Geosyntec consultants

# Innovative Strategies for the Management of Metal Impacted Waters

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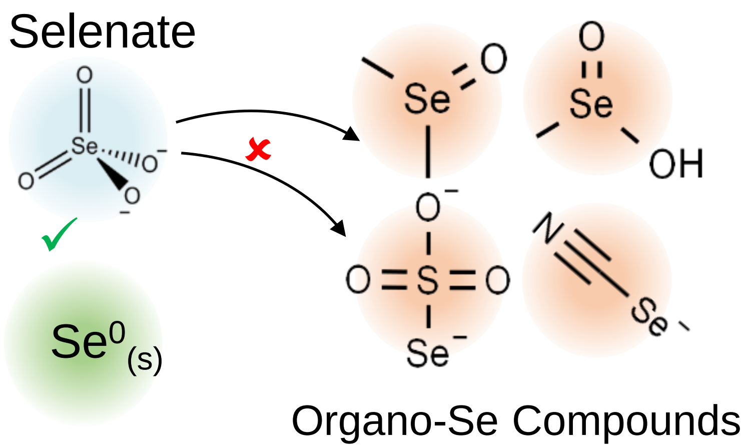
# Water Treatment Challenges

- Constituents
- Treatment
  - Risks of secondary constituent generations
  - Physicochemical vs. biological treatment
  - Regulatory drivers
- Conditions
  - Remote locations
  - Climate conditions
  - Variable flow rates

| Constituents | Examples |
|---|---|
| Heavy metals | Cd, Pb, Hg, Tl, Ni, Co, AMD |
| Metalloids | Se, As, Te |
| TDS | $SO_4$, $CaCO_3$, Mg, Zn |
| Toxicity concerns | Cyanide, TDS, organo-Se |






# The Role of Innovation

- Innovation is the second most important growth strategy
- Cost for compliance
  - Scale is large, $/Liter is increasing
  - More stringent, complex effluent limits
  - Difficult to treat metals (Se, Ni, Ze)
  - Remote sites, harsh climates
- Environmental, social governance and sustainability
  - Water and energy consumption, waste generation
  - Climate change
  - Community relationships and environmental conservation

**Active Water Treatment**


**Highly engineered**

High cost (capital, O&M)

Daily staffing

Footprint constraints

Large power demand

**Innovative Technologies**

**Passive Water Treatment**


**Less engineered**

Lower cost

Footprint constraints

Reliability and seasonality

Sustainability

# Innovative Treatment Examples

Gravel Bed Reactors (GBR) –
Biological Se, $NO_3$

GBR – Chemical
As, pH and other metals

Constructed/Engineered Wetlands
Cu, Pb, Zn

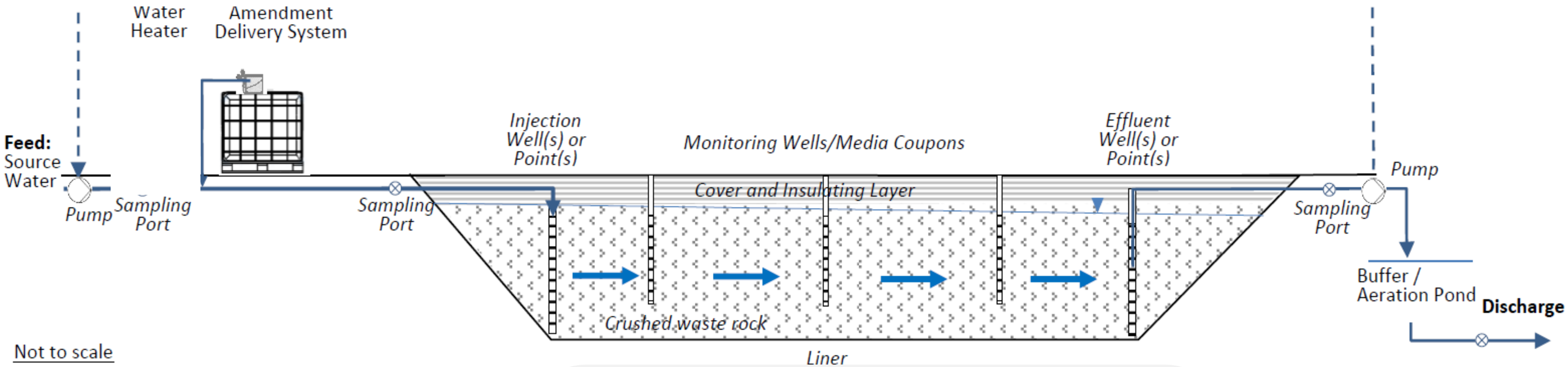
In-Pit Treatment
Ni, Co, Se, $NO_3$

TreeWell® Treatment
Se, Hg, Mn, Ni, Cd, Co, Zn, $SO_4$, $NO_3$

Permeable Reactive Barrier
(PRB) – ZVI Cr(VI)

