

## **ECONOMICAL ASPECTS RELATED TO THE CLEAN UP OF AQUIFERS FROM CHLORINATED HYDROCARBONS**

**Mull, R., Mull, J., Pielke, M.**

Institute of Water Resources, Hydrology and Agricultural Hydraulic Engineering,  
University of Hannover, 3000 Hannover, Germany

### **Problem and Objective**

Chlorinated hydrocarbons are the most frequent and most widespread contaminants in aquifers below urban areas. The main sources from which the substances intrude into the groundwater are abandoned sites, hazardous waste disposals and regions of chemical and metal industries. Concentrations of chlorinated hydrocarbons found in groundwater are relatively high compared with given quality standards for drinking water<sup>1</sup>.

Arrangements are taken to stop further emissions of dangerous compounds from the different sources. In general nobody knows the extent to which the concentrations of the contaminants are decreased, if the sources are eliminated. It was the objective of a case study in the city of Hannover, West Germany, to evaluate the benefit of the remedial actions and the corresponding costs.

The European Community has given standards for maximum tolerable concentrations of substances in drinking water. In many water samples taken from the aquifer the concentrations exceed by far these tolerable values in drinking water. A factor of exceedance is defined as follows:

$$A = c_f / c_t$$

A: factor of exceedance

$c_f$ : concentration of a substance in groundwater samples taken from the aquifer

$c_t$ : maximum tolerable concentration of this compound in drinking water

A measure for the amelioration of groundwater quality can be defined by:

$$B = (c_i - c_r)/c_t$$

$c_i$ : initial medium concentration in a distinct part of the aquifer

$c_r$ : concentration after the remedial action in the given part of the aquifer

The matter of interest are the costs as a function of the factor of amelioration.

### The Case Study

The aquifer under investigation covers an area of around 200 km<sup>2</sup> and has a medium depth of 10 m. Samples were taken from about 200 observation wells. In some parts the concentrations of 11 chemical substances exceed their quality standards given for drinking water. But the chlorinated hydrocarbons are the most widespread substances with the highest concentration related to the maximum tolerable value in potable water.

The areas of contamination in the city of Hannover are known<sup>2</sup>. There are 39 point sources from which chlorinated hydrocarbons intrude into the groundwater and 21 non point sources. These sources were implemented into a groundwater model with given emission rates. The model allowed to simulate the migration of the chemicals within the aquifer including the effects of dispersion and biochemical degradation. The initial condition was a non-polluted aquifer. The sources infiltrated chlorinated hydrocarbons in the non-polluted groundwater over a period of 50 years. After a calibration procedure the so calculated content of chlorinated hydrocarbons coincided with values found in the field 1990. The distribution of chlorinated hydrocarbons in the aquifer of Hannover is shown in Fig. 1. The simulation was extended for a period of hundred years from today under the following assumptions:

- steady state conditions for the groundwater flow
- constant emissions of contaminants from the sources in the future
- no pumping from further wells will decrease the content of substances.

Step by step the emission from every source was stopped and the resulting factor of exceedance was evaluated for the aquifer under investigation in different time intervals.

### Results

To illustrate the major outcome of the investigations the Fig. 2 shows the costs in German Marks related to the factor of exceedance. The more sources are closed the better the quality of the groundwater after a certain time. Under the economical point of view it seems to be impossible to improve groundwater quality up to the level of drinking water in the aquifer within the next hundred years, even if the attention is only focussed on chlorinated hydrocarbons.

