Removal of Selenium by Biological Reduction and Surface Complexation

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WWTF IMWA 2024

Session [illegible] 23, 3:10 pm - 5:00 pm

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AGENDA

1. Why remove selenium?
1. How to remove selenium?
1. Introducing Tracer™ Se
1. Performance

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Why Remove Selenium?

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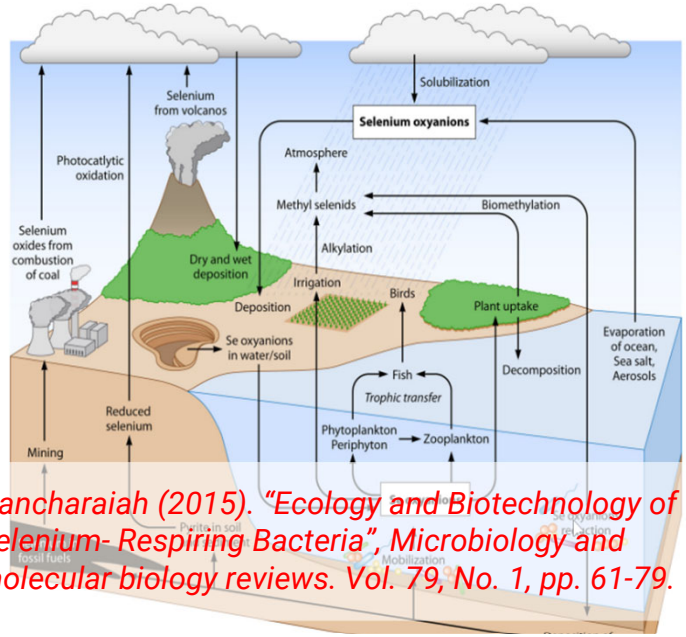
Why Remove Selenium?

Selenium persists in the environment

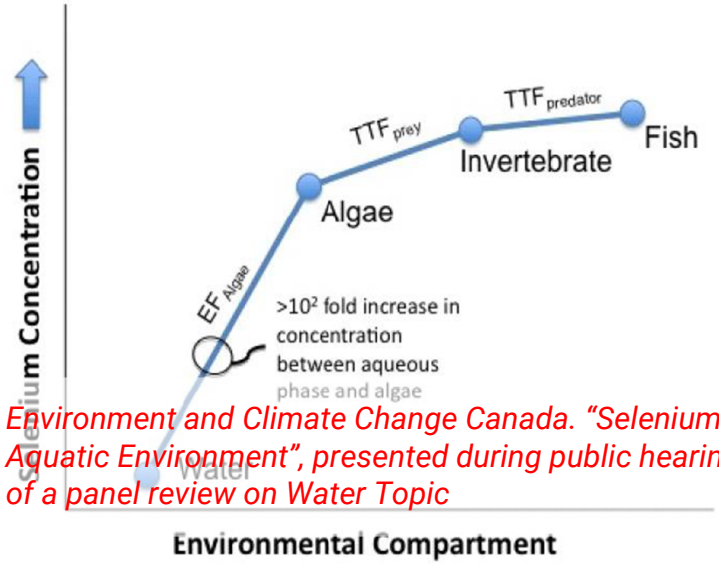
- Selenium evolves in the environment
- Impacts complex to evaluate

