In-situ Biotreatment of Airport De-icing Fluid

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Background

- 2001 relocated central deicing facility (CDF)
- Cause for elevated concentrations investigated
  - Likely cause: Dripping off taxiing aircraft
- Not a concern before
- When pad location changed, glycol dripping off aircraft impacted the storm water that flows into the Rideau River
- Result – orders from both EC and MOE
Assessments

• Hydrogeological Study (Robinson Consultants)
  • To determine ground water flow direction and velocity

• Treatability Study (SAIC Canada)
  • To determine if natural attenuation would work
Hydrogeological Assessment

- OMCIAA selected the most suitable location (no future development potential)
- Confirmed:
  - GW flow to the north
  - GW flow speed $4.0 \times 10^{-2}$ cm/s or 4 yrs to the property boundary
  - Soil consists mainly of sand
- GW has been monitored for past two years: $2 \times 10^{-2}$ cm/s
Relative Locations
Solution

- Not attract wildlife (birds)
- Economical
- Little or no personnel resources
**In-Situ Bio**

- Will it work at this site?
  - Indigenous bacteria
  - Proper soil conditions
    - Nutrient level
  - Hydrogeology
Glycol

Ethylene Glycol
- Sweet, odourless, colourless liquid
- Toxic
- Easier to break down in the Environment

Propylene Glycol
- Tasteless, odourless, colourless liquid
- Non-toxic
- Remains in the Environment longer
Approach

- Bench scale (laboratory)
- Pilot scale
- Full scale implementation
Laboratory Experiments

- Soil nutrient level
- Capacity of indigenous bacteria to degrade glycol
- Aerobic or Anaerobic
- Time frame
Aerobic vs Anaerobic

- Traditional lagoons are aerobic
- In general: aerobic faster than anaerobic
- Different breakdown products
Simple Flask Test

- Actual soil at proposed site for infiltration bed was used as biodegradation medium and source of microorganisms
- Spiked glycol at an initial concentration of approx. 50 mg/l
- Both aerobic and anaerobic tests
- No nutrients added
Flask Test
Soil at selected site not likely to support sustained biological degradation of glycol if glycol impacted water is released into the infiltration bed as is.

Results

<table>
<thead>
<tr>
<th></th>
<th>Initial</th>
<th>Flask A (Aerobic)</th>
<th>Flask B (Aerobic)</th>
<th>Flask C (Anaerobic)</th>
<th>Flask D (Anaerobic)</th>
</tr>
</thead>
<tbody>
<tr>
<td>28 days</td>
<td>52 mg/L</td>
<td>53 mg/L</td>
<td>53 mg/L</td>
<td>53 mg/L</td>
<td>22 mg/L</td>
</tr>
</tbody>
</table>
Bioreactor Test

- Microbes from airport storm water sump
  - Exposure to glycol from de-icing pad
  - Sludge from storm sewer
- Nutrients (Mineral salts)
- Custom-made bioreactor –
  - aerobic and anaerobic operation
  - process parameter control
  - larger reactor volume.
Bioreactor Test results:

- Reactor is anaerobic after 5 days.
- Glycol concentration dropped below detection limit between 7 to 14 days.
- Visible active bacteria culture growth.
- Shows lag phase before glycol degrading anaerobic microbes become active.
Pilot-scale Test

- Mimic field groundwater flow and conditions
- Flow velocity: 15 mm / minute
- Temperature: between 8 and 12 C
- Air tight system with special sampling reservoir
- Nitrogen purge
- Actual sand from proposed infiltration bed site
GLYCOL BIOREACTOR FLOW DIAGRAM

- Bioreactor Column
- Chilled Water Cooling Jacket
- Pressure Gage
- Column Drain
- Low Flow Peristaltic Pump
- Nitrogen Gas In
- Temperature Control Valves
- Chilled Water Circulation Pump
- Chiller
- Sample Reservoir and Sight Glass
- Sample Port
- Air Lock Vent
- Temperature Controller
- Glycol Reservoir
- Air Lock

Column Schematic
Cooling coil and insulation
Nitrogen gas outlet
Temperature controller
Peristaltic pump
Reservoir tank
Sampling reservoir and valve
Test column
Pilot-scale Column Test System
Nutrient / microbe injection port
Pilot-scale Column Test Results

