In Situ Remediation of CHCs within a Bedrock Aquifer, Germany

CASE STUDY

Enhanced reductive dechlorination barriers installed in sandstone to treat chlorinated solvents under a primary school

INTRODUCTION

As the result of a historic industrial spill, high concentrations of chlorinated hydrocarbons (CHCs) were observed in a sandstone bedrock in Middle- Franconia, Bavaria, in southwest Germany.

Initially, CHCs were detected in private water wells, which prompted an environmental site investigation. A secondary contaminant source area was found to be located underneath an elementary school with a dissolved phase plume extending out to nearby residential properties. **Tetrachloroethene (PCE)**, the main contaminant of concern, ranged from 5,000 to 11,000 µg/L with a likelihood of DNAPL being present. Remediation was required in order to reduce the risk posed to human health.

Fig. 1 Location plan © Wood

The hydrogeological conditions were unfavourable. The Keupersandstein aquifer consists of silty sandstone with interbedded clay lenses. These clay lenses also served as a contaminant reservoir. Originally, a recovery trench was planned for, but Environmental Consultant **Wood** concluded that extraction remedial options were not feasible due to the local hydrological conditions, being impermeable and low connectivity. Wood worked with REGENESIS to develop an in-situ groundwater remediation solution for the site.

SITE TYPE

School and Residential Area

GEOLOGY

Silty sandstone with interbedded clay lenses

CONTAMINANTS

5,000 to 11,000 µg/L PCE, DNAPL

PROJECT DRIVER

Human Health

TREATMENT

Enhanced Anaerobic Bioremediation

TECHNOLOGIES

HRC® and HRC-X®

REMEDIAL APPROACH

Low volume electron donors were chosen from REGENESIS' range of injectable substrates. These were Hydrogen Release Compound**:** **HRC®** and an extended version, **HRC-X®**, which were chosen to stimulate and maintain enhanced reductive dechlorination of the target contaminants.

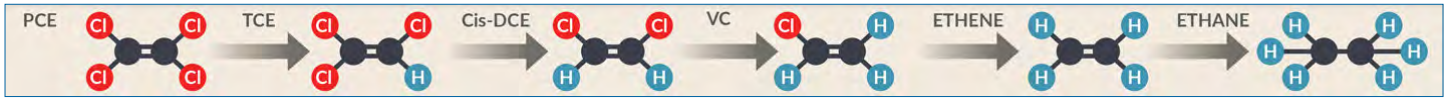


Fig. 2 Reductive dechlorination of chlorinated ethenes

HRC has controlled-release electron donor technology and positional longevity. It has been engineered specifically to achieve enhanced, in situ anaerobic bioremediation of chlorinated compounds in groundwater or highly saturated soils. Upon contact with groundwater, this viscous, poly-lactate ester material becomes hydrated and subject to microbial breakdown producing a controlled-release of hydrogen for periods of up to 18-24 months from a single application.

HRC HYDROGEN RELEASE COMPOUND

HRC enables enhanced anaerobic biodegradation by adding hydrogen (an electron donor) to groundwater, increasing the number and vitality of indigenous micro-organisms able to perform the naturally occurring process of enhanced reductive dechlorination.

HRC-X is a more robust and viscous version of Hydrogen Release Compound. With an additional 3 to 5 years of hydrogen releasing capability when compared to standard HRC, HRC-X is suitable for treating sites with higher dissolved-phase concentrations, including residual DNAPL. HRC-X may also be instrumental in treating sites where only a single remediation treatment application is possible and there is a need to maximize the treatment longevity.

HRC-X EXTENDED HYDROGEN RELEASE COMPOUND

DESIGN AND TREATMENT

4 treatment barriers were formed by creating 4 rows of application wells, drilled into the bedrock across the 3 Ha site, perpendicular to the groundwater flow. In total, 86 injection wells plus 9 for monitoring, were constructed as permanent wells with 127mm PVC screened / riser pipes down to 7 mBGL.

