A two phase anaerobic / aerobic *in situ* treatment zone system for the Bitterfeld region

Biodegradation of chlorinated ethenes and chlorobenzene from bench scale to field tests

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The groundwater in the German Bitterfeld/Wolfen region is heavily contaminated with organic compounds (Figure 1). A Dutch-German consortium is currently testing a 2-phase *in situ* biological treatment zone technology for enhanced attenuation of chlorinated aliphatics and chlorinated aromatics. The research is part of the German SAFIRA programme and the Dutch SKB programme. To prevent spreading of contaminations into surface water, a landscape-integrated and low intensity remediation concept is being developed.
The new elements to be tested in the Bitterfeld region include the engineering and monitoring aspects of the large scale, low-maintenance, and long-term application.

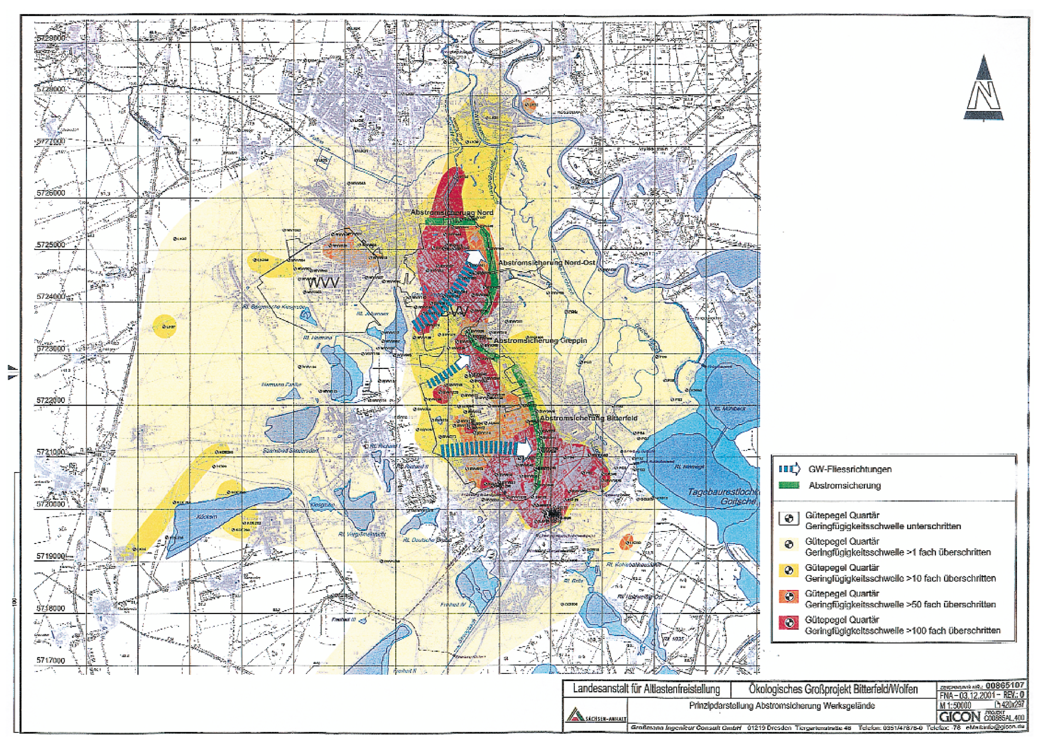


Figure 1 Map of the contaminated Bitterfeld region.

Two-phase enhanced NA approach

First, the chloroethenes are dechlorinated in an anaerobic stage by means of the addition of electron donors. The dechlorination products as well as chlorobenzene are being degraded in a second, (micro)aerobic stage. Research in four *in situ* soil reactors of 4 m^3 each at the test site in Bitterfeld (Figure 2), has shown complete dechlorination of TCE under anaerobic conditions when an electron donor is added and a nitrogen source is supplied. Aerobic degradation of chlorobenzene was shown in a small reactor and is now being scaled up in *in situ* reactors.

