InSights

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## Evolving Design Concepts into Well Engineered Remediation Strategies

Contemporary market conditions have forced many A&E firms to reduce or diversify the roles of staff once dedicated exclusively to the functions of remedial technology transfer and design. Today, design professionals are frequently called upon to undertake a broad range of technical and managerial responsibilities on a variety of projects. In some cases, this trend has impacted remediation projects by limiting the ability of the design professional to dedicate the time and focus necessary to effectively evaluate and refine their design concepts into detailed engineering strategies.

The MD&E business model includes assisting A&E firms by catalyzing the evolution of design concepts into well-engineered solutions ready for implementation. The charter of MD&E is to provide rigorous technical analyses and information transfer to facilitate the progression of design concepts into detailed environmental remediation strategies. Our services range from simple dissemination of expert advice to detailed examination and optimization of technologies and unit operations. Our panel of experts possesses over 40 years of combined environmental site characterization and remediation experience.

MD&E is expanding its capabilities as a premier resource for development and refinement of intelligent strategies for environmental restoration. This month MD&E is pleased to announce the addition of Dr. Michael J. Dybas to our panel of technology experts. In addition, we have opened a new engineering laboratory in association with Michigan State University's Rational Siting/Push-Pull Accelerator to facilitate testing and optimization of biological and physicochemical treatment processes.

Dr. Dybas is a leading researcher in the field of in-situ dechlorination of recalcitrant organic compounds using biological enhancement and augmentation processes. He holds a doctorate in microbiology from the University of Illinois and has been on the faculty of the National Science Foundation Center for Microbial Ecology and Department of Civil & Environmental Engineering at Michigan State University (MSU) since 1991. For the past 12 years, Dr. Dybas has served as a Principal Investigator for the $8.5M MSU Schoolcraft Bioremediation Field Research Program. During his tenure, the program was credited with the development of strategies such as alkaline niche adjustment and delivery of *Pseudomonas sp.* strain KC for rapid dechlorination of carbon tetrachloride in aquifer systems. Dr. Dybas was also the driving force behind one of the first large-scale applications of reductive dehalogenation of TCE in groundwater using a non-native dechlorinating enrichment culture. His work at MSU has involved all phases of technology development, including bench and field-scale demonstrations to full-scale design and construction. For his efforts, Dr. Dybas was honored by the National Ground Water Association in 2002 with their Outstanding Project in Ground Water Remediation award. In 2004, he was named the Groundwater Management Professional of the Year by the Michigan Water & Environment Association. Dr. Dybas has lectured extensively on the effective use of biotechnology for environmental remediation, including sessions for Federal congressional delegations. A list of publications authored by Dr. Dybas is provided at the end of the newsletter.

The new MD&E engineering laboratory offers a broad range of quantitative assessment services, including:

- Biological and physicochemical process simulation and optimization:

  - In-situ bioremediation:
    - *Natural attenuation scoring*
    - *Bioenhancement*
    - *Bioaugmentation*
    - *Batch and column microcosm studies*
    - *Microbial culture maintenance*
    - *Molecular biological analyses*
  - In-situ chemical oxidation
  - In-situ redox manipulation
  - Ex-situ treatment technologies:
    - *Mass transfer processes*
    - *Chemical conversion processes*
    - *Phase separation processes*

- Process, hydrodynamic and pollutant fate and transport modeling:

  - Design calculations
  - Water and mass balances
  - Hydraulic profiles

- Unit operation and appurtenance sizing
- Energy and power requirements
- Process and unit operation simulation
- Groundwater flow/contaminant transport
- Surface water and air dispersion

