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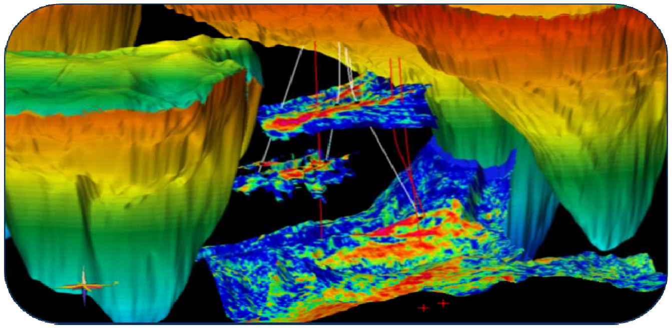

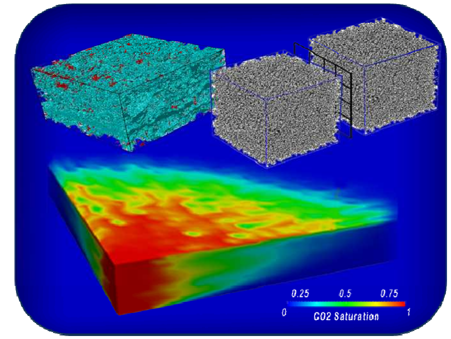


# Implications of Microbiology for the WIPP

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# Gas Generation in the WIPP

## Anoxic corrosion of Fe- and Al-base metals

- Steel waste containers and steels and other Fe-base metals in the waste
- Will produce $H_2$; could consume $H_2O$ initially and release it later

## Possible microbial consumption of cellulosic, plastic, and rubber (CPR) materials

- Could produce $CO_2$, $H_2S$, $N_2$, and $CH_4$; effect on $H_2O$ budget is unclear

## Alpha radiolysis of $H_2O$ in brine, and of CPR materials

- Will produce $H_2$, $O_2$, other gases; and consume $H_2O$

## Relative importance of these processes from the standpoint of gas generation:

- Corrosion $\cong$ microbial activity >> radiolysis

# Requirements for Microbial Activity in WIPP

Halophilic or halotolerant microbes present when repository filled and sealed

Halophilic or halotolerant microbes survive for a significant fraction of the 10,000-year regulatory period

Sufficient $H_2O$ present in brine in the repository and available to microbes

Sufficient electron acceptors present and available

Sufficient nutrients present and available

# Microbes in the WIPP?

## Halophiles present in the WIPP

## Possible sources of these microbes

- Salt lakes in Nash Draw
  - Transport to the excavated areas via wind, the Air Intake Shaft, and the mine ventilation system
- Soils near the WIPP Site
  - Same transport mechanisms
- Salado Formation (Permian microbes)?
  - Viable Permian microbes reported by Vreeland et al. (2000). See also Parkes (2000)
  - Permian microbes still controversial (e.g., Hazen and Roedder, 2001; Vreeland et al., 2000)
  - Permian microbes (if present) not an issue for PA

# Probability of Microbial Activity in WIPP

## Probability of microbial gas generation implemented by the U.S. DOE's WIPP Project

- Significant microbial activity possible, but by no means certain
- Used in the 1996 CCA PA, 1997 PAVT, and CRA-2004 PA
- Certified by the U.S. EPA in 1998

## Probability specified by the U.S. EPA for the CRA-2004 PABC and subsequent PAs

- Microbial activity is certain, but may not be significant because of the use of a sampled "effectiveness factor" (and lower gas-production rates) in PA

# Implementation in WIPP PA

## Conceptual model

- Sequential use of electron acceptors
- Potentially significant respiratory pathways
  - Denitrification
  - $SO_4^{2-}$ reduction
  - Methanogenesis
- Insignificant respiratory pathways
  - Aerobic
  - Fe(III) reduction
  - Mn(IV) reduction

## Rates

- Microbial activity produces gas at rates measured in long-term lab studies

# Implementation in WIPP PA (cont.)

Reactions for potentially significant microbial respiratory pathways

- Denitrification
  - $C_6H_{10}O_5 + 4.8H^+ + 4.8NO_3^- \rightarrow 7.4H_2O + 6CO_2 + 2.4N_2$
  - $CO_2$ yield = 1 mol per mol of organic C consumed
- $SO_4^{2-}$ reduction
  - $C_6H_{10}O_5 + 6H^+ + 3SO_4^{2-} \rightarrow 5H_2O + 6CO_2 + 3H_2S$
  - $CO_2$ yield = 1 mol per mol of organic C consumed
- Methanogenesis
  - $C_6H_{10}O_5 + H_2O \rightarrow 3CH_4 + 3CO_2$
  - $CO_2$ yield = 0.5 mol per mol of C consumed

