IN-SITU REMEDIATION OF CONTAMINATED GROUNDWATER USING THE NEW FUNNEL - AND - IRRADIATION TECHNOLOGY (FIT)

Dr. Matthias Maier; Prof. Dr.-Ing. habil. Dietrich Maier

Stadtwerke Karlsruhe GmbH, Daxlander Straße 72, 76307 Karlsruhe, Germany

Keywords

groundwater remediation, Polycyclic Aromatic Hydrocarbons (PAH), UV-radiation, vinylchloride

Abstract

For the remediation of the groundwater released from the aquifer below the former gas plant site of the city of Karlsruhe, Germany, which is contaminated with Polycyclic Aromatic Hydrocarbons (PAHs) and Vinylchloride (VC) a funnel-and-gate system was designed. The VC present in the aquifer as a result of a plume of degraded volatile organic compounds (VOCs) transported into the contaminated area from upstream can not be efficiently removed with the traditional system based on activated carbon treatment. Therefore, for the removal of both contaminants an in-situ-treatment system consisting of UV-radiation in combination with adsorption on activated carbon was used for the first time. In this paper the results of experiments using a pilot scale equipment for the in-situ-UV-radiation for the oxidation of PAHs and VC and the application at the Karlsruhe gas works are presented.

1 Introduction

At the former gas works site of the city of Karlsruhe, Germany, a contamination of the subsurface soil and the groundwater with Polycyclic Aromatic Hydrocarbons (PAHs) was found. This contamination is mainly dominated by acenaphthene in concentrations up to 600 µg/l. The application of conventional strategies for the rehabilitation of this gas plant site, e.g. by pump-and-treat, was rejected due to the low solubility of the PAHs, the resistant adsorption of these compounds to the aquifer material and the fact, that fast rehabilitation strategies are only possible by excavation of the contaminated area. Moreover, the aquifer downstream the gas-works site exhibits a groundwater resource used for drinking water purposes with a high protection level. In addition to the primary contamination with PAHs from the site itself a secondary groundwater contamination of vinylchloride (VC) is present showing concentrations up to 100 µg/l. This contamination is the result of a plume of degraded volatile organic compounds (VOCs) transported into the area from outside. Due to the less adsorption capacity of the VC to the activated carbon a novel in-situ-treatment system consisting of UV-radiation in combination with adsorption on activated carbon was used for the first time at the gas works site in Karlsruhe, Germany.

The funnel-and-gate system installed at the gas works site consists of a impermeable barrier in the groundwater ("funnel") reaching from the subsurface down to the bottom of the aquifer arranged perpendicular to the groundwater flow. The system is represented by a funnel 240 m in length and 17 m in depth which covers the width of the contaminated water downstream of the gas plant site of an area of 100,000 m² and is interrupted by eight oversized wells ("gates") of 17 m in depth with a diameter of 2000 mm. At the gates a total groundwater flow rate of approximately 1 l/s was calculated by numeric modelling (SCHAD et al., 2000).

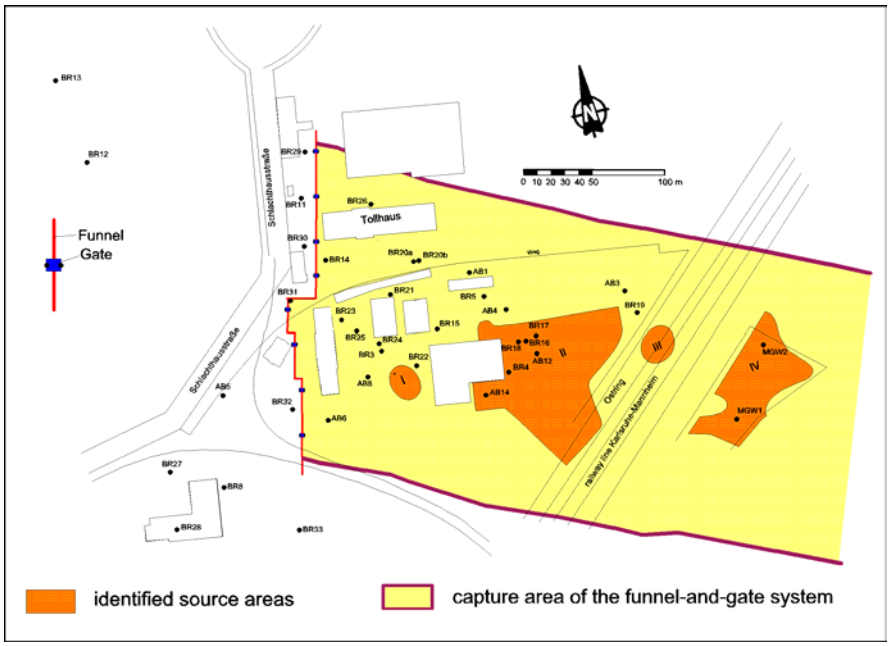

Figure 1: Funnel and gate system on the former gas plant site in Karlsruhe (from: SCHAD et al., 2000)

