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Groundwater Remediation Using the Vacuum-Vaporizer-Well

Operation of the Well and Biological Remediation of a Groundwater Contamination by Triazine

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Summary

World-wide, not only in the industrialized countries, the number of known groundwater and soil air contaminations by hydrocarbons, BTX, pesticides, nitrates, etc. increases. Efficient remediation techniques at low costs are needed.

A new method for the in-situ remediation of groundwater and soil air, contaminated by chlorinated hydrocarbons or pesticides is the Vacuum-Vaporizer-Well (UVB) technology (German: Unterdruck-Verdampfer-Brunnen (UVB), inventor: B. Bernhardt, patents: IEG mbH, both D-7410 Reutlingen).

The Vacuum-Vaporizer-Well technology and the groundwater flow around the UVB are explained, physical desktop aquifer models are used for demonstration.

A case study showing bioremediation of pesticide (triazines) contaminated groundwater is presented. Activated carbon is placed within the UVB well as a biofilter. A decrease of triazine concentrations in the groundwater is documented. An increase in the number of bacteria in the aquifer was observed and suggests a stimulation of biological processes. Development of metabolites within the activated carbon filter provides evidence of triazine biotransformation.

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1 The Operation of the Vacuum-Vaporizer-Well (W. Bürmann)

Some disadvantages of groundwater remediation when applying current pumping methods (groundwater lowering, limited yield, insufficient remediation) may be avoided if pumping and re-infiltration take place in the same well. The UVB is one application of this combined pumping and recharge well.

1.1 The Vacuum-Vaporizer-Well Technology

The UVB produces a circulation flow within the surrounding groundwater, directed from the upper to the lower screen of the UVB (figure 1). The water is sucked into the lower screen, transported upwards inside the UVB by the water pump (air lift pump), cleaned by fresh air in the stripping zone under below atmospheric pressure, and flows out of the UVB through the upper screen. This occurs without the water leaving the aquifer. Soil air from the unsaturated area of the aquifer may be sucked into the UVB through the upper screen and thus may also be cleaned. The contaminants are adsorbed by activated carbon. If necessary, the groundwater is cleaned on site and led back to the well. To avoid precipitation, the stripping air loop is closed. Thus contaminants which are not adsorbed can be kept from escaping into the atmosphere.

In resting groundwater, the circulation flow creates a permanent flow and consequently cleans the soil within the zone of the well, as all the circulating water flows through the well.

Natural groundwater flow which exists in most cases, deforms the circulation flow so that a portion of the water flowing towards the intake zone of the well, due to the continual circulation flow, may pass the well several times, whereas the remainder of the water flows through the well only once. Therefore, dimensioning of the cleaning equipment of the UVB must be made so that one flow through the well is sufficient to ensure decontamination of the water.

1.2 The Groundwater Flow around the UVB

The circulation flow depends on the natural groundwater flow, the water flow rate through the well, the water saturated thickness of the aquifer (corresponding to the length of the well), the length of the lower and the upper screening, the outer radius of the well, and the horizontal and vertical conductivities of the aquifer.

The circulation flow may be influenced only by the design of the well itself, and in particular by the water flow rate. If existing wells must be used, only the water flow rate remains for controlling the circulation flow.