Selenium is absorbed by plants / animals

- Selenium bioaccumulates
- Selenium biomagnifies



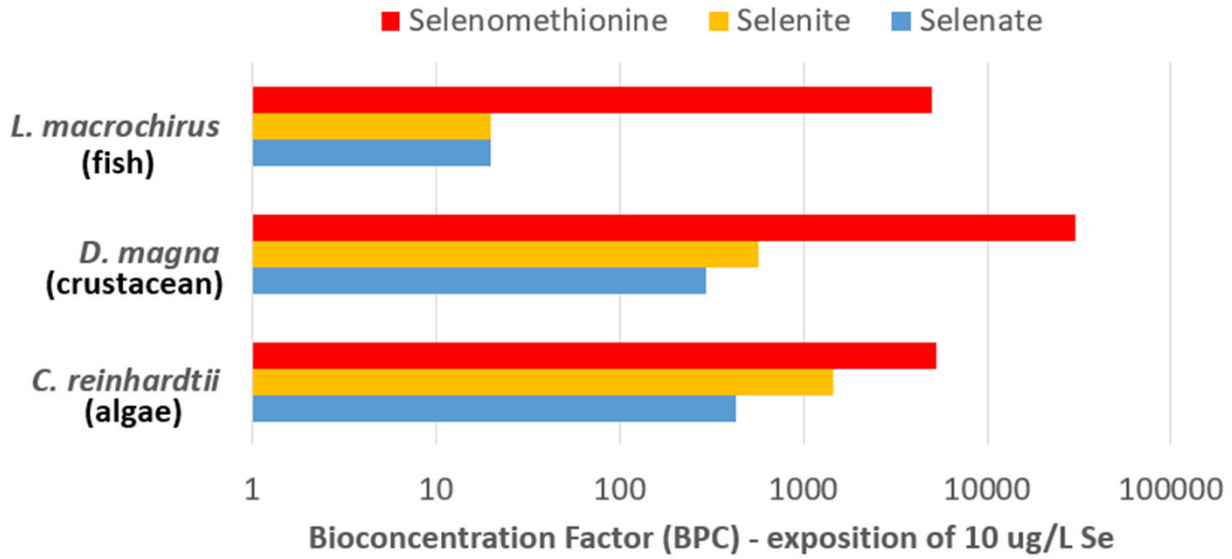
Nancharaiah (2015). "Ecology and Biotechnology of Selenium- Respiring Bacteria", Microbiology and molecular biology reviews. Vol. 79, No. 1, pp. 61-79.



Environment and Climate Change Canada. "Selenium Aquatic Environment", presented during public hearin of a panel review on Water Topic

Why Remove Selenium?

Selenium speciation impacts on its absorption

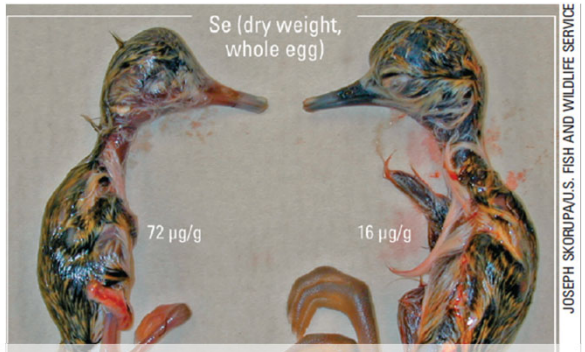


Besser, John M., Timothy J. Canfield and Thomas W. La Point. 1993. "Bioaccumulation of organic and inorganic selenium in a laboratory food chain". Environmental Toxicology and Chemistry: An International Journal, 12, no 1, 57-72.

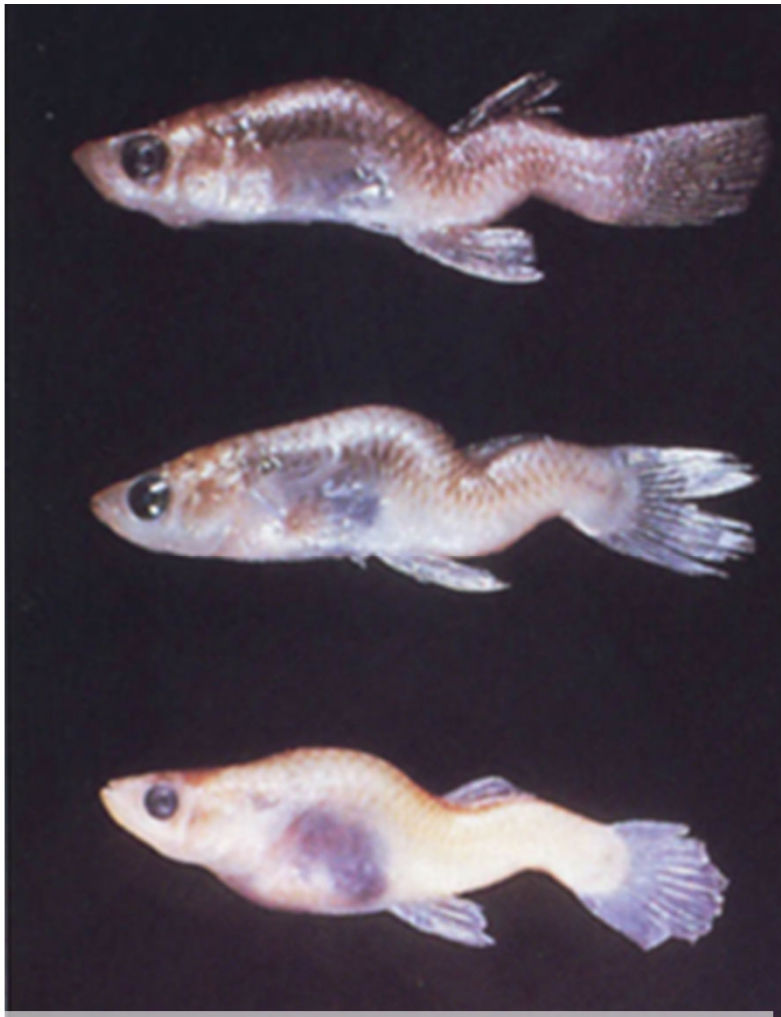
Why Remove Selenium?

