Modelling as a tool for optimization of cleaning plant structures built to remediate the TCE-contaminated Bernau place, Germany

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Abstract: The Bernau place is heavily polluted with trichlorethylene (TCE). To help in solving the remedy problem of the place, a system of hydrogeological models has been developed.

Key words: hydrogeology, modelling, reactive walls, drains.

Introduction

During 1935-1990, the Bernau place (30 km northeastward of Berlin) has been polluted with trichlorethylene (TCE). It is the dense non aqueous phase liquid type substance, which sinks in groundwater until the nearest aquitard is reached. Due to this feature, motion of TCE is controlled both by the hydraulic gradient of groundwater and by the slopeward top surface of the aquitard. In 2001, the German hydrogeological company INGAAS GmbH has started a cleaning plant (CP) for in-situ remediation of contaminated groundwater in high concentrations (75 - 300 mg/l). The main unit of CP consists a groundwater accumulator, which feeds the reactor where dehalogeniation of TCE is accomplished (Hein, 2002). The accumulator occupies the centre of the TCE spill, which is framed by a vertical impermeable wall. Groundwater to be cleaned by the reactor may be taken out from aquifers by pumping from wells and or from horizontal drains. Reactive walls may be used for in-situ cleanup without involving the reactor.

Although general ideas of how CP should be built and controlled afterwards are clear enough, there are questions to be answered if engineering details are considered:

- What factors do control productivity of the system “accumulator → reactor”? What are the best groundwater pump-out and reinfiltration places and regimes?
- How does TCE spread out regionally? What are the optimal measures (drains, reactive walls, wells) to stop this contaminant migration and to clean the place?

Scientific paper

To answer these questions, rather ample modelling has been accomplished. Its main results have been discussed in (SPALVINS ET AL., 2001), and (BURGER ET AL., 2002). In this paper, results of comparative regional modelling of various tools, used for remediation of the place, are presented.

RESULTS AND DISCUSSION

In the Bernau area, two sandy Quarternary aquifers L2 and L3 are TCE – contaminated, and they are joined via the S2 aquitard. The Teufel pool presents there the main natural sink for the TCE transport flow for the upper L2 aquifer. The saturated thickness of the L2 aquitard is 5-8 metres. The permeability of the L2 and L3 aquitards are very heterogeneous (5.2–45.0 m/day and 7.0-28.0 m/day for the L2 and L3 aquifers, respectively). The groundwater flow, in the L2 aquifer, is more intensive (hydraulic gradient ~0.0035) then for the lower L3 aquifer (hydraulic gradient ~0.001).

Regional and local hydrogeological models (HM) were created by the team of the Environment Modelling Centre (EMC) of the Riga Technical University to investigate the Bernau case. Areas of 1.2 km´0.8 km=0.96 km^2 and 0.23 km´0.17 km=0.039 km^2, correspondingly, are covered by them. The HM approximation grid plane steps are 10 metres and 2 metres, accordingly, for regional and local HM. In HM, the L2 and L3 aquifers are split in four (L2a, L2b, L2c, L2d) and three (L3a, L3b, L3c) parts, respectively. Such a fine vertical schematization enables to account for heterogeneity of aquifers and to simulate in details the TCE-transport spatial picture for the contaminated area. Specialists from the university of Tuebingen (UT) used regional HM to optimise reactive walls with gates for the Bernau case.

The MT3D'99 code (PAPADOPULOS, 1999) was used by the EMC team for modelling of various remediation tools (wells, reactive walls, drains). The code was supported by HM of the area.

It takes 2000 – 3000 days to form the TCE plume. For numerical experiments on remediation methods in the L2 aquifer, a hypothetical plume has been designed and applied for the L2d aquifer. The initial TCE-mass of the plume is ~2300 kg. To form the plume, observed TCE concentrations, spatial dispersion and simulation results were accounted for (see the initial plume on Fig. 1).

Regional modelling of drains, reactive walls and wells, as tools for remediation, has provided the following results:

- horizontal drains may be extensively used, because their regimes are easy to control; a system of drains may effectively remediate dissolved TCE of the L2 aquifer;
- reactive walls with gates may serve as effective tools if their location is rightly chosen; it has been proven by specialists from TU that the wall with two gates is the optimal one for the Bernau place;
- for the deep L3 aquifer, pumping from wells seems to be the only realistic remediation choice; to achieve the best TCE outcome, short term pumping from different wells must be accomplished to keep the TCE concentration high as long as possible.

