In-situ bioremediation of oil contaminated soil -practical experiences from Denmark

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Introduction

For a decade Cleanfield has remediated oil polluted soils using a technology built on adding microorganisms capable of degrading oil and stimulating the microorganisms already present in the soil. This is hence a combination of bioaugmentation and bistimulation. The technology is continuously optimized by taking the latest scientific results into account to ensure faster remediation. Besides from adding microorganisms to the soil we also optimize the conditions for the microorganisms in order for the degradation to proceed as fast as possible.

Inputs to efficient bioremediation

Bacteria

The most important input in our bioremediation approach is the oil degrading bacteria. We use a commercially available consortium of oil degrading bacteria, specially selected for their ability to degrade oil. The consortium consists of different bacteria with *Pseudomonas sp*. and *Rhodococcus sp*. as the most predominant.

Nutrients

The bacteria utilize the oil as an energy and carbonsource to build their biomass, but to do so they need additional inputs. The hydrocarbons in oil only contain the elements hydrogen and carbon and the essential nutrients N, P, K and micronutrients are therefore applied to the soil together with the bacteria to ensure optimal growth conditions.

Electronacceptors

Besides from nutrients the bacteria also require an electronacceptor. The most efficient degradation takes place under oxic conditions where oxygen is the electronacceptor:

$$C_{15}H_{32} + 23\ O_2 \rightarrow 16\ H_2O + 15\ CO_2$$

If the redox potential decrease other compounds like nitrate, sulphate and iron can also be used as electronacceptors, but because the energy output for the bacteria is less than when oxygen is used the degradation rate decrease and remediation takes a longer time.

Therefore, we thrive to maintain oxic conditions which is difficult. An efficient way to get oxygen into the soil is by injecting a dilute hydrogenperoxide solution. When the hydrogenperoxide gets into the soil the soil minerals catalyze the decomposition of hydrogenperoxide:

$$H_2O_2 \rightarrow \tfrac{1}{2}\ O_2 + H_2O$$

As can be seen above this leads to the formation of oxygen.

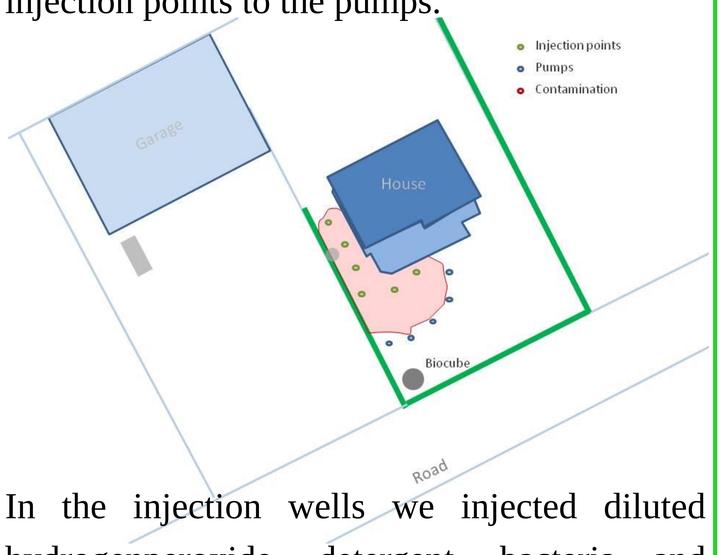
Detergent

The strong sorption of oil hydrocarbons in soil seriously limits the bioavailability and hence decrease the degradation rate. To enhance desorption we add a biodegradable detergent which by micelle formation and other mechanisms enhance bioavailability.

Case 1

Remediation of a minor recent heating oil spill mixed with an older contamination with heavier oil at a site with surface near groundwater, which is also contaminated.

We have installed six injection wells and five pumps. The groundwater moves from the injection points to the pumps.



In the injection wells we injected diluted hydrogenperoxide, detergent, bacteria and nutrients.

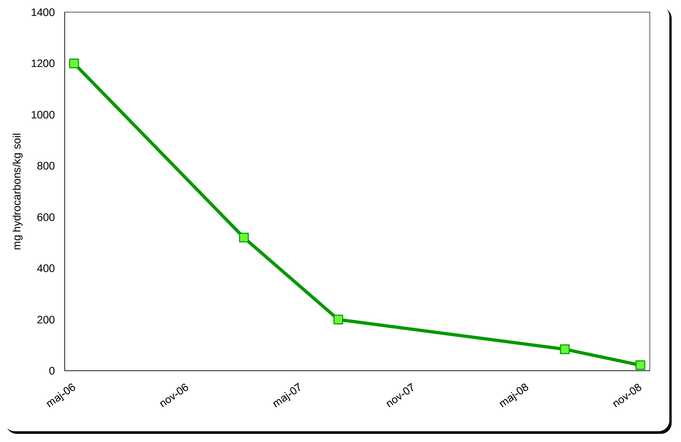
The groundwater is pumped from the soil to a biocube where bacteria degrade the oil so that the outlet water can be discharged to the sewer.

Within four months we have achieved more than a 50% reduction in the amount of oil present in the soil. The concentration in the water has increased demonstrating the desorption by the detergent.

Case 2

Remediation at a site with two heating oil spills. Before the remediation was initiated the first spill covered 120 m^3 with a max.concentration of TPH of 3400 mg/kg. The other spill covered 240 m^3 with max. 7500 mg/kg TPH.

The contamination has been treated by injecting diluted hydrogenperoxide, detergent, bacteria and nutrients through 13 injection wells since july 2006. Groundwater, which was also contaminated, was pumped from the ground and treated before dicharging to the sewer.



The project is now finished, and the above shows results from one of the monitoring points.

Conclusion

Efficient biodegradation requires input of:

- **Bacteria capable of degrading oil**
- **Nutrients for the metabolic processes of the bacteria**
- **Electronacceptors, preferably oxygen for the degradation**
- **Detergent to enhance bioavailability**

Our projects have demonstarted that bioremediation does work in real life.

Questions or comments?
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