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Alcohol Flushing

1. Introduction

The intention of this project (Entwicklung einer weitergehenden Grundwassersanierungstechnologie zur Abreinigung von anthropogenen chlorierten Kohlenwasserstoffen hoher Dichte (CKW) durch Alkoholinjektion: Teil A - Hydraulische Steuerung der gezielten Alkoholinjektion und Teil B - Solubilisierung und kontrollierte Mobilisierung) is to develop an efficient in-situ-technology to remove chlorinated hydrocharbons from the saturated zone. Using a groundwater circulation well (GCW) the alcohol cocktail is injected into the aquifer and flushed through the contaminated zone. The solubilised and controlled mobilised contaminant is subsequently extracted by a GCW from the aquifer. This project, funded by the German Federal Ministry of Education and Research (BMBF), is a cooperation between the Institute for Hydromechanics (Universität Karlsruhe) and the Institute of Hydraulic Engineering (University of Stuttgart).

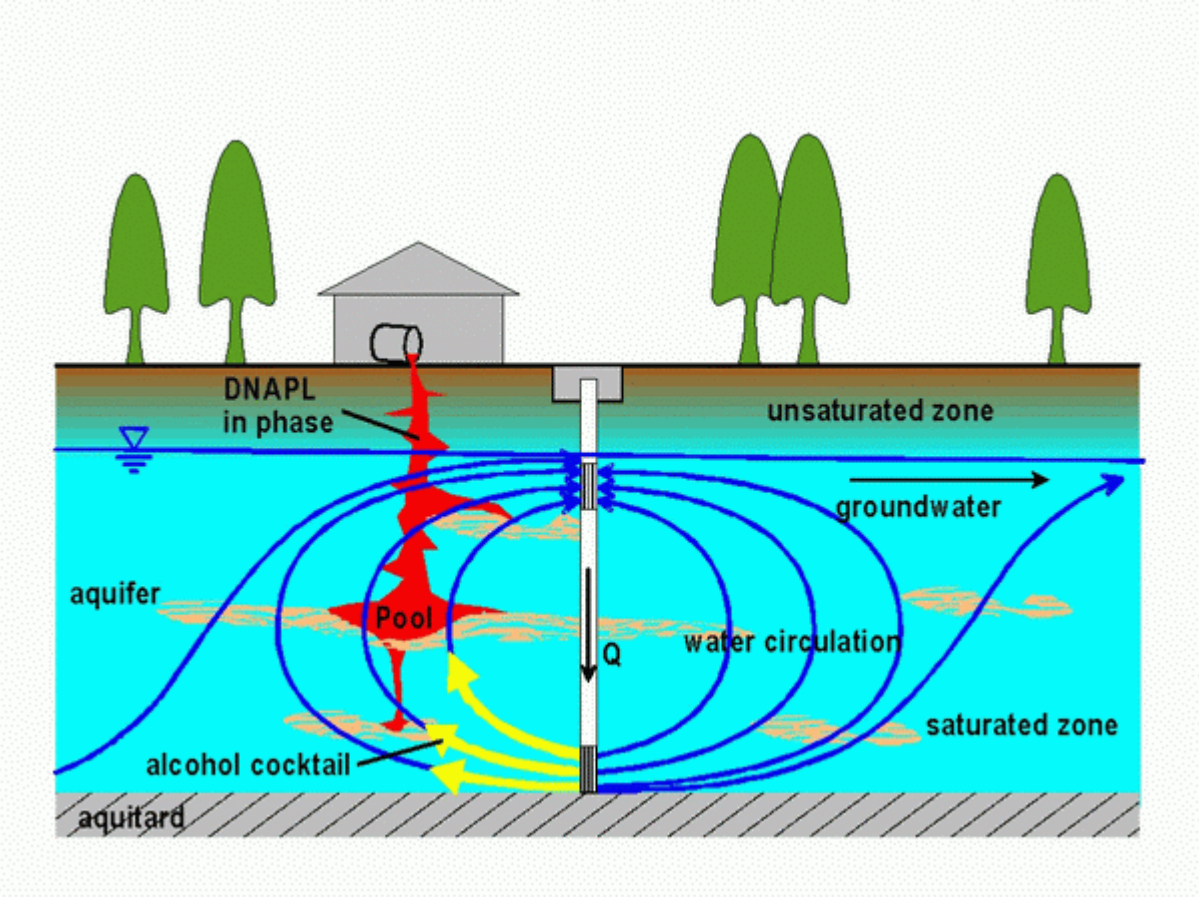

Fig.1: Alcohol flushing with a groundwater circulation well

The Institute for Hydromechanics is working on the hydraulically controlled alcohol injection using a GCW. The solubilisation and controlled mobilisation of chlorinated hydrocharbons is investigated at the Institute of Hydraulic Engineering. Based on different scale experiments and numerical modelling, an effective in-situ-remediation technology is being developed. In batch- and column experiments, a suitable alcohol cocktail was chosen and its behaviour in the porous media and with the contaminant was investigated. 2D-box and large tank experiments are used to investigate the hydraulic system and to estimate the remediation time.

