In-Situ Remediation Strategy Applied to Military Firing Positions Contaminated with Energetic Materials

Isabelle Poulin, Defence R&D Canada - Valcartier

33rd AMOP Technical Seminar on Environmental Contamination and Response

June 7, 2010
**Title:** In-Situ Remediation Strategy Applied to Military Firing Positions Contaminated with Energetic Materials

**Performing Organization:** Defence R&D Canada - Valcartier, 2459 Pie-XI Blvd North, Quebec (Quebec) G3J 1X5 Canada

**DISTRIBUTION/AVAILABILITY STATEMENT**
Approved for public release; distribution unlimited

**ABSTRACT**

**SUBJECT TERMS**

**SECURITY CLASSIFICATION:**
- REPORT: unclassified
- ABSTRACT: unclassified
- THIS PAGE: unclassified

**LIMITATION OF ABSTRACT:**
Same as Report (SAR)

**NUMBER OF PAGES:** 19

**NAME OF RESPONSIBLE PERSON:**

---

*Standard Form 298 (Rev. 8-98)*

Processed by ANSI Std Z39-18
Outline

• Soil contamination
  – Firing Position
  – Target Area
  – Problematic
  – Decontamination techniques
• Goal of this research project
• Tests
  – Heat penetration tests
  – Small scale tests (laboratory)
  – Large-scale test (CFB Gagetown)
• Conclusion
Soil Contamination

• All military personnel have the responsibility to maintain a high standard of training, including weapons with live munitions

• Training on relatively small sites

• Contamination with residues of explosive materials accumulate:
  – Firing positions: incomplete combustion of gun propellant (70% of overall contamination in the first 20 cm of soil)
  – Target areas: dispersion of the explosive filling
Contamination at Firing Positions

- Example: Carl Gustav 84 mm antitank weapon

Deposition studies: 14% (w/w) of unburned NG deposited behind the gunner
Contamination at Firing Positions

- Example: Legacy sites

After 25 years of inactivity:
> 4 000 mg/kg NG on soil surface.
Detection of NG up to 1 m deep.
Contamination at Target Areas

- Example: Unexploded ordnances (craking, corrosion) and low-order detonations
Problematic

- Some compounds:
  - Toxic
  - Persistent
  - Affect soil and water resources (fate and transport)

- Massachusetts Military Reservation (MMR) closed in 1999 by an order of the US EPA because of RDX contamination in the drinking water of the neighbourhood

- Regular maintenance of decontamination of the surface soils could reduce the environmental impacts
Decontamination Techniques* (Non-Exhaustive)

- Biological treatments
  - Aqueous phase bioreactor treatment
  - Composting
  - Landfarming
  - Phytoremediation
  - White rot fungus treatment

- Thermal treatment
  - Hot gas decontamination
  - Incineration (rotary kiln, deactivation furnace)

- Other techniques
  - Soil washing
  - Alkaline hydrolysis
  - Fire ecology (management of vegetation), prescribed burnings

Goal of the Research Project

- To develop a technique that would allow the remediation of contaminated soils by energetic materials at firing positions.

- Should be:
  - Simple
  - Applicable in-situ (i.e. without the removal of the soil for treatment)
  - Inexpensive

- Facts
  - Explosives are organic compounds, they have a relatively low decomposition temperature
  - No vegetation at firing positions
Destruction of Explosive Compounds

• Heat the soil beyond the thermal decomposition temperature of energetic materials
  – Combustion of a fuel which is:
    • Non-toxic (wildlife and plants)
    • Easy to manipulate
    • Possible to spread out and ignite
Heat Penetration Tests

Fuel tested:
- Ethanol
- Methanol
- Isopropanol
- Wood shavings
- Wood shavings soaked with ethanol
- Gelled methanol
- Gelled ethanol (home-made and commercial)
# Maximum Temperature Reached during the Burning of Various Fuels on Sand

