N O T A T

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Sagsbehandler
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Invitation til "Shortcourse on Accelerated Bioremediation of Chlorinated Solvents in Groundwater"

Videncenter for Jordforurening afholder kursus i *stimuleret reduktiv dechlorering* den 3. til 4. juni 2209 på Hotel SIXTUS, Teglgårdsvej 73 i Middelfart.

Kurset henvender sig til den erfarne medarbejder, som gerne vil udbygge deres viden om chlorerede opløsningsmidlers egenskaber og spredningsveje - samt i særdeleshed stimuleret reduktiv dechlorering. Kurset afholdes på engelsk af den henholdsvis amerikanske og canadiske rådgiver Neal Durant og Evan Cox fra Geosyntec - samt af danske Charlotte Scheutz fra DTU. Neal og Evan har tidligere afholdt dette kursus for bla. miljømyndighederne i 12 amerikanske stater.

Kursusleder: Christian Andersen, Videncenter for Jordforurening

Tilmelding skal pr. mail til jordforurening@regioner.dk – eller via www.jordforurening.info – senest fredag den 1. maj 2009.

Med venlig hilsen

Christian Andersen

Preliminary Course Program

Day 1

9.30 – 10.00	Coffee and Refreshments
10.00 – 10.30	Introduction
12.30 – 13.30	Lunch
15.15 – 15.45	Break
15.45 – 17.00	Group Exercise #1 – ERD Performance Evaluation
17.00 – 17.30	Discussion
19.00 – 21.00	Banquet

Day 2

8.00 – 9.00	Breakfast
10.45 – 11.00	Break
12.30 – 13.30	Lunch
13.30 – 14.30	Group Exercise #2 – Modeling for ERD Design
14.30 – 15.00	Discussion

Course Overview

Chlorinated solvents such as tetrachloroethene (PCE), trichloroethene (TCE), and 1,1,1-trichloroethane (TCA) are among the most ubiquitous and persistent groundwater contaminants throughout the industrialized world. At many industrial sites, chlorinated solvents are present in soil and groundwater as pure phase, dense non-aqueous phase liquids (DNAPLs). For over a decade it has been recognized that conventional

groundwater remediation technologies such as pump-and-treat are largely ineffective for DNAPL source areas, and since that time a variety of alternative in situ treatment technologies have emerged, including biological enhanced reductive dechlorination (ERD). ERD involves the injection of fermentable organic electron donors (e.g., fatty acids, sugars, edible oils) and, in many cases, specialized natural bacteria to promote sequential dechlorination of chlorinated solvents to innocuous or less-toxic end-products. The process of injecting electron donors is referred to as "biostimulation" and the process of injecting specialized bacteria is referred to as "bioaugmentation". ERD is a relatively simple remediation technology that, when properly designed and deployed, can yield highly effective results. It is also one of the most sustainable remediation technologies available (e.g., relative to chemical oxidation, or thermal remediation), and is the remediation technology most compatible with monitored natural attenuation (MNA).

Viewed increasingly as one of the most cost-effective remedial options in North America, ERD has become a mature technology for remediation of dissolved chlorinated ethenes, and its use continues to increase. At the same time, there is growing evidence that ERD is a cost-effective technology for remediation of chlorinated ethene DNAPL source areas at certain sites. Use of ERD in Denmark is also increasing, where the technology has been applied at full- or pilot-scale at 9 sites, and is currently planned for implementation 5 more sites. Use of ERD in Denmark includes applications in sandy aquifers, clayey till, and fractured bedrock. In 2007, a team of researchers led by the Danish Technical University completed the first rigorous demonstration of ERD in Denmark at the Rugårdsvej 234-238 in Odense.

This short course will present: background on chlorinated solvent use (including Scandinavian countries), occurrence, fate and transport; introduction to chlorinated solvent biodegradation pathways; biodegradation kinetics; hydrogeologic, chemical, and biological design criteria for ERD systems, including passive ERD designs (e.g., emulsified oil) and active ERD designs (e.g., active/forced gradient recirculation); bioaugmentation methods; molecular methods for assessing the suitability of sites for ERD; and methods for monitoring and quantifying ERD performance. The course will also address ERD design and methods for injecting bioremediation methods in sandy aquifers, clay till, and fractured bedrock. ERD case studies from North America and Denmark will be presented that illustrate successful application of ERD treatment systems in DNAPL source areas, as well as full-scale plume treatment applications employing ERD biobarriers.

Design considerations and case studies for unconsolidated aquifers (sands, gravels, and till) will be covered, as well as fractured bedrock aquifers. ERD design exercises will be used to reinforce pertinent concepts and to strengthen student understanding of the course material. Given the relevance to Scandinavian sites, the effects of cold temperatures on ERD performance will be discussed in the course. In addition, regulatory issues and experience regarding deployment of ERD in Denmark be presented. This course will be ideal for environmental consultants, government representatives, and academic researchers involved in the selection and design of sustainable remediation technologies for groundwater restoration.

