Towards finite aftercare: bioremediation and 3D modelling at a former manufactured gas plant in Utrecht, the Netherlands

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Abstract

The Municipality of Utrecht has commissioned a consortium of Utrecht University, Wageningen University and Deltares to reconsider the soil contamination management measures of the contaminated Griftpark, the site of a former manufactured gas plant. The research is motivated by recent breakthrough[1] in the understanding of microbiological degradation of organic compounds in both contaminant plume fringes and source zones. The research will comprise a combination of field study, laboratory experiments and computational modeling.

Then

During the manufacturing process of city gas, waste products polluted the soil and groundwater, including:

- Aromatic compounds (e.g. PAH, BTEX)
- Aliphatic compounds (e.g. mineral oils)
- Inorganic compounds (e.g. cyanide)

Now

In the 1990s, the contamination within the first aquifer was hydraulically isolated by installing a 60 m deep cement-bentonite wall around the site. To protect the second aquifer that serves as a source for drinking water, groundwater is continuously pumped from the top aquifer, preventing contaminated water from flowing down through cracks in the clay layer, see Figure 1.

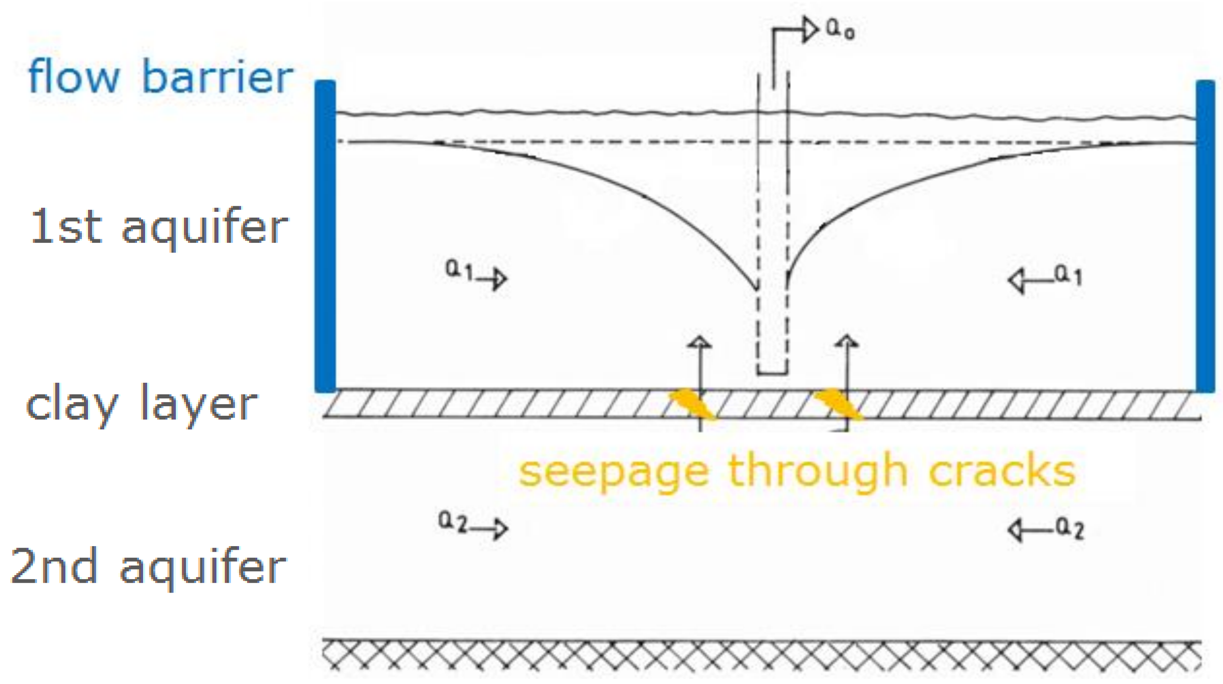
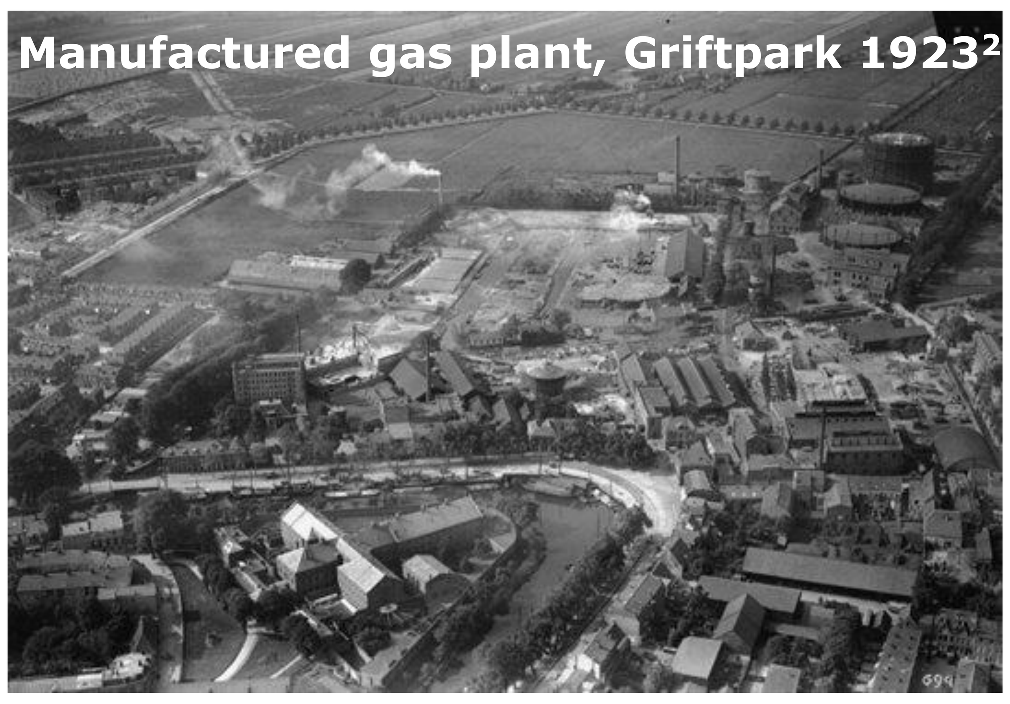


