Modelling of remeditation tools for the contaminated Bernau place, Germany

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1 INTRODUCTION

During 1935-1990, the Bernau place has been polluted with (trichloretilen) TCE, which is the dense non aqueous phase liquid type substance. It sinks in groundwater until the nearest aquitard is reached. Due to this feature, the lateral 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. The accumulator occupies the centre of the TCE spill, which is framed by a vertical impermeable wall. Cleaned water is infiltrated into the ground. Contaminated groundwater to be cleaned may be taken out from aquifers by pumping from wells and or from horizontal drains. Reactive walls may be used as a part of CP.
Although general ideas of how CP should be built and controlled afterwards are clear enough, there are questions to be answered if practical details are considered:

- How does the system "accumulator → reactor" work? What factors do control its productivity?
- How will CP interact with the environment? What is the best choice of the 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 dean the place?

To answer these questions, rather ample modelling has been accomplished. Its main results have been discussed in (Spalvins et al, 2001), which is based on materials of the intermediate reports of EMC (Report 1999, Report 2001a, Report 2001b, Report 2001c, Report 2001d). All information used for creating and calibrating of Bernau hydrogeological models (HM) was provided by INGAAS GmbH. In this paper, results of comparative regional modelling of various tools, used for long time remediation (10-20 years) of the place, are presented.

2 SUMMARY ON BERNAU HYDROGEOLOGICAL CONDITIONS

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 in a groundwater 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 both vertically and horizontally (5.2–45.0m/day and 7.0-28.0m/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 HM were created to investigate the Bernau case. They cover, correspondingly, 1.2km×0.8km=0.96km^2 and 0.23km×0.17km=0.039km^2 areas. 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.

3 MODELLING OF CONTAMINANT TRANSPORT AND REMEDIATION TOOLS

The MT3D'99 code (Papadopulos, 1999) was used as the main tool for modelling of TCE-transport processes. The code was supported by HM of the area. The following main regional problems were considered:

- contaminant transport to the Teufel pool under undisturbed conditions (no remediation measures taken);
- an impact of the former Bernau waterworks on the TCE migration;
- various remediation tools (wells, reactive walls, drains) were modelled for the Bernau place.

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 (Report 2001d, Report 2002). It is located in the *L2d* aquifer. The initial TCE-mass of the plume is ~2300 kg. To form the plume, observed TCE concentrations and simulation results were accounted for (see the initial plume on Fig. 1).

When the former Bernau waterworks were operational, they pumped out practically all dissolved TCE-mass (Report 2001d).

Regional modeling of drains, reactive walls and wells, as tools for remediation, has provided the following results (Report 2002):

- 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 (Fig. 1, Fig. 3);
- reactive walls may serve as effective tools if their location is rightly chosen; otherwise, the cleaned water flow from the gate of the wall may unnecessarily dilute the part of the TCE plume which is located down gradient (see Fig. 2);
- 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 (Report 2002);

An example of modeling remediation by the horizontal drain is illustrated by Fig. 1. The hypothetical contaminant plume is supported by constant concentration sources (wells with maximal observed TCE-concentrations) accounting for the 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. The upgradient part is caught by the drain and stabilisation of TCE-concentrations here is achieved

dient part is caught by the drain and stabilisation of TCE-concentrations here is achieved during 500 - 1000 days.

The TCE-mass graphs of Fig. 3 suggest that the remaining dissolved TCE mass is ~ 200 kg. However, the cumulative outflow of TCE follows the linear TCE inflow graph (~ 0.7 kg/day), if the elapsed time exceeds 1000 days.