2 The Remediation Concept

A vertical section of the aquifer showing the general function of the system is depicted in figure 2. The water is directed to the eight gates which contain the combined in-situ-UV-/AC-groundwater treatment system developed by the authors as shown in figure 3 (MAIER et al., 2000, MAIER & MAIER, 2001). The gate volume is divided in two sections. The main volume of the gate is filled with activated carbon for the removal of PAHs. Due to the fact that vinylchloride can not be removed by activated carbon over a long term period UV-radiation is used as a pre-treatment step for the PAHs and as the main treatment step for the removal of vinylchloride. Therefore, on the side of the inflow of the groundwater into the gate an open area is constructed by using a horizontal perforated metal sheet (figure 4).

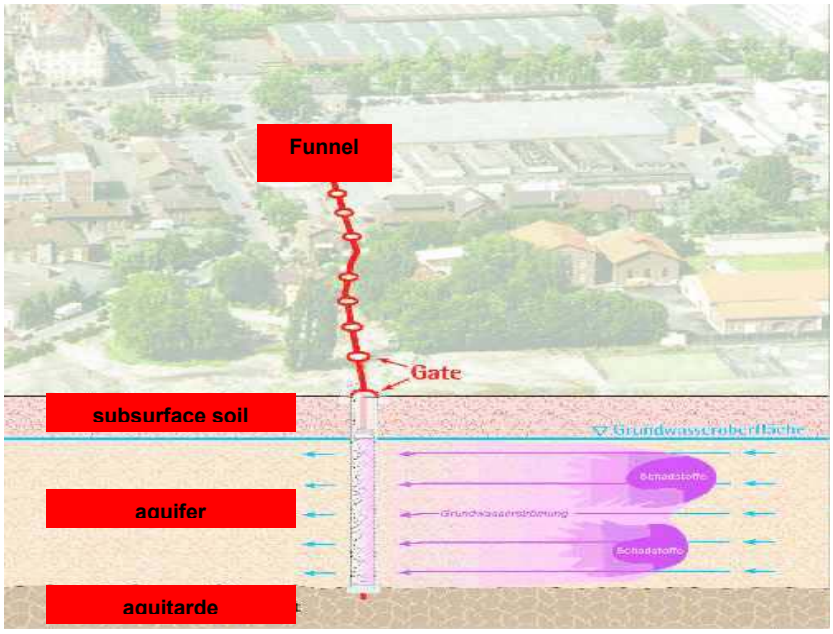

Figure 2: Vertical section of the groundwater treatment system

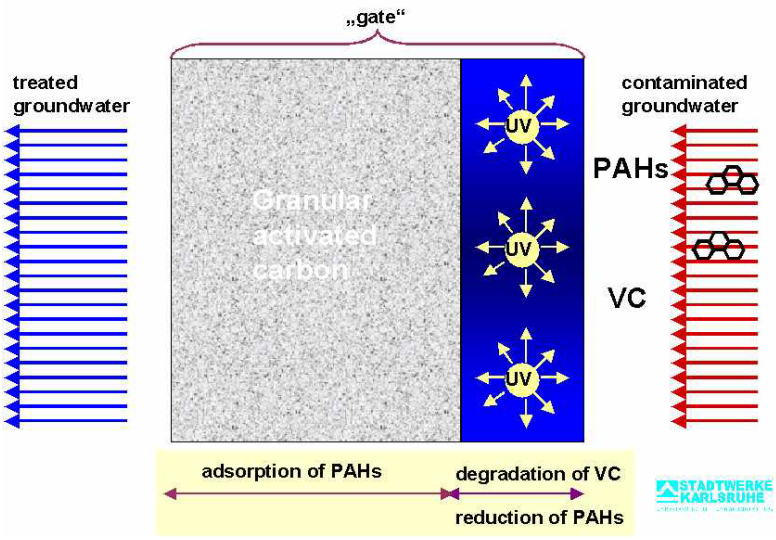

Figure 3: The Remediation Concept of Funnel-and Irradiate (FIT)

This area is intended for the installation of the UV-radiation system comparable to a rope ladder where the pegs exhibit the UV-lamps and the ropes are made by a steel rope carrying the electrical power supply. The advantages are the easy accessibility to the equipment after the installation into the gates and the possibility for modifications of the equipment over the expected remediation time of approximately 30 years.