# Gravel Bed Reactors (GBR)

***GBR as a solution for inorganics, pH adjustment, and metal/metalloid treatment***



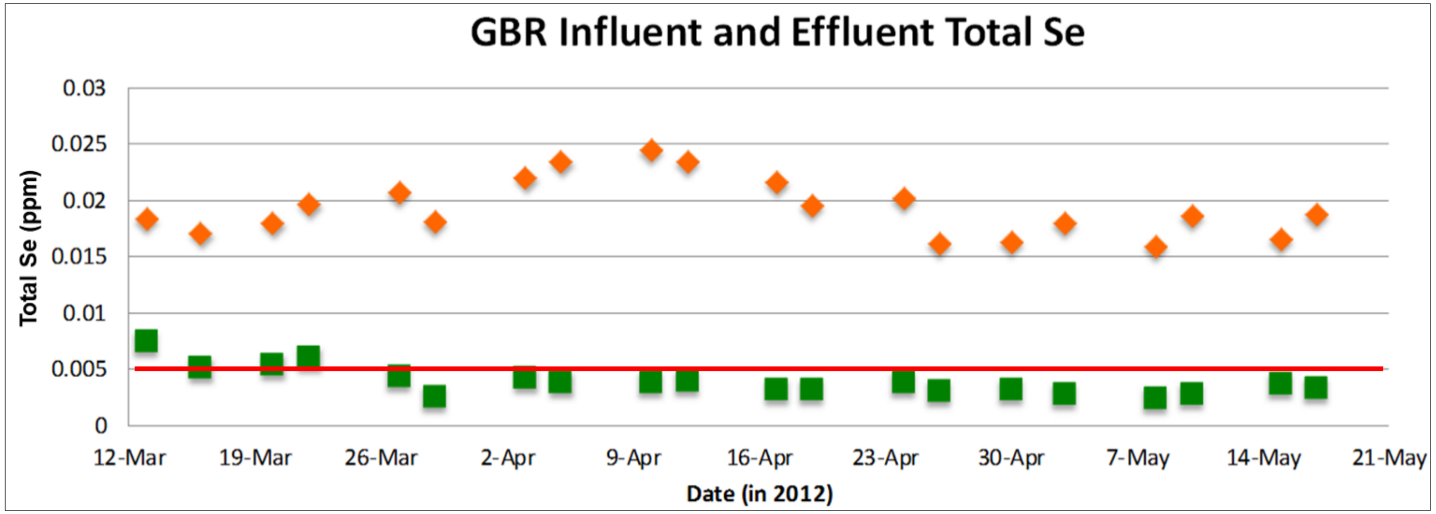



# GBR Advantages

- Can be place proximal to sources
- Predictable control of flow and residence time
- Inexpensive monitoring infrastructure – automation possible
- Easy integration of biofouling controls and rehabilitation measures
- Hydraulic isolation from surrounding environment
- Cold climate operation possible