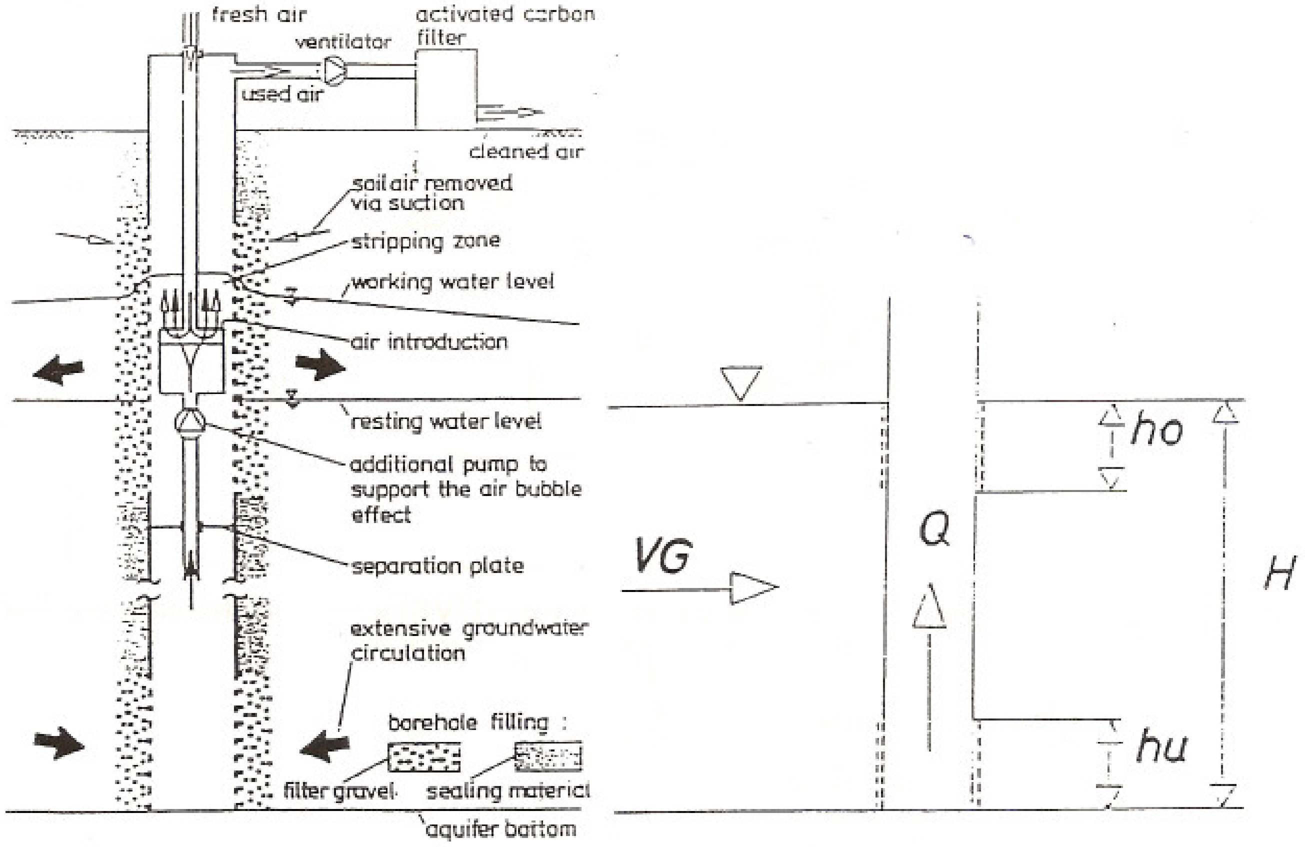

Fig. 1: Typical Vacuum-Vaporizer-Well (UVB)

In resting groundwater, the investigations give a theoretically unlimited zone of effect of the well. For a realistic judgement of the zone of effect, a radius around the well is chosen which contains a certain percentage of the total quantity of water flowing inside the well. The influence of the screening length is small. For realistic values of anisotropy of the aquifer, the radius of effect is approximately 1.5 to 2 times the water saturated aquifer thickness.

The circulation flow in moving groundwater shows two separating streamlines, at the bottom and at the top of the aquifer, similar to the perfect well (figure 2). In a well with upward flow, the lower separating streamline corresponds to the withdrawal well and the upper one to the infiltration well. Between these two separating streamlines at the lower and upper boundaries of the aquifer lies the separating stream surface of the flow around the well in the natural groundwater. This surface consists of spacial streamlines and shows a different contour in each horizontal section.

The dimension of the separating stream surface is characterized by the distance of the stagnation point S from the well. Figure 3 shows the water flow rate over the stagnation point distance of the upper separating streamline. The lower stagnation point distance gives the same curves for equal lengths in the lower and upper screening, and even for very different screening lengths the curves remain essentially the same.