High selenium concentration results in:

- Reproductive defects
- Growth deformities
- Mortality



Luoma, S.N. (2009), "Emerging Opportunities in Management of Selenium Contamination", Environmental Science & Technology, Vol. 43, No. 22, pp. 8483-8487.



Davis, E.A. (1988), "The biological consequences of selenium in aquatic ecosystems", California Agriculture, January-February (pp. 18-29)

How to Remo
Selenium?

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Removal at the source - Mitigation

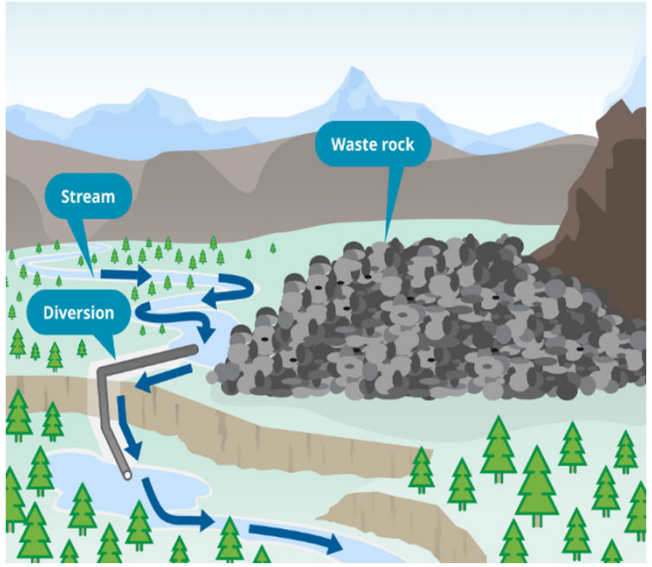
Diversion of the water

Containment of Se containing rocks

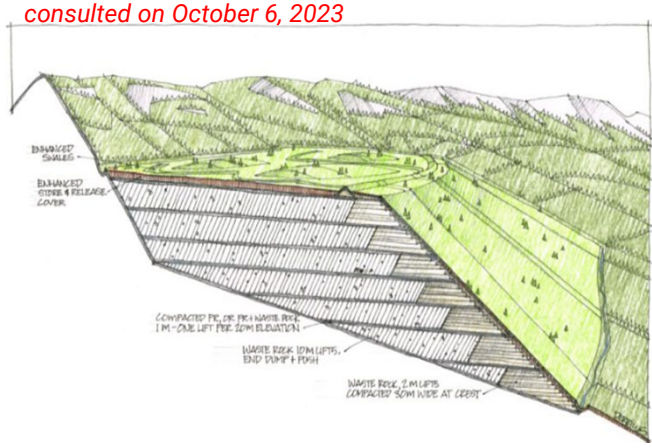
- Prevent oxidation
- Prevent solubilization

When none of these strategies work or it is too late:

- Need to remove selenium from the water



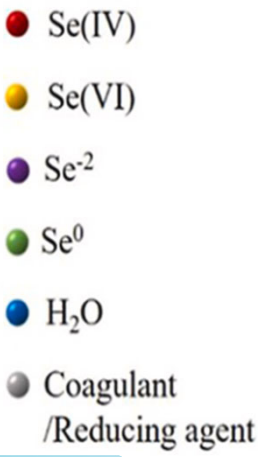
British Columbia Water Quality Hub, "Water treatment strategies", https://elkvalleywaterquality-bcgov03.hub.arcgis.com/pages/water-treatment, consulted on October 6, 2023

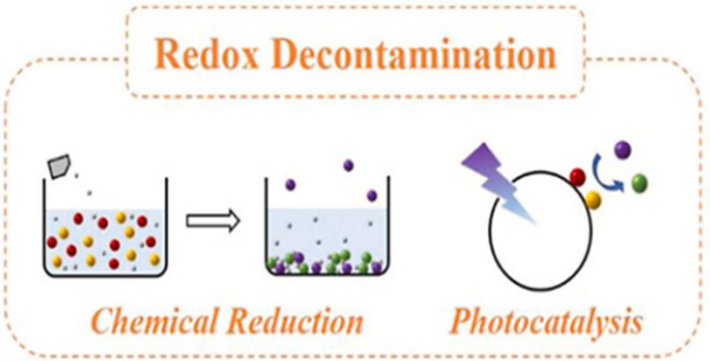


North Coal - Michel Coal Project, "Water protection", https://northcoal.ca/michel-coal-project,consulted on October 10, 2023

How to Remove Selenium

Different ways, different challenges





FROM: Li, T. (2022), "Treatment technologies for selenium contaminated water: A critical review", Environmental Pollution, Vol. 299, No. 15.

