Theme 1. Dealing with contamination of soil, groundwater and sediment
1c. remediation technologies and approaches

FULLY AUTOMATED ENHANCED BIODEGRADATION OF CHLORINATED ETHENES WITH AN ON SITE ANAEROBIC BIOREACTOR

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ABSTRACT:

Overvieuw

A special category of soil remediation covers sites that have been contaminated by the use of solvents, especially chlorinated ethenes. These contaminants can be removed by enhanced natural attenuation using the so-called TCE concept. Artificially cultivated bacteria (*Dehalococcoides ethenogenes, DHC*) with the required carbon source and nutrients are introduced into the soil in order to stimulate anaerobic degradation. The process can be controlled by constantly monitoring the influent, infiltrate and bioreactor streams for pH, oxygen and ORP. The strength of this concept lies in its relatively short active degradation phase with complete degradation of the chlorinated hydrocarbons to harmless end products.

The general remedial approach involves extraction, amendment and re-circulation of groundwater in the targeted aquifer zone. Extracted groundwater is passed through an anaerobic bioreactor to enrich the water with DHC. After filtration, the feed is infiltrated through injection screens or wells located up gradient of the treated zone. This anaerobic bioremediation approach can be applied in urbanized areas with limited site access to prevent site disruption and reduce impacts to the environment. This semi-passive method can expedite the time of remediation, compared to passive approaches. Over the last ten years, NTP Enviro has optimized the use of the bioreactor system in several bio-remediation projects, including the development of an automated application of the carbon source. The fully automated remotely controlled bioreactor system provides clients with a complete biodegradation of chlorinated ethenes.

Specifications

The system consists of a control unit, a bioreactor and a filtration and charging system. Once the DHC inoculum is added to the bioreactor, their growth is enhanced by feeding the system, until a cell count of 10^5 cells/ml is achieved. Bioreactor operating conditions include ORP levels of less than -300 mV, while oxygen levels are reduced to zero at a temperature of about 20 ºC. The bioreactor operates at an extraction/infiltration flow rate of about 10 m^3/hr. Depending on the size of a pore volume for the targeted zone, the system may be able to treat a site within a period of several months. Based on previous experiences, amendment of one pore volume of the targeted aquifer zone is sufficient for complete chlorinated ethenes treatment at most sites.

Process and performance monitoring

Monitoring our process and performance is crucial to the success of the enhanced bioremediation projects. Therefore, defined parameters such as oxygen concentration, pH, water temperature (ºC) and oxidation-reduction potential (ORP) are monitored continuously. When the parameters exceed threshold levels, the bioreactor is automatically switched off. Monitoring wells in the field are used to assess the efficacy of enhanced bioremediation. The design and operation of this in-situ system of extraction and infiltration can be adjusted depending on the volumes of groundwater to be treated, site specific circumstances and remedial targets to be met.

Technology application

Leakages that had occurred because of a former dry cleaner in the center of The Hague in The Netherlands left the shallow and deeper groundwater up to 15 m –gl contaminated with chlorinated solvents (PCE and TCE).

Soil properties, in the area of The Hague, are characterized by sediments of medium fine sand and heterogeneous intermediate layers of clay and/or peat. Groundwater contamination plumes had spread to a volume of 400,000 m^3 underneath private properties and form a thread for the deeper aquifers and the abstraction of drinking water.

We opted for a phased approach, with the infiltration and extraction filters all in the public road. The plume was divided into six successive steps which were provided with a carbon source and micro-organisms. After completion of the first phase, the extraction wells of phase 1 were used as infiltration wells for phase 2. This function shift is also applied in subsequent phases, for which a total of 55 wells are placed. The wells are placed in so-called pulse borings. The filter section of the wells was designed at 6-11 and 12-16 m -gl. On average, each filter with a capacity of 1.6 m^3/hr extracted and infiltrated a total of 10 to 12 m^3/h.

From the monitoring data, the following conclusions can be drawn:

- the remediation was performed in 525 days which, in the original planning, was estimated to take 540 days;
- the total infiltrated volume of 124,229 m^3 of groundwater is less than the planned 129,600 m^3. The adjustments that have been made during the active phase are the reason for this;
- the difference in the length of time between the various phases is the result of the differences in distance between the extraction- and infiltration wells.

After the bacteria and nutrients were introduced into the soil, the conditions for biological remediation improved, leading to the next results:

- cell copies DHC in the infiltration water $5.1 * 10^4$ / ml in a flow of 10 m^3 / hour;
- redox potential -475 mVolt;
- oxygen concentration 0 mg/l;
- increased DOC concentrations;
- decreasing chloroethene concentrations.

The contaminants are biologically degraded within the course of a few months to a few years at most. After this time the risks will have been removed and we are left with clean groundwater. The location in The Hague is situated in an urban area; even so, the entire remediation system could be placed without problems. All required wells and pipes were placed underground. The remediation unit was on-site for approximately sixteen months. This is very short when compared to more traditional remediation techniques. This also meant that the disturbance to the community was kept to a minimum. Furthermore, this technique is sustainable and environmentally friendly, as it requires very little energy and only natural nutrients are used. In a period of sixteen months, the bacteria and nutrients were introduced into the soil. A large portion of the contamination had already been entirely degraded in that time. The remediation project was therefore a great success.

Conclusions

The TCE treatment results in a complete degradation to ethane/ethane.

Using the fully automated telemetric system, it is possible to continuously control the pH, redox and oxygen in the groundwater.

Logging data indicated the working of the TCE unit with minimum human supervision and maximum efficiency.

TCE is a sustainable solution for large plume remediations in comparison to conventional techniques.

The project was completed in time, with no rebound observed and with no cost overruns.