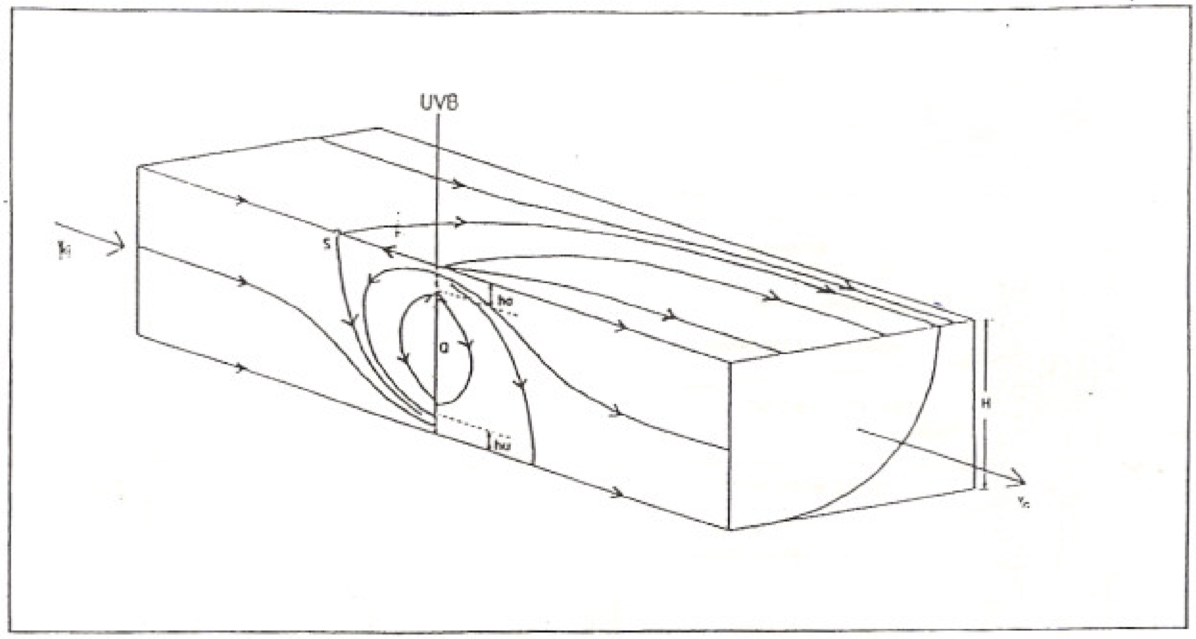

Fig. 2: Typical flow pattern of the Vacuum-Vaporizer-Well (UVB) in natural groundwater flow

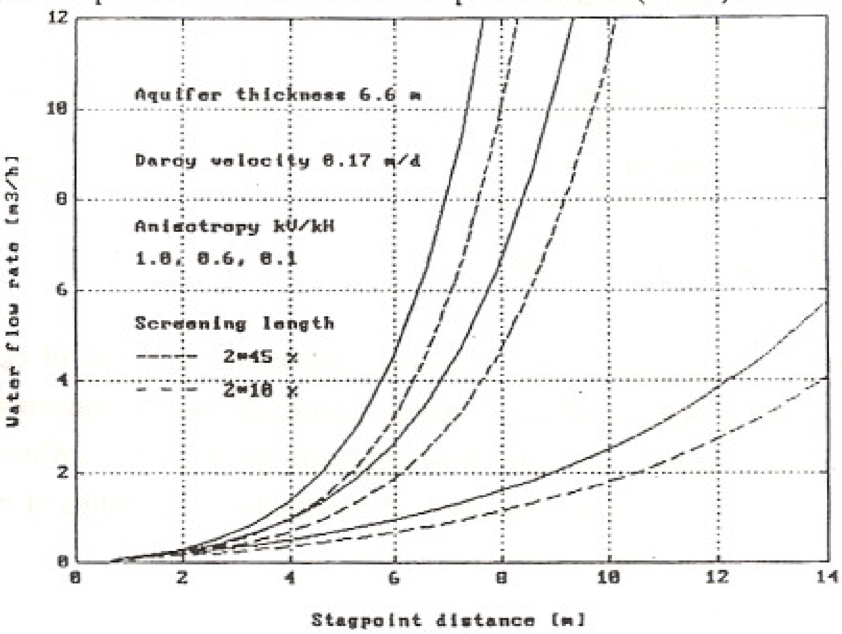

Fig. 3: Water flow rate over stagnation point distance of the Vacuum-Vaporizer-Well (UVB) in natural groundwater flow

The smaller the ratio of vertical and horizontal conductivity, the greater the stagnation point distance and the influence zone of the well.

