U.S. DEPARTMENT OF ENERGY | Nuclear Energy

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DRAFT 3

Panel 7: Efficacy of Deep Borehole Disposal and Risk Analysis

Peter Swift
Senior Scientist, Sandia National Laboratories
National Technical Director
DOE Office of Nuclear Energy Used Nuclear Fuel Disposition R&D Campaign

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Discussion Topics

- What are the advantage and disadvantages of deep borehole (DBH) disposal relative to other disposal options?
- What is the projected post-closure dose from a deep borehole disposal program and how does it compare to projected doses from a conventional geologic repository for disposal of the same waste quantities and forms?
- What are the key uncertainties with the expected performance from a deep borehole disposal facility?
- What is the effect of sustained elevated temperatures on the performance of deep borehole disposal?
- How will the lack of international experience in implementing a deep borehole disposal program affect DOE's approach?

Advantages and Disadvantages of Deep Borehole Disposal

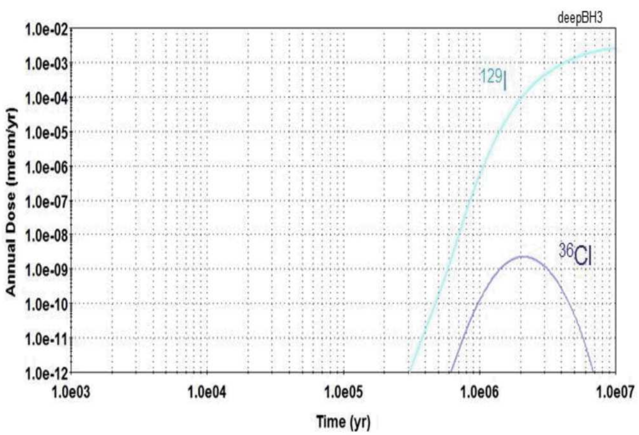
Advantages

- Conceptual simplicity
- Minimal reliance on engineered materials for long-term performance
- Long transport pathway to the human environment
- Modularity
- Low potential for future human disruption

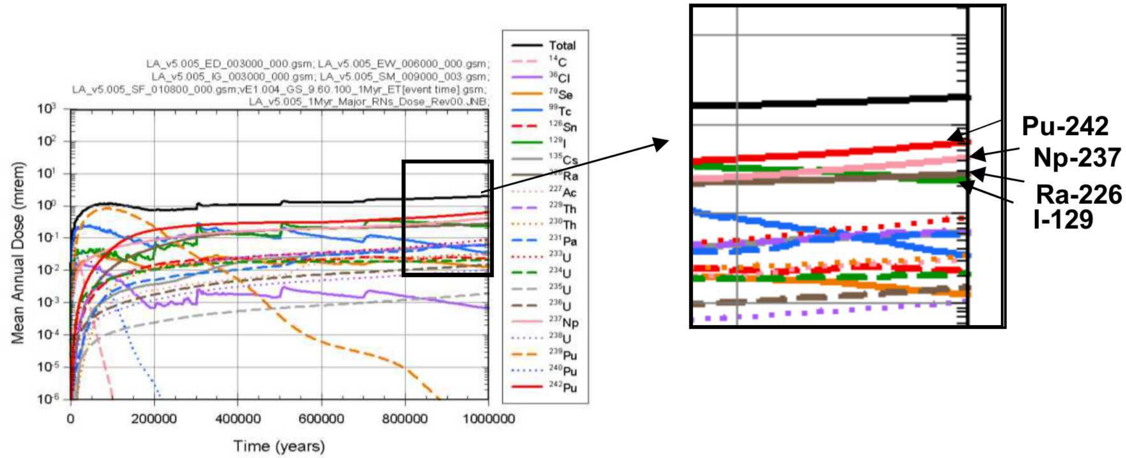
Disadvantages

- No field-scale demonstration to date
- Unproven operations
- Relatively small capacity of individual boreholes
- Incomplete regulatory framework in the US
- Less amenable to long-term retrievability after the repository is sealed

