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In situ bioremediation

Practical cases and projects

In this folder a number of practical cases are summarised in which biological in situ techniques have been applied for remediation of contaminated sites. In the last decade in situ bioremediation has developed into a robust alternative to the more conventional remediation techniques, such as excavation and groundwater extraction. Biological processes consume less energy and are therefore more sustainable when compared to other techniques. Bioremediation is often a cost-effective, yet robust and at times fast remediation approach.

Content

Rapid biological remediation of chlorinated solvents using the TCE technique

In sandy soils there is often only limited natural attenuation of chlorinated solvents. However, using biological processes still may be interesting since these are very sustainable (energy efficient). That is why, using the TCE concept, we help nature out by injecting the required micro-organisms and nutrients for degradation.

The TCE system consists of a bioreactor in a 30 foot container that is connected to a groundwater extraction and infiltration system. From the bioreactor the bacteria and nutrients required for the degradation of the contaminants are infiltrated into the soil where they are transported throughout the location. By flushing the entire contaminated location just once or twice it is provided with the capacity for biodegradation. Once this has occurred, biological degradation rapidly commences and the mobile bioreactor can be removed.

At drycleaner facility in an urban area a severe groundwater contamination with chlorinated solvents has been treated quickly and efficiently using this new biological remediation technique. The active phase (during which the container is on-site) lasted only three months. From monitoring results obtained after nine months it transpired that the contamination had already virtually disappeared. In the source PCE and TCE were degraded to concentrations below the detection limit. More than 99% of the contamination had been converted into harmless ethene. These impressive results demonstrate that bioremediation can also be a rapid remediation option and that it is therefore no longer a technique of the future but a realistic and cost-effective alternative for remediation of PCE and TCE contaminations in urban areas.

In situ remediation of an oil contamination at a train station

As a result of a leaking underground tank containing domestic heating oil the soil at a train station has been contaminated with hydrocarbons up to a depth of 9 meters. The contamination is located mainly under the platform and under the train rails. Owing to the large amount of traffic passing through the station, traditional remediation approaches were proved problematic and excavation of the contaminated soil was not an option. That is why a biological remediation approach was chosen: aerobic degradation through biosparging. By introducing air and nutrients into the soil, biological degradation of the oil contamination is stimulated.

Feasibility studies prior to remediation showed that degradation could be stimulated effectively and based on these results the remediation period was estimated at 1.5 to 2 years. Through trials the area influenced by the injection of air was determined and based on these results the remediation design was optimised further.

During remediation a soil volume of 6,000 m^3 was treated and a total load of approximately 10,000 kg was removed. De concentration prior to remediation was up to 5,000 mg/kg dw and 30,000 µg/L of oil and BTEX. These concentrations were reduced to 200-1,000 mg/kg dw and <50 µg/L within two years. By using an oil characterisation – a specific analysis to determine the composition of oil – it was shown that all components that could pose a risk, such as those that easily dissolve in water or the volatile components, had been removed. Based on these results the remediation project was successfully brought to an end.

Biological source zone remediation of chlorinated solvents

At a site in the old centre of Appingedam, the Netherlands, a former dry cleaner has caused a contamination with chlorinated solvents. The source of the contamination covered a relatively small area (45 m^2) with contaminants up to 8 meters in depth, with a load of approximately 600 kg of chlorinated solvents. A plume of contaminated groundwater had formed up to 70 meters from the source. It was the risks posed by the spreading of the contamination that necessitated remediation. Excavation of the source area was not possible owing to the instable soil structure (peat and clay) and the proximity of old and vulnerable buildings. A continuous containment of the contamination through pump & treat seemed the most logical option.

In order to come to a cheap and final solution, Bioclear researched both the potential for natural attenuation and the possibility of stimulated biological degradation.

The results of this research demonstrated that bacteria were present at the site that can degrade the contamination. Natural attenuation however was too slow to be considered as a viable option. Therefore a more unconventional approach was chosen: stimulating biological degradation in the source. By applying a mixture of sodium lactate and molasses in the soil through direct injections degradation in the source was increased by a factor of 5.

Because of the increase in biological degradation in the source, spreading of the contamination to the plume was drastically cut back. The naturally occurring bacteria have meanwhile had time to degrade the contamination in the plume. As a result the plume is shrinking. The contamination of ground and groundwater has therefore been contained by stimulating biological degradation in the source. Unconventional, but very effective and cost-saving.

Rapid detection and quantification of PCE and TCE degraders

Thousands of locations across the world have been contaminated with chlorinated solvents such as tetrachloroethene (PCE) and trichloroethene (TCE). In the presence of the bacterial species *Dehalococcoides* these contaminants can be degraded to the harmless compound ethene. Bioclear has developed a rapid and robust method with which these bacteria can be detected and quantified in ground and groundwater. Samples can be taken by the client using a simple sampling method. Once received by Bioclear the samples are analysed and results communicated to the client within 10 days.

