drinking Water < 50 ppb

- Se can also substitute S in organic compounds like amino acids and can cause chronic effect and genetic mutation through DNA and proteins.

BQE Water

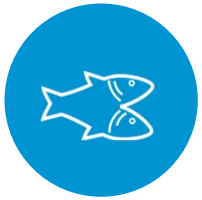



**When regulations were implemented the only BAT for Se removal was Biological Treatment.**

# Challenges with Biological Treatment

BQE Water

**Reliance on Dilution**
Hard to reach < 5 ppb



**Risk of Bioaccumulation**
Generation organo-selenium species

**Acute Toxicity in Effluent**
Adding BOD, COD (H2S, NOx, NH4) to treated water

**Stability of Residue**
No evidence on long term stability

**Lack of Adoptability**
Flow and mass loading - Temperature

# Successful Selenium Treatment Approach

BQE Water

| | |
|---|---|
| 1 | Reach end-of-pipe target of < 2 µg/L |
| 2 | Avoid organo-selenium issues & chronic effects |
| 3 | Avoid introducing unintended consequences: nutrients, $H_2S$, COD/BOD, $H_2Se$ |
| 4 | Low volume residue with a proven long-term stability |
| 5 | Handle large fluctuations in flow and mass loading |
| 6 | Provide seasonal or intermittent treatment |

- These criteria couldn't be achieved by sustaining innovation and a disruptive innovation was needed

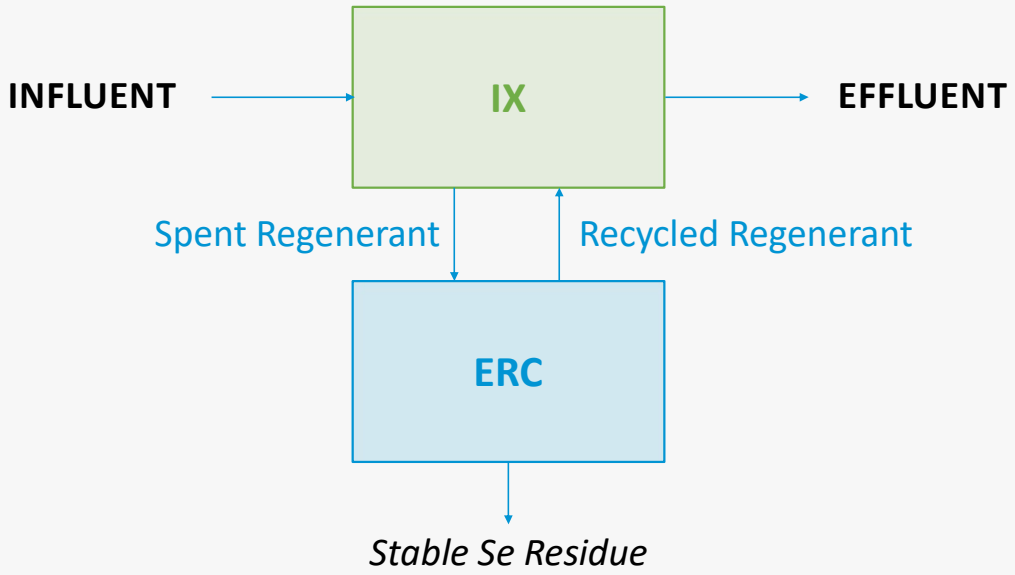
BQE Water

# Selen-IX™ Development Approach and Chronology

# BQE Water's Selen-IX Technology

BQE Water

## Selen-IX™ = Ion Exchange Combined with Electro-reduction




- Selective sequestration of Se from impacted mine water
- Produce treated water with Se < 1 ppb – end of pipe
- Pre-concentrate Se in the brine by factor of 20 to 2000x

- Remove Se from pre-concentrated brine solution
- Produce brine free of Se and re-use in resin regeneration in IX and eliminated the brine management issue
- Stabilize Se into small quantity of non-toxic inorganic residue

# Selen-IX™ Commercialization Timeline

BQE Water

**2012 to 2017**

Lab – proof of concept/fatal flaw testing

**2013 to 2017**

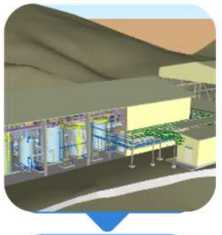
-4 Pilots
-Modification of process
-Testing to support environmental permitting

**2018**

Industrial Demonstration – risk mitigation of electro-reduction scale-up

**2020**

1st Full-scale Plant



**2020 to 2024**

3 other Full-scale Plant

# Challenges & Successes

## Challenges

- Funding
- ERC performance and design
- Molybdenum release of from anodes
- Why should we be better than BAT

## Successes

- Environmental approvals for multiple projects
- Characterization and demonstration of long-term stability of residue
- Early adaptors and implementation of the technology