Figure 1 (left): Hydrogeological schematisation of the Griftpark. Q0: pumping rate extraction well; Q1 and Q2: flow of water being extracted from the first and second aquifer respectively.



Project objectives and preliminary results

Natural biological degradation potential

Investigate the natural biological degradation potential of environmental risk determining contaminants at field conditions, by:

- Assessing the composition of mobile toxic contaminants that are at risk to be transported with the groundwater into the second aquifer,
- Determining if and to what extent biodegradation occurs for several toxic mobile contaminants under field conditions,
- Determining where, at locations with varying anaerobic conditions and electron acceptors, biodegradation of toxic mobile contaminants does or does not occur.

B22 Batches	Benzene	Toluene	Ethylbenzene	M/P-Xylene	O-Xylene	Indane	Indene	Naphtalene
O_2 A,B	III	III	III	III	III	III	III	III
O_2+Nu A	II	III	III	III	III	III	III	III
O_2+Nu B	I	I	I	I	I	I	I	I
Sterile A,B	I	I	I	I	I	I	I	I
Nitrate A,B	I	II	II	I	I	I	I	I
Sulphate A,B	I	I	I	I	I	I	I	I
Chlorate A,B	I	I	II	I	I	I	I	I
Ferrihydrite A,B	I	I	III	I	I	I	I	I
No Additives A,B	I	I	I	I	I	I	I	I

Table 1. Results of duplicate batch experiments with highly contaminated groundwater in 214 days. I (red) indicates no or almost no degradation measured, II (orange) indicates partly degraded over time and III (green) indicates completely or almost completely degraded.

