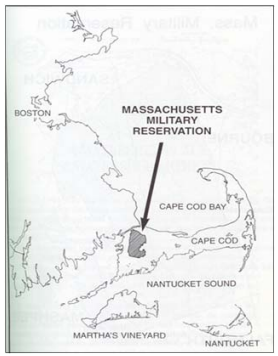
Field Evaluation of *In Situ* Aerobic Bioremediation of 1,2-Dibromoethane in Groundwater at Joint Base Cape Cod

Abstract

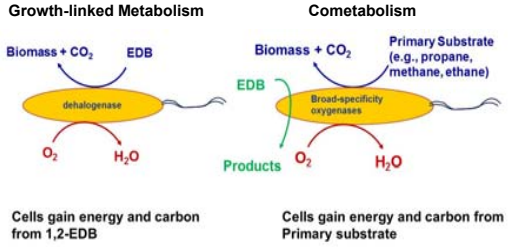
The lead scavenger 1,2-dibromoethane (ethylene dibromide; EDB), which was widely used in leaded gasoline for several decades, is subject to slow biotic and abiotic degradation under anaerobic conditions. However, in some instances, EDB is now present in oxic groundwater, having been transported beyond zones that were impacted by other fuel components, where it can be very persistent. This is the case at Joint Base Cape Cod (JBCC) (formerly Massachusetts Military Reservation: MMR), where three pump-and-treat systems are being used to remove EDB from groundwater. The objective of this AFCEC project was to evaluate options to enhance the aerobic degradation of EDB in groundwater, with a particular focus on possible *in situ* remediation. Laboratory studies conducted with aquifer solids and groundwater from the FS-12 plume at JBCC revealed that the addition of ethane gas, nutrients, and oxygen resulted in the rapid biodegradation of EDB, and a culture capable of biodegrading EDB (*Mycobacterium sphagni* ENV482) was subsequently isolated from the site. Based on the laboratory results, a field-scale *in situ* groundwater treatment system was designed, installed and operated at JBCC. This system captured a side stream of extracted groundwater from the FS-12 plume (~ 10 GPM from a 120 GPM extraction well), amended that groundwater with ethane gas, oxygen and inorganic nutrients, and then recharged the groundwater at an upgradient location, creating an active treatment zone in the subsurface. A series of nested monitoring wells were installed to evaluate system performance. After 4 months of active operation (following a 3 month mixing and equilibration period) EDB concentrations declined from ~ 0.3 µg/L to < 0.02 µg/L, the Massachusetts MCL, in six of the plot monitoring wells. Moreover, complete consumption of ethane and nutrients occurred throughout the treatment plot. The data indicate that aerobic cometabolism using ethane gas can be a viable option to sustainably treat EDB to below regulatory MCLs in the JBCC aquifer.

Site Location & History



- JBCC (formerly MMR) – Founded in 1911
- Training facility for Army, Air Force, National Guard, Coast Guard
- FS-12 plume originated from 1970s spill of aviation gasoline
- Fuel components at source remediated in 1990s
- EDB persists downgradient – Pump & Treat current remedy

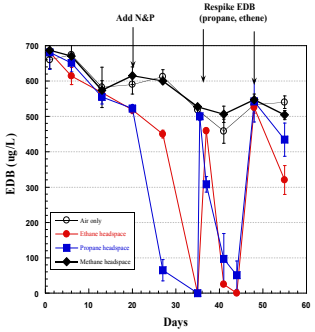
Cometabolism



- Stimulate biodegradation of contaminants for which growth-linked degradation is slow or non-existent (organisms absent, geochemistry incorrect, difficult structure)
- Potential to enhance degradation of trace contaminants

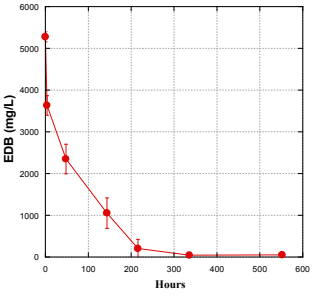
Laboratory Studies

Microcosm study with FS-12 aquifer solids and groundwater



- Pre-incubate with gases for 1 month, then add EDB
- Propane & ethane effective
- Methane ineffective
- Inorganic nutrients critical
- Degradation to < 0.02 µg/L

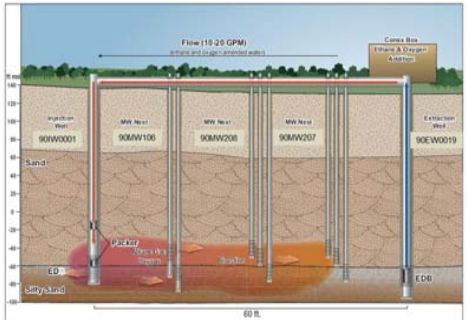
EDB degradation by *Mycobacterium sphagni* ENV482



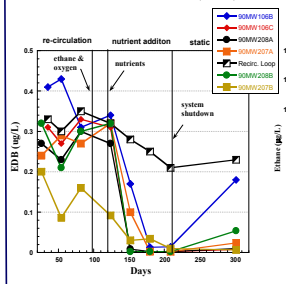
- Pure culture *M. sphagni* ENV482
- Isolated from FS-12 samples
- Grows on C2-C5 alkanes
- Degrades EDB after growth on all
- Enzymes under study (NCSU)
- Pathway under study (U Porto)

Field Demonstration

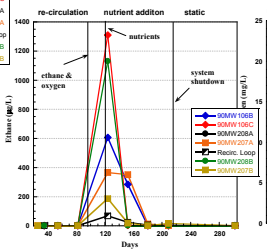
- **Recirculate 3 months to establish equilibrium**
  11 GPM average flow
  1.6 million gallons total recirculated
  EDB at equilibrium ~ 0.3 µg/L
- **Begin ethane and oxygen addition (Day 97)**
  0.04 GPM ethane; 0.05 - 0.13 GPM O_2
- **Begin nutrient addition (Day 119)**
  1kg diammonium phosphate (3x /wk)
- **Shut down on Day 216**
  Two additional sampling events after shutdown



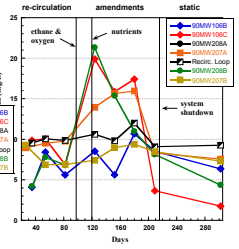
1,2-Dibromoethane (EDB)



Ethane Gas



Dissolved Oxygen



EDB before and after ethane and nutrient addition

Well	Day 82	Day 209
106B	0.31	0.014
106C	0.33	< 0.002
207A	0.16	< 0.002
207B	0.24	0.0097
208A	0.30	< 0.002
208B	0.30	< 0.002
Recirc loop	0.35	0.21

Summary and Conclusions

- Indigenous bacteria capable of aerobically biodegrading EDB are present in regional aquifer at JBCC (FS-12 plume).
- These organisms can be stimulated using ethane as co-substrate. Inorganic nutrients were also required to stimulate activity.
- Using ethane as a co-substrate and DAP as a source of inorganic nutrients, EDB biodegradation to concentrations of < 0.02 µg/L (Massachusetts MCL) was observed.
- This co-metabolic approach may be applied via biosparging or passive diffusion devices at other sites with differing hydrogeology.

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