The water flow rate through the well rises more than proportional with the stagnation point distance. Therefore, instead of one single well of a large water flow rate, several wells of small rates may be useful.

1.3 Physical Groundwater Flow Demonstration Models

Physical desktop aquifer models show the basic flow phenomena of the UVB remediation technology with respect to the natural groundwater flow. These demonstrations include the remediation of an artificial plume containing an impermeable, horizontal lens.

2 Case Study of a Biological Remediation (G. Bott and R. Krug)

The UVB-Technology offers not only an innovative method of physically remediation contaminated sites, but also makes in-situ biological remediation of groundwater possible. As a case study, a combined physical-biological remediation of groundwater containing pesticides (triazines) is presented (figure 4).

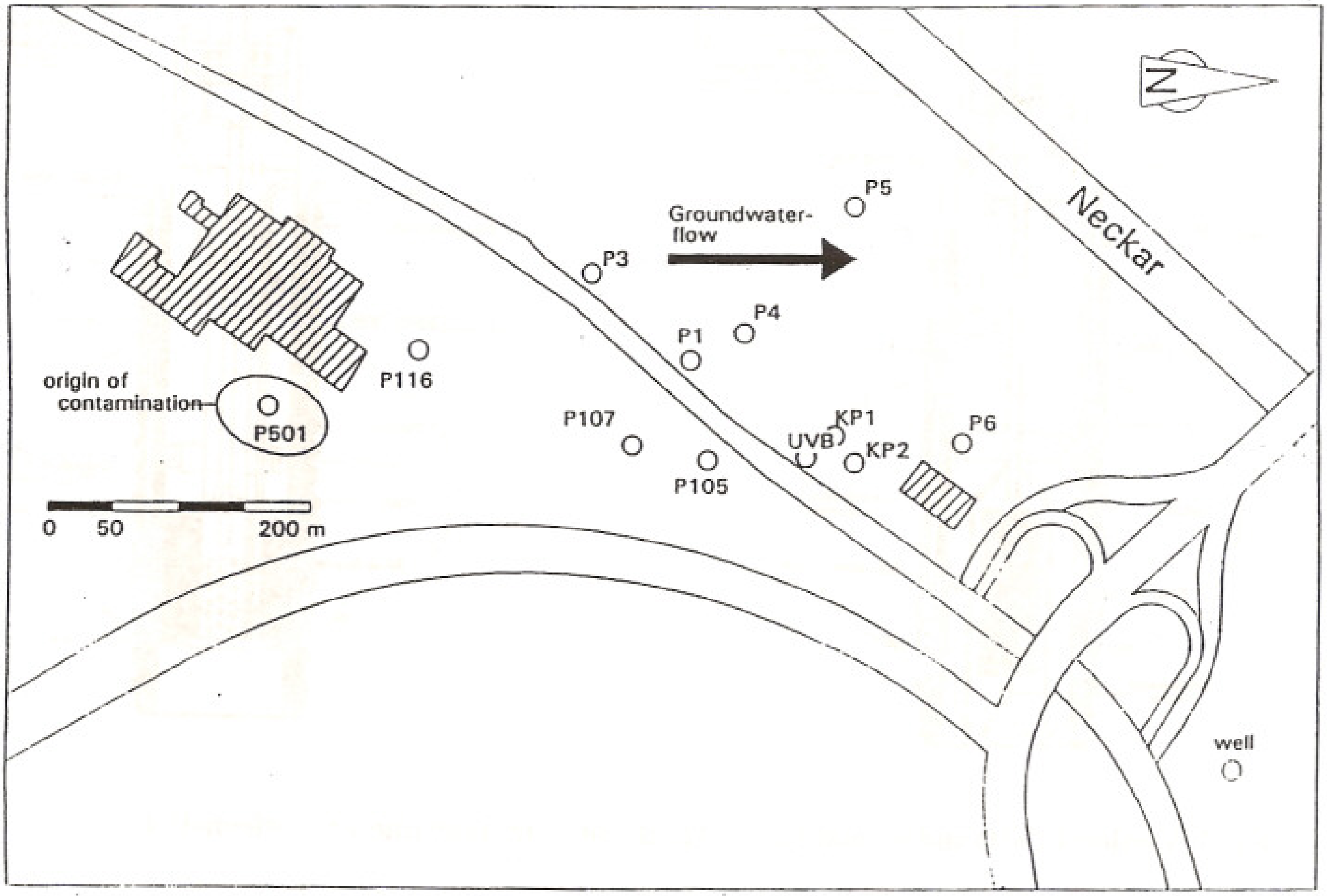

Fig. 4: Schematic map of the contaminated site

The Darcy velocity of the natural groundwater flow of 0.17 m/d, the water saturated heigth of the aquifer of 6.6 m, the anisotropy kV/kH of 0.1, the screening length of 2 m. and the water flow rate inside the UVB of 4 m^3/h give the stagnation point distance of about 13 m from figure 3.

