Advanced In Situ Remediation Technologies in The Netherlands

Steam injection

Gasoline spill caused by corrosion of pipes; Groundwater Technology removes free product, soil and groundwater pollution by steam injection.

Gasoline spill in a difficult place
A gasoline spill occurred in an aboveground pipeline trench in August 2003. Under high pressure an unknown quantity of gasoline leaked into the soil. This resulted in a serious contamination consisting of a free product layer (LNAPL), groundwater and soil contamination. Complete excavation of polluted soil is not possible due to the high density of above and underground transport pipelines. Groundwater Technology was contracted to remediate the spill and is responsible for the design, construction, process monitoring and project management of the entire project.

Figure 1: Steam manifold

Step by step
Our approach is a step by step approach. In order to remove the LNAPL, we directly installed vertical free phase collection filters. Part of the contaminated soil, where feasible, was removed by excavation. The remainder of the contamination, is remediated with in-situ techniques. Dutch law requires the entire removal of the contamination due to the fact that the spill occurred very recently. The remaining contamination after excavation still showed very high concentrations (BTEX: 200 mg/kg d.s. and Mineral oil: 8000 mg/kg d.s.).

The availability of plant steam (produced by the client and used on the site for pumping services) combined with the product specifications of the spilled gasoline made it possible for us to select steam enhanced remediation as the most cost-effective alternative.

Site background
The groundwater table is about 4 meter bgs. The soil is fine silty sand. After excavation 200 m^3 contaminated soil required in-situ remediation.

Design of the steam enhanced remediation system

Figure 2 gives an schematic overview of the steam injection concept applied for this case. The remediation system consists of:

- vertical steam injection wells in the vadose zone;
- vertical groundwater extraction wells attached to a high vacuum extraction unit including cooling;
- horizontal soil vapor extraction drains.

In order to prevent the underground parts of the transport pipelines (still in use after repairs) from (over) heating, we designed and installed a layer of insulation material at the most crucial parts of the site. The maximum temperature of the soil in the direct neighborhood of the underground pipes was specified by the client to be 35 ^{o}C.

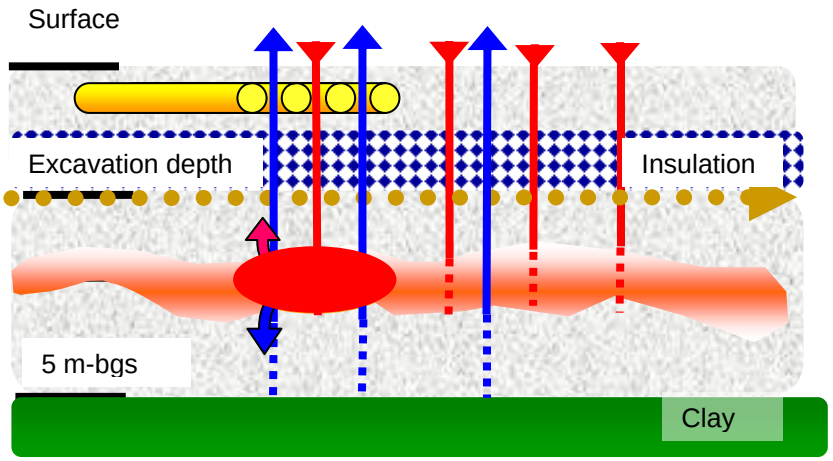

Figure 2: Scheme of steam injection

Monitoring
Process monitoring is the key to success for an in-situ remediation. To monitor the process we installed 15 temperature sensors at several depths and above the insulation layer. These sensors continuously monitor the temperature in the ground and allow us to regulate the steam injection flow. The steam injection is automated based on the temperature setpoints. Each temperature sensor has it's own alarm setpoint and hysteresis.

Results
Steam injection is automatically regulated so that the temperature in the treatment zone remains between a bandwidth of 80 to 90 ^{o}C. An estimated amout of 10 tons of contamination was considered to be present prior to the start of the remediation. Monitoring results indicate that more than 90 % of the contamination is removed within 5 months.

In the following month, the soil temperature was raised to 105 ^{o}C. The 'hot zone' remained confined to the intended zone that required remediation; inadvertent movement of steam outside of this zone did not occur. This demonstrated the controllability of steaminjection.

The final stage removed contamination to residual concentrations in the original free phase zone of less than 500 mg/kg.

Creosote case

A railway sleeper conserving site operated a creosoting installation ever since 1830. Spills of creosote soaked the soil with the product. Non-aqueous product is found at various depths, up to at least 15 m below grade. Excavation is no option: the impacted volume is far to large.
This case requires innovative in situ solutions. The clients consultant suggested to conduct a steam-enhanced remediation pilot project. For safety reasons (and to avoid creosote vapours escaping from the soil, the client requires that the ground surface a shallow groundwater remain cool.
Groundwater Technology's proposal was selected to carry-out the pilot.
The purpose of the pilot is two-fold:

1. to determine the effectiveness and operating parameters for a steam enhanced extraction process, and:
2. to determine the differences in cost-effectiveness between pump-and-treat and steam enhanced remediation

As contractor, we are responsible for the installation and operation of the project, which includes installation of wells, equipment, steam generation, process monitoring and control. A dense network of monitoring points is installed.

Solution

Steam is very effective to transport heat into the soil. Most processes run quicker at elevated temperatures. Free product removal is much more effective as a number of processes coincide. Viscosity decreases, allowing product to flow more freely. The partial vapour pressure increases, which leads to more product going into vapour phase. Solubility increases while sorption onto the soil matrix decreases. An automated and dedicated steam distribution system gives total control over injection pressure and monitors temperature at more than 100 spots.
Steam consumption, injection pressure and temperature at the injection points as well as temperature distribution throughout the pilot area, mass removal, volume of extracted water etc. etc. Is monitored

Results

The first month of operation (extraction only, no heat) removed approximately 300 grams of creosote, in dissolved form.
In the second month (heat enhanced remediation), we removed some 3000 kilograms of creosote. This was collected in the product collection unit and transported to a licensed waste handler.
Residual concentrations in the former free product zone were approximately 300 mg/kg soil.
Pump and treat costed approximately € 70.000,- per kilogram of product removed. Steam enhanced remediation costed only € 50,- per kilogram removed.

The land surface and the upper few meters of groundwater remained cool.

Figure 3: Heat distribution at maximum