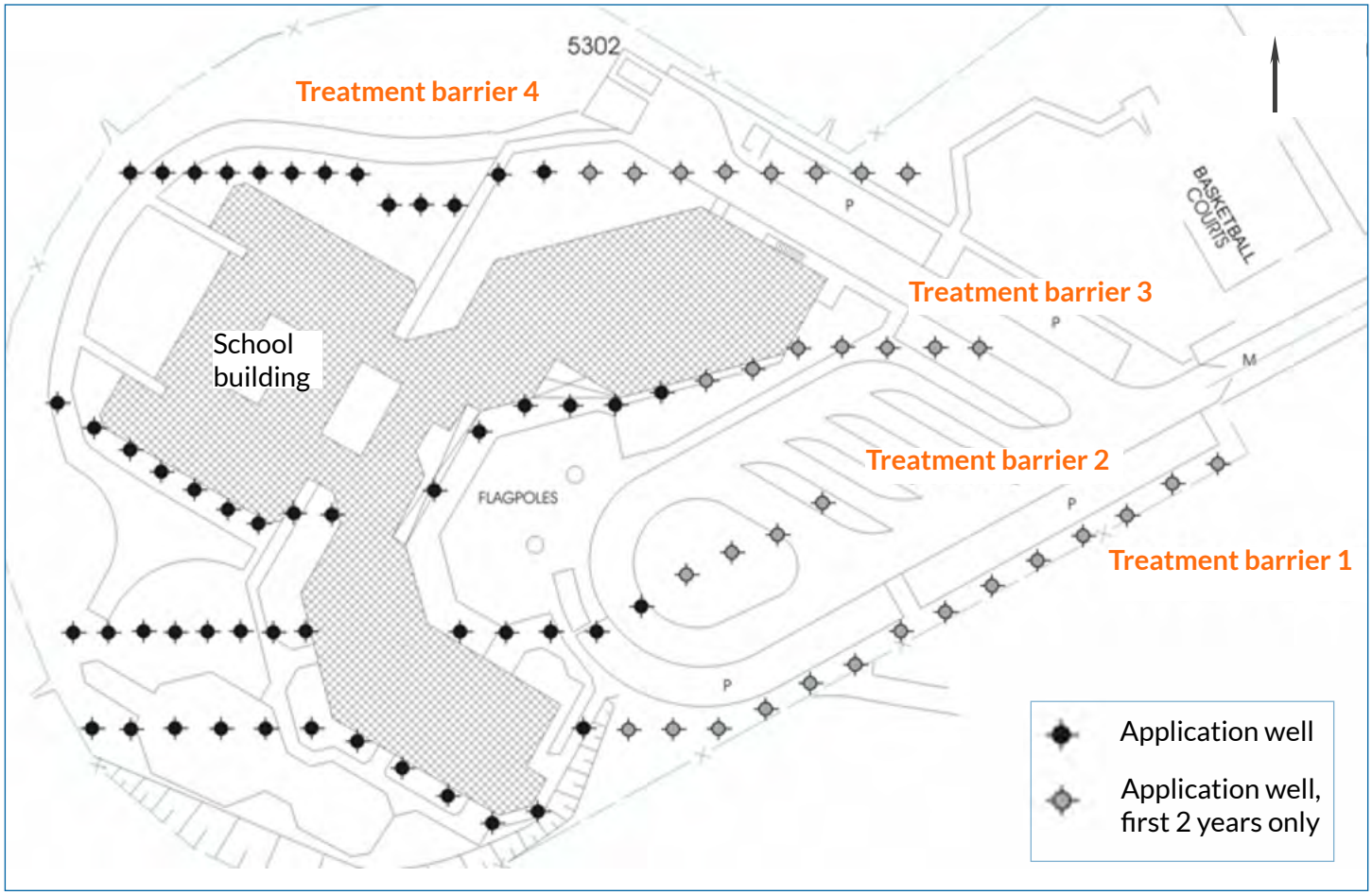


Fig. 3 Remedial plan

HRC and HRC-X were gravity-fed into the application wells in order to disperse and diffuse into the surrounding bedrock. This created and maintained 4 optimum zones of enhanced reductive dechlorination, through which groundwater would pass, but the chlorinated solvent contamination would be degraded.

Further HRC applications were performed; initially into all 86 injection wells, but then as the plume diminished, the barrier applications could be reduced to 53 and finally 23 injection wells located in the plume centre. The remediation took place over a 5-year period, with groundwater validation monitoring performed on a quarterly basis.