2.1 Principle of Bioremediation

The principle behind every bioremediation is optimizing the environmental conditions for the naturally existing, already adapted microorganisms. Oxygen is often a limiting factor for aerobic degradation. The part of the aquifer that the UVB creates a continous circular flow in is regarded as an in-situ bioreactor, and is constantly supplied with oxygen enriched water.

Additional nutrients needed by the bacteria can easily be injected into the circulation flow that the UVB creates within the aquifer. This enables optimal conditions to be created for the micro-organisms bound on grain surfaces.

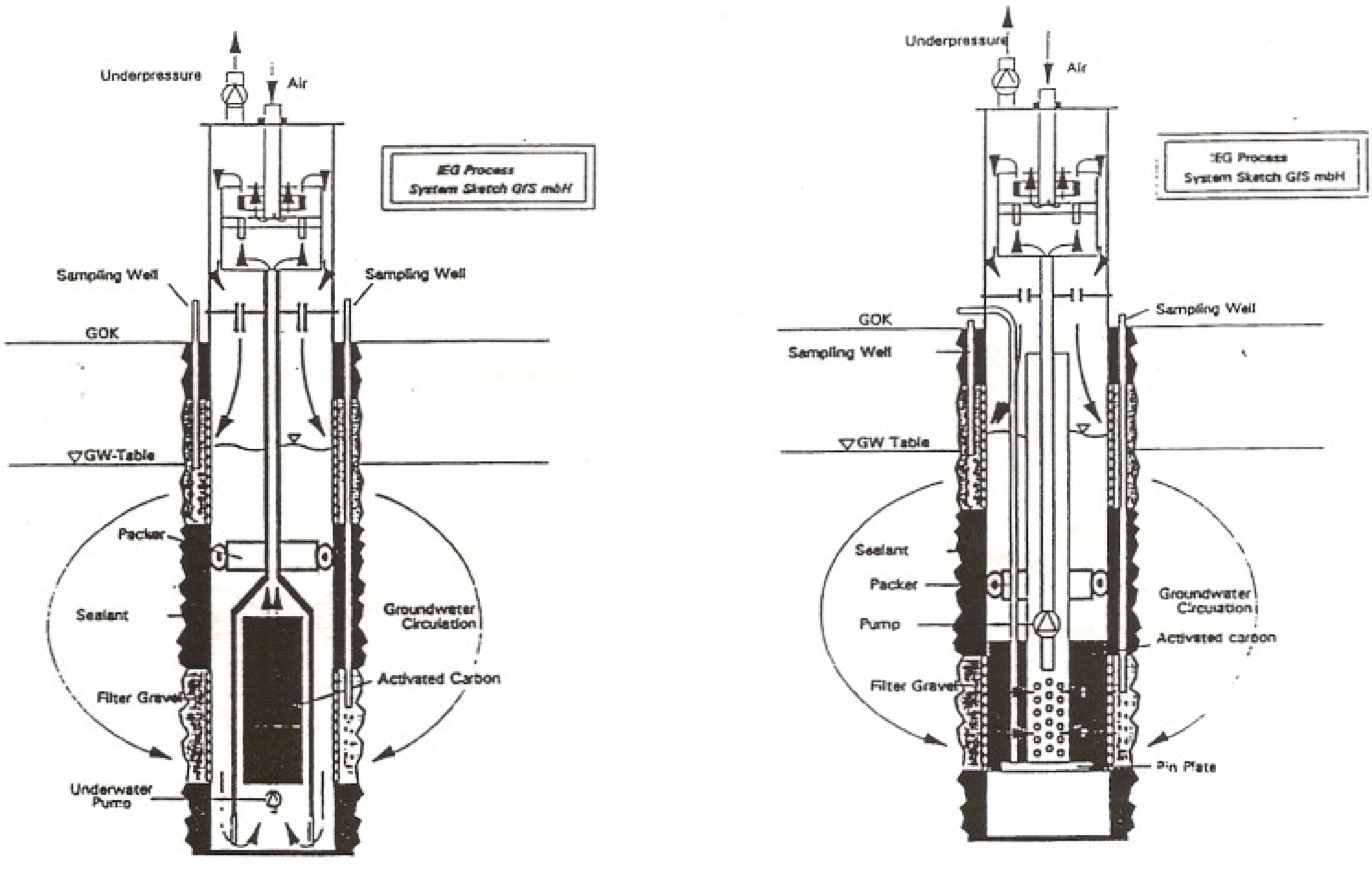

Fig. 5: Version 1 (left) and version 2 (right) of the biofilter implemented (schematic)

In the case study presented in this paper, activated carbon was used as a biofilter within the UVB well. Two variations seen in figure 5 were tested. In both cases the contaminants and the triazine-degrading bacteria are adsorbed onto the activated carbon by constant circulation of contaminated groundwater in the well. This accumulation is a special advantage in cases with low contaminant concentrations or few bacteria in the groundwater. The specific nutrient supply for the bacteria in the biofilter is possible.

2.2 Results of the Triazin Remediation

In figures 6 and 7 the triazine concentration curves during the remediation to date are depicted. The amount of triazines in the groundwater entering the activated carbon (figure 6) is greater than that after the biofilter (figure 7). This decontamination is the result of adsorption of triazines onto and biological degradation processes within the activated carbon.