Comparison of Technologies

Biological treatment is in commercial use

- Kinetics are slow, so systems are expensive
- Toxicity is a concern
- Sludge management (Se^0)
- Post-treatment (advanced oxidation) is possible, but…

Physico-chemical treatment has not found wide acceptance

- No organo-selenium production
- Membranes and IX work well, but it just moves the selenium; concentrate / brine management
- Harder to apply in large scale applications

Comparison of Technologies- Biological

	Wetlands	Saturated Rock Fill (SRF)	MBBR	ABMet (biofilter)
Pre/ Post treatment requirement	**None; however does require periodic maintenance**	TSS removal	NO_3^- removal TSS removal	TSS removal
Inhibitors	None	high NO_3^-, metals	NO_3^-, metals	high NO_3^-, metals
Reject	Excess biomass to be removed	**None during operation**	Biological sludge (Se^0)	Biological sludge (Se^0)
Good for…	Site remediation No chemical use	**Low OPEX**	**Proven techno**	**Proven techno, low Se (with UF) < 2 ppb**
Limitations	**Low flows applications (high footprint)** **Need site protection**	**Se management once SRF is filled and biomass dies?**	**Higher Se_{diss} (10 ppb)** **Se_{org}**	**Sensitive to flow variation**
CAPEX OoM (USD) **(DB: 6,000 m^3/d, no pretreatment, with sludge management)**	No information Passive treatment	$22 M	$36 M	$24 M

Comparison of Technologies- Physico Chemical

	Ferric precipitation	Membrane	Ion exchange	Zero Valent Iron (ZVI)
Pre/ Post treatment requirement	Se transformation to Se^{+4}	Hardness, metal, **TSS** removal	Competing ions, TSS removal	Competing ions, TSS removal Post treatment for Fe and NO_2^- removal
Inhibitors	**None**	-	Similar ions (SO_4^{-2}, NO_3^-)	Nitrates, other oxidizers, passivation
Reject	Ferric sludge	**Concentrate (++)**	Brine (+)	BW water / ferric sludge (column vs mixed tank)
Good for…	Se^{+4} containing waters	**Ultra clean effluent, low Se**	**Polishing when no SO_4^{-2}**	Low NO_3^- concentrations
Limitations	**Selenite containing waters**	Scaling potential	**Competing ions, flow variation**	**Competing ions, passivation of media, plugging of column**
CAPEX OoM (USD) **(DB: 6,000 m^3/d, no pretreatment, with sludge management)**	$5 M	$82 M	$45 M	$30 M

Comparison of Technologies- Most Versatiles

	ABMet (biofilter)	Membrane	Tracer™ Se (HYBRID)
Pre/ Post treatment requirement	TSS removal	Hardness, metal, **TSS** removal	None
Inhibitors	high NO_3^-, metals	-	metals
Reject	Biological sludge (Se^0)	**Concentrate (++)**	Metallic Biological sludge
Good for…	**Proven techno, low Se (with UF) < 2 ppb**	**Ultra clean effluent, low Se**	**Flow variation, NO_3^- + metals**
Limitations	**Sensitive to flow variation**	Scaling potential	**Technology Readiness**
CAPEX OoM (DB: 6,000 m^3/d, no pretreatment, with sludge management)	$24 M	$82 M	$8 M

Selenium Removal: What's Best

Many options are available, the selection must consider:

- Flow
- Se speciation
- Water composition (inhibitors)
- Sensitivity of receiving body (organo-selenium)
- Rejects management possibilities
- Footprint
- Regulators

There is not one perfect option, and the best option will vary according to each site.