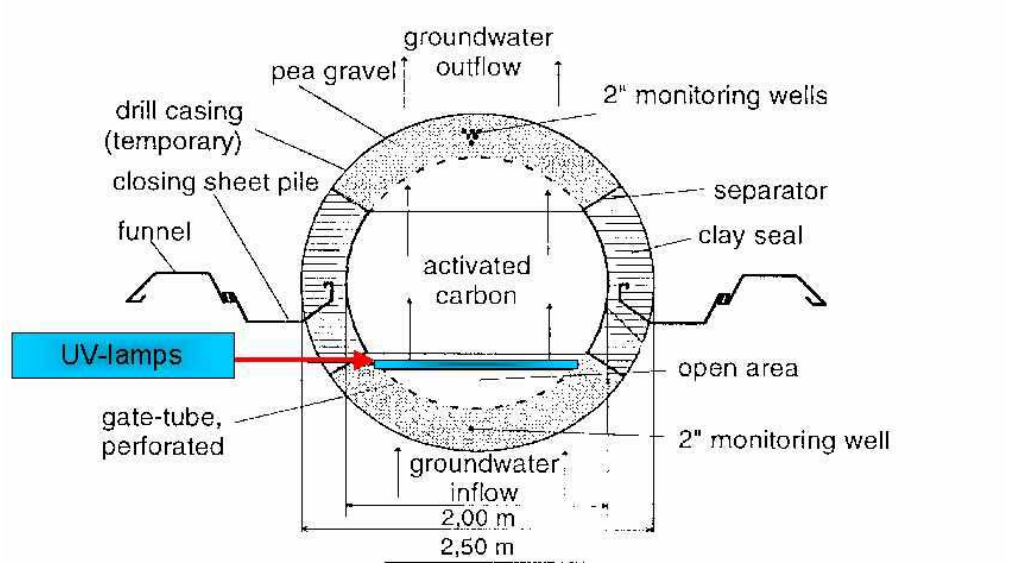

Figure 4: Plan View on the Main Components of the Gates

3 Laboratory Experiments on the Degradation of the Contaminants using UV-Radiation

Preliminary experiments in the laboratory investigating the effect of the radiation at a wave length of ♦=200-400 nm using water from the contaminated aquifer showed that a decontamination was possible during a period of radiation of t= 2 minutes. The initial concentration of 16 EPA-PAHs of 132,642 ng/l could be reduced to 240 ng/l in the lab-scale experiment. This corresponds to a reduction in PAH concentration of 99.8%. The major constituent in the non-radiated water was represented by acenaphthene with a value of 130,000 ng/l. In the treated water acenaphthene was the only constituent detectable. For the VC concentration a reduction of 100% from 58 µg/l below the limit of detection of 0.05 µg/l was possible. The radiation process was carried out using an Enviolet® -UV-Oxidation reactor (a.c.k. aqua concept GmbH).

4 Results of Experiments in a Pilot Scale Equipment

As a result of these findings a simulation of the in-situ-UV-radiation of the groundwater on site flowing through the gate using a pilot scale equipment in a portacabin was carried out. Therefore a stainless steel water tank with the dimensions of 20 x 40 cm in flow direction and a length of 140 cm was built. The water passed a series of UV-lamps arranged perpendicular to the flow direction with a distance of 12.5 cm between each UV-lamp. The flow velocity of the water in the UV-radiation equipment was v= 0.2 m/h according to the results of the characterisation of the hydraulic properties of the aquifer. The radiation was carried out with UV-lamps at a wave length of ♦= 185 and ♦=254 nm having an electric power of 40 W inserted in a protective quartz-glass pipe of 25 mm in diameter. The depth of the expected optimum of the radiation of the water by the UV-

lamps was specified at 6.25 cm. The geometric dimensions of the pilot scale equipment and the flow velocity guaranteed a minimum radiation time of the contaminated water of t= 30 minutes. The scheme of the pilot-scale equipment for UV-radiation tank is depicted in figure 5.