Stimulated biological degradation

Explore the potential and different designs for stimulated biological degradation of contaminants that cause a threat to the second aquifer. The potential of the naturally occurring microbiome will be studied to determine improvement of biodegradation rates at minimal technological intervention like redox manipulation, addition of nutrients, bioaugmentation etc.

	Scenario I- No nutrients		Scenario II- with nutrients		Scenario III- nutrients + trace elements+ vitamins	
	Lag phase (day)	Biodegradation rate (mmol/L·d^{-1})	Lag phase (day)	Biodegradation rate (mmol/L·d^{-1})	Lag phase (day)	Biodegradation rate (mmol/L·d^{-1})
Benzene	5	0.18	2	0.21	0	0.25
Toluene	2	0.12	2	0.18	0	0.23
Ethylbenzene	5	0.10	3	0.07	0	0.11
Xylene	1	0.10	1	0.11	0	0.11
Naphthalene	1	0.11	1	0.16	0	0.15

Table 2. Bio-degradation of BTEXN under aerobic conditions. Lag phases in groundwater in three scenarios show that the microbial conversion can be stimulated by optimisation of environmental conditions.

Modelling contaminant transport and biodegradation

The program that will be used for the simulations is the **reactive multi-component transport** model for saturated porous media **PHT3D**. Using the results of field and lab studies on soil properties and bioremediation potential, the model will be used to forecast the feasibility and safety of potential future scenarios at the Griftpark and benefit other similar sites worldwide. In particular, implications on risk assessment of different concepts of heterogeneity in the subsoil will be studied through 3D stochastic hydrogeological modelling.

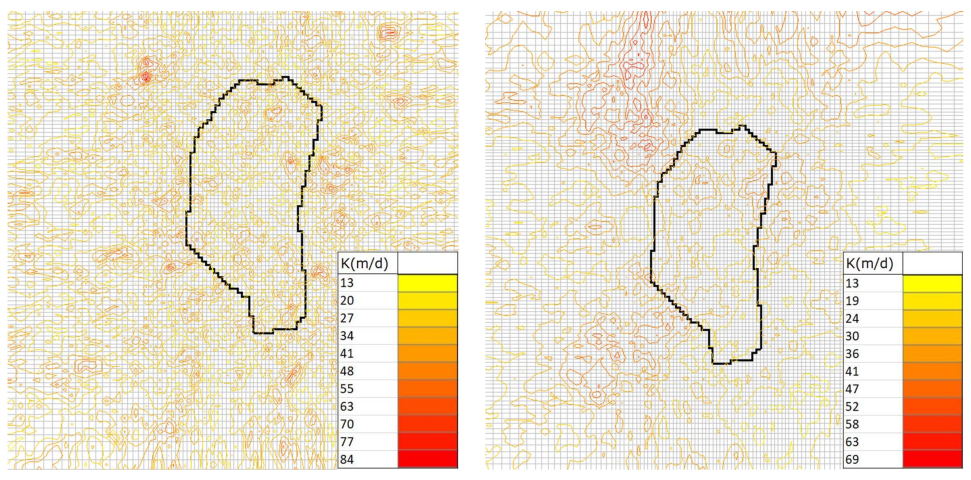


Figure 2: Hydraulic conductivity profiles of random fields with lognormal mean 1.47 (i.e. 30 m/d), standard deviation 0.1, and correlation lengths 50m (left) and 500m (right). Cement bentonite wall surrounding the site indicated in black.

References

1. R.U. Meckenstock, M. Elsner, C. Griebler, T. Lueders, C. Stumpp, J. Aamand, S.N. Agathos, H. Albrechtsen, L. Bastiaens, P.L. Bjerg, N. Boon, W. Dejonghe, W.E. Huang, S.I. Schmidt, E. Smolders, S.R. Sørensen, D. Springael and B.M. van Breukelen. Biodegradation: Updating the Concepts of Control for Microbial Cleanup in Contaminated Aquifers. *Environ. Sci. Technol.* 2015, 49, 7073−7081.
2. Het Utrechts archief (http://www.hetutrechtsarchief.nl/collectie/beeldmateriaal).