2. Procedure

1. Development of a suitable alcohol cocktail
2. Verification of hydraulic control of the density driven multi phase-/multi component flow
3. Development of a well directed alcohol injection
4. Further development of partitioning tracer tests (PTT) to locate contaminated areas in an aquifer
5. Further development and improvement of the waste water treatment/alcohol recycling
6. Numerical modelling and development of a mode for the STOMP (subsurface transport over multiple phases) code
7. Large scale experiments in the VEGAS facility
8. Planing, design of a pilot study based on the experimental results and searching for a suitable location

3. Status Quo

The relevant processes for alcohol flushing were investigated in batch- and column experiments. In the batch tests, numerous alcohol-water-mixtures (alcohol coktails) were analyzed as remediation fluids.

Fig. 2: Preparation of alcohol-water-mixtures to determine the mixing behaviour

The remediation eficiency of suitable alcohol cocktails were investigated in column experiments. The alcohol cocktail was flushed in an upwards direction through the sand filled and water saturated column. Perchloroethylene and trichloroethene (representative DNAPL) were used as contaminants in residual saturation. The experiments were conducted with different porous media and different flow velocities.

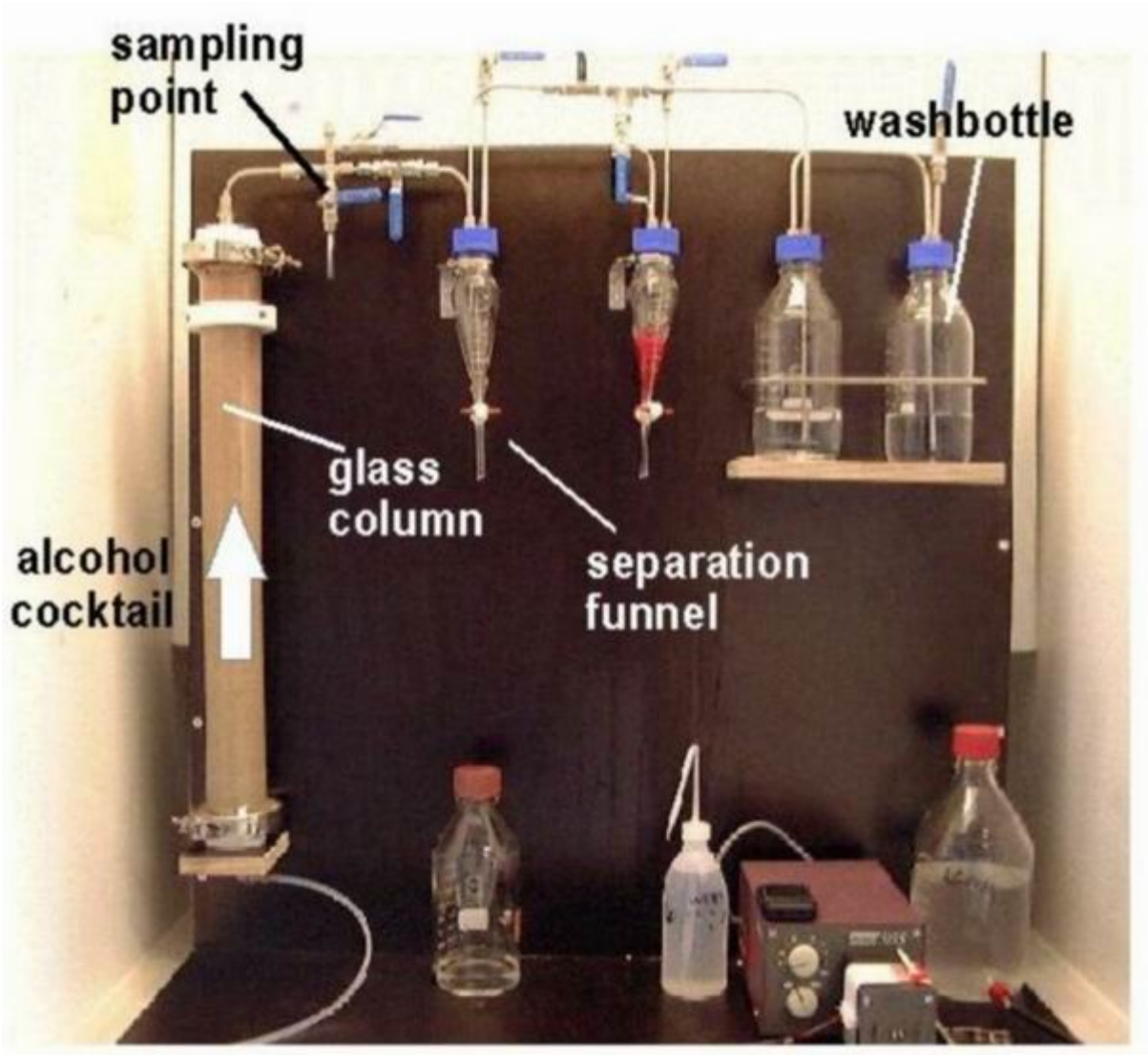

Fig.3: Setup for the alcohol flushing column experiments