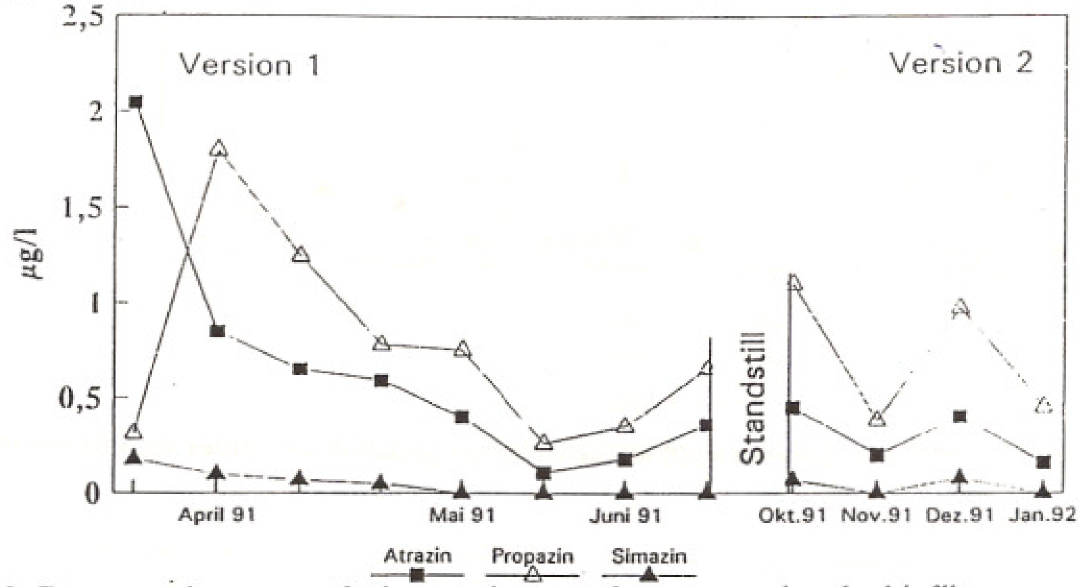

Fig. 6: Concentration curve of triazenes in groundwater entering the biofilter

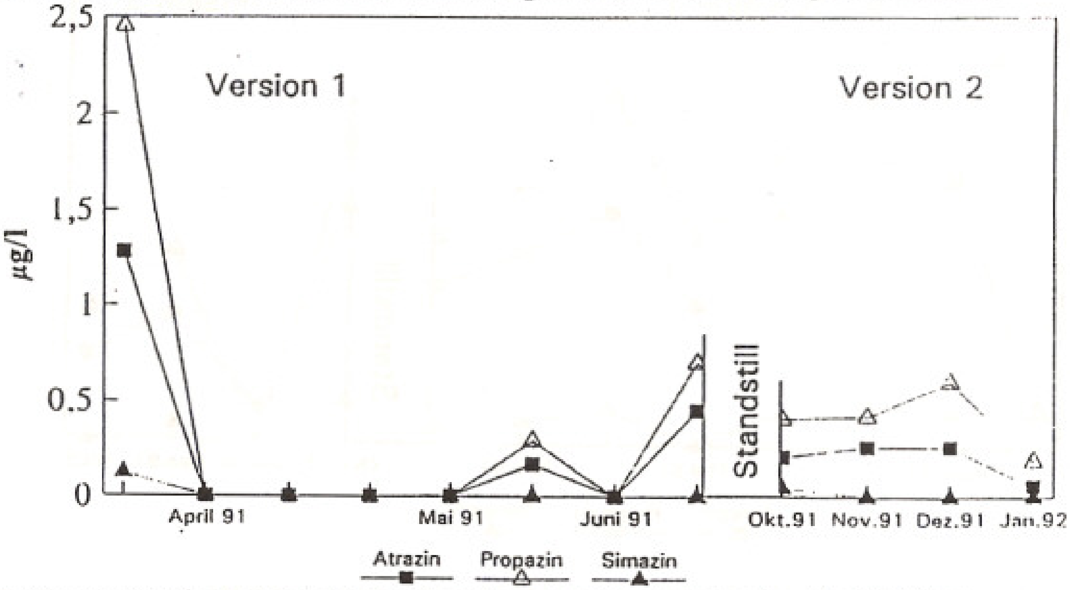

Fig. 7: Concentration curve of triazines in groundwater leaving the biofilter

During biodegradation of triazines various intermediates are formed (Cook 1987). These were detected in the aquifer before remediation with the UVB technique began. Figure 8 shows the concentration of one of these metabolites, Desisopropylatrazine, in groundwater before and after the activated carbon. From