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*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

Groyne 42 is a 20,000 m$^2$ former chemical dump site in Denmark contaminated with 100-200 tons of **organophosphorous 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).

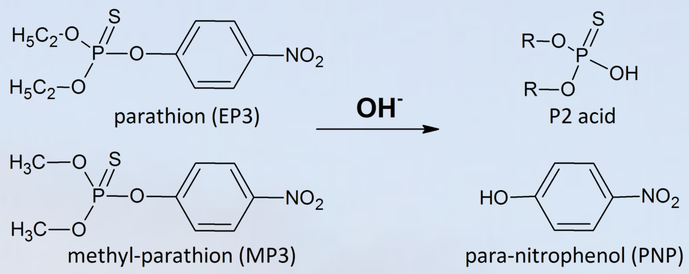



*Fig. 1: The alkaline hydrolysis of OPPs.*

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

| Parameter | Compounds |
|---|---|
| **SUM OPPs** | parathion (EP3), methyl-parathion (MP3), malathion, ethyl-sulfotep |
| **SUM P2 acids** | O,O-diethylthiophosphoric acid (EP2), O,O-dimethylthiophosphoric acid (MP2) |
| **PNP** | para-nitrophenol |

## Bench scale testing

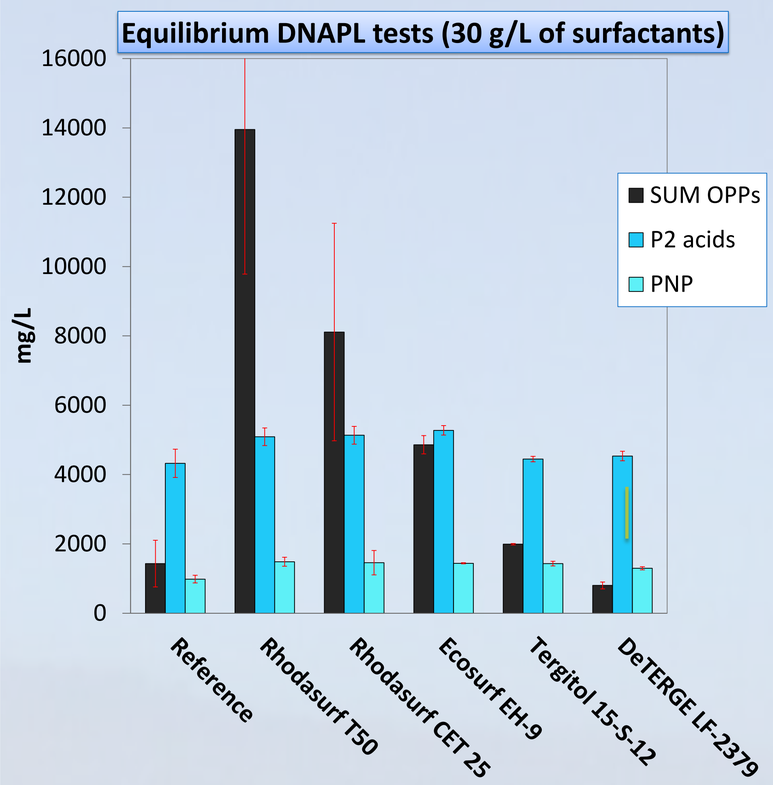



*Fig. 4: Batch equilibrium tests of ethoxylate surfactants at pH 13 with a 10:1 surfactant:DNAPL volumetric ratio. Reaction time was 7 days.*

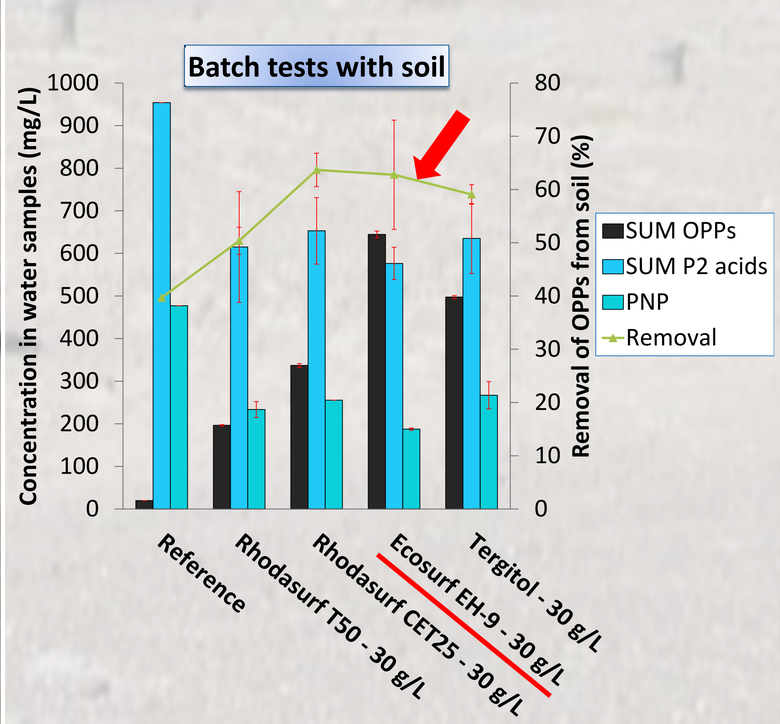
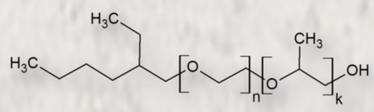



*Fig. 5: Bacth soil tests with contaminated soil / surfactant water ratio of 4 g/mL. No extra DNAPL was added. Results presented are aquesous concentrations and soil removal of four alcohol ethoxylates after 7 days of reaction at pH 13.*

**Ecosurf EH-9** was chosen for pilot scale testing due to best performance in soil test (lower soil sorption compared to Rhodasurf) and cost of the chemical (3-4 € / kg).



