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Numerical modeling to bridge the gap between laboratory and field scale experiments of UNE Signatures

NST17-V-UNESE-PD2Pc

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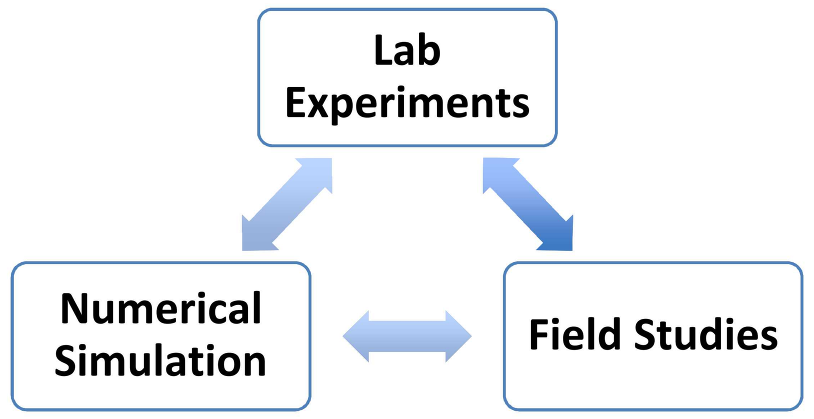
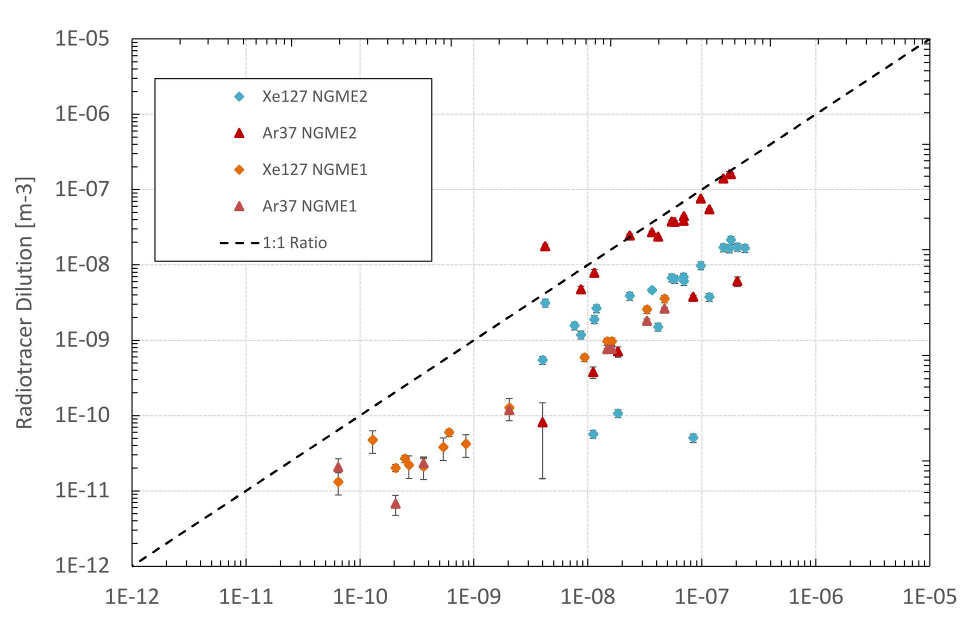
Goals and Objectives

- Use results of focused laboratory-scale experiments of gas transport to inform numerical models of field-scale gas transport.
- Enhance understanding of the results of the UNESE Noble Gas Migration Experiments (NGME).



Introduction

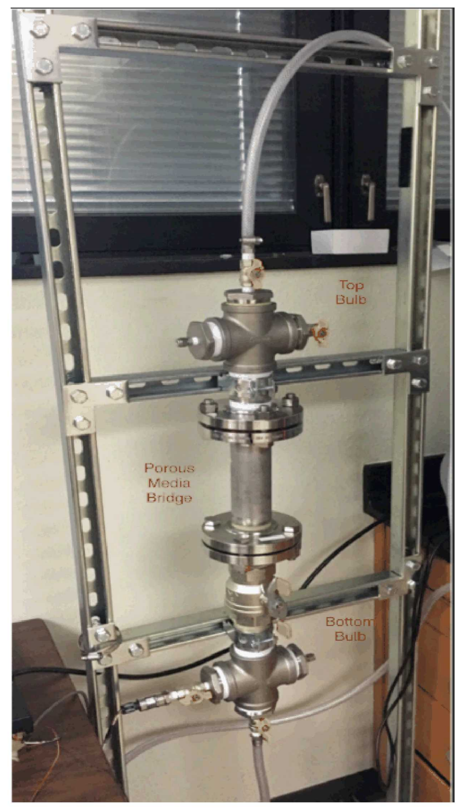
NGME1 in 2013 saw the injection of ^{127}Xe, ^{37}Ar and SF_6 gas into the Barnwell UNE chimney at NNSS. After 100 days, the chimney was pressurized and resulted in surface measurements that were relatively enriched in SF_6. Similarly, in 2016 NGME2 had the same tracers injected and results of measurements made at depth and at the surface showed differential transport among the tracers.