Introduction t
Tracer™ Se

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Introduction to Tracer™ Se

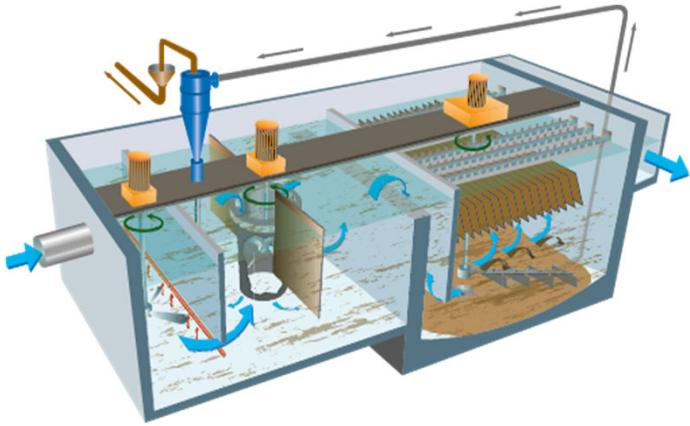
All-in-one process:

- Nitrate removal
- Metals and oxyanions removal (Se^{+4})
- TSS removal (Se_{part} + Se^{0})
- Reox (detox + Se_{org})

Concept based on proven / robust technologies

- Fixed film Bioreactor (MBBR)
- Ballasted flocculation (Actiflo)