# Technology Development Summary

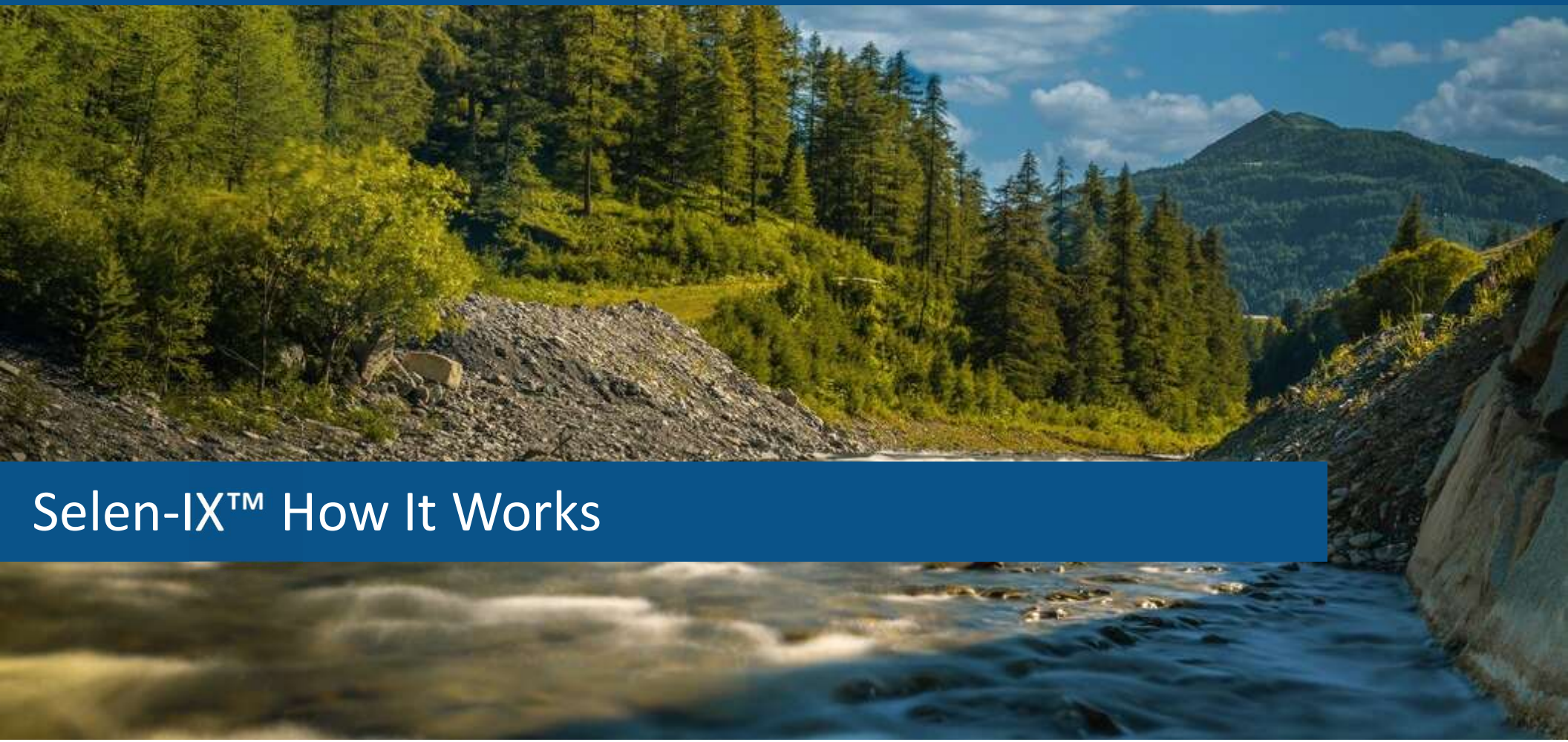
BQE Water

| Source of Wastewater | TDS , mg/L | Se in feed, µg/L |
|---|---|---|
| Refineries (base and precious metals)<br>Brines/RO retentates | High >3000 | 5 - 500 |
| Uranium deposits<br>Mine process waters | Medium - 1000 -3000 | |
| Waste rock runoff<br>Surface water<br>Ground water | Low - 30 - 500 | |

Over the course of 8 years development:

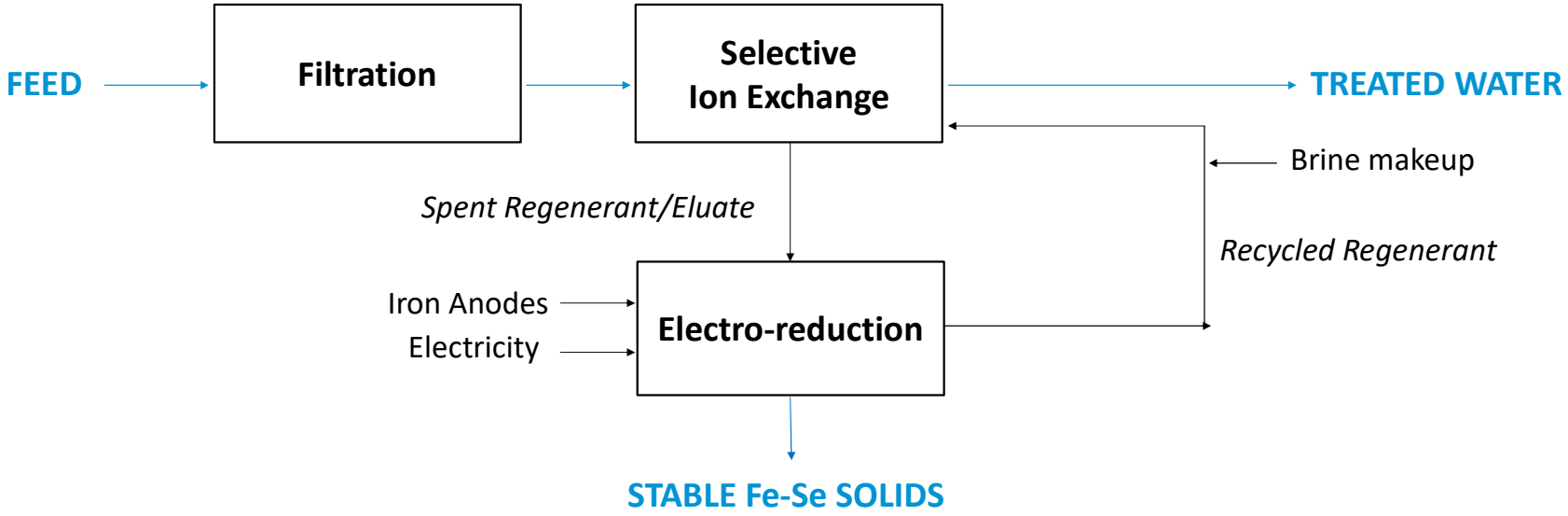
- 20,000 numbers of assays was performed.
- Over the course of eight years of development, ~ $6 M was spent.

BQE Water

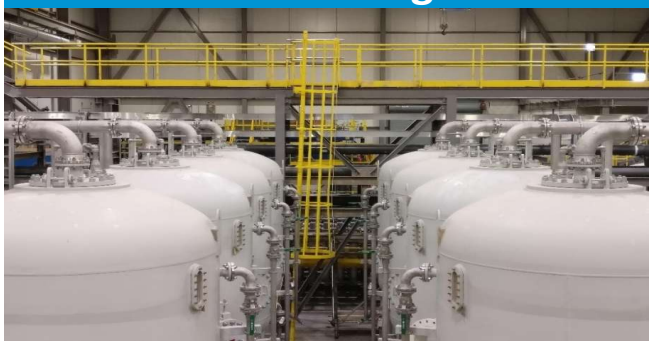


# Selen-IX™ How It Works

# BQE's Selen-IX Technology




**Ion Exchange**



+

**Electro-reduction**

→

**Final De-watered Residue**

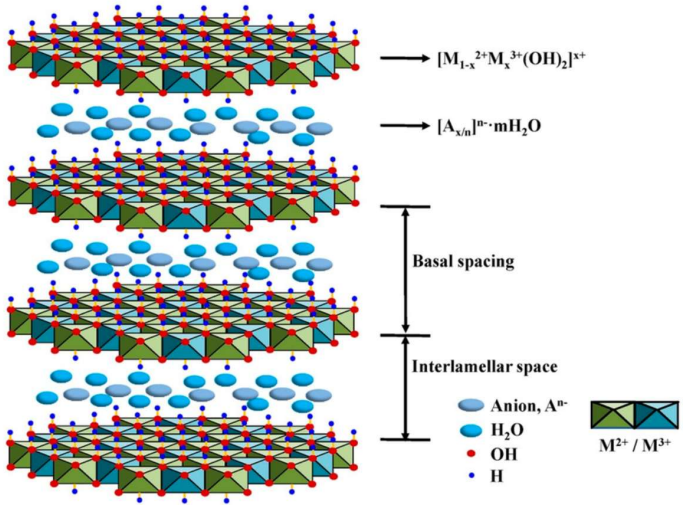
# Selenium Electro-Reduction

BQE Water

- The ERC circuit is generating a ferrous-ferric Double Layer Hydroxide (DLH) solids with a high reductive capacity that capture selenate and reduce it to elemental selenium.

