Efficient ex-situ salt-impacted soil remediation technology

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Salt-Impacted Soil: Current Solutions

- Passive remediation with calcium amendment (e.g.: weeping tile)
  - Slow (several years) and variable efficiency
  - Surface treatment approach with little control
  - Possibility of recontamination (upward capillary movement and off-site migration)
  - Ineffective for mixed contamination (PHC and salt)
- Off-site disposal
  - Limited by the distance to the landfill
  - Non-sustainable solution
- Electrokinetic
  - Still to be proven at full-scale (technico-economical efficiency)
- Phytoremediation
  - Not suitable for many salt-impacted sites
  - Long-term process that requires extended site monitoring

Biogenie’s Salt-Impacted Soil Treatment Process

- Based on Biopile technological platform
- Ex-situ Engineered Leaching Process
  - Engineered cation exchange process
- Single Technological Platform
  - Mixed contamination is sequentially treated on same treatment platform (Biopile switched to leaching pile)
- Based on a deep understanding of the contaminant, soil characteristics and involved physico-chemical phenomena
  - Assess applicability of the technology
  - Optimize leaching and avoid clay dispersion (clogging)
  - Design an optimized soil leaching technology
Salinity Characteristics

- The process solubilises precipitated ions and mobilizes dissolved ionic species (reduction of EC and chloride)
- Cation exchange reaction displaces adsorbed Na\(^+\) from clay particles (reduction of SAR and ESP)

<table>
<thead>
<tr>
<th>Salinity</th>
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<tbody>
<tr>
<td>Precipitated</td>
</tr>
<tr>
<td>Dissolved (in soil water)</td>
</tr>
<tr>
<td>Adsorbed (CEC)</td>
</tr>
</tbody>
</table>

- CaMg(CO\(_3\))\(_2\)
- CaCO\(_3\)
- CaSO\(_4\)
- KCl
- MgSO\(_4\)
- Na\(_2\)SO\(_4\)
- Na\(^+\)
- Ca\(^+\)
- K\(^+\)
- Mg\(^+\)
- Cl\(^-\)
- SO\(_4^{2-}\)
- HCO\(_3\)
Biogenie’s Salt-Impacted Soil Treatment Process

Proprietary Know-how

- Biogenie has developed proprietary
  - Characterization protocols
  - Amendment mixes
  - Irrigation strategies
  - Process monitoring tools

- Patent application has been submitted (patent pending)
Biogenie’s Approach

ADVANTAGES

- Price competitive vs disposal to the landfill
  - As low as in the order of 50$/m³ for the treatment process
  - No long distance transportation required, nor importation of backfill
- Increase safety by decreasing truck traffic for an on-site approach
- Reach site-specific objectives within a 1-year timeframe (typically 2 months)
- Eliminate the use of imported backfill
- Low energy requirement
- In line with sustainable development
- Applicable on remote sites
- Better control of treatment parameters

Treatability Studies - Typical Results

- Reduction of EC and SAR achieved during different projects
- Final EC and SAR values are related to soil texture and soil chemical characteristics rather than to initial salinity levels

![Graph showing Electrical Conductivity (EC) and Sodium Adsorption Ratio (SAR)]
Treatability Studies – Leaching Kinetic

- Typical salt removal evolution during column trials as expressed by leachate electrical conductivity and sodium concentrations
- Reduction of EC and sodium display similar trend for different types of soil and degree of contamination
- Salt leaching kinetic is affected by soil texture, amendment dosage and initial EC and SAR values.

Soil Piling

Soil 1

Soil 2
Demonstration

- Demonstrations highly successful
  - EC, SAR and chloride reduction. Chloride mass balanced matched (from soil to water)
- Increased efficiency with improved irrigation system (#2)
- Ready for full scale implementation

<table>
<thead>
<tr>
<th>Demonstration</th>
<th>Soil</th>
<th>Treatment strategy</th>
<th>Electrical conductivity (dS/m)</th>
<th>SAR</th>
<th>Chloride (mg/kg)</th>
<th>Initial soil rating*</th>
<th>Final soil rating*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Upstream Oil and Gas site # 5</td>
<td>Irrigation system# 1</td>
<td>Initial 20.8, Final 5.7, Reduction 73%</td>
<td>Initial 13.5, Final 3.8, Reduction 72%</td>
<td>Initial 4755, Final 834, Removal 82%</td>
<td>Unsuitable Unsuitable</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Roadsalt storage site # 1</td>
<td>Irrigation system# 1</td>
<td>Initial 14.4, Final 1.5, Reduction 90%</td>
<td>Initial 27.9, Final 3.6, Reduction 87%</td>
<td>Initial 2700, Final 184, Removal 93%</td>
<td>Unsuitable Good</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Roadsalt storage site # 1</td>
<td>Irrigation system# 2</td>
<td>Initial 15.5, Final 0.7, Reduction 95%</td>
<td>Initial 39.0, Final 2.0, Reduction 95%</td>
<td>Initial 3000, Final 29, Removal 99%</td>
<td>Unsuitable Good</td>
<td></td>
</tr>
</tbody>
</table>

* : Based on Alberta Tier 1 Soil and Groundwater Remediation Guidelines (ABENV, 2010) for subsol
Optional process water treatment

- Demonstration: 10 m³ of process water successfully treated using reverse osmosis
- Pre-treatment is required
- Treated water quality is good enough to be reused in the process
- Recovery ratio: up to 75%
- With such recovery, ratio water / soil (vol/vol) as low as 0.2

Water Supply and Disposal Options

- Water supply options
  - Dugout
  - Surface water
  - On-site well
  - Municipal water
  - Imported on site
- Water disposal options
  - Sewer disposal
  - Well injection
  - Brine reuse
  - Treated water surface disposal / reuse
Commercial implementation

- Under commercial implementation phase with several oil and gas clients
- Example of full scale implementation for an oil & gas client (proposal submitted)
  - Design and implementation of a 10,000 m³ capacity treatment cell on a former gas plant as a semi-permanent soil treatment facility
  - Excavation and treatment of 10,000 m³ of salt-impacted soil collected from a nearby well site
  - Treated soil stockpile for future backfilling purpose
  - Water supply and disposal from on-site wells (injection well already on-site)
  - Total potential volume to be treated of at least 75,000 m³ (in-situ volume)
  - CAPEX cost as low as approx. 4-5 $ / m³ (amortized on 75,000 m³)
  - OPEX (process only) in the order of 50 $ / m³

Conclusions

- Biogenie as developed efficient ex-situ salt-impacted soil treatment process
- Process has demonstrated its technical, financial and regulatory efficiencies
- Patent application has been submitted (patent pending)
- Under full scale commercial implementation
- Semi-permanent or permanent soil treatment facility (STF) present the best advantage for the client
- Supported by a robust commercial and technical know-how of STFs operation
  - Biogenie’s network of 22 STFs through Canada, France and UK, where more than 1.5 million tonnes of organic pollutant-impacted soil are decontaminated every year.
- R&D initiated to measure its implementation in an in-situ configuration
Question?