AnoxKaldnes™ MBBR

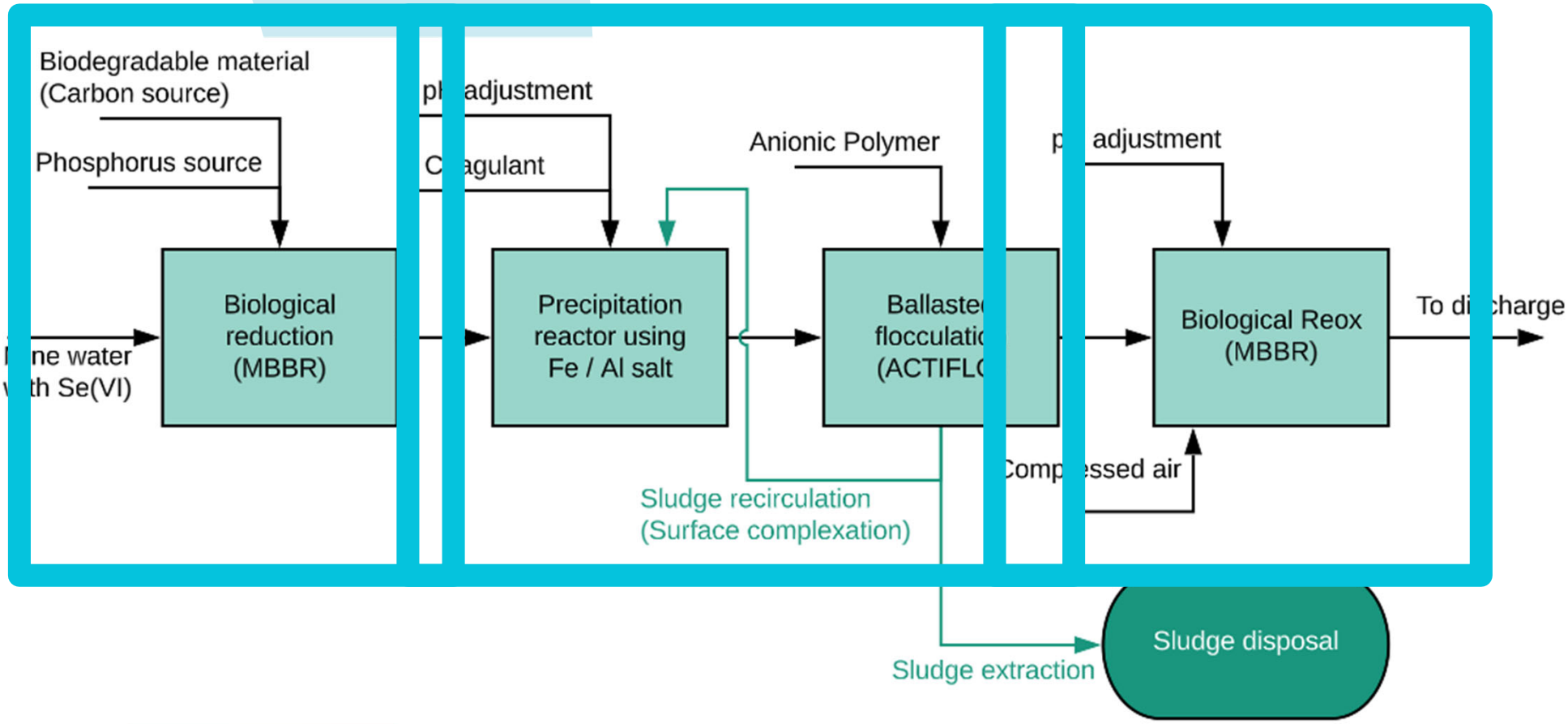


Actiflo

Biological reduction of Se^{+6} to Se^{+4} + Se adsorption on biom

Se^{+4} precipitation using surface complexation

Biological oxidation of residual Se to Se^{+6}



Performance Tracer™ Se

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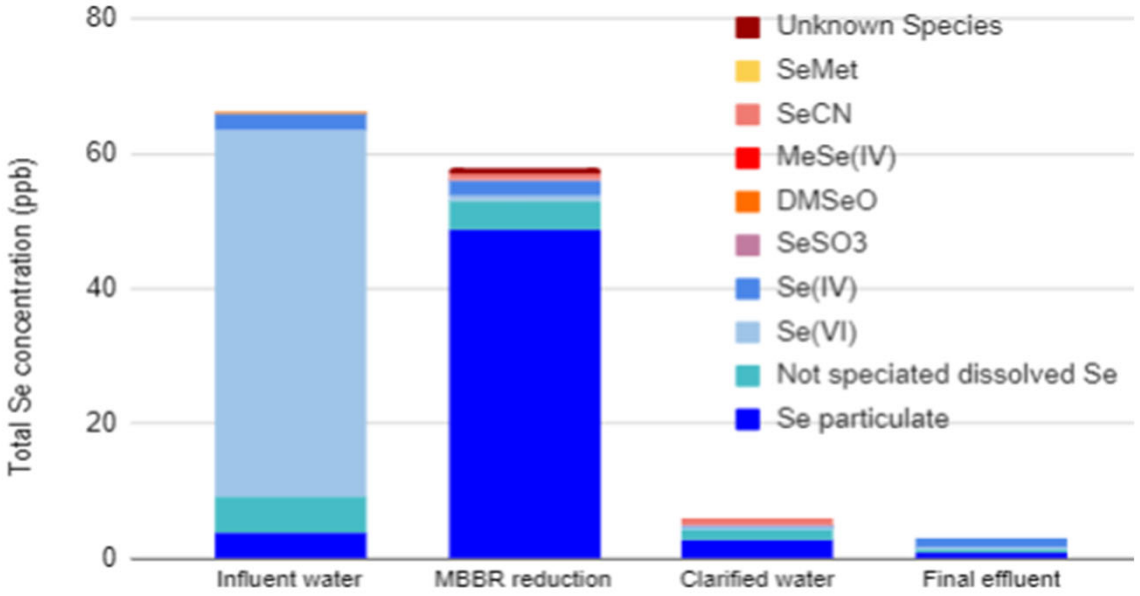
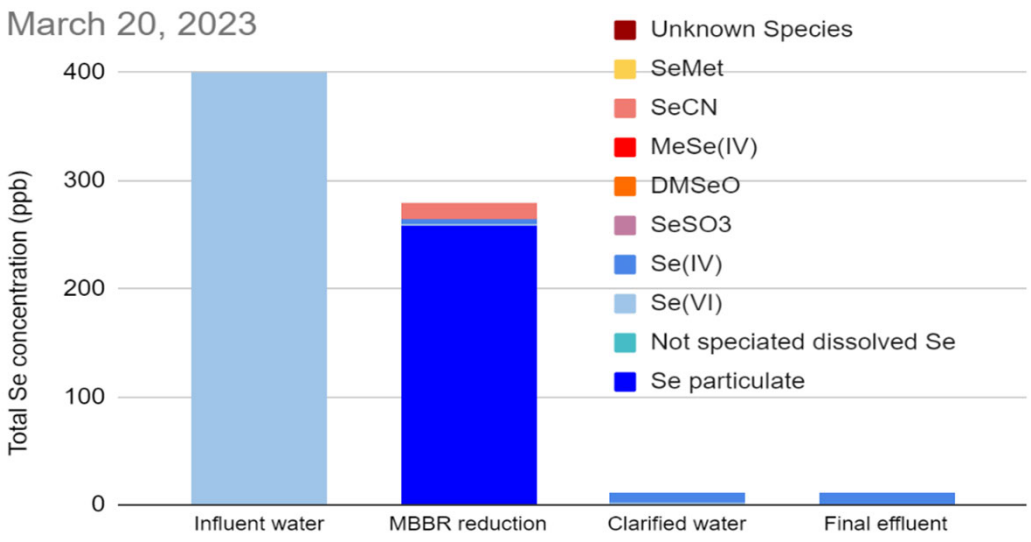
Performance