*Fe-Se solids generated in ERC*

*FeII/FeIII double layer hydroxide structure*

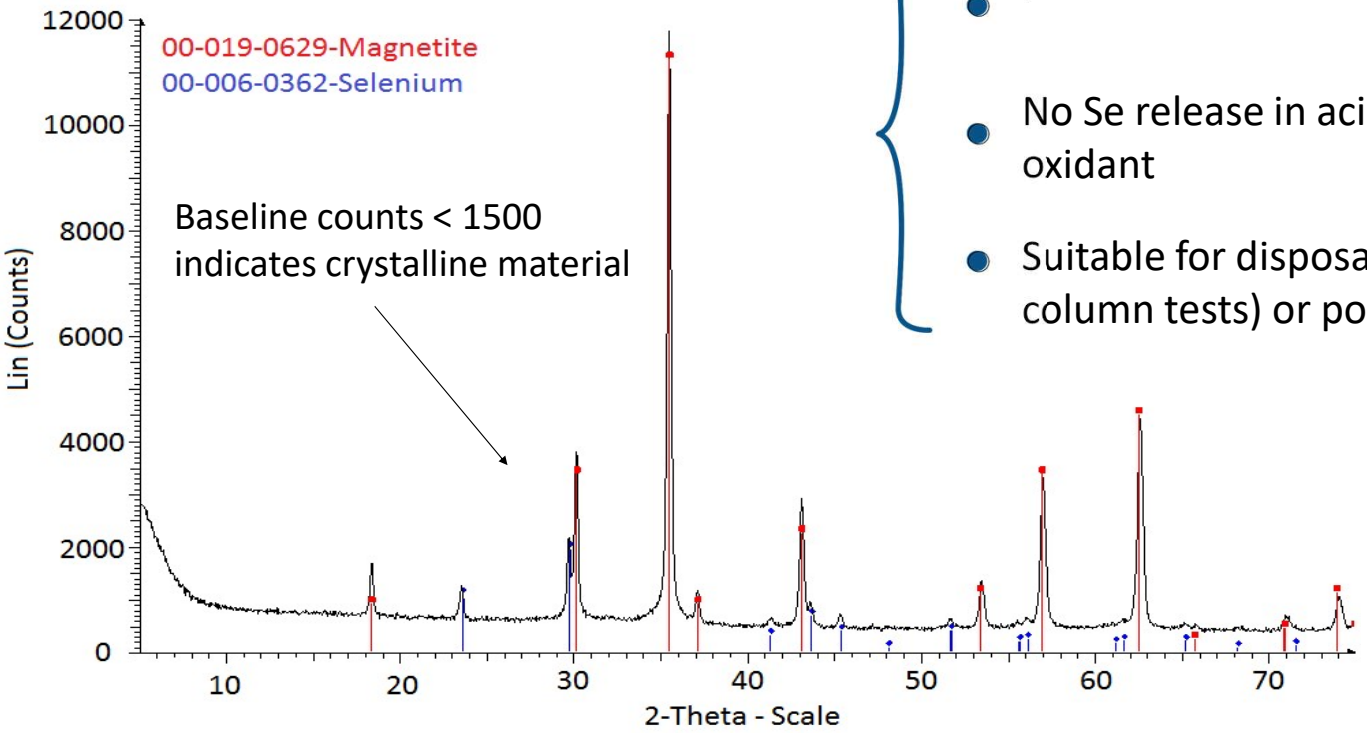



- Compared to the ZVI, ERC offers constantly fresh anodes surface with no passivation

# Compact Stable Residue

BQE Water

- Depending on the TDS level in the water the solid generation rate is 0.2 - 4 mg solids/μg Se in water.

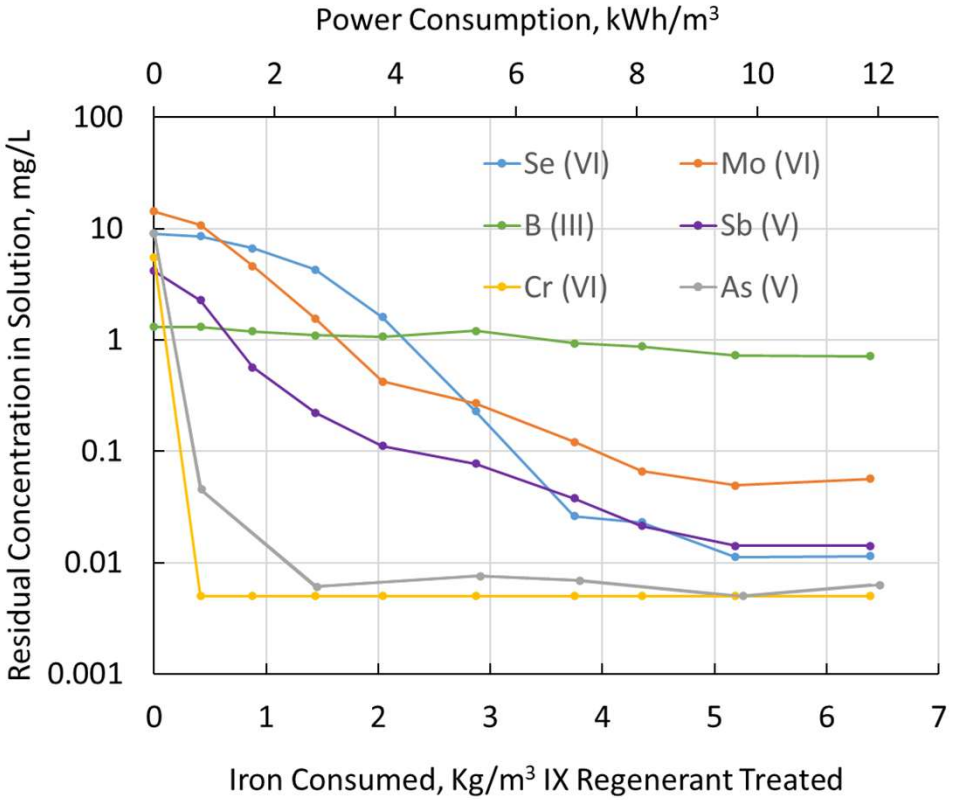



- Passes TCLP
- No Se release in acid without oxidation by strong chemical oxidant
- Suitable for disposal with tailings (demonstrated in column tests) or potential off-take