This course has been popular with State environmental agency and U.S. EPA regulators in the U.S., and has been presented in over 12 States in the U.S. since 2002. The course in the U.S. has been presented through the Interstate Technology & Regulatory Council and the Remedial Technologies Development Forum.

Biographies of Course Instructors

NEAL D. DURANT, Ph.D.
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Dr. Durant is a Principal Engineer with over 20 years experience in characterization and remediation of property impacted by chlorinated solvents. His current engagements include strategic and program management of site portfolios for multinational corporations and the United States Department of Defense. Specializing in the design and implementation of in situ remediation systems, Dr. Durant has designed and/or evaluated in situ bioremediation, chemical oxidation, nanoscale zero valent iron (ZVI), and co-solvent flushing systems at over 40 sites. In Denmark, he has led the design of bioremediation (ERD) systems at sites in Tommerup, Odense, Svendborg, and Årup. Recognized internationally for his expertise in chlorinated solvent remediation, Dr. Durant has co-authored guidance manuals on this topic for U.S. EPA, U.S. Air Force, the Swedish EPA, and the Danish EPA. Dr. Durant holds a part-time Faculty position in the Johns Hopkins University Part-Time Engineering Program, and has given invited lectures at Tufts University,

University of Virginia, Bucknell University, Lehigh University, Johns Hopkins University, and the Technical University of Denmark.

Selected Publications Co-authored by N. Durant on Chlorinated Solvent Remediation

N.D. Durant and E.E. Cox. 25 April 2007. "Management of Megasites in the United States: Remediation Strategies, Technology Selection, and Cleanup Costs.". ATV Conference on Megasites. Schæffergården, Denmark. http://www.atv-jord-grundvand.dk/Afholdte_moeder/070425/6%20-%20Neal%20Durant.pdf

Jørgensen,T.H., Nissen,L., Nielsen,L., Petersen,P.A., Hansen,M.H., Scheutz,C., Jakobsen,R., Bjerg,P.L., Larsen,T.H., Durant,N.D., Cox,E. & Rasmussen,P. (2007): Pilotprojekt med stimuleret in situ reduktiv deklorering - Hovedrapport. Miljøstyrelsen, København. Miljøprojekt, 1148.
http://www.er.dtu.dk/publications/fulltext/2007/MR2007-064.pdf

Jørgensen,T.H., Scheutz,C., Durant,N.D., Cox,E., Bordum,N.E., Rasmussen,P. & Bjerg,P.L. (2005): Stimuleret in situ reduktiv deklorering. Videnopsamling og screening af lokaliteter. Miljøstyrelsen, København. Miljøprojekt, 983. pp. 1-153.
http://www.er.dtu.dk/publications/fulltext/2005/MR2005-013.pdf

N.D. Durant, D.W. Major, E.E. Cox and M. McMaster. (2004). "Bioaugmentation to Enhanced Anaerobic Bioremediation of Chlorinated Solvents in Groundwater: Six Case Studies," In: *Principles and Practices of Enhanced Bioremediation of Chlorinated Solvents*. AFCEE. San Antonio, Texas. http://www.afcee.brooks.af.mil/products/techtrans/bioremediation/downloads/PrinciplesandPractices.pdf.

Berman, M.H., N.D. Durant, R.J. Weisman, and S. Guenther. (2000). "Engineered Approaches to In Situ Bioremediation of Chlorinated Solvents: Fundamentals and Field Applications," U.S. EPA Office of Solid Waste and Emergency Response, Technology Innovation Office. EPA 542-R-00-008. http://www.epa.gov/tio/download/remed/engappinsitbio.pdf.

EVAN E. COX, M.Sc.
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Mr. Cox is a Principal and Senior Remediation Scientist with extensive experience in the development, feasibility evaluation and application of innovative in situ remediation technologies, including monitored natural attenuation (MNA), enhanced in situ bioremediation (EISB), in situ chemical oxidation (ISCO), and metal-catalyzed reduction of chlorinated and recalcitrant chemicals in subsurface environments. Currently serving on the Board of Directors of Geosyntec, Mr. Cox is a top leader in the firm for groundwater remediation design, and is widely recognized throughout the United States for his expertise. Over the past seventeen years, Mr. Cox has pioneered the use of the MNA and EISB technologies, including bioaugmentation, for remediation of chlorinated solvents in porous media and fractured bedrock, co-authoring several guidance documents and educational courses on these subjects. Expanding on these efforts, Mr. Cox has pioneered the use of EISB to treat rocket fuels such as perchlorate in soil and groundwater. Mr. Cox is currently directing multiple field demonstrations of ISCO using permanganate to treat chlorinated solvents in fractured bedrock groundwater, as well as several demonstrations of zero-valent metal-catalyzed reduction of chlorinated solvents, explosives (RDX and TNT) and propulsion energetics (NDMA) in groundwater using both permeable reactive barrier and nanoscale metallic particle approaches. Mr. Cox has published more than 30 articles regarding the degradation of hazardous contaminants in subsurface environments. Mr. Cox has taught the short course "*Accelerated Bioremediation of Chlorinated Solvents*" for the Remedial Technologies Development Forum since 2001.