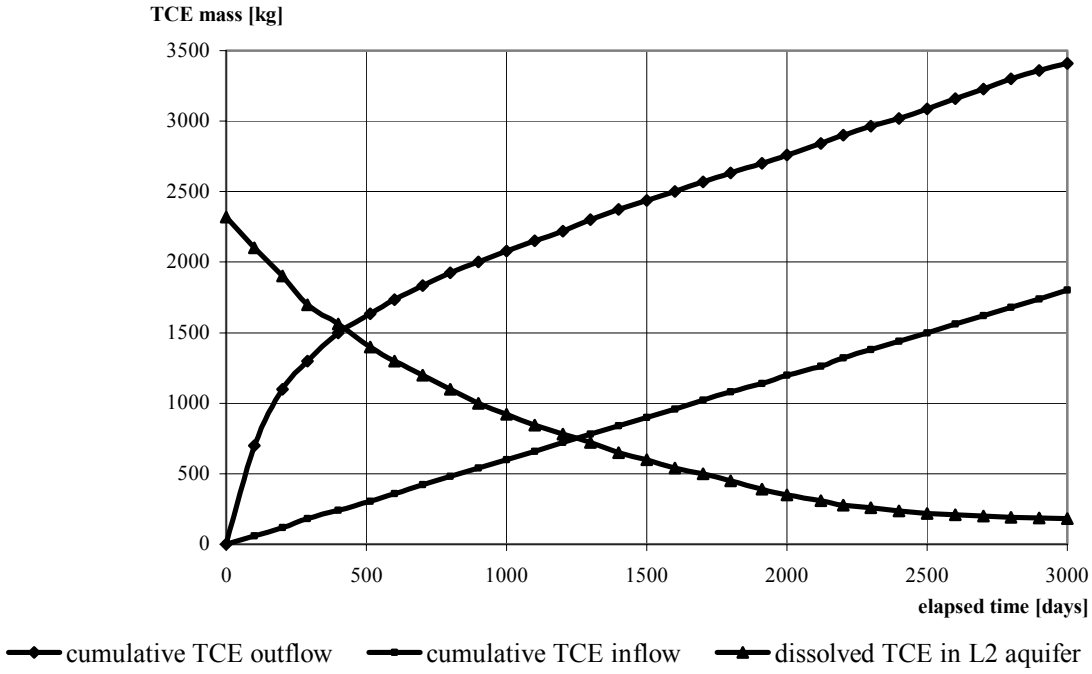

Fig. 3. Graphs of the TCE mass versus time when the hypothetical L2d plume is remediated by the drain of Fig. 1

It follows from Fig.2 that a wrongly located reactive wall causes the following unwanted consequences, for the part of the plume collected by the pool:

- water cleaned by the wall dilutes the plume and enlarges the polluted area;
- reduces effectiveness of the pool as the sink, because the hydraulic gradient here lowers under influence of the wall.

At present, no attempt has been made, to find the optimal solution how to remediate the Bernau place, because more field information is needed about the regional spread out of the TCE migration under impact both of the hydraulic gradient of groundwater and the motion of TCE governed by the top surface of the S2 aquitard.

4 CONCLUSIONS

Regional and local hydrogeological models have been designed for the TCE-contaminated Bernau place. The local model will serve for optimization of the cleaning plant regimes.

Mathematical modeling of the TCE-migration has been accomplished by using the regional hydrogeological model as the driver. Basic remediation methods have been tested.

When new field data will come in, the hydrogeological and transport models will be improved.

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Spalviņš A., Šlangens J., Janbickis R., Lāce I., Hein P. Vides atveseļošanas līdzekļu modelēšana piesārņotajam Bernau apgabalam Vācijā.
Bernau apgabals (atrodas ~50km uz austrumiem no Berlīnes) ir ļoti piesārņots ar trihloretānu (TCE). Lai palīdzētu atrisināt šī apgabala atveseļošanas problēmu, Rīgas Tehniskās Universitātes Vides Modelēšanas Centrs ir izveidojis hidroģeoloģisko modeļu sistēmu. Šajā rakstā apkopota informācija, kas iegūta modelējot TCE transportu, ja vides attīrīšanai izmanto dažādus atveseļošanas līdzekļus (drenas, reaktīvās sienas, urbumus).

Spalvins A., Slangens J., Janbickis R., Lace I., Hein P. Modelling of remeditation tools for the contaminated Bernau place, Germany.
Modelling of Remeditation Tools for the Contaminated Bernau place, Germany
ABSTRACT: The Bernau place (located ~ 50 km east of Berlin) is heavily polluted with trichlorethene (TCE). To help in solving the remedy problem of the place, a system of hydrogeological models has been developed by the Environment Modelling Centre of the Riga Technical University. The paper summarizes information by modeling TCE – transport if various remediation tools (drains, reactive walls, wells) are applied for cleaning the place. Advantages and drawbacks of these tools are explained if they are used for long term (10 – 20 years) remediation of the soil and groundwater of the Bernau place.

Спалвиньш А., Шлангенс Я., Янбицкис Р., Лаце И., Хейн П. Моделирование средств оздоровления для загрязненной области Бернау, Германия.
Область Бернау (расположена ~50км восточнее Берлина) сильно загрязнена трихлорэтаном (ТСЕ). Для решения проблемы оздоровления этой области, Центром Моделирования окружающей среды из Рижского Технического университета создана система гидрогеологических моделей. В статье обобщена информация, которая получена моделированием транспорта ТСЕ, если для очистки среды применяются различные средства оздоровления (дрены, реактивные стены, скважины).