# Laboratory Studies

## Mid-late 1970s

- M. A. Molecke, SNL, Principal Investigator (PI)
- Carried out by investigators at the University of New Mexico
- Supported the development of the WIPP Waste Acceptance Criteria

## 1988-2003

- L. H. Brush and Y. Wang, both SNL, PIs
- Carried out by investigators at Stanford University and Brookhaven National Laboratory
- Used short-term experiments (a few years long) to establish parameters for the WIPP CCA PA and long-term experiments (≈10 years long) to establish less conservative parameters

# Laboratory Studies (cont.)

## Current

- Julie Swanson, LANL – CO, PI
- Experiments underway in Carlsbad, NM, to reduce conservatism

# Use of MgO in the WIPP

Functions as the WIPP engineered barrier by consuming essentially all $CO_2$ that could be produced by microbial activity, thereby decreasing actinide solubilities

- Will prevent acidification of brine that would result if microbes consumed significant quantities of cellulosic, plastic, and rubber materials during the 10,000-year regulatory period
- Will limit the extent of complexation of actinide elements by $CO_3^{2-}$
- Will buffer the pH at mildly basic values

Consumption of significant quantities of $H_2O$ by MgO (and other materials) could also affect long-term performance

# Geochemical Role of MgO in the WIPP

## Reaction that will buffer $f_{CO_2}$ initially

- $5Mg(OH)_2 + 4CO_2$(aq or gas) $\rightleftharpoons$ $Mg_5(CO_3)_4(OH)_2{\bullet}4H_2O$
  - Hydromagnesite (5424) is metastable with respect to magnesite, but could persist for hundreds to thousands of years
  - The EPA has specified that the brucite-hydromagnesite carbonations reaction be used to calculate $f_{CO_2}$ for actinide solubility calculations

## Possible long-term $f_{CO_2}$ buffer reaction

- $Mg(OH)_2 + CO_2$(aq or gas) $\rightleftharpoons$ $MgCO_3 + H_2O$(aq or gas)
  - Magnesite is stable with respect to hydromagnesite (5424), and is present in the Salado

## Reaction that will buffer pH

- $Mg(OH)_2 \rightleftharpoons Mg^{2+} + 2OH^-$

# Predictions of Near-Field Conditions[A]

$f_{CO_2} \cong 3.14 \times 10^{-6}$ atm (for both GWB and ERDA-6)

- TIC $\cong 3.79 \times 10^{-4}$ M (GWB) or $4.55 \times 10^{-4}$ M (ERDA-6)

Very low $f_{O_2}$ (at or even below the lower stability limit of $H_2O$ on an Eh-pH diagram)

- $H_2O$ unstable in the WIPP (reduced to $H_2$ by steels and other Fe-base metals, Al, and Pb

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A. Predicted for the minimum volume of brine required for a release from the repository to the surface. Compositions for larger volumes not shown

# Predictions of Near-Field Conditions (cont.)[A]

## Brine pH

- Pitzer pH = 8.82 (GWB) or 8.99 (ERDA-6)
  - The Pitzer scale is an unofficial pH scale consistent with pH values calculated using single-ion activity coefficients based on the Pitzer activity-coefficient model and the Harvie-Møller-Weare (HMW) database (DB) for brines and evaporite minerals, extended to include Nd(III), Am(III), Cm(III), Th(IV), and Np(V).
  - T. J. Wolery of Lawrence Livermore National Laboratory in Livermore, CA, proposed the term "Pitzer scale" unofficially.

## Brine pcH

- pcH = 9.54 (GWB) or 9.69 (ERDA-6)

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A. Predicted for the minimum volume of brine required for a release from the repository to the surface. Compositions for larger volumes not shown

# Effects of Microbial Activity on WIPP PA

## $H_2$ from anoxic corrosion of Fe- and Al-base metals

- Will pressurize the repository to $\geq$ 8 MPa (hydrostatic pressure) in many PA vectors, which will result in direct brine releases (DBRs) of radionuclides to the surface
- Will pressurize the repository to ≈ 15 MPa (lithostatic pressure in some vectors
  - Fracturing in the near field will limit pressurization to 15 MPa
  - Fracturing will be limited in extent and does not affect PA

## Microbially generated gases will not affect repository pressure

- $CO_2$ will be consumed by MgO
- $H_2S$ will be consumed by reactions with steel waste containers and steels and other Fe-base metals in the waste

# Effects of Microbial Activity on PA (cont.)

## Microbially generated gases will not increase actinide solubilities

- MgO will consume essentially all $CO_2$ and establish conditions favorable for actinide solubilities
- Microbial colloids could enhance actinide concentrations to some extent

## Microbes will reductively immobilize actinides

## Microbial activity will not affect the near-field region of a repository for spent fuel or HLW

- Microbes could reductively immobilize actinides in the far-field of a repository for spent fuel or HLW