# Metalloid Oxyanion Removal by ERC

BQE Water

- Selen-IX™ is broadly applicable to removing metalloid oxyanions to ultralow levels through IX and ERC without waste brine generation



BQE Water

# Selen-IX™ Full-Scale Industrial Plants

# Kemess Selen-IX™ Plant

*Plant effluent discharged directly to environment*

BQE Water

**Background**

- Selenium present in legacy wasterock seepage
- Development of new gold copper deposit estimated to be $1B, predicated on succusses of demonstrating ability to manage Se ($30M).
- Local communities on-board subject to discharge into creek with minimal dilution

**Objectives:**

- Meet Se limit of 2 ppb at the end-off-pipe
- Manage residues within legacy site
- Seasonal operation from April to November

# Kemess Selen-IX™ Plant Design Criteria

BQE Water

## Sizing Capacity

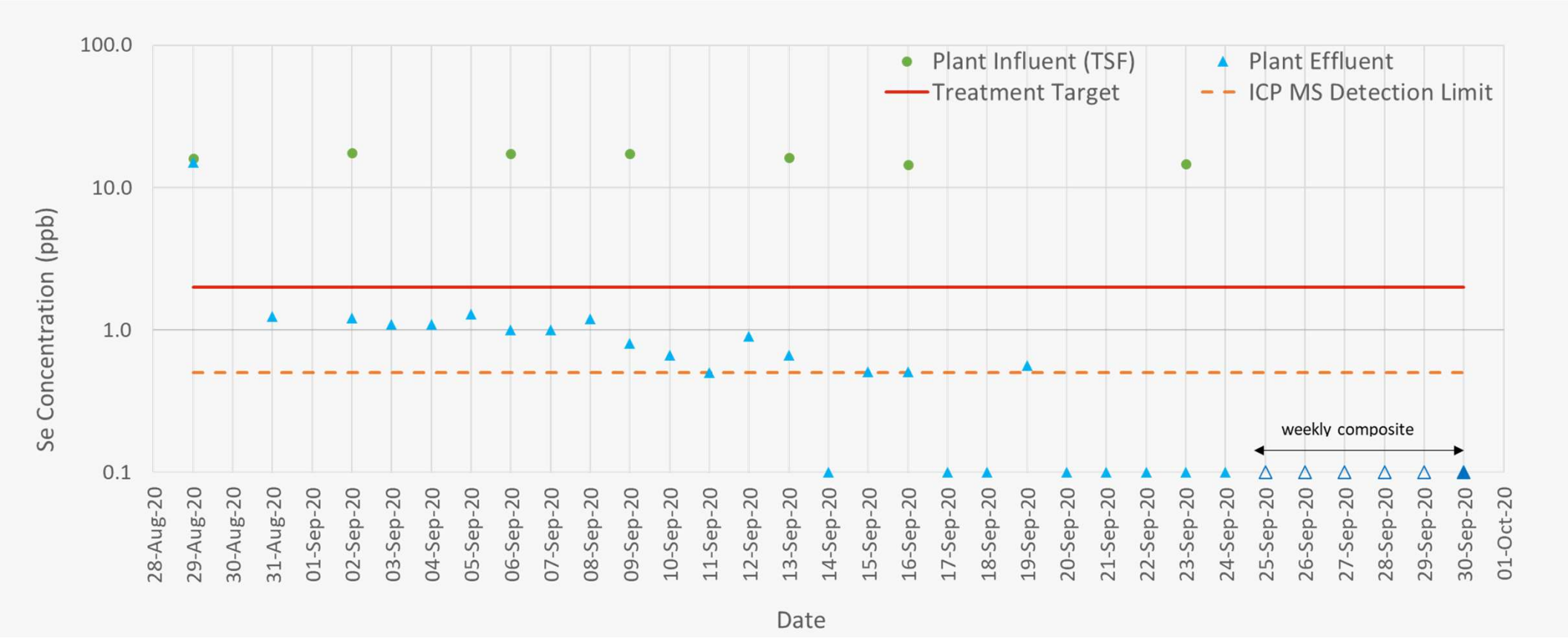
*Flow rate*: **1,200 GPM (6,500 $m^3$/d)**
Se in feed: **~ 50 ppb**