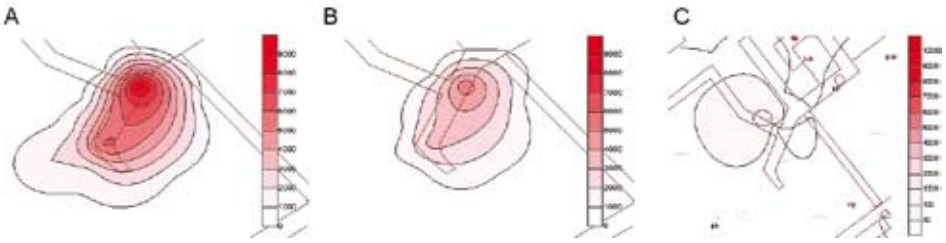
The results of these analyses combined with data on redox potentials and available carbon source give a direct insight into the actual biological degradation capacity of the soil. The analyses also allows the growth of *Dehaloccoides* in the ground to be monitored, thereby providing a tool to follow the progress of a remediation project.

Natural attenuation in Rotterdam harbour

Natural attenuation formed a crucial part of a cost-effective plan to deal with a number of deep groundwater contaminations in the region of Rotterdam harbour. Because of the large scale of the contaminations, the sites were not considered individually. Instead the groundwater system as a whole was considered. Owing to the slow dispersal of the contaminants in the groundwater of the harbour area, the occurrence of natural attenuation, even if slow, played a decisive role in this approach. Therefore it was crucial to determine the capacity for natural attenuation.

For this project the capacity for biological degradation of the most common groundwater contaminants (aromatics and chlorinated solvents) was analysed and quantified at five locations. To this end hydrogen and isotope analyses were performed, as well as degradation tests and analyses on micro-organisms capable of degrading contaminants as well as their specific enzymes. By translating the measured degradation rates to the entire harbour region using computer models, it was possible to determine the influence natural attenuation is having on the dispersal of contaminants in deep groundwater. Using this approach it was determined whether NA would be adequate for specific locations, or whether remediation is necessary. This enabled a prioritisation to be made of locations that require remediation as well as an efficient distribution of available funds. As a consequence the maximum risk reduction in terms of dispersal of contaminants in the entire region can be achieved.

Cost-effective treatment of BTEX contamination



Many sites are contaminated with aromatics, such as benzene, toluene, ethylbenzene and xylene (BTEX). These contaminants can be removed by aerobic degradation by injecting air into the ground. However, if the contaminants are present in deeper layers or in soils rich in organic content, injection of air becomes expensive or may cause problems owing to settling of the soil. Bioclear tested a new concept using an anaerobic approach to treat BTEX contaminations. In demonstration projects concentrations of BTEX decreased by more than 90% in 2 years.

In most soils bacteria that can degrade BTEX occur naturally. However, in deeper layers conditions for degradation are often less favourable. At sites used for the demonstration projects a lack or depletion of so-called “electron acceptors” (e.g. nitrate and/or sulphate) needed for bacteria to be able to degrade BTEX, seemed to be limiting degradation. Depending on site-specific conditions addition of sulphate could therefore stimulate this anaerobic degradation. This approach has a number of important advantages: sulphate distributes easily in the soil, it is highly soluble and has no fertilising value. Furthermore the approach is inexpensive.

The demonstration projects showed that an efficient removal of benzene and other aromatics was attained, even after just one round of sulphate injections. Benzene degradation occurred over a period of approximately 2.5 years decreasing benzene concentrations from 10,000 µg/l to less than 10 µg/l (see figures). This easy-to-use technique can contribute to effective treatment of (residual) BTEX contaminations in deeper soil layers.

In company training in situ remediation

Reviewing the design, tendering and surveying of in situ remediation projects requires specialist knowledge. The customized workshops and in company courses provided by Bioclear are based on more than twenty years' practical experience with in situ remediation. Technical aspects as well as the process implicated in applying (biological) in situ remediation approaches are covered.

Our clients consist of public authorities, industries, consultants and contractors. The exact content is always tailored to the specific wishes and needs of the client. Many subjects are covered such as:

- Being able to assess the opportunities and risks prior to remediation;
- Determining realistic remediation targets;
- Designing an in situ remediation approach;
- The opportunities of natural attenuation and the sustainability of these processes.

For the last couple of years Bioclear has been providing courses for Van Walt Ltd, a company based in the UK specialising in the sale of equipment for soil and groundwater monitoring (mainly on the UK and Irish markets but lately also to the Middle East). Vincent of Van Walt Ltd explains: "Five years ago we started providing in house, intensive training courses in Groundwater Sampling and Monitoring several times per year. The course is continuously evolving, so in 2007 we decided to incorporate risk assessment, traditional remediation and biological remediation techniques at an intermediate level.

Bioclear was asked to teach these modules and accepted the challenge. "The Bioclear teachers approach and authority which comes from years of experience with a market leader in the appropriate field has meant that the modules they present have been received with unanimous acclaim from delegates, including those who themselves had substantial experience in the sector before coming on the course. It has been a pleasure to work with Bioclear and we look forward to continuing to do so in the future."

Bioclear's strengths:

- Reliable, sustainable and cost-effective solutions
- Experts in natural attenuation, in situ bioremediation and ecological risk assessments
- Leaders in developing new remediation methods
- Supporting policymaking
- Over 20 years' experience
- In house laboratories and R&D

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