Fig. 4 HRC being gravity-fed into one of the application wells

Fig. 5 View east along treatment barrier 3

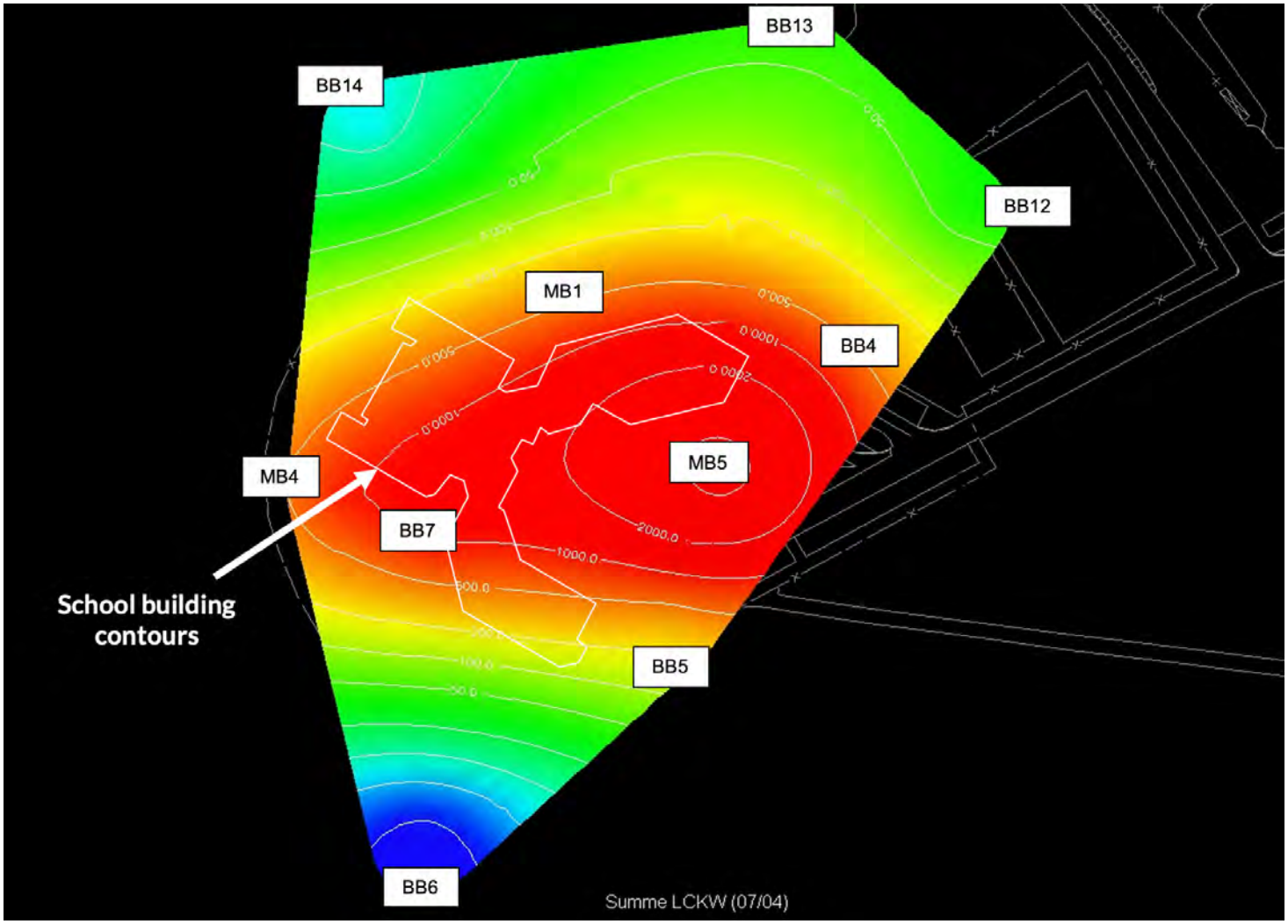


Fig. 6 Plume area concentrations (in ppb) prior to remediation, in relation to the location of the monitoring wells and school building © Wood

RESULTS

The predicted dechlorination of CHC contaminants is clearly demonstrated by the development of degradation compounds at the monitoring well located in the plume center.

Within the first year of remediation, the parent compound, PCE, had degraded to trichloroethene (TCE). Sequential biological degradation produced cis-1,2 dichloroethene (cis-1,2 DCE), vinyl chloride (VC) and ethene, showing full reductive dechlorination was occurring.