## Pilot scale testing

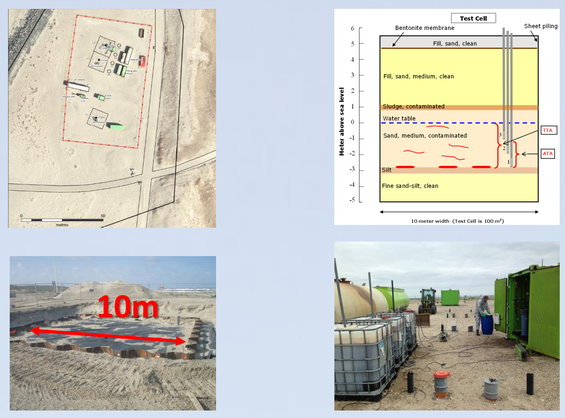



*Fig. 6: Pilot testing was completed in 10x10 m test cells (TCs) with TC2 used for testing of surfactants in cycle 3. 1600 kg Ecosurf EH-9 was mixed with extracted water in a 25% solution and added the 60 m3 effective pore volume of the targeted treatment area (TTA) resulting in a concentration of about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

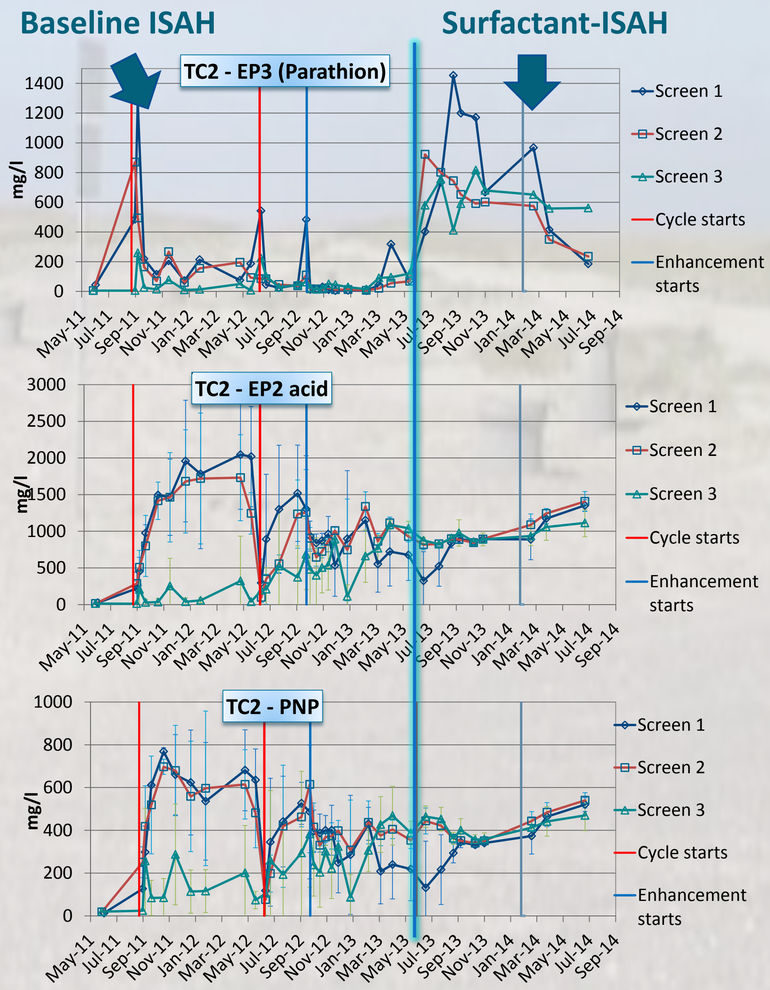



*Fig. 7: Results showed an increase in EP3 and a slight increase in hydrolysis products up to 1 year after surfactant addition.*

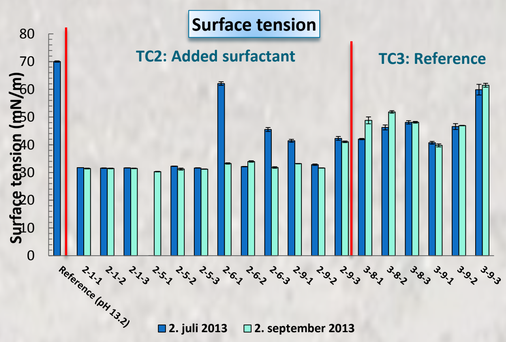



*Fig. 8: Surface tension analysis showed an equal distribution of surfactant in the TTA of TC2.*

## Conclusion

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