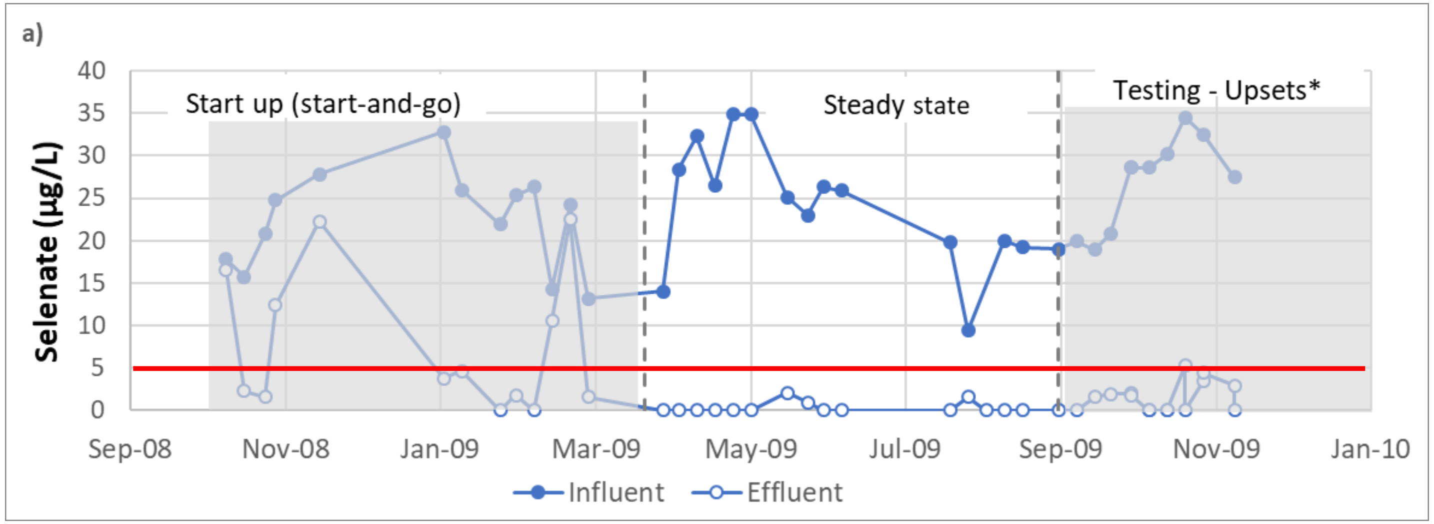

# GBR Examples


Coal Mine – Se and $NO_3^-$





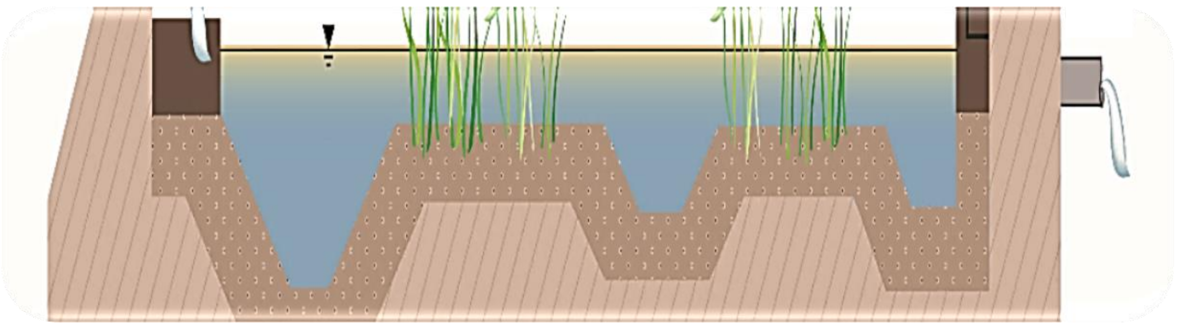
Urban Stream – Se and $NO_3^-$



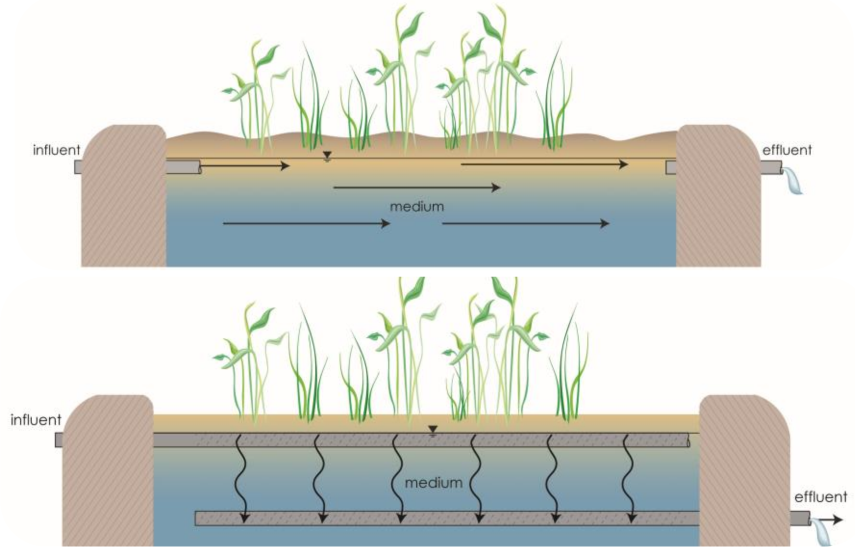
# Constructed Wetlands

***Solution for treatment of metals and inorganics***

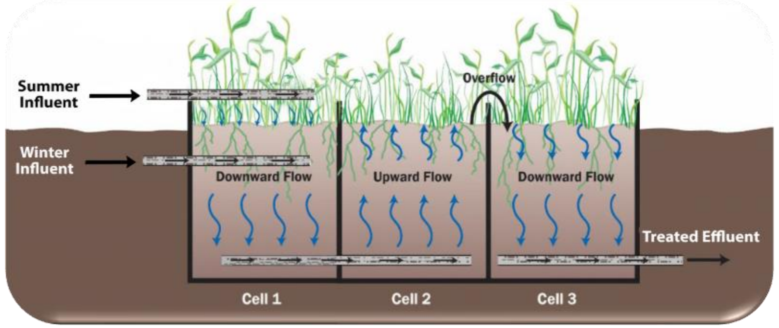
- Surface flow wetlands
  - Aerobic processes
    - Nitrification of ammonia
    - Aerobic biodegradation of organics
    - Precipitation of metals as carbonates, oxides and hydroxides

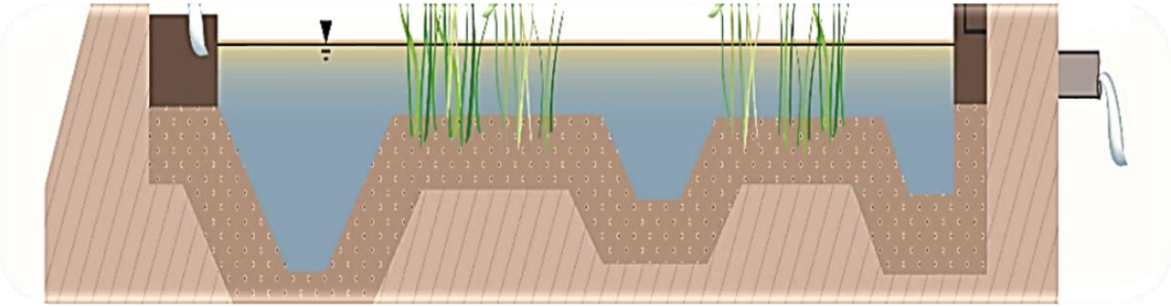


- Subsurface flow wetlands (horizontal and vertical flow)
  - Aerobic and anaerobic processes
    - Denitrification of nitrate to $N_2$
    - Precipitation of metals as sulfides



# Constructed Wetlands Comparison



| Efficacy Category | Hybrid Vertical Subsurface Flow Wetland System | Surface Flow Wetland |
|---|---|---|
| Cold Climate / Seasonal Treatment | Yes | Limited |
| Long Term Stability | Adaptable design with isolated treatment mechanism | Limited |
| Operation and Maintenance | Low; passive | Low; passive |
| Treatment Flow per Unit of Land Area | High | Low |
| Footprint | Mid | Large |
| Cost for Implementation | Mid | Low |
| Power Demand | Low | Low |
| Isolated Treatment Cells | Yes | Yes |

# Constructed Wetland Examples

- Constructed wetland
  - Landfill leachate sites
  - Pilot (Wetland on Wheels) and full scale for high strength leachate
  - Operation in cold winter
- Hybrid passive water treatment system
  - Metals-impacted water; Silver Mine, Western USA
  - Series of passive technologies: sulfate-reducing bioreactor followed by constructed wetlands as a polishing system
  - Cd, Cu, Fe, Pb, Mn, Ni, Ag, and Zn
  - Remote, high altitude environment; cold temperatures, high variability in flow and metals concentrations



| Parameter | Removal |
|---|---|
| Alkalinity (mg/L) | 69% |
| TKN (mg/L) | 96% |
| TSS (mg/L) | 94% |
| Cd (mg/L) | 72% |
| Se (µg/L) | 52% |
| Zn (mg/L) | 86% |