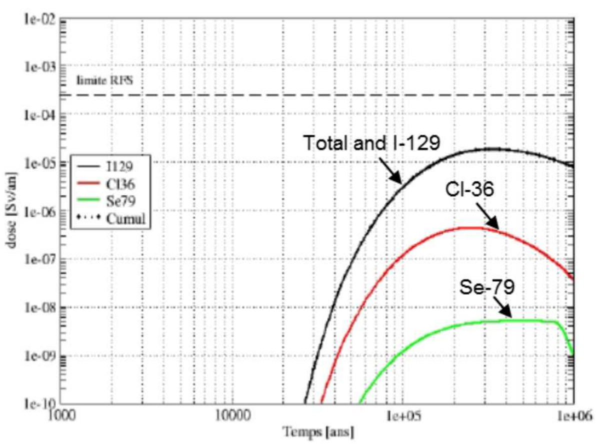
Mined Repository and Borehole Dose Estimates



Ten-million-year dose estimates for a single deep borehole containing 174 MTHM SNF (Freeze et al., 2013, Figure 4-8).



Million-year dose estimates for the Yucca Mountain Repository, 70,000 MTHM SNF and high-level radioactive waste (HLW) (DOE/RW-0573 Rev 0 Figure 2.4-20b).



1 mrem/year = 10^{-5}Sv/year

Million-year dose estimates for a French Argillite repository, 54,000 SNF assemblies (Andra 2005a, SEN million year model, CU1 SNF, Figure 5.5-18 and table 2.1.7). Estimated approx. 28,000 MTHM SNF (Andra 2005b, table 3.2.4).

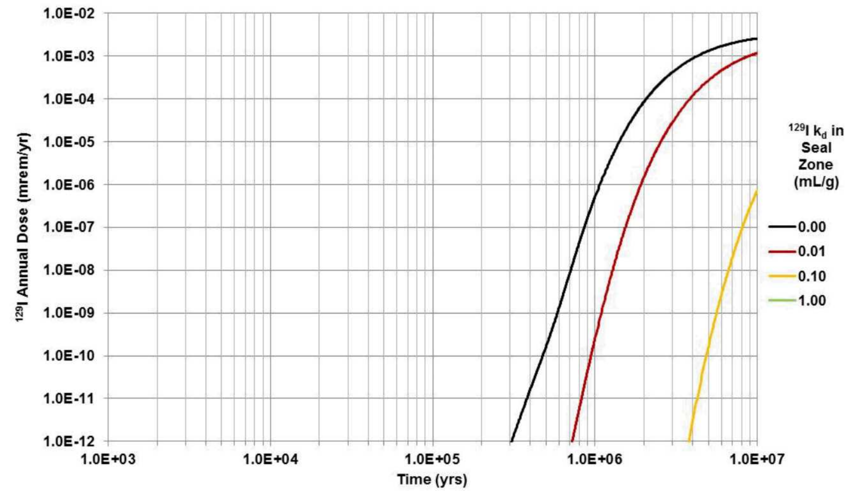
Examples include disposal of spent nuclear fuel (SNF) to be as close to comparable as possible, but DOE is not considering DBH disposal of commercial SNF

Examples use different inventories (e.g., deep borehole inventory is approx. 1/400 of the Yucca Mountain inventory)

Estimates for all three examples are below regulatory limits

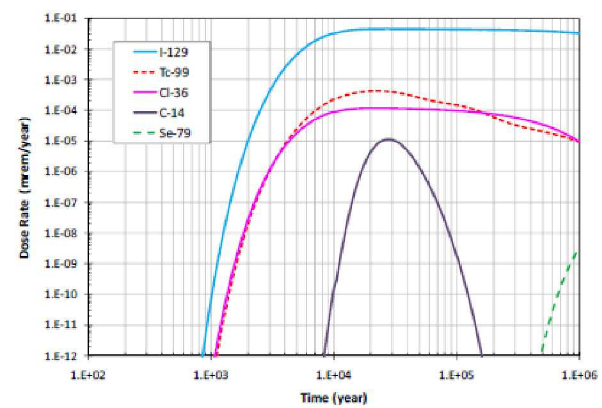
Key Uncertainties for Expected Performance

- **Site characterization**
  - Does the site have favorable properties?
    - Old saline groundwater
    - Low-permeability rock
    - Absence of fast transport pathways
- **Natural System performance**
  - Iodine sorption?
  - Lateral diffusion?
- **Engineered systems**
  - Waste inventory
  - Waste form degradation
  - Seal performance
  - Iodine sorption?
- **Biosphere assumptions**
  - Mixing at a pumping well



Ten-million-year dose estimates for a single deep borehole containing 174 MTHM SNF showing possible impact of iodine sorption in the seal zone (Freeze et al., 2013, Figure 4-33).