- Remediation process optimization and troubleshooting

## Technology

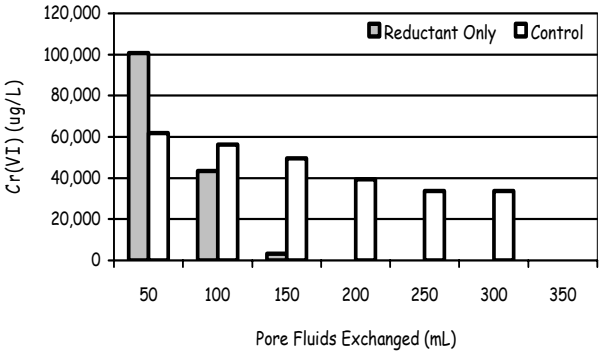
*In Situ Redox Manipulation (ISRM) for Treating Metals in Soils*

Unsaturated alluvium beneath a former metal plating facility in Manistee, Michigan is impacted with up to 2,700 mg/Kg (ppm) of hexavalent chromium {Cr(VI)}. The Cr(VI) mass in the unsaturated zone is a source of groundwater contamination in the area. The Michigan Department of Environmental Quality (MDEQ) is coordinating cleanup efforts at this facility and recently commissioned a study to evaluate the efficacy of In-Situ Redox Manipulation (ISRM) for treating the Cr(VI)-impacted alluvium.

To test the applicability of the process and develop preliminary engineering and operating parameters for full-scale implementation, MD&E personnel executed an experimental program to simulate ISRM at the bench-scale using impacted alluvium and groundwater from the site. The bench study was designed specifically to identify an aqueous reducing agent and application dosage that: 1) effectively reduce Cr(VI) to less soluble and less toxic trivalent chromium {Cr(III)}; 2) are safe to handle; and 3) are economical compared to other comparably effective, commercially available reductant solutions. An additional goal of the study was to verify that post-treatment re-oxidation and mobilization of chromium is unlikely.


The experimental plan consisted of three distinct tasks. The first task entailed a series of bottle tests to select an appropriate reductant and treatment dosage. Flow-through column microcosms were then prepared with site soil to evaluate the effectiveness of controlled reductant application by gravity driven infiltration through the alluvium.

The column data indicated that three pore volumes of a 0.5% solution of sodium metabisulfite (SMB) were sufficient to reduce leachable chromium levels to below 10 µg/L. Mass balances developed from soluble chromium levels measured in the effluent from the treated and control columns indicate that ISRM reduced and "fixed" approximately 840 mg of Cr (VI). The mass of solute removed per unit mass of soil was approximately 6,000 mg-Cr(VI)/Kg-soil. Treated columns were then flushed with oxygenated groundwater to evaluate the potential for re-oxidation of Cr(III) to and mobilization of Cr(VI). After each flushing event, soluble Cr(VI) levels remained below 10 µg/L.




Field-scale implementation of ISRM using an existing infiltration system began in the fall of 2002. The dimensions of the source area at the site include a footprint 60 feet in length and 30 feet wide.

The depth to the water table is approximately 25 feet. Therefore, the resulting treatment volume is approximately 45,000 $ft^3$ (1,275 $m^3$). The pore volume requiring treatment is conservatively estimated to be 472,000 L. With an application rate of 25 gal/minute, the duration to deliver one pore volume of reductant solution to source soil is approximately 6 days. Given that an estimated 4.5 pore volumes (e.g. 3 pore volumes + 50% safety factor) will be necessary to complete treatment, and assuming that at least three 10-day long incubation (no infiltration) periods occur between delivery periods, the total estimated duration of treatment will be 50 – 60 days. A reductant mass of approx. 1,000 Kg will be conveyed through the soils in the process. – *T. Mayotte, Ph.D., P.E.*

Mayotte Design & Engineering, PC is a highly responsive advocate and risk management partner for clients in the A&E, automotive, lithographic printing, textile, pharmaceutical, chemical, real estate and home improvement industries. The MD&E staff is active in brownfield redevelopment projects across the Upper Midwest, and with academia in development of innovative environmental remediation technologies. Learn more about MD&E at our web site at mayottedesign.com.