Plot of measured field tracers in NGME1/2

Methods

Differences in tracer dilution seen in NGME1 were unexpected, which motivated laboratory experiments to understand the relative gas behavior. Using such experiments allows for precise environmental control of transport variables and isolation of processes, which is critical for benchmarking numerical models.



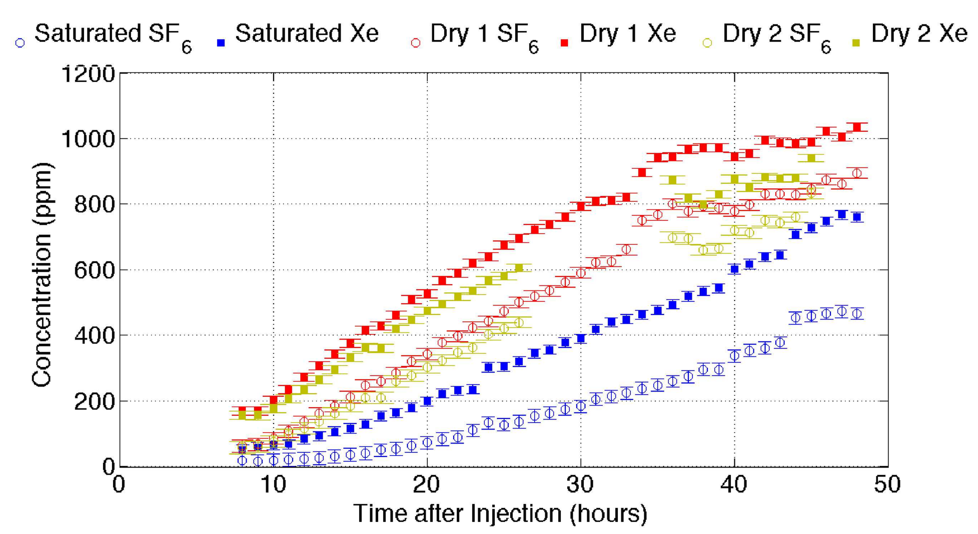
2-bulb gas column located at UT Austin

A variety of experiments have been conducted under UNESE using compacted soil/sand columns and solid core material, **exploring diffusion rates, water saturation, surface adsorption, and temperature sensitivity**. Results of these experiments were used to benchmark numerical models of simple transport physics, which in turn continue to define relevant parameters in field scale transport models like the Subsurface Transport Over Multiple Phases (STOMP) simulator.

Results or Major Findings

Column Study Results

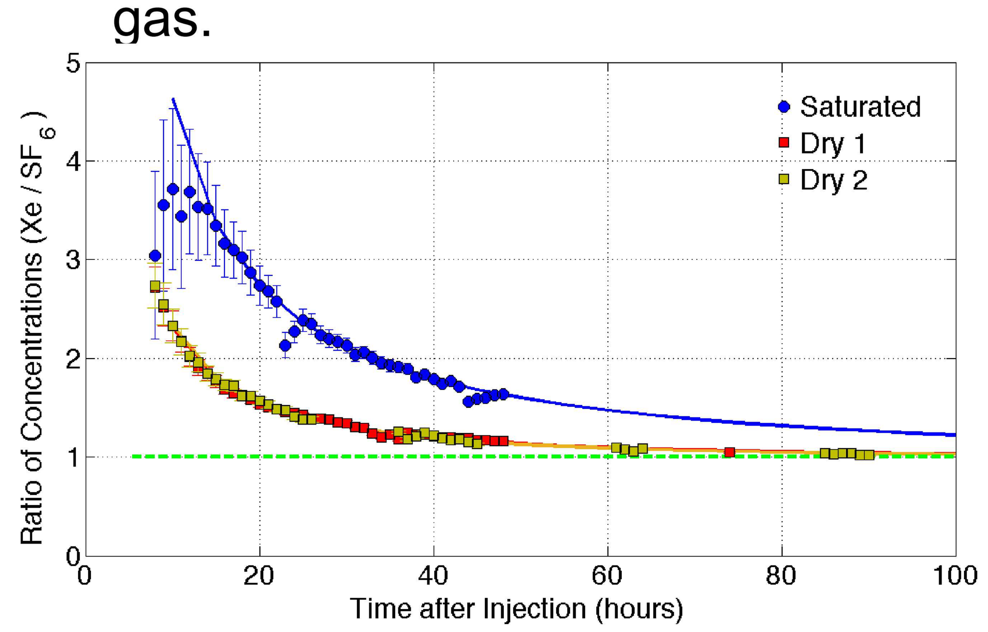
Results of one experimental campaign are summarized here. In the figure below, results suggest differential diffusion rates and adsorptive capacities among Xe and SF_6.



