Evaluation of Sorptive Amendments for Use in Earthen Liners at Waste-Disposal Facilities

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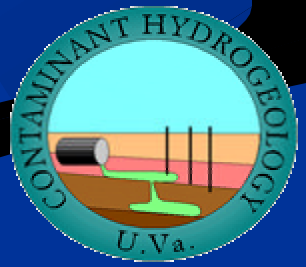


Acknowledgements

James A. Smith
Susan E. Burns
Natalie Soule

Partial support for this project was provided by:
Department of Defense Graduate Research Fellowship
Institute of Hazardous Materials Management
ARCS Foundation, Metropolitan Washington Chapter
National Science Foundation

Motivation

Various case studies have indicated that contaminants migrate through waste-disposal liners due to advection through flaws in the liner or geomembrane or by molecular diffusion

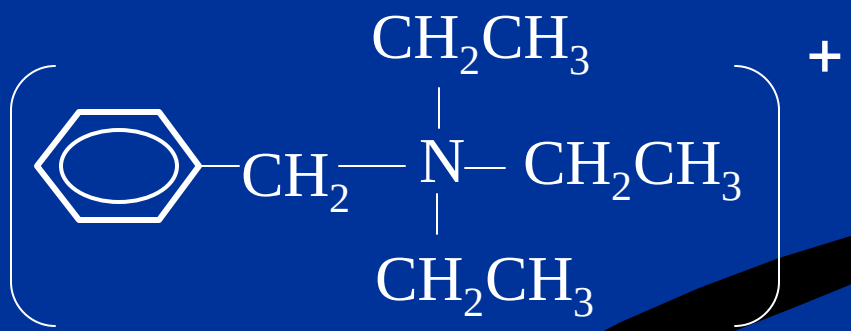
Research Hypothesis

Amendments with a large sorptive capacity can be added to earthen liners to reduce the mass flux of contaminants through the bottom of the liner. The proposed amendments should not reduce the overall permeability or negatively impact the mechanical properties of the liner.

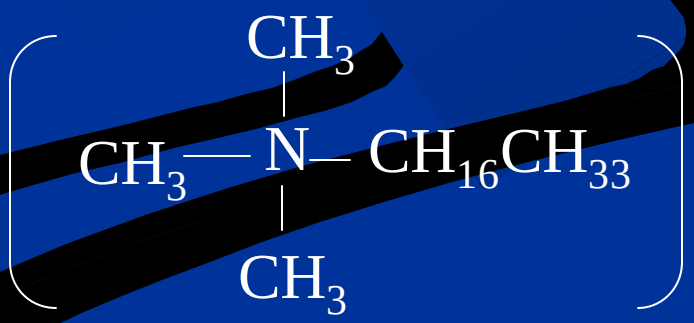
Proposed Amendments

- Shale
- Granular Activated Carbon
- Organobentonites

Benzyltriethylammonium bentonite (BTEA-bentonite)