## Projects Activated or Completed since January 2005

Wastewater Engineering at Aerospace Facility
Environmental Characterization/Remediation at Paint Formulation Operation
Characterization/Remediation of former Automotive Components Facility
Environmental Site Assessment of Tool and Die Facility
RCRA Closure of Former Metal Finishing and Annealing Facility
Corrective Action at Abandoned Metal Working Facility
Redevelopment of Vacant Machining Facility
Remediation of Chlorinated Solvents at Former Truck Terminal
Peer Review/Remedial Consultation for multiple Automotive OEM Facilities in MI
Brownfield Redevelopment of Former Printing Facility
In-Situ Bioremediation of Chlorinated Solvents and Hexavalent Chromium
SPCC Planning and Certification at Automotive Parts Plant
Acquisition Due Diligence of Printing Operations in NJ, MA, OH, IL, MO, TX and CA
Acquisition Compliance/Due Diligence of Textile/Apparel Operations in CA
Title V CAAPP Annual Emissions Reporting for Printing Plants in IL
UST/LUST Closures at Metals Fabrication Facility in OH
Remedial Investigation and Feasibility Study for closure of ash landfill in MI
Hazardous waste site delisting of a manufacturing facility in central MI
Modeling of hydrodynamics and contaminant transport at a chemical plant in UT
Due diligence for property transfer in central MI
Preparation of application for brownfield funding for remediation of closed plant in OH

## Publications/Presentations


Zhao, X., Dybas, M.J, Wallace, R.E., Hyndman, D., and T. Voice. (2005). "Heterogeneity of Chlorinated Hydrocarbon Sorption Properties in a Sandy Aquifer". Accepted for publication in Journal of Contaminant Hydrology

Forrester, S.B., Han, J.I., Dybas, M.J., Semrau, J.D. and C. M. Lastoskie. (2005). "Characterization of a mixed methanotrophic culture capable of chloroethylene degradation". *Environmental Engineering Science,* **22**:270-279.

Phanikumar, M.S., Hyndman, D.W. , Zhao, X., and M.J. Dybas. "A three dimensional model of microbial transport and biodegradation at the Schoolcraft, Michigan site". *Water Resources Research*, doi:10.1029/2004WR003376 (2005).

Tenney, C.M., Lastoskie, C.M. and M.J.Dybas. (2004). "A reactor model for pulsed pumping groundwater remediation". *Water Research*, **38**:3869-3880.

Williams, S.M., Dybas, M.J. and C.S. Criddle. (2004). "Assessing the potential for biological Cr(VI) reduction in an aquifer contaminated with mixed wastes". Chromium (VI) Handbook, J. Jacobs, ed. CRC Press, Boca Raton, FL.

Phanikumar, M.S., Hyndman, D.W., Wiggert, D. C., Dybas, M.J., Witt, M.E., and C.S. Criddle. (2002). "Simulation of microbial transport and carbon tetrachloride biodegradation in intermittently-fed aquifer columns". *Water Resources Research*, **38**(4):1-13.

Dybas, M.J., Hyndman, D.W., Heine, R., Tiedje, J., Linning, K., Voice, T., Wiggert, D., Zhao, X., Dybas, L., and Craig S. Criddle. (2002). "Development, operation and long-term performance of a full-scale biocurtain utilizing bioaugmentation". *Environmental Science & Technology*, **36**(16):3635-3645.

Hyndman, D.W., Dybas, M.J., Forney, L, Heine, R., Mayotte, T., Phanikumar, M.S., Tatara, G., Voice, T., Wallace, R., Wiggert, D., Zhao, X., and C.S. Criddle.(2000) "Hydraulic characterization and design of a full-scale biocurtain." *Groundwater,* **38**(3):462-474.

Witt, M.E., M.J. Dybas, R. M. Warden and C. S. Criddle. (1999). "Motility-enhanced bioremediation of carbon tetrachloride-contaminated aquifer sediments." *Environmental Science & Technology,* **33***, 2958-2964.*

Hyndman, D.W., Dybas, M.J., Chan, A., Heine, R., Phanikumar, M.S., Voice, T., Wallace, R., Wiggert, D., Zhao, X. and C.S. Criddle. (1999). "The role of heterogeneous aquifer properties in remediation design: the Schoolcraft aquifer". EOS **80** (14), p.s115.