October 1991 through January 1992 the concentrations after the biofilter are higher than those before, suggesting that biological transformation of triazines is occuring in the biofilter. The consequential decrease in metabolite concentration can be explained by further degradation of the metabolite.

Fig. 9 depicts the decrease of triazine concentrations in groundwater of the monitoring well KP1.

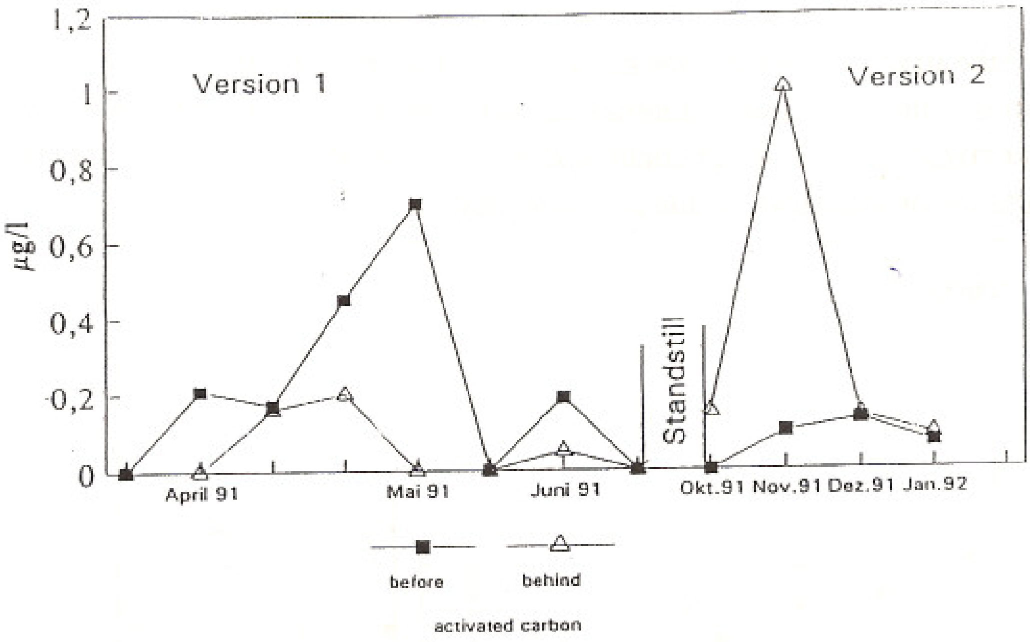

Fig. 8: Metabolite concentration (desisopropylatrazin) in the groundwater entering and leaving the biofilter