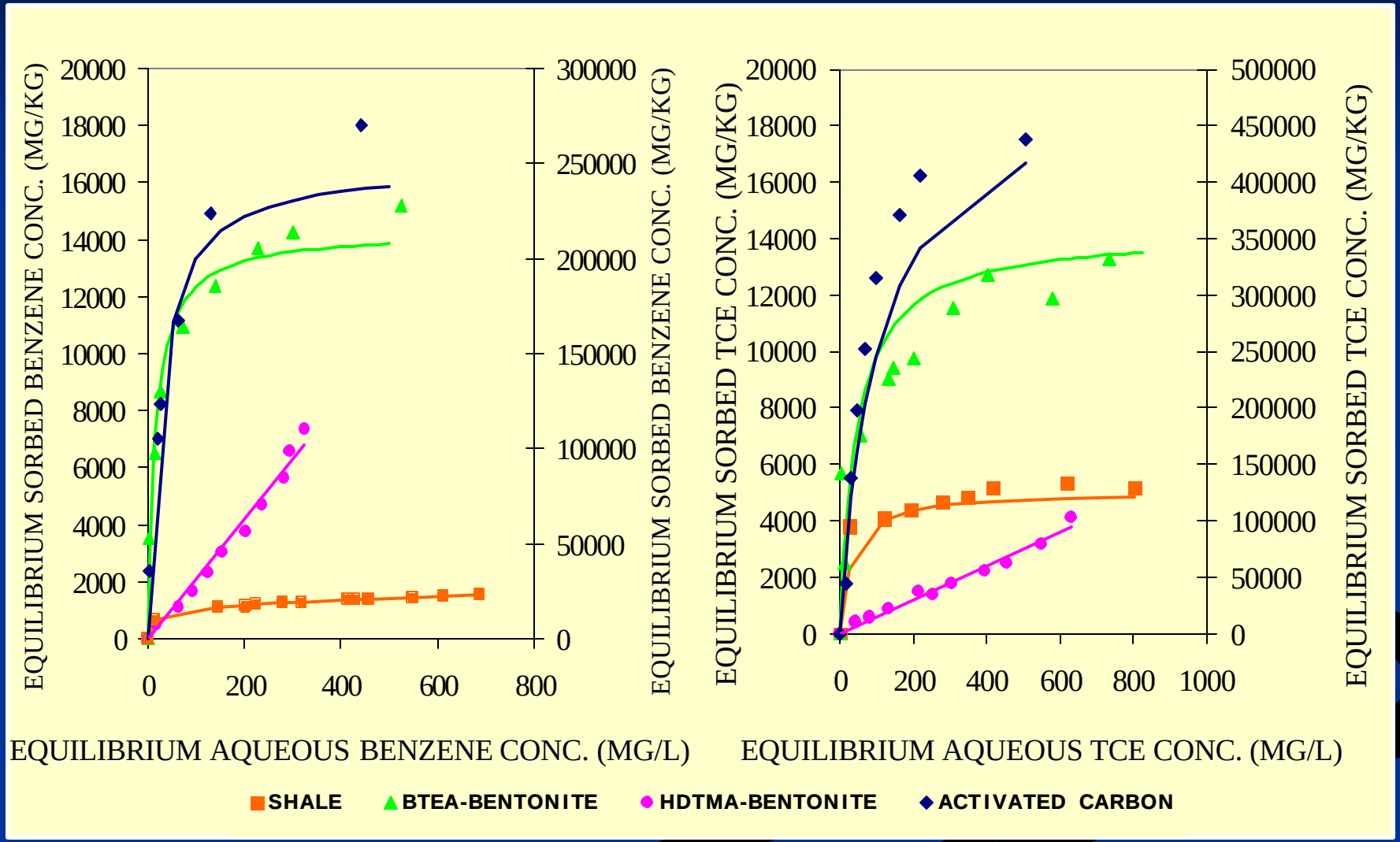
Hexadecyltrimethylammonium bentonite (HDTMA-bentonite)



Evaluation Criteria

- Sorption Capacity
  - solutes: benzene and trichloroethylene
  - solvent: 0.002 N $CaSO_4$ solution
  - equilibrium batch isotherms performed using C-14 labeled solute
- Permeability Testing
  - cores tested with 0, 3 and 9% amendment, 10% untreated bentonite, and remainder Ottawa sand
  - permeant liquid: 0.002 N $CaSO_4$ solution
- Mechanical Properties
  - Atterberg Limits
  - Consolidation
  - Direct Shear Tests