*IX Columns Residence time*: **5 mins**
*Residue*: **Max ~ 4 t/d filter cake**

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

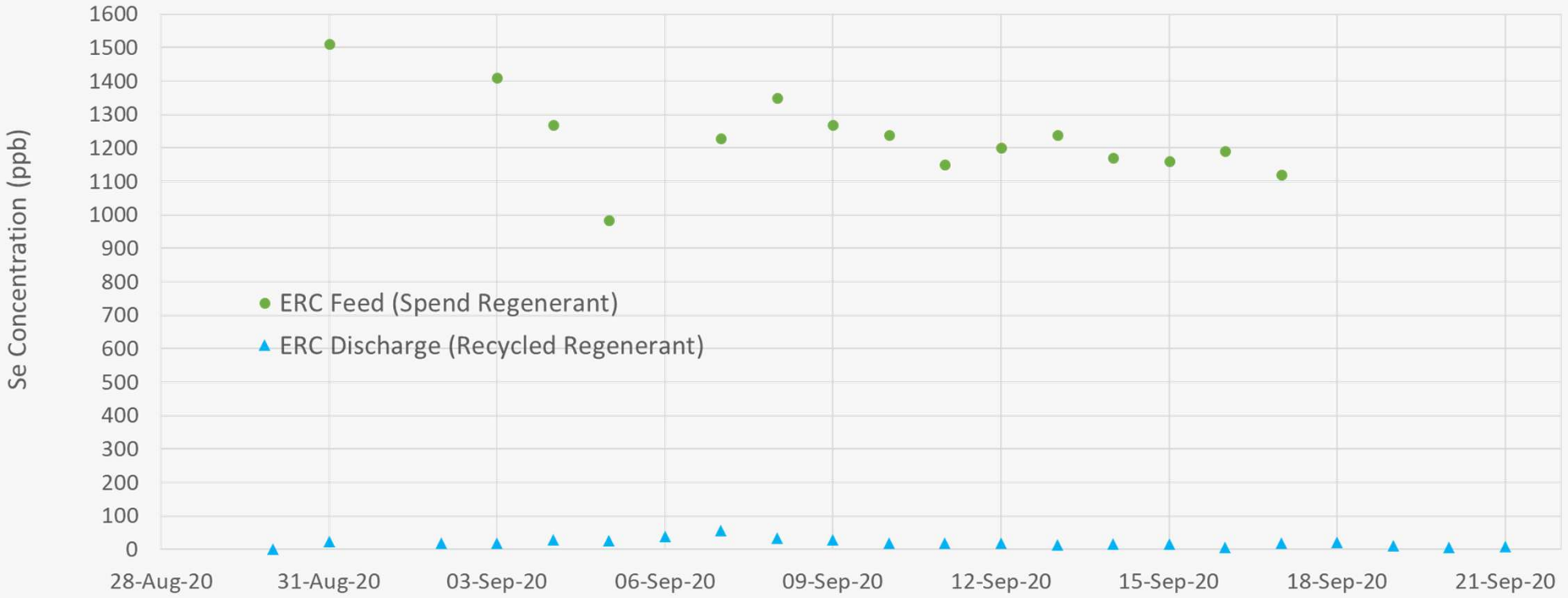
# Se Removal from Plant Feed

BQE Water



# ERC Performance – Se Removal into Solid Residue

BQE Water



# Coal Ash Pond Remediation with Selen-IX™

BQE Water

**Background**

- Old coal combustion residue pond
- Risks and impacts for surface and ground water

**Objectives**

- Intermittent operation with fast ramp up/ramp down with Work schedule: 5 d/wk day shifts only
- Dewater pond and discharge treated water into environment
- Remove selenate to < 5 µg/L and fix into stable residue for tailings disposal

# Selen-IX™ Plant Design Criteria

BQE Water

## Sizing Capacity

*Flow rate*: **0-750 GPM (up to 4000 $m^3$/d)**
Se In Feed: **5 – 150 ppb**

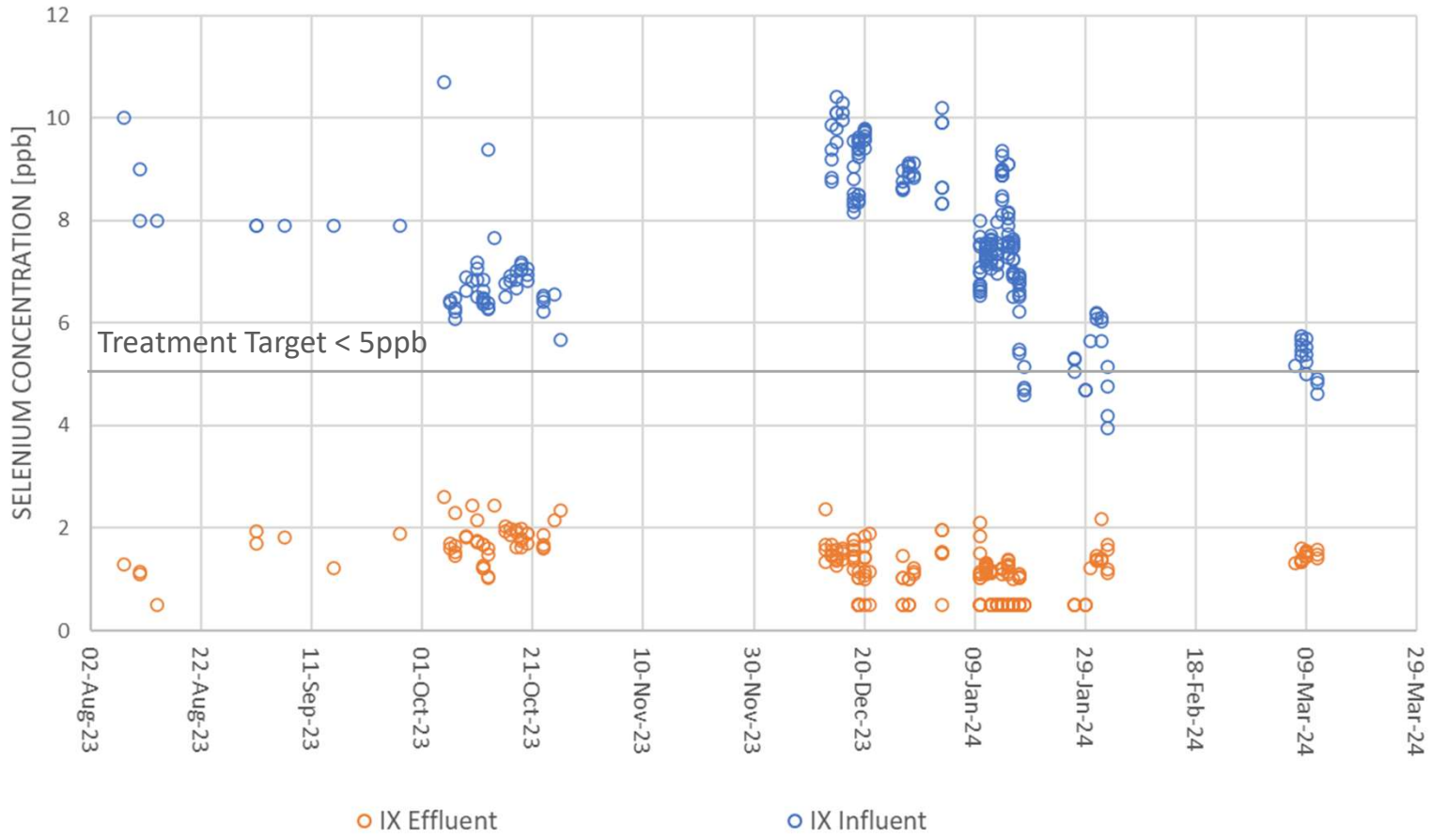
*IX Columns Residence time*: **6 mins**
*Residue*: Max ~ **0.5 t/d filter cake**