In all column experiments, the DNAPL was removed quickly and without uncontrolled downward mobilisation. Besides a suitable alcohol cocktail,an upward flow is necessary to avoid a downward migration of the DNAPL. In the column experiments the minimal upward flow velocity (critical velocity) which avoid a downward migration (uncontrolled mobilisation) was determined for different porous media.

In the following figure, the density decrease of the organic phase and the PER removal over flushed pore volumes is demonstrated. In this experiment, an alcohol cocktail consisting of 54% 2-propanol, 23% water and 23% 1-hexanol was pumped with a darcy velocity of about 4 m/d through the fine sand which was residual saturated with PER.

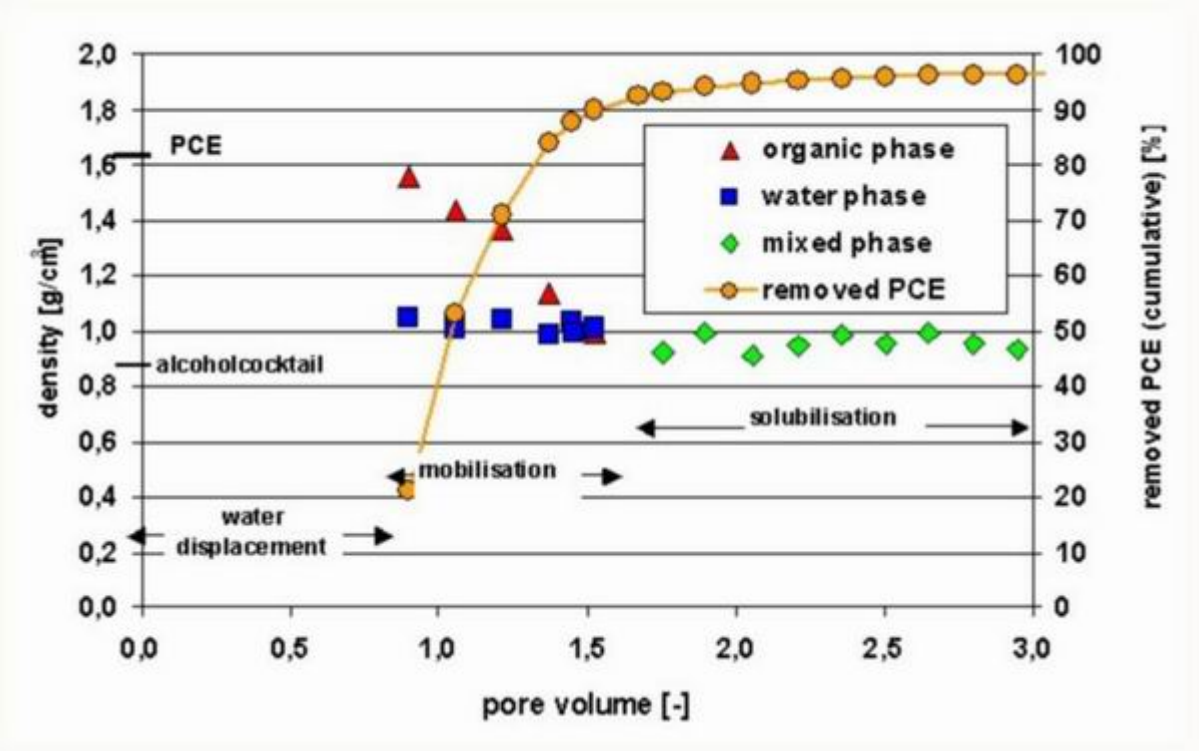

Fig.4: Density change and PER removal during a column experiment

The first pore volume of alcohol cocktail was needed to displace the water in the column. When the alcohol Contacted the organic phase, the interfacial tension was reduced and the PER was controlled mobilised. During this alcohol flushing more and more 1-hexanol partitioned into the organic phase, so that after 1.5 flushed pore volumes the PER density was idecreased from 1.62 g/cm³ to the density of water. After that, only a single phase, containing the solubilised contaminant, was extracted from the column.

The experimental results were used to develop a new mode for the numerical model STOMP The equations for the relevant parameters (density-, viscosity changes, phase behaviour and change of the interfacial tension) were implemented in the numerical model.

Alcohol flushing is currently optimised in 2D experiments. The use of partitioning tracer tests (PTT) to detect DNAPL source zones is being investitgated at the same time.