ConSoil 2005 - Abstract form

Title of abstract	Alcohol Flushing: Parameter Estimation for a cost efficient in-situ remediation of an aquifer contaminated with DNAPL		
Author(s) + organisation, company, university	Philipp Greiner, Jürgen Braun, Johannes Schnieders, Hans-Peter Koschitzky VEGAS, Institut für Wasserbau - Universität Stuttgart Ulf Mohrlok, Klass Heinrich Institut für Hydromechanik – Universität Karlsruhe		
Most appropriate theme (see Call: theme A-G)	D	**ORAL presentation** (type O) **or POSTER** (type P)	O

Main author and/or contact person			
Name	Philipp Greiner	**Ph.D.student** (if so: type X)	X
Mail address	Universität Stuttgart – Institut für Wasserbau, Pfaffenwaldring 61, 70569 Stuttgart, Germany		
E-mail	philipp.greiner@iws.uni-stuttgart.de		
Phone	+49 - 711 / 685 4602	**Fax**	+49 - 711 / 685 7020

Topics:
Alcohol flushing, in-situ remediation technology, effective and fast DNAPL remediation, density and viscosity driven flow, alcohol cocktail, multi-component-/multi-phase-flow, parameter estimation, process understanding

Abstract

In-situ remediation of aquifers contaminated with DNAPL (Dense Non Aqueous Phase Liquid) is very challenging due to the physical and chemical properties of this contamination group. DNAPLs have a density higher than water and are hardly soluble in water. Due to these solubility limitations, conventional pump and treat methods are very ineffective.

A suitable mixture of alcohols and water can be used to increase the DNAPL solubility. So called swelling (lipophilic) alcohols penetrate into the DNAPL and increase its volume, hence reducing the DNAPL density. These alcohols are not hydraulically controllable because of their lipophilic character. A second, non-swelling (hydrophilic) alcohol is necessary to obtain a water miscible mixture. In order to make this work, both alcohols must be chosen to suit the DNAPL to be flushed out of the aquifer.

A suitable alcohol cocktail can be injected into an aquifer and flushed through the DNAPL pool where it “reacts” with the contaminant. The alcohol cocktail – DNAPL solution is removed with an extraction well, followed by a water flood to remove remaining alcohols from the aquifer. The removed mixture has to be sent to a treatment plant in order to separate the alcohols for reuse (alcohol recycling).

To use this technology effectively it is important to have a good process understanding. In the last few years a systematic study, from batch tests to big container experiments, was conducted at the VEGAS facility in Stuttgart (Research Facility for Subsurface Remediation). The experiments were used to improve the efficiency of this technology and to investigate all relevant processes parameters and describe them mathematically.

If an alcohol contacts a DNPAL the interfacial tension between the aqueous and the contaminant phase is reduced. Small ratios of alcohols (< 10 % v/v) can be sufficient to decrease the interfacial tension enough to pose a potential threat of uncontrolled downward mobilisation of the DNAPL. Such a downward migration of the mobilised DNAPL into deeper regions of the aquifer must be prevented at all costs. The swelling alcohol helps to avoid the uncontrolled mobilisation due to its reduction of the DNAPL density. In addition, an upward flow gradient produced by the well configuration is necessary to counteract gravitatinal forces. The change of the interfacial tension as a function of alcohol ratios was investigated for the two alcohols 2-propanol (hydrophilic alcohol) and 1-hexanol (lipophilic alcohol), water and the contaminant tetrachloroethylene (PER). Also the minimum upward velocity necessary to avoid a downward migration was measured for different soil materials and contaminants.

Alcohol flushing in an aquifer is a multi-component / multi-phase-system. The properties which influence the flow conditions change during the alcohol flushing. At the fringe of the streamtube between the alcohol cocktail and the surrounding groundwater, the alcohol concentration is decreased, causing a change of

density and viscosity. This effects the flow condition of the alcohol cocktail. Moreover, the change of viscosity, which is a function of the mixing ratio (alcohol concentration) and the temperature, were investigated and constitutive relationsships were described.

As the aqueous concentration in the alcohol cocktail increases, the mixture can be separated in two phases. This relationship can be described in a so called “ternary phase diagramm” (equilateral triangle). The binodal curve in such diagramms marks the boundry between the one phase- and two phase-region. The theory of these diagramms was extended to the a four component mixture, consisting of a lipophilic alcohol, a hydrophilic alcohol, water and the contaminant. In this new quaternary phase diagram (pyramid) a surface separates the two phase region from the one phase region. The mathematical description of this surface is of course much more complex.

For all possible mixing ratios the number of co-existing phases has to be determined and the properties of each phase, such as its viscosity and density, have to be identified. More than a hundred data points on different scales of experiments at the VEGAS facility were necessary to enhance existing equations or to develop new ones. All these equations need to be implemented in an numerical model in order to support planning and optimising of alcohol flushing in the field.

At the VEGAS facility, the in-situ technology “alcohol flushing” will be shown to be a safe, fast and efficient remediation method for DNAPL contaminated aquifers. The parameter estimation for the relevant processes is one step of this technology development.

References

Greiner, P., Braun, J., Schnieders, J., Koschitzky, H., Trötschler, O. und Weber, K. (2004): Alcohol Flushing: From Lab Scale to Field Scale.Fourth International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, California, USA, 5/2004.

Greiner, P., Braun, J., Hofstee, C., Koschitzky, H., Schnieders, J., Weber K. (2003): Alcohol flushing: Detection and In-Situ-Remediation of DNAPL. 8. International FZK/TNO Conference on Contaminated Soil (ConSoil 2003-Proceedings), The Netherlands Organization for Applied Scientific Research (TNO), Gent, Belgium, 5/2003.

Heinrich, K., Mohrlok, U., Jirka, G.H. (2003): Hydraulically regulated alcohol circulation using groundwater-circulation-well (GCW) for targeted in-situ remediation. In D. Halm, P. Grathwohl, Proceedings of the 2nd International Workshop on Groundwater Risk Assessment at Contaminated Sites (GRACOS) and Integrated Soil and Water Protection (SOWA), 20-21 March 2003, Tübingen, Tübinger Geowissenschaftliche Arbeiten (TGA) C69. 179-181.

Hofstee, C., Gutiérrez Ziegler, C., Trötschler, O., Braun, J. (2003): Removal of DNAPL contamination from the saturated zone by the combined effect of vertical upward flushing and density reduction. - J. Cont. Hydrol., No. 67, 61-78.