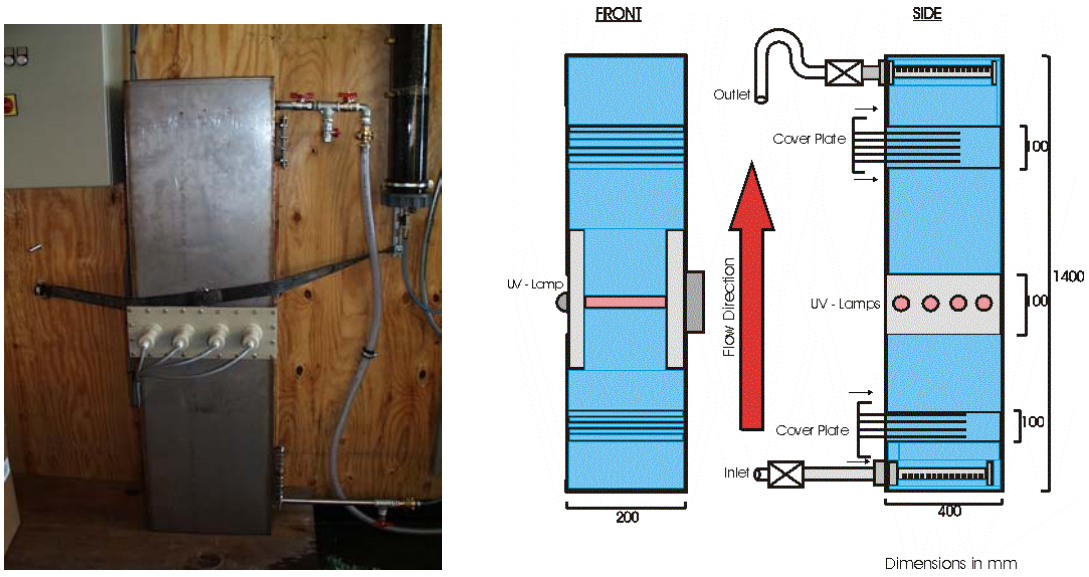

Figure 5: Pilot scale equipment for UV-radiation in its portacabin

The UV- radiation tank was fed with a water volume of 16 l/h abstracted from the groundwater of the gasworks site over a period of three months. The initial PAH concentrations (16 EPA-PAHs) reached values between 8672 and 18555 ng/l (approx. 95% represented by acenaphthene) and VC concentrations between 23 and 72 µg/l. As a result of the UV-radiation the PAH concentrations were reduced to values between 1441 and 3667 ng/l corresponding to an average reduction of more than 80%. The reduction of the VC concentrations was also significant showing a reduction of 82 % to an average value of 8.9 µg/l at the outlet of the pilot scale equipment (figures 6 and 7).

The comparison of the iron, manganese, calcium and magnesium concentrations of the water of the inlet and the outlet gave no indication that a precipitation has to be expected on the quartz-glass cover of the UV - lamps. This could be also confirmed by a visual inspection of the quarz-glass covers after a period of 13 weeks of operation.

The results showed clearly that the application of UV-lamps in the gates of the funnel-and-gate system is a novel and suitable technology for the in-situ remediation of groundwater contaminated with multiple organic constituents eg. PAHs and VC. Moreover, further analytical results on a lab scale showed that the application of this technology is also possible for the treatment of water contaminated with volatile aromatic compounds like xylene, trimethylbenzene, and methyl-ethylbenzene.