An example of modeling remediation by a horizontal drain is illustrated by Fig. 1. The contaminant plume is supported by constant concentration sources (maximal observed TCE-concentrations) accounting for a possible residual TCE part accumulated in the layers L2d and S2. The length of the drain is 100 metres, and its outflow rate is 60 m^3/day. The drain is located in the L2d aquifer. For the TCE plume, the Teufel pool and the drain serve as sinks for dissolved TCE. The drain cuts the plume into two parts and the downgradient one is caught by the pool. It follows from Fig. 1 that ~ 2500 days are necessary, to sink the downgradient plume by the pool. To remediate the L2 aquifer, three tasks should be performed: a) to stop the flow of TCE caused by the original spill area as shown in Fig.1; b) to block the inflow of TCE into the Teufel pool; c) to clean the vicinity of the pool. It may be necessary to use a second reactor for cleaning water taken from the area of the pool, if extra drains or wells are used here.

It is shown in Report on Permeable Walls, Wells and Biological systems for Remediation (2003) that a fully permeable reactive wall, containing no gates may serve as a possible alternative for the wall with gates due to the following advantages:

- the wall does not disturb the groundwater flow;
- it is considerably shorter, because its length may be equal to the width of the plume to be cleaned.

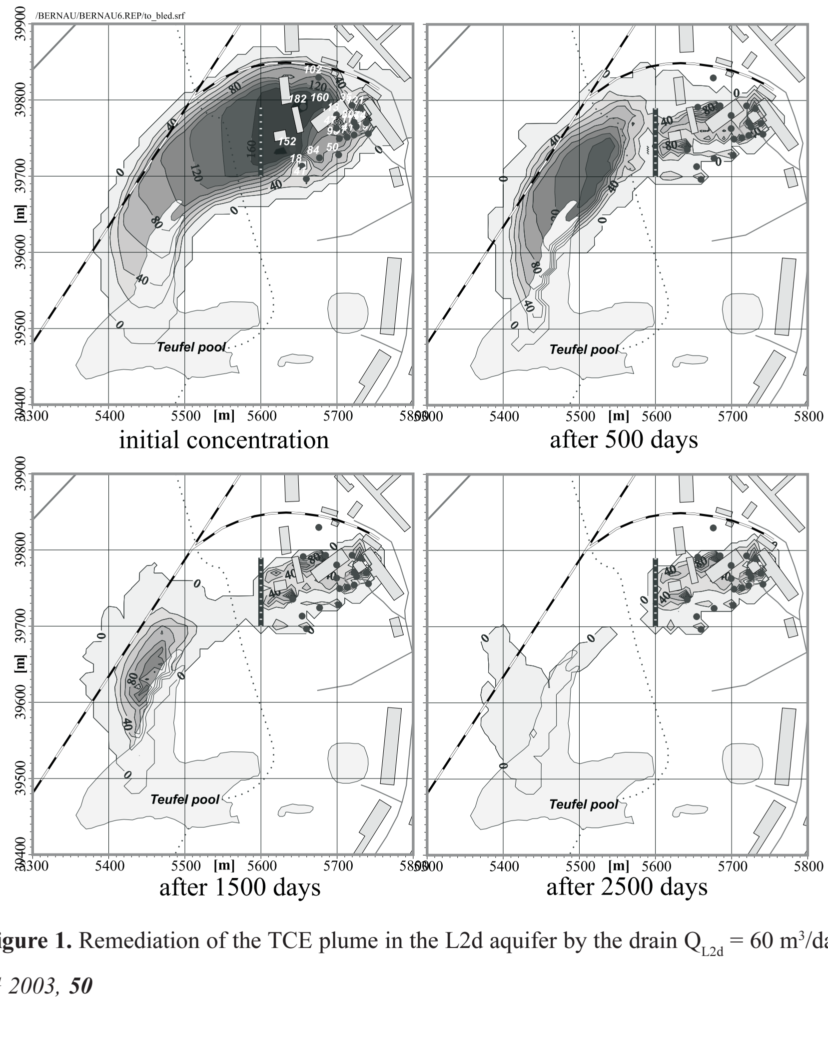

Figure 1. Remediation of the TCE plume in the L2d aquifer by the drain Q_{L2d} = 60 m^3/day

The wall with gates causes the following side effects (SPALVINS ET AL., 2002):
- it considerably deforms the groundwater flow;
- due to this deformation, downgradient the wall, the flow to the Teufel pool gets considerably slower and cleaned water enlarges the polluted area here.

At present, no final decision regarding long term remediation of the Bernau place has been taken. More field data are needed about the TCE regional spread out under impact both of the hydraulic gradient of groundwater and the migration of TCE caused by gravity. No full understanding is reached yet how has the lower L3 aquifer got contaminated so heavily.

CONCLUSIONS

A system of hydrogeological models has been designed for investigating of the TCE-contaminated Bernau place.
Mathematical modeling of various remediation scenarios and tools has been accomplished by using the regional hydrogeological model as the driver.
More field data and modelling are needed to take the final decision how to carry out a long remediation of the Bernau place.

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