Please refer to technical paper for the complete discussion on performances

Total Selenium Concentration Repartition



Phase 1- Se_{in} = 60 ppb

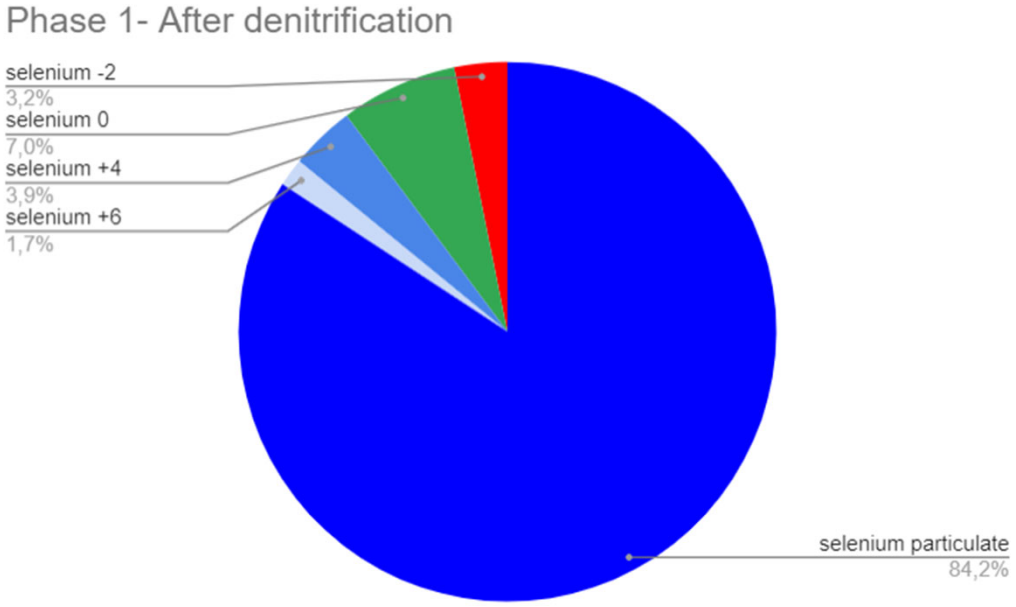


Phase 2- Se_{in} = 350-400 ppb

Performance

Please refer to technical paper for the complete discussion on performances

Se removal mechanisms- biological reduction effluent quality



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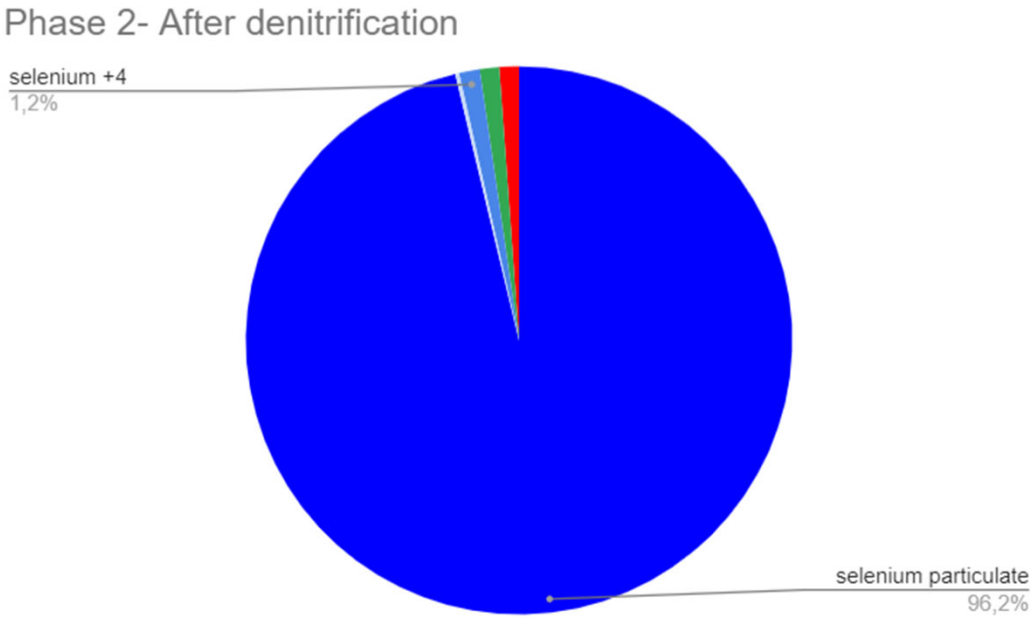