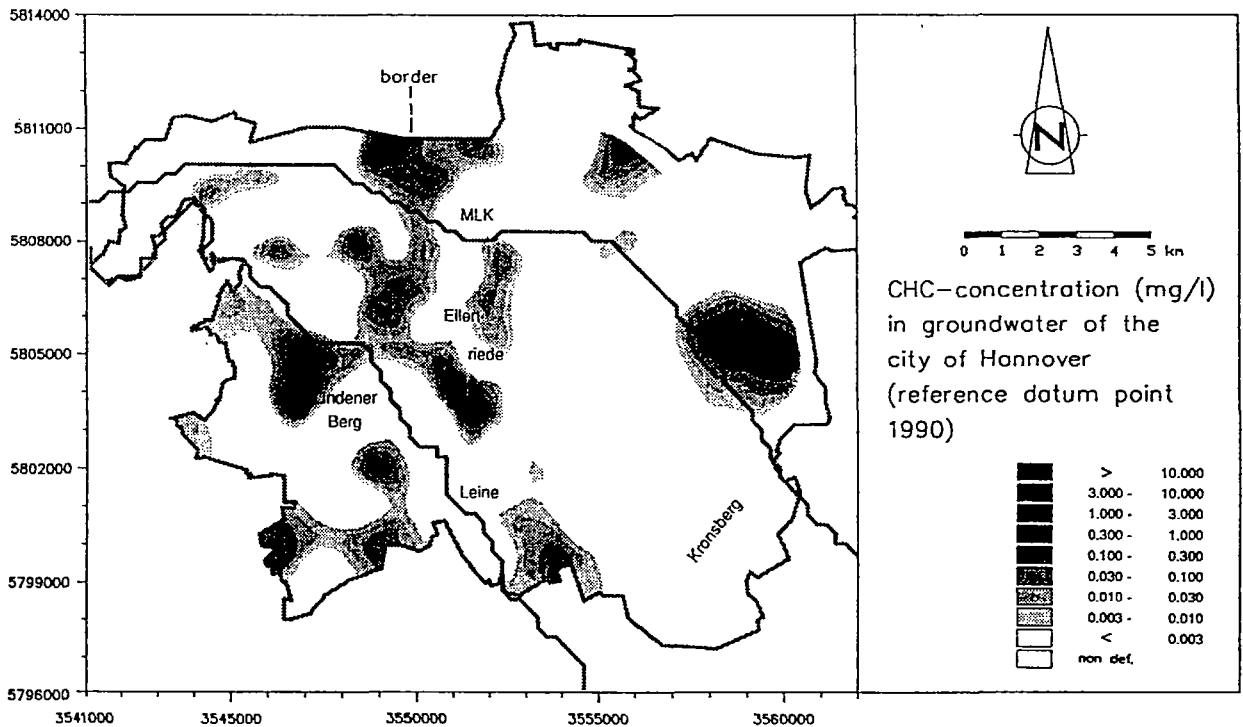


Fig. 1.: Concentrations of chlorinated hydrocarbons in the aquifer below the city of Hannover (1990)

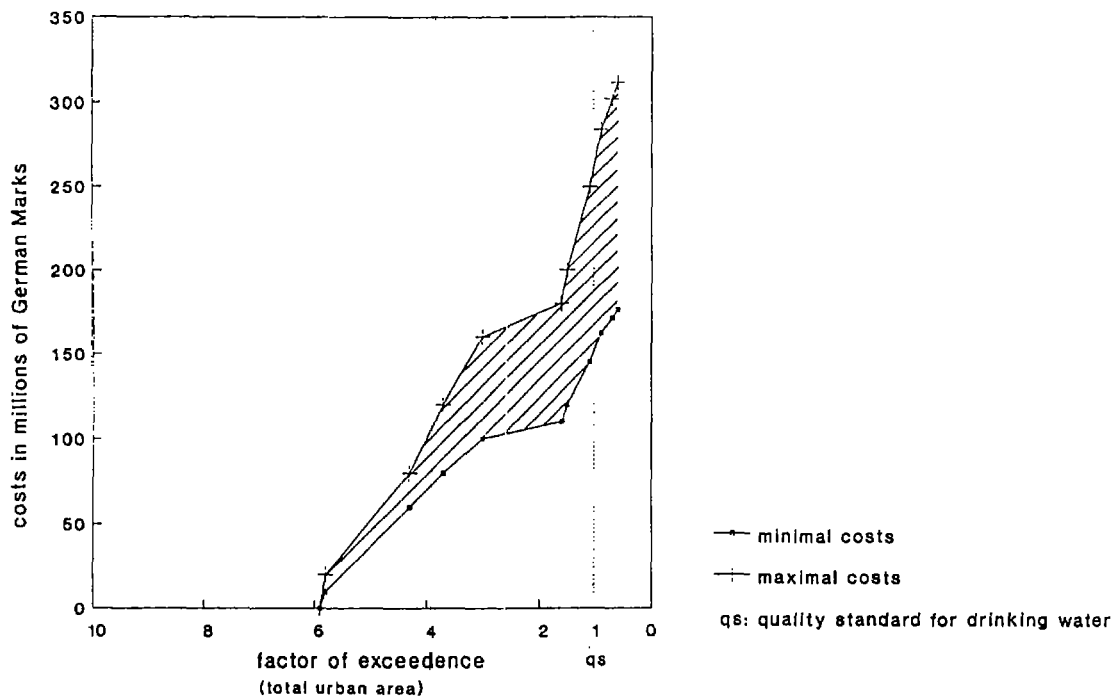


Fig. 2: Costs for the sanitation of "sources" emitting chlorinated hydrocarbons as a function of the factor with which the maximum tolerable concentration in drinking water is exceeded in the urban groundwater below the city of Hannover, Germany

### Conclusion

The evaluated function costs versus the factor of exceedance which characterizes the degree of groundwater contamination enables decision makers to see the advantage of measures taken to eliminate sources of contaminants, especially of chlorinated hydrocarbons, but with the related costs in their mind.

### Acknowledgement

The investigation was financed by the Federal Minister of Research and Technology and the Council of the City of Hannover.

### Reference

- 1 Mull R, Härig F, Pielke M. Groundwater Management in the Urban Area of Hannover. *Journal of the Institution of Water and Environmental Management*, Vol 6, 1992, No 2, 199 - 205.
- 2 Kues J, Schneider J. Erfassen potentiell kontaminierter Standorte in Hannover. In: *Tagungsband zu dem Seminar Altlastentage, Hannover, 1991.*