After 5 years of monitoring, 6 validation wells were used to show compliance with a remedial target of <10 µg/L for total CHCs. The contaminant concentrations in 4 monitoring wells were below detection limit, and in the other 2 monitoring wells, below 3 µg/L.

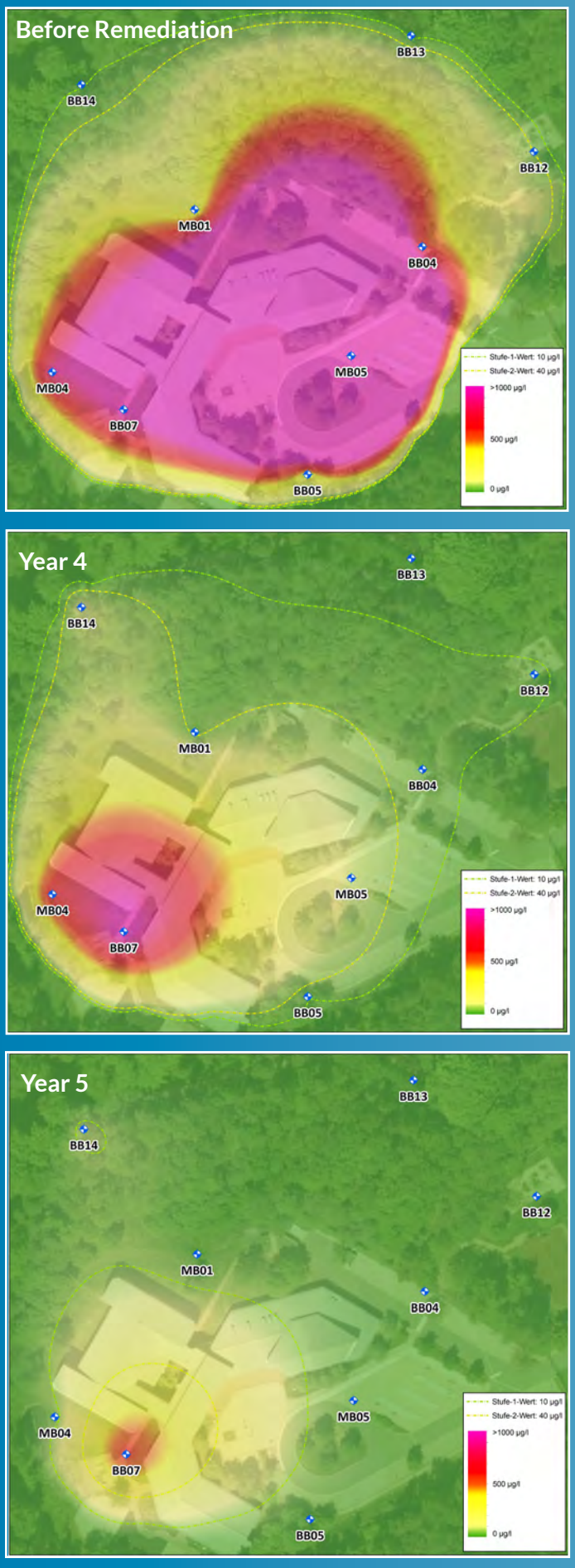
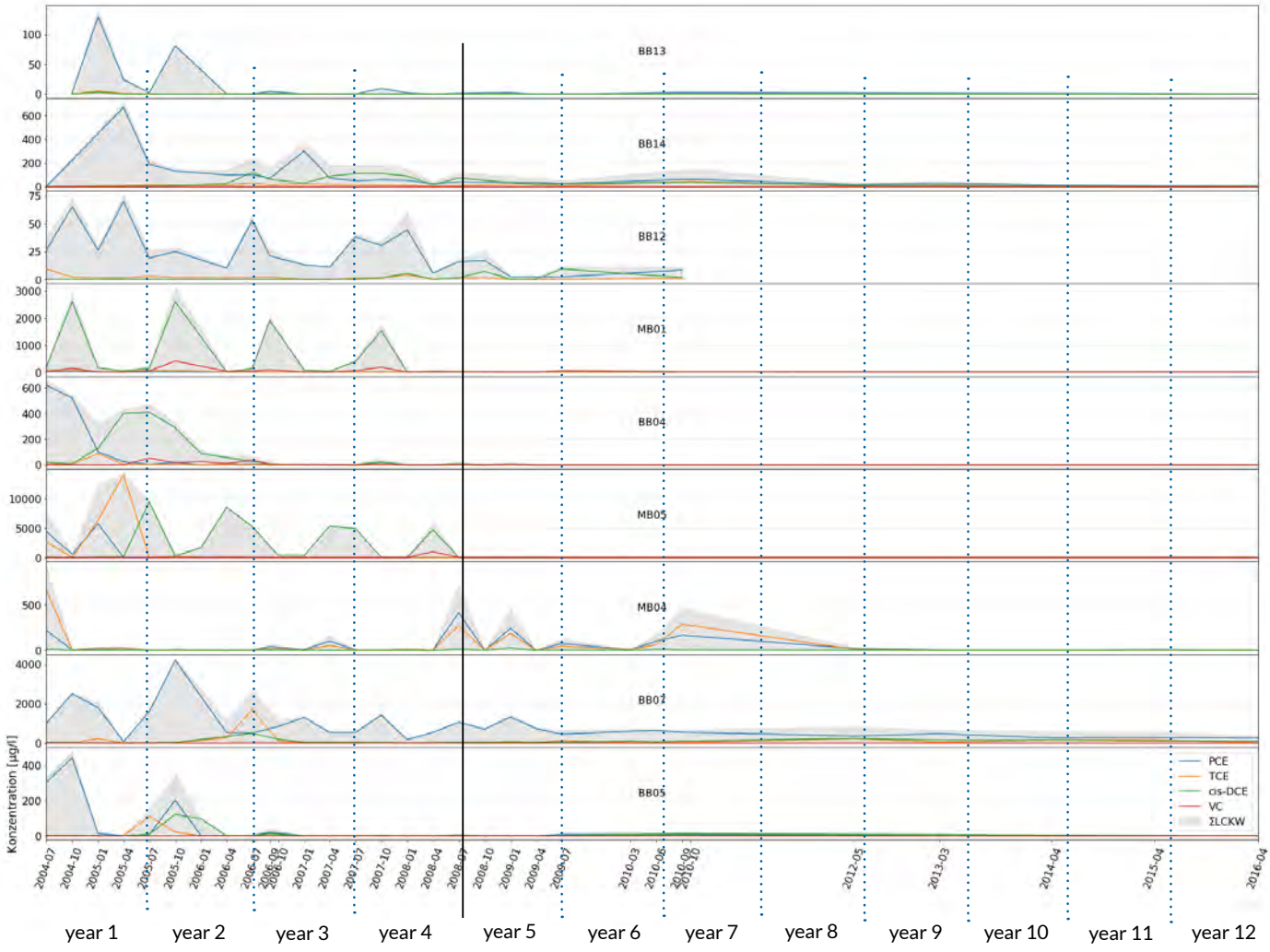