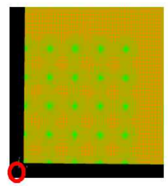
Million-year dose estimates for a single deep borehole containing 174 MTHM SNF assuming seal permeability at 10^{-12} m^2 (Clayton et al. 2011, Figure 3.4-19)



Effect of Sustained Elevated Temperatures

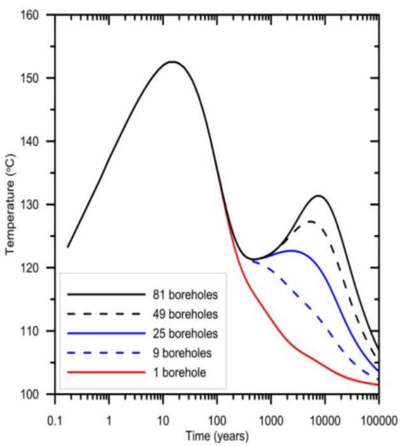
SNF Disposal

25-Borehole Array Schematic

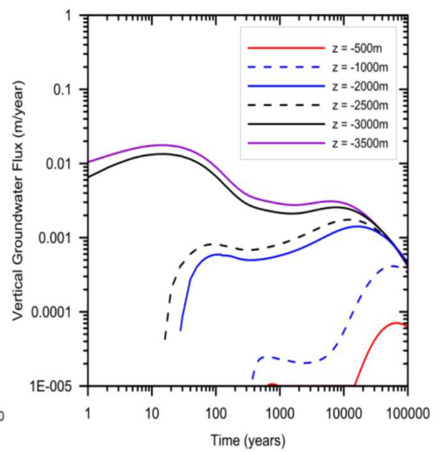


- 3-D multi-borehole configuration
- 400 PWR WPs per borehole (2000 m disposal zone)
  - ~ 240 W/m borehole length

Temperature in Disposal Zone (4,000 m depth, r=0.8 m) Central Borehole in 81-Borehole Array



Vertical Groundwater Flux (at various depths) Central Borehole in 81-Borehole Array

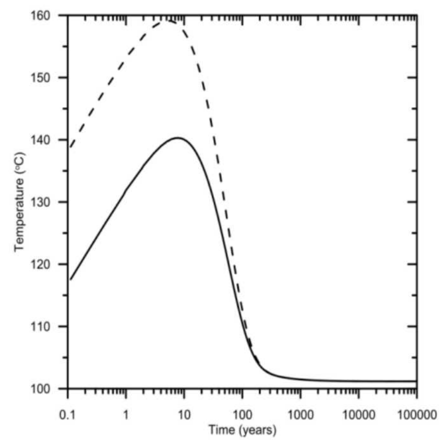


Arnold et al. 2013, Figures 4-4 and 4.5

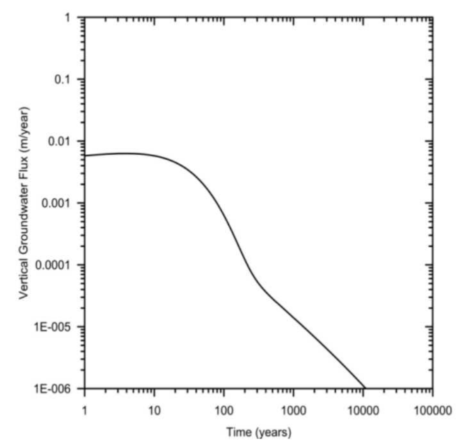
Cs/Sr Capsule Disposal

- 3-D single-borehole configuration
- 1936 Cs/Sr capsules in 1 borehole (1,300 m disposal zone)
  - 200–300 W/m borehole length (avg.)

Temperature in Disposal Zone (4,000 m depth, r=0.0 and 1.0 m) of Single Borehole



Vertical Groundwater Flux At Top of Disposal Zone (3,700 m depth) in Single Borehole



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Effect of Lack of International Experience on DOE's Approach

- **There is significant international experience in deep scientific drilling, and the DOE is drawing from that experience**
  - Extensive literature from past deep scientific drilling activities
  - LBNL is collaborating with the ongoing Swedish COSC (Collisional Orogeny in the Scandinavian Caledonides) drilling program
  - SNL is collaborating with University of Sheffield, UK on multiple topics
- **DOE has proposed a field test to address fundamental R&D needs associated with implementing deep borehole disposal**

References

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