Sorption Isotherms



Isotherm Parameters

Benzene - Activated Carbon
a = 10000 mg/kg
b = 25 L/mg
R^2 = 0.99

Benzene – Shale
K = 382.2 L/kg
n = 0.211
R^2 = 0.97

Benzene – BTEA-bentonite
a = 14300 mg/kg
b = 0.0636 L/mg
R^2 = 0.99

Benzene – HDTMA-bentonite
K_d = 24.3
R^2 = 0.98

TCE - Activated Carbon
a = 5000 mg/kg
b = 100 L/mg
R^2 = 0.95

TCE – Shale
K = 2601 L/kg
n = 0.106
R^2 = 0.90

TCE – BTEA-bentonite
a = 10000 mg/kg
b = 0.0054 L/mg
R^2 = 0.89

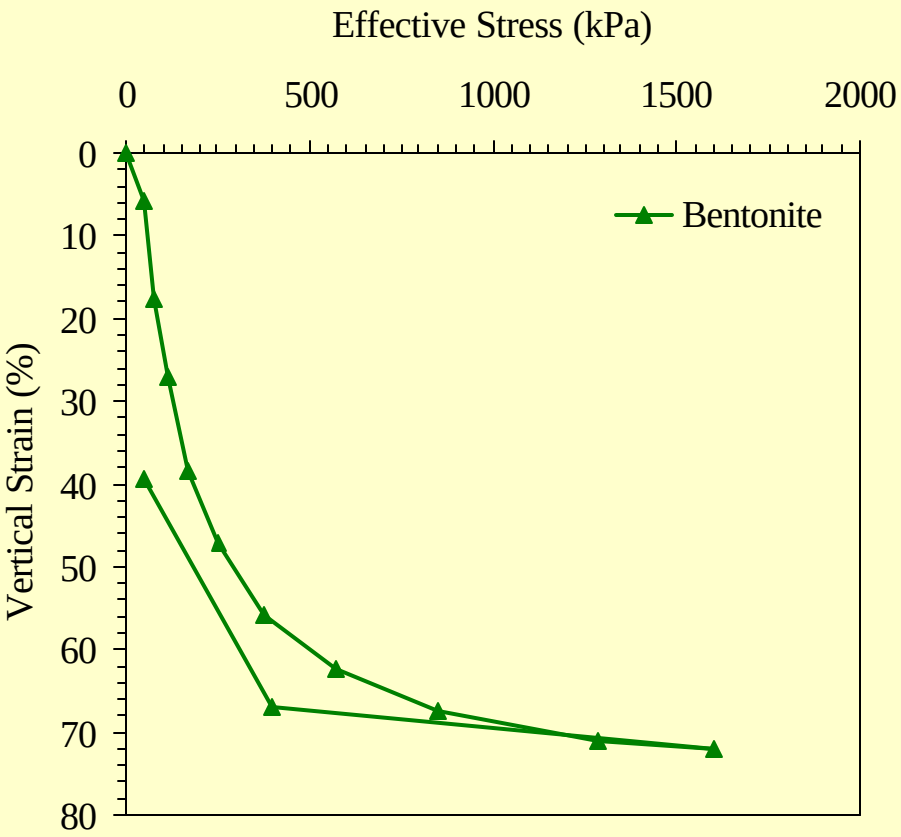
TCE – HDTMA-bentonite
K_d = 10.7
R^2 = 0.98

