In-Situ Formaldehyde and PHC Spill Response (a Case Study)

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Agenda

• What is Formaldehyde?
• The Spill
• Bench & Pilot Results
• Full Scale Clean-up
• Questions
Formaldehyde

- Both naturally occurring and produced by humans
- In 2012, the global production >42 million MT
- $145 billion: 2003 formaldehyde & derivative products sales
  - 1.2% of the gross domestic product (GDP) in the USA & Canada
- Uses
  - Resins: pressed wood products - particle board, plywood paneling (furniture and cabinets)
  - Wallpaper, cardboard
  - Paints, adhesives, varnishes and floor finishes
  - Textile: resins used to make fabrics crease-resistant
- In 2011, the US National Toxicology Program described formaldehyde as "known to be a human carcinogen"
Formaldehyde

• 30 mL (1 oz) of a solution containing 37% formaldehyde has been reported to cause death in an adult human
• No established clean-up guideline
• Maximum Acceptable Concentration (MAC) for drinking water of 350 ug/L has been suggested
• Health Canada Guidelines (air):
  – 123 ug/m3 (100 ppb) for one hour
  – 50 ug/m3 (40 ppb) for eight hours
• **What is the danger?**
  – Formaldehyde quickly breaks down in air (UV light)
  – At low concentrations: human body can process
  – Danger exists at high concentrations
“Fifteen short seconds changed our lives”, local resident
Project History

- May 21, 2012, 8:30 am: Truck carrying ~35,000 L of heated waste formaldehyde overturned on hwy 63 in North Bay.
- Formaldehyde and diesel (fuel) released.
- Cascaded down embankment, along a secondary road, through a culvert, and down to Trout Lake.
  - Trout Lake supplies drinking water to North Bay
- Truck driver died. Cottagers who tried to stop the spill brought to the hospital.
- Residents from 30 properties were evacuated.
- Drinking water ban.
Project History

City of North Bay
Project History

Truck Overturned
Post-Excavation Concentrations

Legend:
- ROAD EDGE
- EXCAVATION COMPETED (APPROX.)
- DRIVEWAY
- HOUSE FOOTPRINT
- SMW MONITORING WELL (SHALLOW)
- DMW MONITORING WELL (DEEP)
- UTILITY POLE (HYDRO/BELL)

Site features and dimensions approximate only; drilling locations completed as boreholes not shown.

Phenol (gw)

Formaldehyde (gw)

PHC Impacts (soil)

Release

Highway 63
# Post-Excavation Concentrations

<table>
<thead>
<tr>
<th></th>
<th>Concentration</th>
<th>Clean-up Goal</th>
<th>% Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formaldehyde (shallow gw)</td>
<td>3,050,000 ug/L</td>
<td>&lt;10 ug/L</td>
<td>99.9997%</td>
</tr>
<tr>
<td>Formaldehyde (bedrock)</td>
<td>600,000 ug/L</td>
<td>&lt;10 ug/L</td>
<td>99.998%</td>
</tr>
<tr>
<td>Formaldehyde (surface water)</td>
<td>487,000 ug/L</td>
<td>&lt;10 ug/L</td>
<td>99.998%</td>
</tr>
<tr>
<td>PHC (F2)</td>
<td>~2,500 mg/kg</td>
<td>150 mg/kg</td>
<td>94.0%</td>
</tr>
</tbody>
</table>
Project Approach - Vertex

- Review project data to date
- Bench Scale Test
  - Purpose: confirm oxidant will destroy formaldehyde
- Pilot Scale Test
  - Field-based test
  - Verify the injection rate and oxidant distribution
- Full-Scale Remediation
Bench Scale Results
Bench Results

• Collected groundwater from Site wells
  - Transported to Vertex laboratory

• Set-up Bench Test
  - Control (groundwater sample, “worst case”)
  - 2.3% Unactivated Hydrogen Peroxide
  - 2.3% Activated Hydrogen Peroxide
  - 6.3% Activated Hydrogen Peroxide

• Sampling Times (Day 0 – dose groundwater samples)
  - Day 0
  - Day 1
  - Day 5
Formaldehyde Concentration (µg/L) vs Time (days)

- Control - no oxidant
- Test A - 2.3% oxidant, no activator
- Test B - 2.3% oxidant, activator
- Test C - 6.4% oxidant, activator
Formaldehyde Concentration (ug/L) vs. Time (days)

- **Control - no oxidant**
- **Test A - 2.3% oxidant, no activator**
- **Test B - 2.3% oxidant, activator**
- **Test C - 6.4% oxidant, activator**
Pilot Scale

Purpose:
- Assess equipment access
- Test Injection Well design
- Measure injection flow rate and pressure
- Estimate Radius of Influence (ROI)
Pilot Scale

Injection Well Layout

N

IWZ3-4

3 m

IWZ3-3

IWZ3-1

2 m

IWZ3-2
Pilot Scale
Pilot Scale
Pilot Scale

Results:
- 2 Pilot plots tested
- Injection Wells
  - installed successfully
  - some issues with cobbles
- Flow rate and pressures
  - Gravity Feed: 10 litres per minute
  - Pump: 30 litres per minute at 15 psi
- Radius of Influence (ROI)
  - see next slide
Full Scale

Formaldehyde:
- Treatment of impacted groundwater
- Injection into wells and temporary injection points

PHCs:
- Treatment of unsaturated soils
- Injection into temporary injection points

Approach
- Injection wells installed in stages
  - ~5 m spacing between Injection Wells within a Reactive Zone
  - ~20 m spacing between Reactive Zones
  - Fifty four (54) vertical wells installed in three (3) Reactive Zones
  - Eight (8) horizontal wells installed under roadway
- Injections every 3 to 4 weeks (peroxide)
Full Scale
Post-Excavation Concentrations
Full-Scale Results
PHCs Treatment
- Percarbonate (RegenOx)
- 2 Applications
- PHCs <150 mg/kg
- Soils clean for PHCs
Formaldehyde Concentration (ug/L)

- SMW-6
- SMW-8
- SMW-12
- DMW-3
- Spill Event
- First Full-Scale Inj

Dates:
- 15-May-12
- 1-Dec-12
- 12-Oct-12
- 11-Mar-13
- 19-Jun-13
- 8-Aug-13
- 27-Sep-13
- 5-Jan-14
- 24-Feb-14
- 15-Apr-14
- 4-Jun-14
- 24-Jul-14
Post-ISCO Formaldehyde Conc.
Conclusions:
- **Excavation**
  - Very expensive, but excellent for soil removal
  - In-situ remediation was required for groundwater impacts
- **In-situ injection completed under planned approach**
  - Selection of appropriate oxidant
  - Testing at bench
  - Confirmation at pilot
  - Modifications during full-scale
- **Results**
  - Overall: >97% reduction in plume size
  - Overall: >99% reduction in concentration
  - SMW-12 gw conc 3,050,000 ug/L to <10 ug/L
  - Combined digging and ISCO works
Questions?

Thank You for Your Time

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