Results of gas transport tests comparing diffusion of Xe and SF_6 in two dry and one saturated porous media scenario test

Model benchmarking

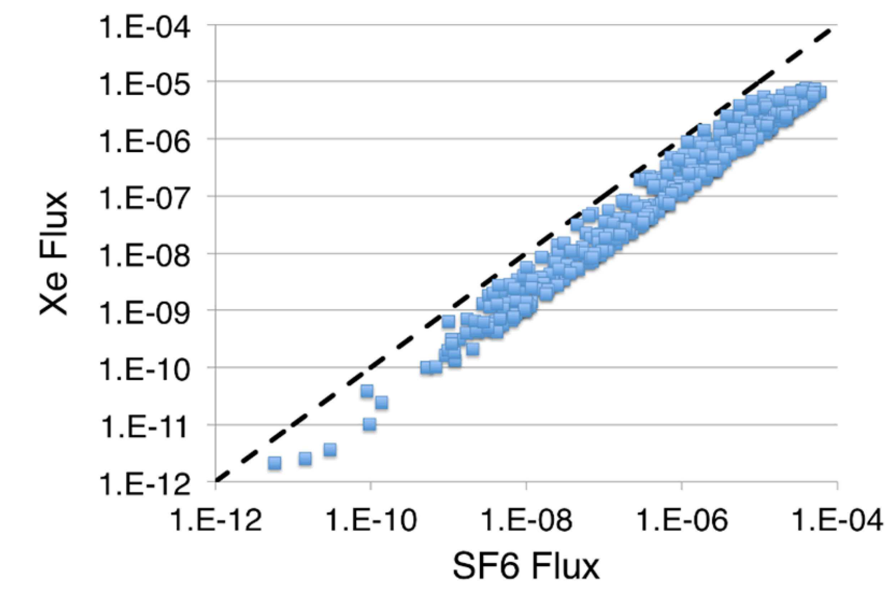
Experimental lab results were used to benchmark exact analytical solutions of simple1-D transport to estimate diffusion and adsorption rates of Xe, Ar and SF_6 gas.



Measured ratios of Xe to SF_6 gas collected from the top of the experimental column with fitted curves

Discussion

Simple extrapolation from benchmarked numerical models to field scale transport scenarios does indeed suggest differences in dilutions at the field scale.



Xe versus SF_6 fluxes resulting from the simple gas migration scenario modeled in STOMP

Initial results indicate that a combination of diffusive and adsorptive differences can at least partially explain dilution differences seen in NGME1/2. Some major things to note:

- Diffusion rates: D(Ar) > D(Xe) > D(SF_6); in fractured flow, higher D means greater losses out of fractures
- Sorption rates: S(Xe) > S(Ar) > S(SF_6); higher S means greater loss
- NGME1 – Pressurization of chimney means surface measurements were indicative of bulk gas that had largely been stagnant in chimney.
- NGME2 – Measurements indicative of natural seepage at depth and surface.
- Lab results are consistent with noble gases being more diluted than SF_6, but the Xe vs. Ar differences in NGME2 are more complicated.

Impact

Field results in NGME1/2 combined with benchmarked results of laboratory experiments demonstrate how small transport effects can have large, aggregate impacts on surface arrival time and relative concentration of UNE signature gases.

Site-specific geologic conditions can have enormous impact on expected gas seepage. An example identified in UNESE is the impact of zeolitic tuff, which SNL and PNNL continue to research for Its particularly-large capacity to adsorb xenon gas. Understanding such impacts are critical to further building and interpreting of models of UNE signature transport.

Future Work

Experimental work on various aspects of transport is ongoing. Field scale models of NGME1/2as well as the UNESE P-tunnel experiment continue to be refined and are needed to better deconvolve the effects of diffusion, affection and adsorption on resulting isotopic signatures.

Publications/Deliverables:

Johnson et al., Noble gas migration from the site of an underground nuclear explosion at the Nevada National Security Site (anticipated 2019)

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