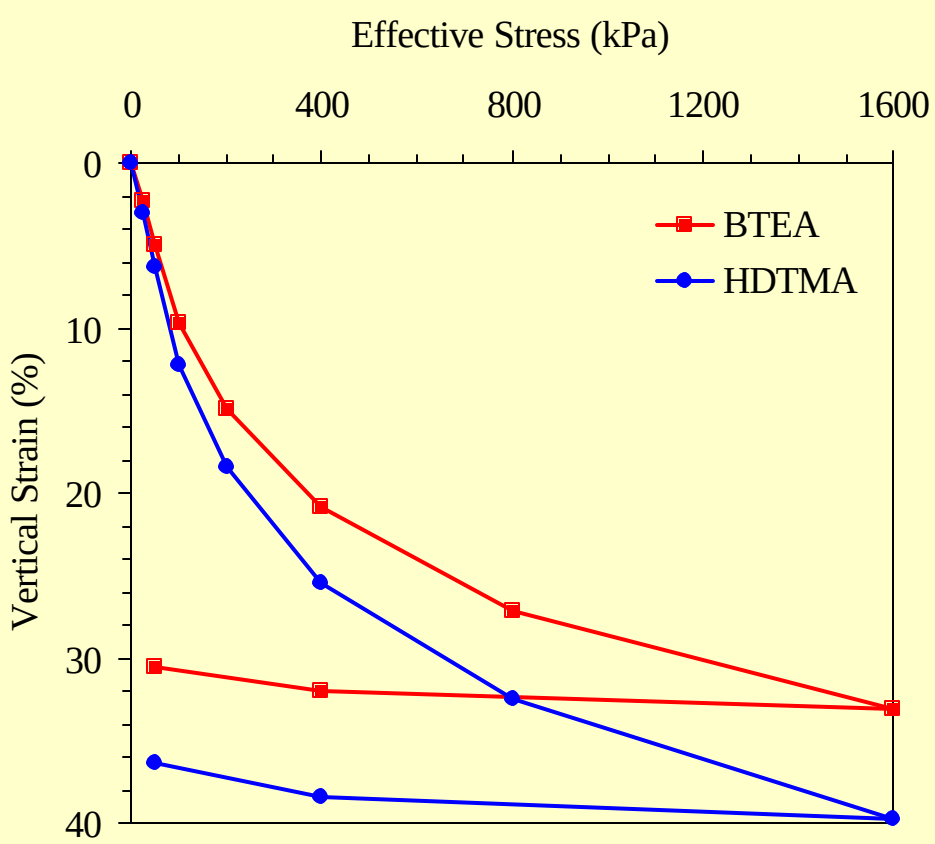
Permeability Testing

AMENDMENT	HYDRAULIC CONDUCTIVITY (CM/S)	POROSITY	DRY BULK DENSITY (G/CM^3)	BULK DENSITY (G/CM^3)
no amendment	1.8E-07 ± 3.0E-08	0.47 ± 0.01	1.74 ± 0.01	2.21 ± 0.01
3% BTEA	1.6E-08 ± 2.4E-09	0.38 ± 0.01	1.74 ± 0.01	2.12 ± 0.01
9% BTEA	~ 2.0E-08			
3% HDTMA	3.5E-08 ± 1.0E-08	0.50 ± 0.02	1.86 ± 0.04	2.37 ± 0.05
9% HDTMA	7.3E-07 ± 4.0E-07	0.40 ± 0.01	1.77 ± 0.01	2.16 ± 0.02
3% CARBON	3.1E-07 ± 6.4E-08	0.48 ± 0.01	1.63 ± 0.01	2.11 ± 0.01
9% CARBON	1.3E-06 ± 9.5E-07	0.53 ± 0.03	1.59 ± 0.09	2.13 ± 0.12
3% SHALE	2.5E-08 ± 5.0E-09	0.41 ± 0.01	1.79 ± 0.01	2.20 ± 0.01
9% SHALE	3.3E-09 ± 1.4E-09	0.37 ± 0.01	1.76 ± 0.02	2.14 ± 0.03

Mechanical Properties

Consolidation Results





Solute Transport Simulations

1-D benzene transport through amendment-modified liners was compared to conventional sand-bentonite liner

$$R\frac{\partial C}{\partial t} = -u\frac{\partial C}{\partial x} + D\frac{\partial^2 C}{\partial x^2}$$

For linear and Freundlich sorption:

$$R = 1 + \frac{r_b}{n}\left[qK_d + (1-q)nKC^{n-1}\right]$$

For linear and Langmuir sorption:

$$R = 1 + \frac{r_b}{n}\left[qK_d + (1-q)ab(1+Cb)^{-2}\right]$$

For HDTMA-bentonite:

$$K_d = \frac{q_{Bentonite}K_{d,Bentonite} + q_{HDTMA}K_{d,HDTMA}}{q_{Bentonite} + q_{HDTMA}}$$

Where:

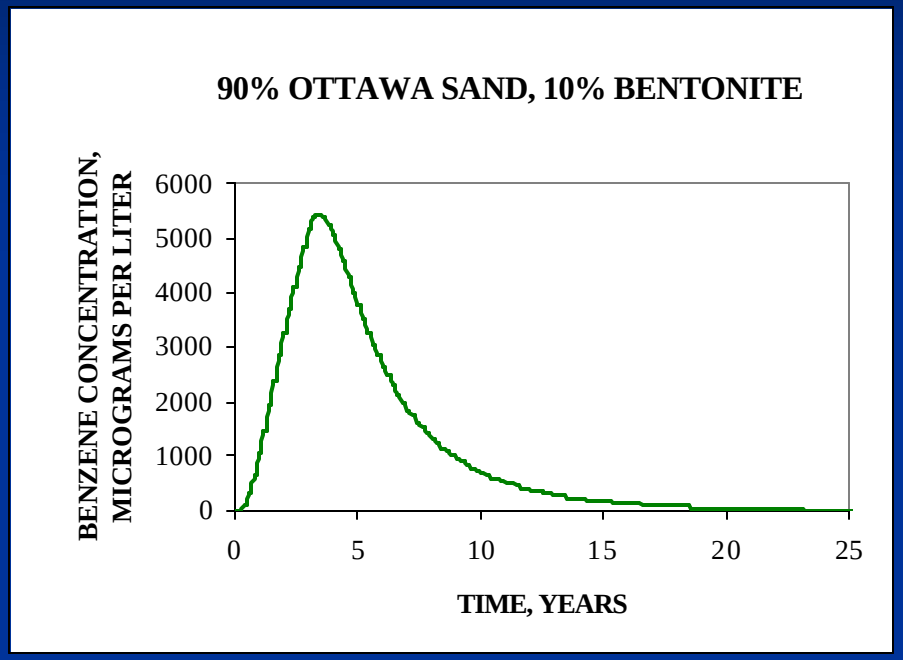
q = mass fraction of soil that obeys linear sorption