Over the past five years, Mr. Cox has been retained for numerous chlorinated solvent remediation projects in Scandinavia, including:

- Senior Technical Advisor for the development of a Guidance Manual for assessment of Monitored Natural Attenuation of contaminants in subsurface environments in Sweden. This project was funded by the Swedish EPA, and was conducted in association with SWECO VIAK of Sweden.
- Senior Technical Advisor for the development of a Guidance Manual for feasibility assessment for remediation of chlorinated solvents in subsurface environments in Sweden. This project was funded by the Swedish EPA, and was conducted in association with SWECO VIAK of Sweden and COWI A/S of Denmark.
- Senior Technical Advisor for the development of a Feasibility Study for remediation of a complex mixture of chlorinated solvents, aromatics, anilines, sulfonamides and barbiturates in

groundwater (source and plume) at a high profile former pharmaceutical disposal site in Denmark. The project was conducted in association with COWI A/S of Denmark.

- Senior Technical Advisor for the development of a Guidance Manual and Site Screening Protocol for the use of enhanced reductive dechlorination and bioaugmentation to treat chlorinated solvents in groundwater in Denmark. This project was funded by the Danish EPA & County of Funen, and was conducted in association with COWI A/S of Denmark.
- Senior Technical Advisor for the design and implementation of two enhanced in situ bioremediation systems at an industrial site in Denmark. Two bioremediation approaches were evaluated, including a passive electron donor addition approach (chitin, emulsified edible oil) to treat chlorinated solvents in low permeability silts and clays, and an active (recirculation) delivery system for soluble electron donors (lactate). This project was funded by the Danish EPA & County of Funen, and conducted in association with COWI A/S in Denmark.

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Reductive dechlorination: www.sara.env.dtu.dk
http://www.env.dtu.dk/Forskning/Forskningsgrupper/Contaminated%20sites.aspx

Dr. Scheutz is an Assistant Professor in remediation of polluted soil and groundwater at the Department of Environment & Resources DTU, Technical University of Denmark, where she teaches courses in Air Pollution and Environmental Sustainability. She obtained her M.Sc. (1998) and Ph.D. (2002) at DTU in Environmental Science and Engineering, working with landfill gas emission, methane oxidation in landfill cover soils, degradation of halogenated organic compounds in soils, aquifers, and waste, (H)CFCs, loss of blowing agents from isolation foam. She is actively engaged in research projects investigating

state-of-the-science approaches for measuring methane oxidation in closed landfills. In addition to her research in the DTU Solid Waste group, Dr. Scheutz is a leading researcher in DTU's Contaminated Sites Group. Her current research thrusts include methods for injection of in situ treatment agents into clayey till, and use of in situ anaerobic microbial reductive dechlorination for remediation of clayey till and source areas contaminated with chlorinated solvent mixtures. Dr. Scheutz is a research partner on the REMTEC (Innovative Assessment and Remediation Technologies for Soil and Groundwater) project at DTU, a new 4-year research initiative funded by the Danish Research Council aimed at expanding the capabilities and understanding of chlorinated solvent bioremediation technologies (see: http://www.remtec.dk).

Example Peer-Reviewed Publications

Scheutz, C., Durant, N., Dennis, P., Hansen, M., Jorgensen, T., Jakobsen, Cox, E., and Bjerg, P. (2008). Concurrent ethene generation and growth of *Dehalococcoides* containing vinyl chloride reductive dehalogenase genes during a stimulated reductive dechlorination field demonstration. *Environmental Science and Technology*, 42: 9302–9309.

Scheutz, C., Dote, Y., Fredenslund, A., Mosbæk, H., Kjeldsen, P. (2007). Attenuation of fluorocarbons released from foam insulation in landfills. *Environmental Science and Technology*, 41:7714-7722.

Scheutz,C. & Kjeldsen, P. (2005): Biodegradation of trace gases in simulated landfill soil cover systems. *Journal of Air and Waste Management Association*, **55**, 878-885.

Scheutz,C. & Kjeldsen,P. (2003): Capacity for biodegradation of CFCs and HCFCs in a methane oxidative counter-gradient laboratory system simulating landfill soil covers. *Environmental Science and Technology*, **37**, 5143-5149.

Kjeldsen,P. & Scheutz,C. (2003): Short- and long-term releases of fluorocarbons from disposal of polyurethane foam waste. *Environmental Science and Technology*, **37**, 5071-5079.