# In-Pit Treatment

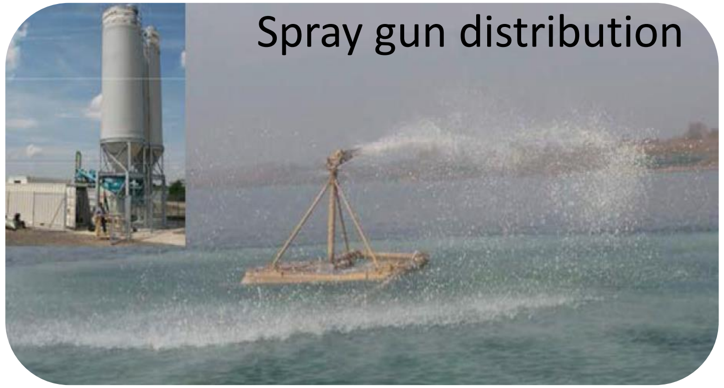
***Solution for treatment of metals and acidic water***

- Chemical amendment to pit-lake
- Treatment of legacy pit-lakes
- Most common treatment is lime application
- Increase pH causing precipitation of metals


# In-Pit Treatment Advantages

- High treatment throughput
- Multiple options for amendment application (pipeline, jets, sprays)
- Treatment can be automated
- System can be re-used for subsequent pit-lake treatment
- Pit lake stratification







Scholz, E. et al., In-lake neutralization of post-mining lakes, LMVB, 2017

# Full Scale Applications

| Lake Name | Distribution Method |
|---|---|
| Berkeley Pit-Lake | Shore-based plant, lime applied using pipeline |
| Meirama Mine Pit-Lake | Liming of influent stream |
| Rävlidmyran Pit-Lake | Lime injected through a pipeline from trucks |
| Lake Senftenberg | Lime applied using hopper barges without mixing |
| Lake Geierswalde | Resuspension of lime from bottom of pit-lake and applied using sprinklers |
| Lake Bockwitz | Soda applied into the lake using air/solid mixture injection |
| Lake Hain | Shore-based plant, slurry applied using sprinklers and distributed via lake convective currents |
| Lake Bernstein | Limed using a commercial barge and underwater pipeline |
| Lake Scheibe | Shore-based plant for application of lime slurry and $CO_2$ for buffering |
| Lake Nero | Shore-based plant used to create slurry and applied via pipeline |

Gammons, C. H., & Icopini, G. A. (2020). *Mine Water and the Environment*, *39*(3), 427–439


# From Innovation to Implementation

***Stakeholder and Rightsholder Engagement***

***Environmental Permitting***

SiREM
Leading Science · Lasting Solutions

| Laboratory | Field Pilot | Demonstration | Full Scale |
| --- | --- | --- | --- |


# Permitting Innovation

**Stakeholder & Rightsholder Engagement**

**Environmental Permitting**

Technology → Treatability → Field Pilot → Demonstration → Full-scale

**Technology**
- Options evaluation & selection
- Identification of key uncertainties
- Formation of workgroups, innovation workshops with stakeholders and rightsholders

**Treatability**
- Proof of concept
- Test uncertainties (mechanism, fundamental science)
- Test materials/leachate testing
- Share results

**Field Pilot**
- Design to be minimal risk or no dependency on permitting
- Mitigation options
- Focus on addressing site specific technical uncertainties
- Share reporting

**Demonstration**
- At reasonable scale
- Expt'l design plan including stress testing
- Addressing design, construction uncertainties
- Third party review

**Full-scale**
- Phased approach for different site conditions

# Water Treatment – Closing Thoughts

- Innovative, passive treatment provides potential solutions for a variety of impacts
- Innovative, passive treatment is estimated to cost ~50-70% of CAPEX and ~25-40% of OPEX costs compared to active treatment systems, depending on site conditions
- Supports ESG and integrated management and closure approaches
- Key to success…collaboration and early engagement

| Chemicals of Concern | Gravel Bed Reactor | Wetland | TreeWell® | Permeable Reactive Barrier | In-Pit Treatment |
|---|---|---|---|---|---|
| pH (acidity) | ✓ | ✓ | | ✓ | ✓ |
| Alkalinity | ✓ | ✓ | | ✓ | ✓ |
| Suspended Solids | | ✓ | | | |
| Nitrate, Phosphate | ✓ | ✓ | ✓ | ✓ | ✓ |
| Metals | ✓ | ✓ | ✓ | ✓ | ✓ |
| Metalloids (Se, As) | ✓ | ✓ | ✓ | ✓ | |
| Cr(VI) | ✓ | ✓ | ✓ | ✓ | |

# ADDITIONAL RESOURCES

## For more information, please visit

***www.geosyntec.com***

***www.geosyntec.com/webinars***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QUESTIONS?