Phytoremediation with Poplar Trees

Project Details

COMPANY

The Dow Chemical Company (Dow Benelux BV)

COUNTRY

The Netherlands

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Phytoremediation as a Sustainable Approach for Groundwater Contaminated with 1,4-Dioxane

CONTEXT

The Dow Chemical Company (Dow) combines the power of science and technology to passionately innovate what is essential to human progress. Dow is driving innovations that extract value from the intersection of chemical, physical, and biological sciences to help address many of the world's most challenging problems such as the need for clean water, clean energy generation and conservation, and increasing agricultural productivity. Dow's integrated, market-driven, industry-leading portfolio of specialty chemical, advanced materials, agrosciences, and plastics businesses delivers a broad range of technology-based products and solutions to customers in approximately 180 countries and in high-growth sectors such as packaging, electronics, water, coatings, and agriculture. In 2014, Dow had annual sales of more than US$ 58 billion and employed approximately 53,000 people worldwide. The company's more than 6,000 product families are manufactured at 201 sites in 35 countries across the globe. More information about Dow can be found at www.dow.com.

1,4-Dioxane (dioxane) is an emerging contaminant of concern receiving much attention. At a large chemical production plant in Terneuzen, The Netherlands, historical site activities led to dioxane-contaminated groundwater (Figure 1). More than 20 years after the dioxane production has stopped, groundwater in the source zone still contains high concentrations of dioxane, and migration with groundwater is threatening nearby surface water. Pending the implementation of a source zone remediation, a sustainable method for preventing offsite migration of dioxane is required.

The primary stakeholders for this project were Province of Zealand (Provincial Regulators) and Dow Benelux BV.

Figure 1. Phytoremediation at Terneuzen

OBJECTIVE AND PROJECT OVERVIEW

The primary purpose of the project was to develop a cost-effective and sustainable remediation method for dioxane in groundwater and prevent further offsite migration. Dow has installed and is reviewing the performance of a phytoremediation system of poplar trees to adsorb and degrade dioxane in groundwater.

THE BUSINESS CASE

Classic hydraulic containment of dioxane-contaminated groundwater requires a groundwater recovery system with effluent treatment using advanced oxidation technology. This is unattractive both from an economic and a sustainability point of view. After carefully assessing several sustainable alternatives, phytoremediation was selected as the most promising approach.

DECISION MAKING PROCESS

A cost evaluation showed that the cost of containment over 10 years for the two alternatives were:

- Pump and treat with advanced oxidation: EUR 1,800,000
- Phytoremediation: EUR 900,000

Although the phytoremediation cost is relatively high because of site-specific aspects (bench-scale study, offsite pilot tests, working in areas with strict safety regulations), it was selected as the most promising approach based on its sustainability.

The application of this innovative technology at a chemical production plant required feasibility studies on several topics:

- Dioxane phytotoxicity. Bench-scale experiments showed that trees can grow in sweet and brackish water with up to 1.5 percent dioxane. Since concentrations in the phytoremediation area are much lower, dioxane phytotoxicity was not expected to be an issue.
- Compliance with safety regulations. A safety review identified the potential of gas accumulation between the trees as the main risk. This risk was mitigated by choosing the correct type of tree and widening the planting grid. To prevent the risks of accidents and delay during installation, an offsite trial in the presence of safety officers and onsite gas testing and monitoring was performed.
- Fate of dioxane. The regulatory authorities have accepted the well-established process of ultraviolet-oxidation of dioxane in leaves and the atmosphere as removal mechanism. A study was performed to determine the fate of dioxane during phytocontainment implementation to provide evidence for dioxane degradation.

Dow's Environmental Remediation & Restoration Department was involved and took the final decision, collaborating with Dow's Environmental Health and Safety, and Process Safety departments and provincial regulators.

PROJECT DETAILS

Dow has installed and is reviewing the performance of the contaminant plume with a phytoremediation system of poplar trees to adsorb dioxin in groundwater.

Design and Implementation

A design was made based on hydrological calculations and available space. To target the contaminated aquifer at 5 to 11 meters below ground level, a modified version of the *TreeWell®* system designed by Applied Natural Sciences was used.

With the aid of the Treemediation technology, the roots of the tree were paled in a large waterproof bag buried in the ground. A seal was created at the bottom of the hole with the aid of bentonite. A monitoring well was

drilled to the depth of the groundwater contamination. Groundwater pressure difference causes groundwater from the contamination zone to flow via the well into the hole so the roots can soak up impacted groundwater. Thus, the roots can aspirate the contaminated groundwater.

These modified *TreeWell®* units were installed in November/December 2012. In early 2013, a total of 240 poplars had been planted. To study the hydrological effect in a groundwater system with tidal influences, an intensive monitoring system with novel groundwater level loggers was installed in early 2014.