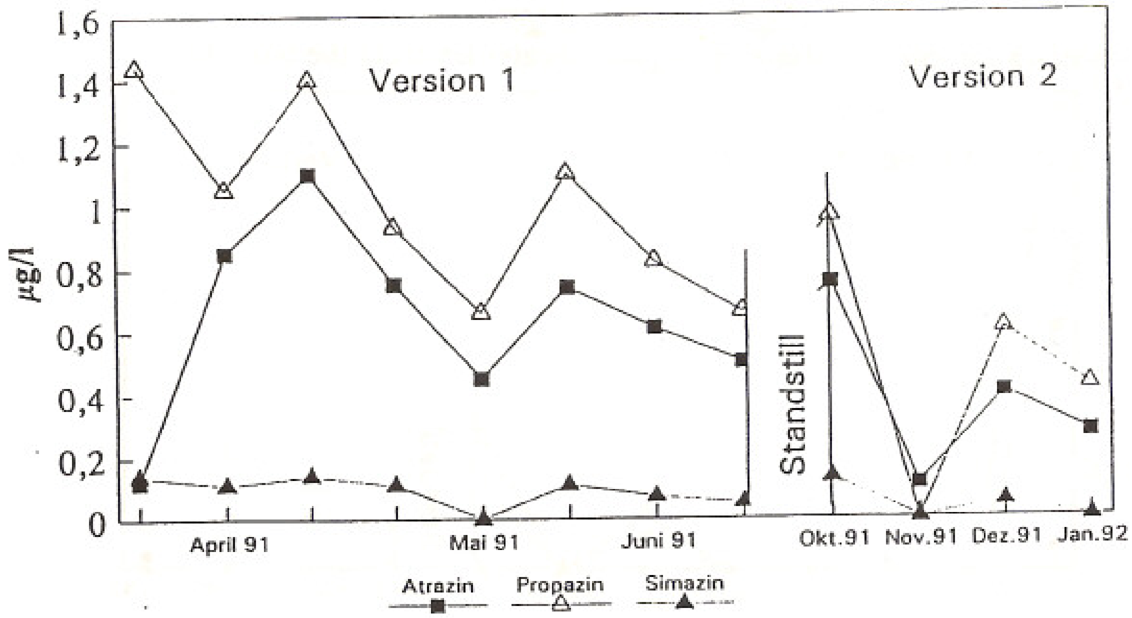

Fig. 9: Triazine concentrations in the groundwater at the monitoring well KP1

In addition to using intermediates as an indication of biodegradation, it is possible to count the number of bacteria in a sample. This was carried out by the CFU Method, in which bacteria are cultivated under aerobic conditions on a defined standard nutrient supplier.

Table 1 shows the development of the number of bacteria in samples taken from various wells. Within three months the number of bacteria in the monitoring well KP1 increased by a factor of one thousand, the triazine concentration decreased here accordingly.

	entering activated carbon	leaving activated carbon	Monitoring well KP1	Monitoring well KP2
October 1991	$4,7*10^2$		$2,5*10^3$	
January 1992	$1,8*10^3$	$3,1*10^4$	$3,5*10^6$	$7,5*10^3$

Table 1: Development of bacteria (CFU/ml groundwater)

A biofilm developed on the activated carbon from April to June 1991. It was analysed qualitatively and quantitatively. The number of CFU was 7,7 x 10^4/g activated carbon, which is an enrichment compare to the number of bacteria (470 CFU/ml groundwater) before the activated carbon biofilter.

2.3 Conclusions

The combined physical and biological remediation of triazin contaminated groundwater shows good success in decreasing the triazine concentrations for the duration remediation to date. The simultaneous increase in the number of bacteria in the aquifer suggests stimulation of biological processes. The development of metabolites within the activated carbon is evidence of biological triazine transformation. Further investigations include determination of degradation rate, looking to proof of specific triazine degrading bacteria both in the aquifer and in the biofilter, and optimizing the biofilter.

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