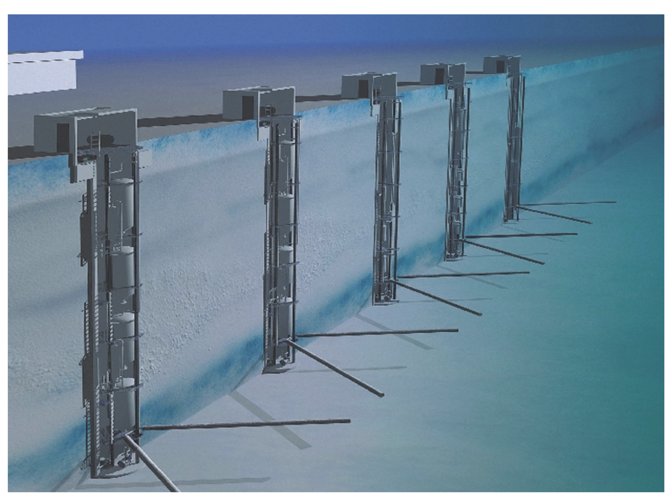


Figure 2 Reactor shafts at the SAFIRA test site.

Upscaling

The upscaling of the system to field scale includes the application of *in situ* electron donor infiltration wells for the anaerobic phase and a landscape-integrated aerobic phase. In the first phase, electron donors will be injected in the subsoil to create anoxic conditions to dechlorinate aliphatic compounds like TCE. Downstream, a buffer zone will be followed by an aerobic phase. Naturally engineered oxygen influx methods will create this oxic zone.

The technical design for aerating the groundwater that drains into the surface water needs to be tailor-made for the local situation. Here, we will highlight two options that can be considered:

1. *Natural attenuation at the interface between anoxic groundwater and oxic surface water.*

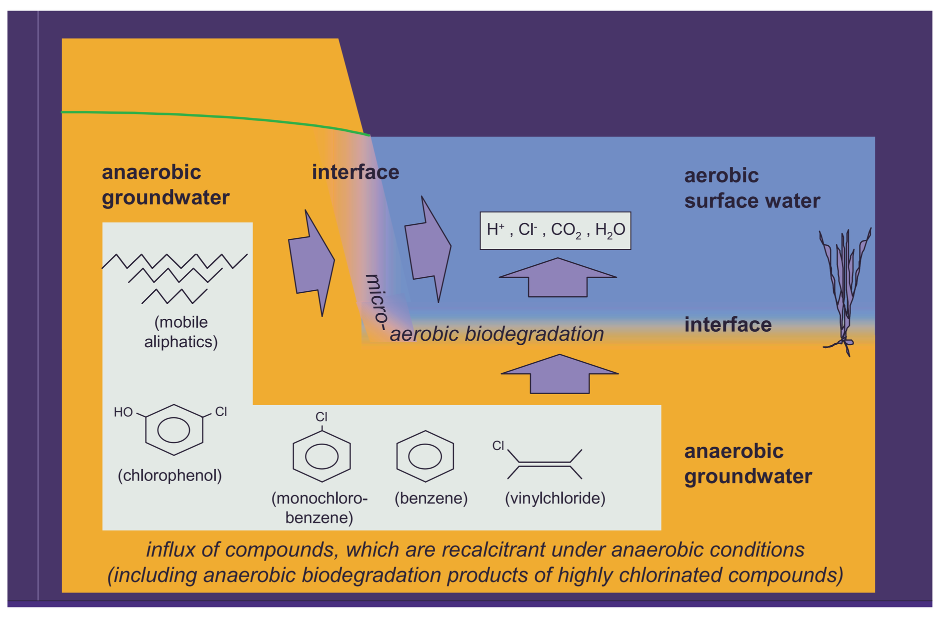


Figure 3

In the Netherlands, TNO is running a project, together with Delft Hydraulics and Geodelft, which studies the capability of groundwater-surface water interfaces to (micro)aerobically degrade pollutants once they arrive in the oxic interface (Figure 3). Promising results have been obtained from sampling devices installed in a ditch on a mono-chlorobenzene polluted site (Figure 4). Macrochemical footprints of the interface processes and strong attenuation of MCB in the interface were observed (Figure 5).