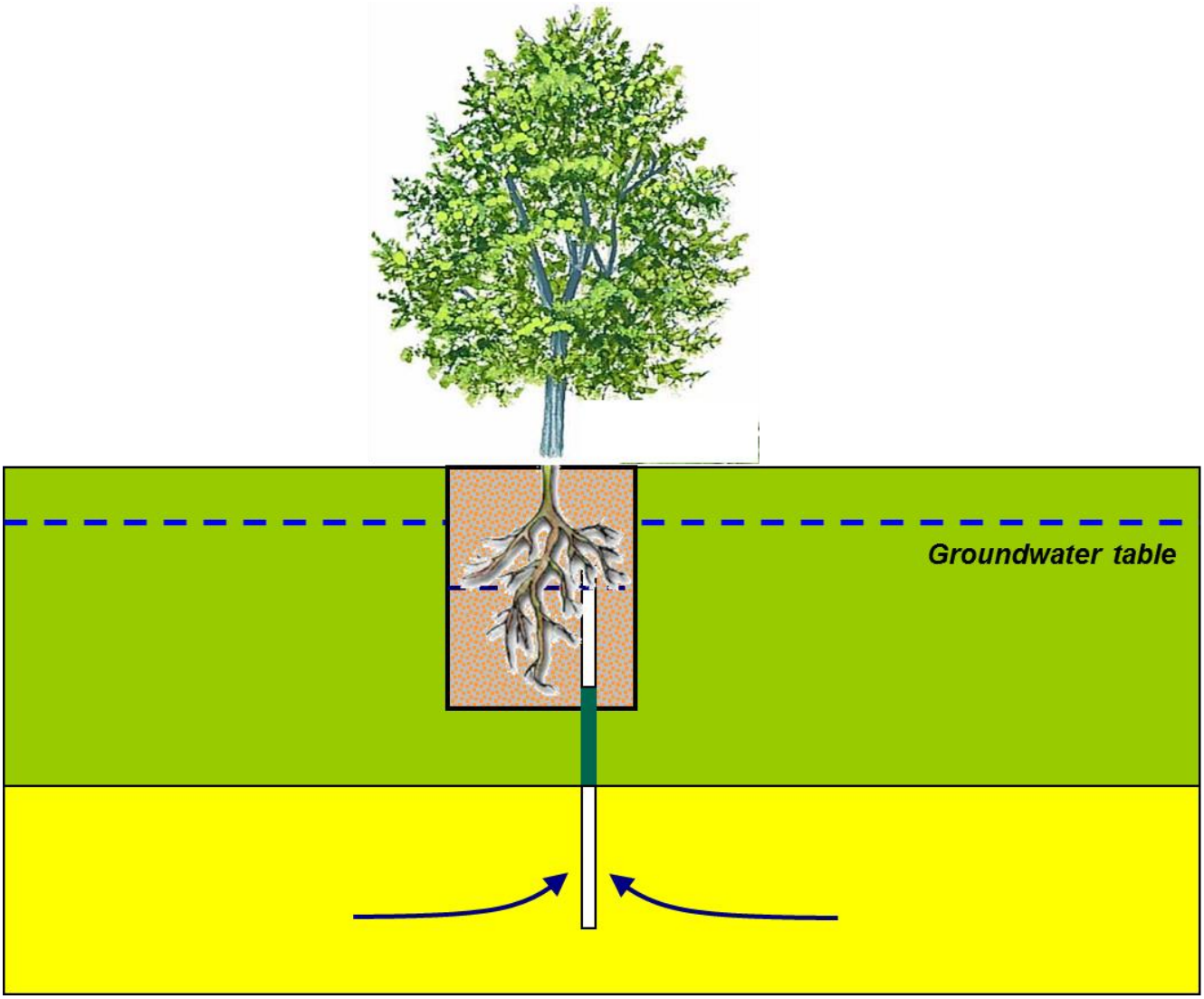

Figure 2. Pytoremediation System

Regular measurements were taken to monitor the tree functions, including the effect on groundwater (quality and flow), evaporation by the trees (water and dioxane), impact on air quality, and growth of the trees.

The results of the first 2 years of monitoring are promising. The trees are showing excellent growth, and a clear hydrological effect has been observed during the growing season. Groundwater measurements show that, in line with the expectations, the dioxane plume is being drawn into the phytoremediation area as a result of the water uptake by the trees. The evaporation of dioxane by the trees was significantly less than what was calculated based on uptake rates and dioxane concentrations in groundwater, indicating dioxane degradation is

occurring. In the coming years, the containing effect is expected to become more pronounced as the trees become mature and take up more water.

To demonstrate the feasibility of this phytoremediation approach as an effective and sustainable method for the containment of the dioxane plume, the intensive monitoring program will be continued.

LESSONS LEARNED

Conclusions drawn were that phytocontainment is a feasible option for containing dioxane-contaminated groundwater at active chemical production plants and can be an attractive and sustainable alternative for conventional hydraulic containment.

One notable health and safety risk observed was the collapse of planting holes (1 meter wide, 2.5 meters deep). To address this, drilling and root sleeve placement procedures were optimized, and a special protective frame was developed. As a result, holes no longer collapse.

Care was taken for potential explosion risk near gas pipes and tank farms by having sufficient distance between projected tree and underground piping.

FUTURE IMPLEMENTATION AND NEXT STEPS

As a result of the project, the baseline situation was established, trees are growing well, and the monitoring system is operational with hydraulic effects visible. Because of the investment in the bench-scale study and offsite pilot test, Dow is leveraging the results of this as a pilot study and continues the intensive monitoring program to demonstrate the feasibility of this phytoremediation approach as an effective and sustainable method for containing the dioxane plume.

REFERENCES

Applied Natural Sciences, Dow, and Tauw. 2014. “Engineered phytoremediation as a sustainable approach for groundwater contaminated with 1,4-dioxane.” Presented at Ninth International Conference on Remediation of Chlorinated and Recalcitrant Compounds. May.

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