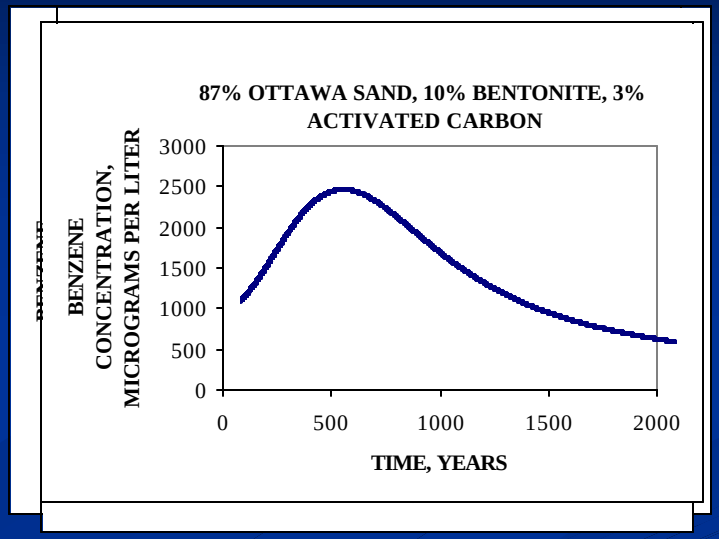
K_d = distribution coefficient (L/kg)

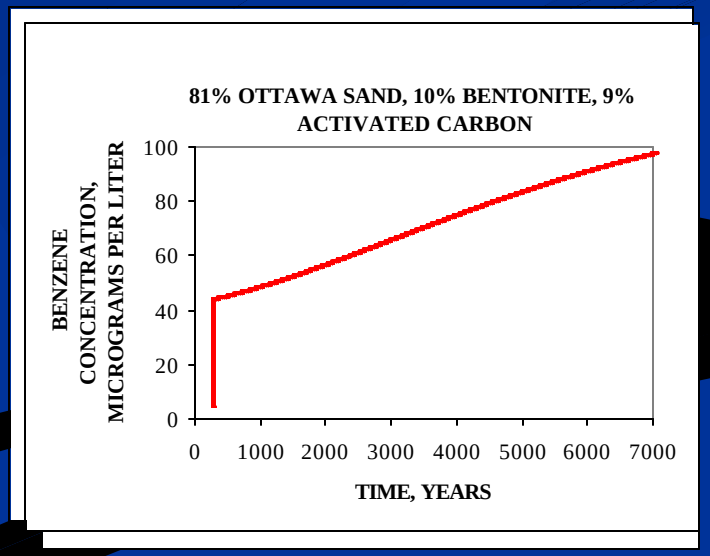
K, n = Freundlich sorption parameters (L/kg)

a,b = Langmuir sorption parameters (mg/kg), (L/mg)

Simulation Results







$K_{d,\ bentonite}$ = 0.207 L/kg (Smith and Jaffé 1994)

D = 2.74 x 10^{-5} m^2/d (Rowe and Booker, 1985)

$\upsilon = K\ i\ /\ n$, where i = 2.0 and n = total porosity

Conclusions

- All proposed amendments exhibit a larger sorption capacity for organic contaminants than untreated bentonite or sand

- Permeability values for amendment-modified cores are comparable to sand-bentonite core
  - cores modified with activated carbon are highly variable
  - cores modified with shale have a much lower permeability

- Mechanical properties of organoclays may slightly improve liner design

- 1-D transport simulation of benzene through amendment-modified liner is highly sensitive to permeability values