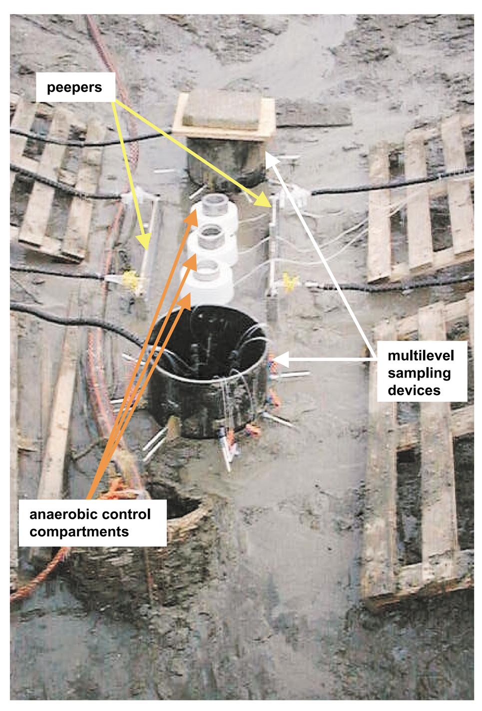
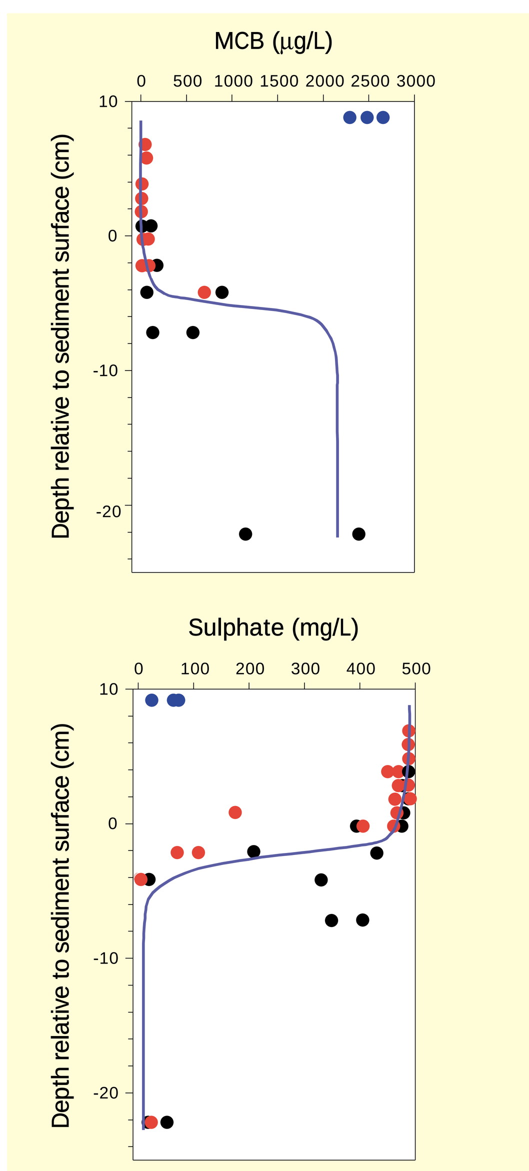


Figure 4 Sampling systems in a temporarily emptied ditch at the polluted site.