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Maximum temperature at various depths (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 cm</td>
</tr>
<tr>
<td>Gelled ethanol (1.25 cm thick)</td>
<td>131</td>
</tr>
<tr>
<td>Gelled ethanol (1.25 cm thick) (duplicate)</td>
<td>106</td>
</tr>
<tr>
<td>Gelled ethanol (2.5 cm thick)</td>
<td>80</td>
</tr>
<tr>
<td>Gelled methanol (1 cm thick)</td>
<td>90</td>
</tr>
<tr>
<td>Wood shavings (3.8 cm thick)</td>
<td>25</td>
</tr>
<tr>
<td>Wood shavings (3.8 cm thick) soaked with ethanol</td>
<td>80</td>
</tr>
<tr>
<td>Ethanol (500 mL)</td>
<td>63</td>
</tr>
<tr>
<td>Isopropyl alcool (500 mL)</td>
<td>33</td>
</tr>
<tr>
<td>Methanol (500 mL)</td>
<td>28</td>
</tr>
<tr>
<td>1st cm of sand mixed with gelled ethanol (~ 1:1 v/v)</td>
<td>191</td>
</tr>
<tr>
<td>Home-made ethanol gel (with calcium acetate) (1.25 cm thick)</td>
<td>65</td>
</tr>
<tr>
<td>Home-made ethanol gel (with calcium acetate) (1.25 cm thick) (duplicate)</td>
<td>53</td>
</tr>
<tr>
<td>1st cm of sand mixed with home-made ethanol gel (with calcium acetate) (~ 1:1 v/v)</td>
<td>85</td>
</tr>
<tr>
<td>Activated carbon (50 mL) mixed with home-made gel (500 mL)</td>
<td>80</td>
</tr>
</tbody>
</table>
# Laboratory Tests: Burning of Selected Fuels on Contaminated Dry Soil

NG concentration in surface (0-1 cm deep) soil samples

<table>
<thead>
<tr>
<th>Thermal process</th>
<th>[NG] (mg/kg) before</th>
<th>[NG] (mg/kg) after</th>
<th>Reduction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5 cm gelled ethanol (commercial)</td>
<td>2365</td>
<td>557</td>
<td>76</td>
</tr>
<tr>
<td>Mix 1:1 ethanol (commercial) + contaminated soil</td>
<td>2548</td>
<td>152</td>
<td>94</td>
</tr>
<tr>
<td>5 min of propane burning</td>
<td>2480</td>
<td>1547</td>
<td>38</td>
</tr>
<tr>
<td>2.5 cm methanol gel</td>
<td>2075</td>
<td>1847</td>
<td>11</td>
</tr>
</tbody>
</table>
Large-Scale Burning

• Canadian Forces Base Gagetown
• Wellington range: active antitank range
• Gel spread and mixed with soil
• Samples taken before and after the burning
• Analyses by HPLC (in-house method based on EPA 8330b)
Burning Test at Wellington Range
### Efficiency of the Thermal Treatment at Wellington Firing Position

<table>
<thead>
<tr>
<th>Setup</th>
<th>Reduction % of the NG concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
</tr>
<tr>
<td><strong>Surface (0-1 cm deep) samples</strong></td>
<td></td>
</tr>
<tr>
<td>Gel poured directly on soil</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>60</td>
</tr>
<tr>
<td>Soil mixed (5 cm deep) before the gel was added and mixed in the softened soil</td>
<td>89</td>
</tr>
<tr>
<td></td>
<td>85</td>
</tr>
<tr>
<td>Soil mixed (5 cm) deep. Gel was poured on top</td>
<td>83</td>
</tr>
<tr>
<td></td>
<td>86</td>
</tr>
<tr>
<td><strong>Subsurface (2 cm deep) samples</strong></td>
<td></td>
</tr>
<tr>
<td>Gel poured directly on soil</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>49</td>
</tr>
<tr>
<td></td>
<td>-14*</td>
</tr>
<tr>
<td>Soil mixed (5 cm deep) before the gel was added and mixed in the softened soil</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>51</td>
</tr>
<tr>
<td>Soil mixed (5 cm) deep. Gel was poured on top</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>25</td>
</tr>
</tbody>
</table>
Results and Future Work

- Results: A gel-type fuel based on ethanol is efficient: more than 80% reduction of NG in the first 2 cm of soil.
- Most of the heat is directed upwards.
- Need to determine:
  - Gaseous emissions
  - Effects of: soil humidity, organic content, soil size fraction, presence of winds, temperature, etc.
- Procedure could be used on a regular basis to avoid build-up and transport in the deeper layers of soil.
- NOT a decontamination procedure for a large site and deep contamination.
Acknowledgements

- Canadian Forces
- Director Land Environment
- CFB Gagetown: R. Melancon, K. Keys, S. Downe, Corp. Legaarden, Corp. Cummings
- DRDC Valcartier: G. Nadeau, S. Trudel, H. Gagnon