Witt, M.E., Dybas, M.J., Wiggert, D.G., and C.S.Criddle. (1999). "Use of bioaugmentation for continuous removal of carbon tetrachloride in model aquifer columns." *Environmental Engineering Science,* **16**(6),475-485

Sepulveda-Torres, L.C., N. Rajendram, M.J. Dybas and C.S. Criddle. (1999). "Generation and characterization of Pseudomonas stutzeri KC mutants with impaired ability to degrade carbon tetrachloride." *Archives of Microbiology* **171**:424-429.

Dybas, M. J., Barcelona, M., Bezborodnikov, S., Davies, S., Forney, L., Heuer, H., Kawka, O., Mayotte, T., Sepulveda-Torres, L., Smalla, K., Sneathen, M., Tiedje, J., Voice, T., Wiggert, D. C., Witt, M. E., and Criddle, C. S. (1998). "Pilot-scale evaluation of bioaugmentation for in-situ remediation of a carbon tetrachloride-contaminated aquifer." *Environmental Science & Technology*, **32**(22), 3598-3611.

Criddle, C.S., Dybas, M.J., Tiedje, J., Hyndman, D., Voice, T. and R. Wallace. (1998). "Full scale remediation of carbon tetrachloride using bioaugmenatation, intermittent substrate addition, and closely spaced wells". EOS **79**(45), p. F372.

Mayotte, T. J., Dybas, M. J., and Criddle, C. S. (1996). "Bench scale evaluation of bioaugmentation and transformation of carbon tetrachloride in a model aquifer system." *Groundwater*, **34**(2): 358-367.

Dybas, M. J., Tatara, G. M., and Criddle, C. S. (1995). "Localization and characterization of the carbon tetrachloride transformation activity of *Pseudomonas* sp. strain KC." *Applied and Environmental Microbiology*, **61**(2), 758-762.

Dybas, M. J., Tatara, G. M., Knoll, W. H., Mayotte, T. J., and Criddle, C. S. (1995). "Niche adjustment for bioaugmentation with *Pseudomonas* sp. strain KC." Bioaugmentation for Site Remediation, R. E. Hinchee, A. Leeson, and L. Semprini, eds., Battelle Press, Columbus, OH, 77-84.

Tatara, G. M., Dybas, M. J., and Criddle, C. S. (1995). "Biofactor-mediated transformation of carbon tetrachloride by diverse cell types." Bioremediation of Chlorinated Solvents, R. E. Hinchee, A. Leeson, and L. Semprini, eds., Battelle Press, Columbus, OH, 69-76.

Witt, M. E., Dybas, M. J., Heine, R. L., Nair, S., Criddle, C. S., and Wiggert, D. C. (1995). "Bioaugmentation and transformation of carbon tetrachloride in a model aquifer." Bioaugmentation for Site Remediation, R. E. Hinchee, A. Leeson, and L. Semprini, eds., Battelle Press, Columbus, OH, 221-227.

Tatara, G. M., Dybas, M. J., and Criddle, C. S. (1993). "Effects of medium and trace metals on kinetics of carbon tetrachloride transformation by *Pseudomonas* sp. strain KC." *Applied and Environmental Microbiology*, **59**(7), 2126-2131.

Dybas, M.J. ,and J. Konisky. 1992. "Energy transduction in the methanogen *Methanococcus voltae* is based on a sodium current." J. Bacteriol. **174**:5575-5583

Dybas, M.J., and J. Konisky. 1989. "Transport of coenzyme M (2-mercaptoethanesulfonic acid) and methyl coenzyme M [(2-methylthio)ethanesulfonic acid in *Methanococcos voltae*: Identification of specific and general uptake systems." J. Bacteriol. **171**: 5866-5871.

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