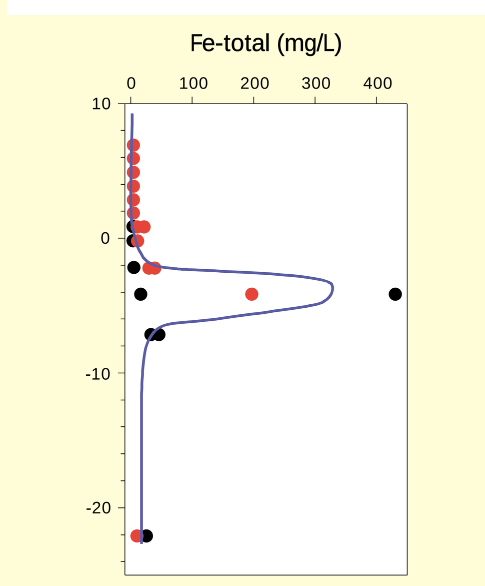


Figure 5 Profiles of MCB, sulphate and total iron as measured at different depths in the ditch sediment.

2. *Artificially created or natural wetlands, helophytic filters or aeration cascades.*

Within the EU project WELCOME, a pilot plant will be installed at the SAFIRA test site to simulate the effect of infiltration of contaminated anoxic groundwater in aerobic systems such as e.g. helophytic filters or cascades (Figure 6).

Figure 6 One of the suggested landscape-integrated designs of the oxic phase: a cascade system.

Added value

The discussed treatment system is a typical (edge of) plume treatment technology and will offer a large scale technology to manage the intermediate and long term risks, i.e. impacts on surface water quality. The technology is complementary to the source zone oriented measures already planned for the Bitterfeld region (Figure 7).

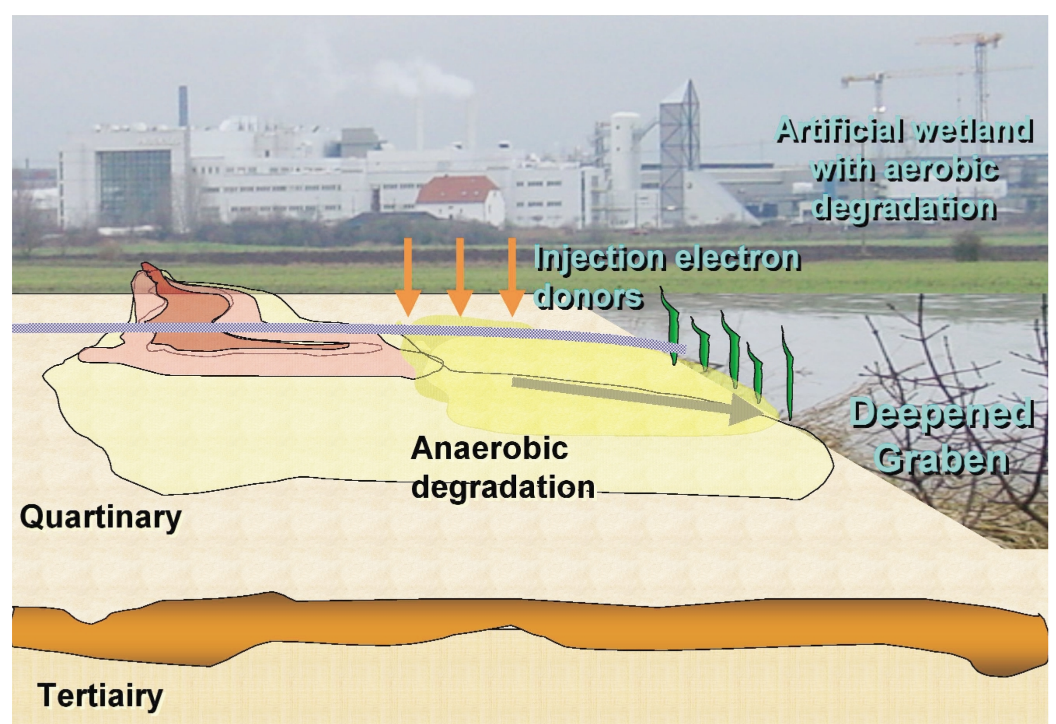


Figure 7 Schematic cross section of the degradation zones.

Acknowledgments

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