Surfactants as enhancement of In Situ Alkaline Hydrolysis (ISAH) of pesticide DNAPL

Results of bench and pilot scale field tests

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**Surfactants as enhancement of In Situ Alkaline Hydrolysis (ISAH) of Pesticide DNAPL: Results of bench and pilot scale field tests**

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**Background**

Groyn 42 is a 20,000 m² former chemical dump site in Denmark contaminated with 100-200 tons of organophosphorus pesticides (OPPs). The majority of contaminant mass is present as sorbed phase and residual DNAPL. The NorthPestClean project was established to determine the effectiveness of using *in situ* alkaline hydrolysis to treat the DNAPL (Fig. 1).

The primary challenge was in situ mixing, establishing sufficient contact between hydroxide and DNAPL and surfactants were tested as 1 of 3 enhancement technologies at bench and pilot scale.

**Site and sampling**

Fig. 2: The site is located directly at the waterfront. Residual OPP DNAPL is widespread in hot spots.

Fig. 3: Sampling of site water and soil with visible DNAPL. Over 2½ years, more than 2000 water samples and 1200 soil samples were analyzed in NorthPestClean.

**Initial selection**

Previous work has identified non-ionic surfactants as the best performing type of surfactants for increasing OPP solubility. Ten non-ionic candidates were tested in bench scale, and equilibrium solubility tests showed that alcohol ethoxylate non-ionic surfactants was superior with respect to increasing OPP solubility compared to the alkaline tap water reference.

**Data representation**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Compounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUM OPPs</td>
<td>parathion (EP3), methyl-parathion (MP3), malathion, ethyl-sulfotep</td>
</tr>
<tr>
<td>SUM P2 acids</td>
<td>O,S-dimethylthiophosphoric acid (EP2), O,S-dimethylthiophosphoric acid (MP2)</td>
</tr>
<tr>
<td>PNP</td>
<td>para-nitrophenol</td>
</tr>
</tbody>
</table>

**Bench scale testing**

![Equilibrium DNAPL tests (30 g/L of surfactants)](image)

Fig. 4: Batch equilibrium tests of ethoxylate surfactants at pH 13 with a 10:1 surfactant:DNAPL volumetric ratio. Reaction time was 7 days.

**Pilot scale testing**

![10m](image)

Fig. 6: Pilot testing was completed in 10x10 m test cells (TCs) with TC2 used for testing of surfactants in cycle 3. 1600 kg Ecosurf EH-9 was mixed with extracted water in a 25% solution and added the 60 m³ effective pore volume of the targeted treatment area (TTA) resulting in a concentration of about 2.7%.

**Baseline ISAH**

![Screen 1](image)

Fig. 7: Results showed an increase in EP2 and a slight increase in hydrolysis products up to 1 year after surfactant addition.

**Surfactant-ISAH**

![Screen 1](image)

![Screen 2](image)

![Screen 3](image)

Fig. 8: Surface tension analysis showed an equal distribution of surfactant in the TTA of TC2.

**Conclusion**

Surfactant enhanced ISAH increased dissolved OPP concentration (x10) and total mass removal was 20-40% higher compared to baseline ISAH.