- 4 weeks system conditioning
- Injection of nutrients and microbes
- Between 10-21 days, glycol concentration dropped to below detection limit
**In-situ Glycol Bioremediation**

### Bench-Scale Results

<table>
<thead>
<tr>
<th>Day</th>
<th>Glycol (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>39</td>
</tr>
<tr>
<td>7</td>
<td>32</td>
</tr>
<tr>
<td>14</td>
<td>&lt;5</td>
</tr>
</tbody>
</table>

### Column Results

<table>
<thead>
<tr>
<th>Day</th>
<th>Glycol (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>182</td>
</tr>
<tr>
<td>10</td>
<td>163</td>
</tr>
<tr>
<td>21</td>
<td>&lt;5</td>
</tr>
</tbody>
</table>
Conclusion

• Able to biodegrade glycol in an anaerobic environment using indigenous microbes

• Soil at selected site not likely to sustain biological degradation of glycol if glycol is released into the infiltration bed

• Infiltration bed system should include nutrient and bacteria injection
Bioremediation System Design

- Septic field 130m X 5 m
- Flow diversion valve
- Stormceptor™ to collect oil and grit
- Capacity of 340 L/s
- Overflow to ground surface
- Containment berm
System design
OTTAWA INTERNATIONAL AIRPORT GLYCOL BIOTREATMENT SYSTEM SCHEMATIC

NOTES:
- BUG TRAYS TO BE 1m x 2m x 0.15m x 1.5mm THK. STAINLESS STEEL. QTY.5.
- BUG TRAYS ARE TO BE LOCATED BENEATH STANDPIPES 2, 3, 5, 7 & 9.
- PROVIDE SAMPLING WELL FOR BUG TRAYS LOCATED BENEATH STANDPIPES 2 AND 5.
Concentric Injection Pipe
System Specifics

- Five bacterial trays for inoculation
  - Monitoring ports for bacteria (pre-winter sampling)

- Injection piping for nutrients (salts) (weekly – winter)
  - Monopotassium phosphate
  - Ammonium chloride
  - Calcium chloride and
  - Magnesium chloride

- Monitoring wells (degradation of glycol and by-products)
Installation of ‘Bug’ Tray
Manifold Installation
Inoculation

• Initial Idea:
  • Collect bacteria from existing storm sewer
  • Add nutrients and ethylene glycol
  • Let acclimate
  • Re-inject acclimated bacteria into treatment system
Canadian Environmental Protection Act

- CEPA
  - New Substances Division
- NO!
  - Cannot re-inject any bacterial solution that has been modified *ex-situ* unless:
    - The exact bacterial consortium has been determined **and:**
    - The consortium is on the DSL **or:**
    - The new consortium has been *proven* to be benign
Plan ‘B’

- Collect bacteria from existing storm sewer
- Dilute in 200 litres of nutrient solution
- Re-inject into system
- Add glycol (dilute) to acclimate the bacteria
  - This was done a few weeks before to overcome the lag phase
Collection of sludge
Inoculation of Tray
Performance Monitoring

- Initially 5 monitoring wells (2003-2004)
  - To confirm GW flow and glycol degradation
  - To achieve a confidence level
- Monitoring for glycols, nitrate, sulphate, phosphate, ethanol, acetate, temperature and dissolved oxygen
- Monitoring done weekly
Monitoring Results

- Glycol degrades within a week
- By-products are ethanol, acetate, methane
- Ethanol degrades very rapidly
- Methane not-encountered
- Acetate degrades within 6 months (low concentrations)
1st Year Results

BH-05

mg/L

Days

Glycol  Ethanol  Acetate
Results over 3 years at 40m from infiltration bed
Results after 3 years 6m from infiltration bed
Conclusions

• System appears to have become more efficient in second year of operation
• Glycol degrades readily when the system is enhanced with local bacteria
• Regulators are very satisfied with the system
• System cost $400,000
• Operational cost $50,000/year to date
Conclusions

- Bench testing valuable
  - Initial approach for an aerobic system too energy intensive
  - Defined minimum operating parameters
- Be Flexible /Adaptable
  - Inoculation technique had to be modified to meet regulations
- Bioremediation best when simple
  - Original design utilized a series of injection points and pumps – new system single point, gravity feed
Injection
Next Steps and Goals

• As knowledge gained, reduce monitoring and injection events

• Ultimate Goals
  • Self sustaining system
  • Monitoring quarterly only
System Photo