Fig. 7 Heatmap of CHC concentrations over time based on monitoring results: (a) existing conditions prior to remediation, b) 4 years into remediation, (c) concentrations after 5 years © Wood

Fig. 8 Long-term validation monitoring



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"I enjoyed working with REGENESIS very much. The remediation setup, including the annual application of HRC, resulted in a low impact on highly sensitive site activities and eventually the project resulted in full client's and regulator's satisfaction."

Konstantin Summ, Senior Geologist
Wood PLC

CONCLUSION

- The groundwater in the sandstone bedrock was cost-effectively treated using enhanced reductive dechlorination. An approximate **50% cost reduction** was achieved compared to the planned physical recovery trench.
- The contamination was **fully dechlorinated**, with **no build-up of daughter products** occurring.
- The HRC and HRC-X application **did not affect the permeability of the fracture-flow dominated bedrock**; instead the products created anaerobic treatment zones through which groundwater could flow and be remediated.
- The treatment **minimised site disturbance**, with only a short period of drilling and application by pouring into the wells, after which the slow-release of electron donor from the HRC provided years of treatment in situ.
- Remediation was **finished within the expected time frame and within budget**, despite the complex conditions.

ABOUT THE CONSULTANT

Wood is a leading international provider of consulting, environmental and engineering services. With over 60,000 employees in more than 60 countries, Wood combines international expertise with highly qualified local teams.

With its headquarters in Frankfurt and offices in Kaisers-lautern, Stuttgart, Nuremberg, Hamburg and Munich, Wood E&IS GmbH has been active in the environmental consulting and environmental services sector in Germany for over 25 years.

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