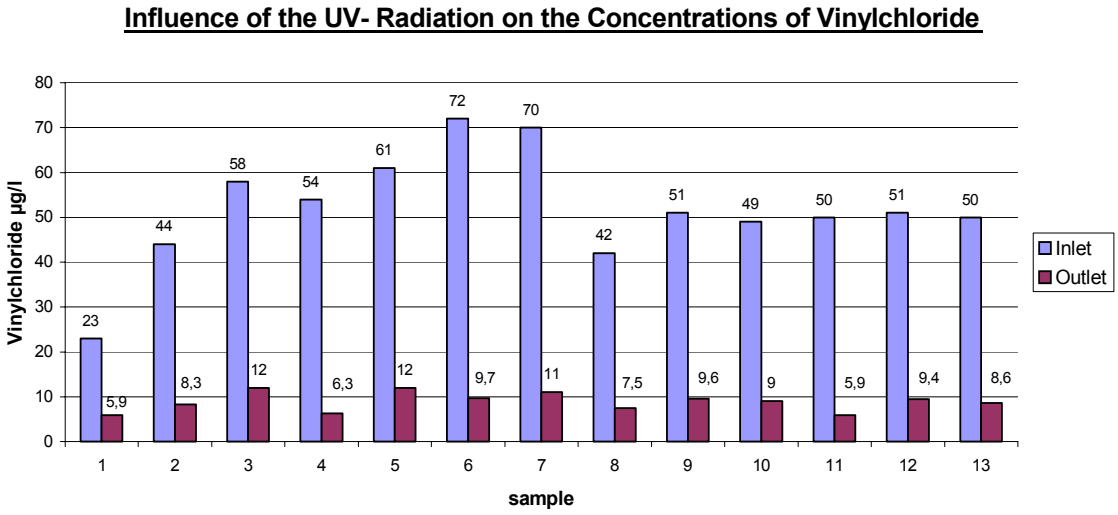

Figure 6: Reduction of the Concentrations of Vinylchloride after UV-radiation

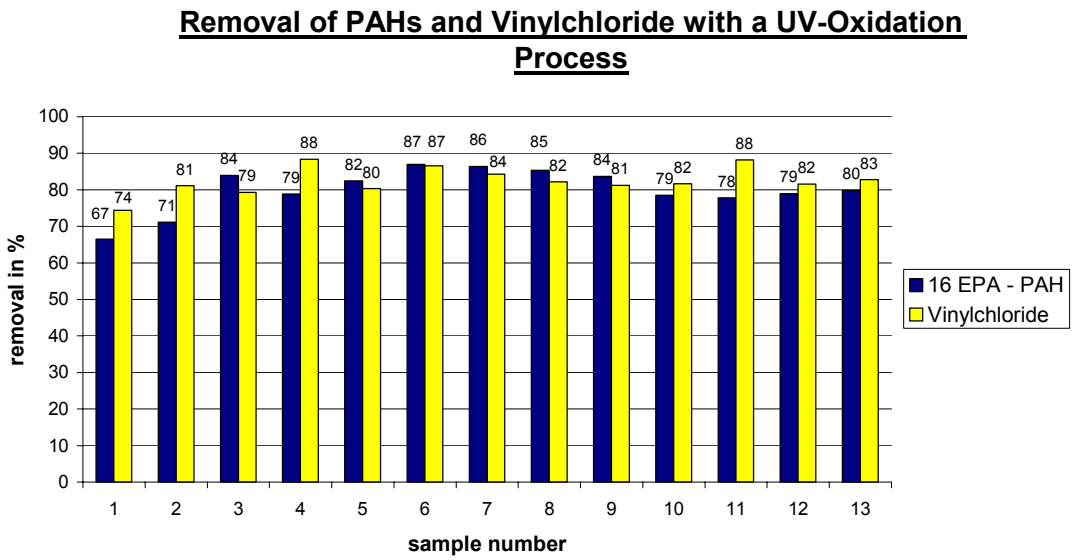

Figure 7: Removal of PAHs and VC in the pilot-scale equipment

5 Conclusion

The application of the UV-radiation in this concept with its two major goals firstly, the removal of the vinylchloride concentrations and secondly, the reduction of the PAH concentrations of the water flowing into the activated carbon column of the gates has shown its suitability for the treatment of contaminated groundwater with organic constituents. Due to the good results achieved with the UV-radiation in the pilot scale-equipment in the next step the application of this technology is intended in a pilot-gate on the gas works site commencing in July 2001.

6 Acknowledgement

This project was funded by the Federal State of Baden-Württemberg, Germany.

7 References

Schad, H., Haist-Gulde, B.; Klein, R.; Maier, D.; Maier, M.; Schulze, B. (2000): Funnel-and-Gate at the former manufactured Gas Plant Site in Karlsruhe: (1) Hydraulic Design and Sorption Results, Proc. of the *ConSoil-Conference* Leipzig, Germany, September 18-22

Maier, M.; Maier, D; Sörensen, M.: (2000) Funnel and Radiation - a new Technique for Groundwater Remediation. Proc. IWA – Conference "Innovations in Classic and Conventional Water Treatment Processes", Amsterdam, Netherlands, 26.-29.09.2000.

Maier, M., Maier, D. (2001) Funnel-and-Irradiation: A Novel Irradiation System for the In-Situ Remediation of Groundwater Contaminated with PAHs and Vinylchloride. Proceedings of the Conference "Water, Air and Soil Treatment by Advanced Oxidation Technologies: Innovative and Commercial Applications" Poitiers, France, 28.2.-2.03.2001.