Phase 2- Se_{in} = 350-400 ppb

Performance

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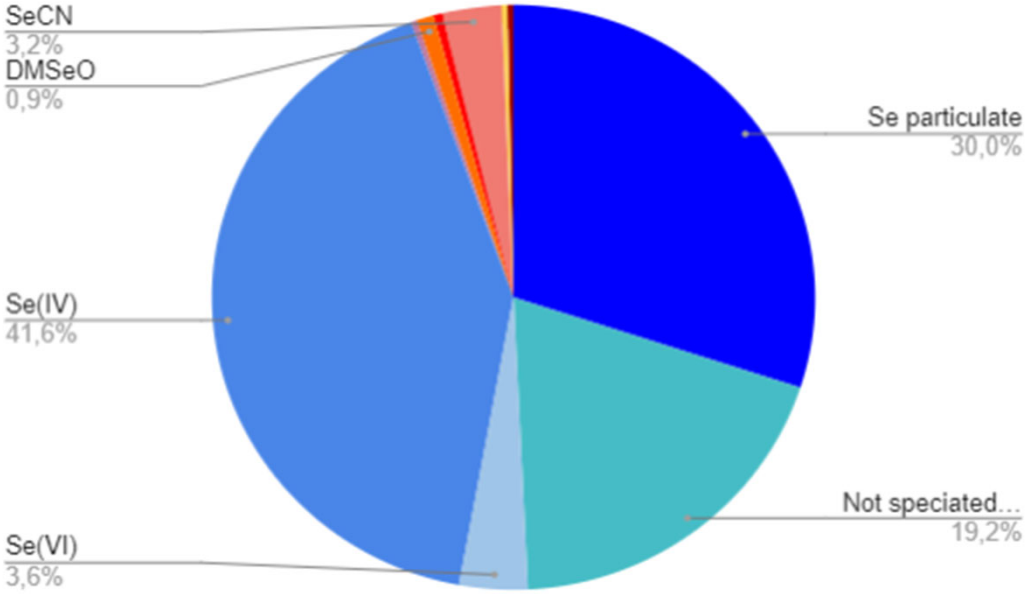
Speciation of selenium at **final effluent**



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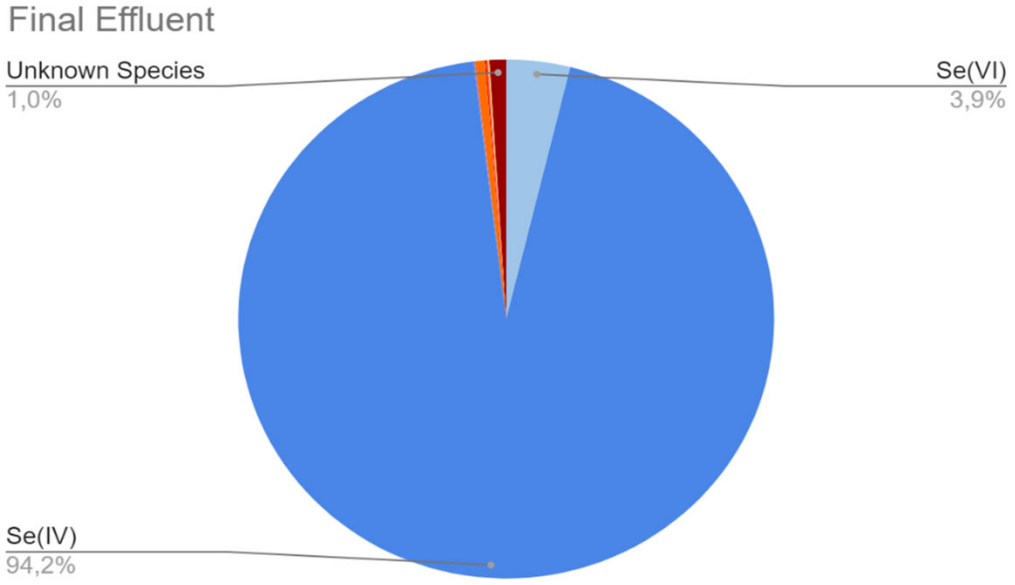

Phase 2- Se_{in} = 350-400 ppb

Tracer™ Se Performance Discussion

Good performance with Se_{in} < 400 ppb

Total Se dissolved < 5 ppb

Low final organic concentrations

Total Se Organic < 0.25 ppb

Take Away

- Importance of Se removal
- Many options are available, but none are universal
- Tracer™ Se: Combination of proven biological and physico-chemical treatments allowing Se_{diss} < 5 ppb

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Thank you

more information:

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