*IX Columns - full-scale Selen-IX™ plant, Coal Ash pond*

*Electro Cells- Selen-IX™ plant, Coal Ash pond*

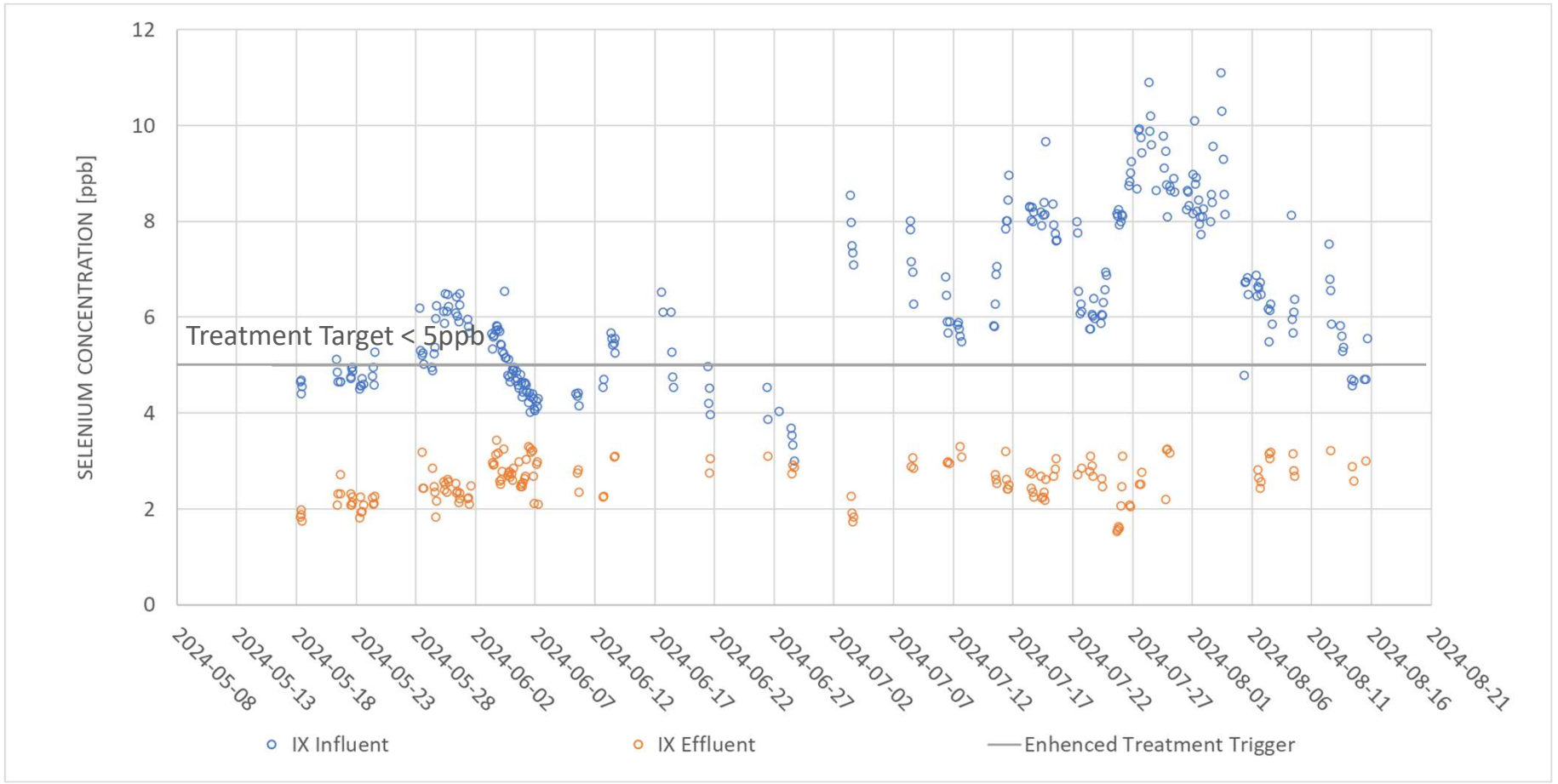
# Se Removal from Plant Feed

BQE Water



# Se Removal from Plant Feed

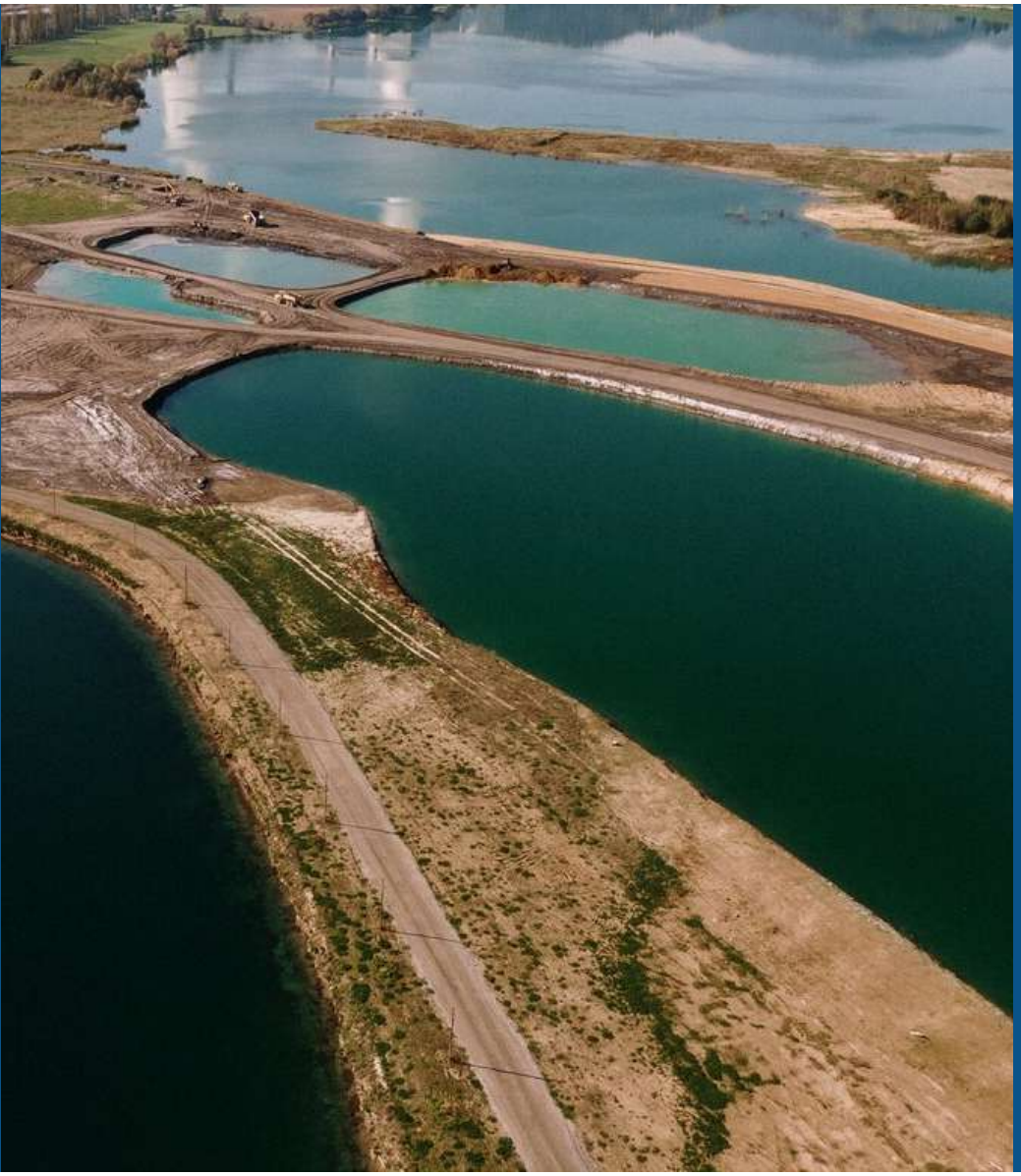
BQE Water



# Key Takeaways

*"The electric light did not come from the continuous improvement of the candle"*
*Oren Harari*

- A disruptive innovation was needed to address emerging regulations for Se
- Motivated early adaptors shorten the development
- Danger of BAT
- BQE continues to innovate. BQE is positioned as a leading source of innovation in water space.



# CONTACT US

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