9

NRC's Insights into Seepage and Release

Richard B. Codell
(301) 415-8167
RBC@NRC.GOV

Performance Assessment and HLW Integration Branch
Division of Waste Management
Office of Nuclear Materials Safety and Safeguards
U.S. Nuclear Regulatory Commission

Contributors: S. Mohanty (CNWRA), T. McCartin (USNRC)

For presentation at the NRC/DOE Technical Exchange on Total System Performance Assessment, Center for Nuclear Waste Regulatory Analyses, San Antonio TX May 25-27, 1999

Objectives

Determine the release rate of radionuclides entering the geosphere. This involves knowing:

- The quantity of water entering the drifts
- The fraction of this water dripping onto waste packages
- The fraction of dripping water entering failed waste packages
- The fraction of fuel wetted by the water
- The release rate of radionuclides from the spent-fuel waste form into the water
- The transport of released radionuclides from the waste package to the rock

Presentations

- Overview of NRC and DOE models for seepage and release
- Process-level presentations by:
  - Tae Ahn (Basis for NRC's choice of base-case dissolution model)
  - William Murphy (Natural analog and schoepite source term models in TPA 3.2)
  - Debora Hughson (Isothermal and coupled thermal models for infiltration to the drift)

Major Differences Between DOE and NRC Models for Seepage and Release

- Quantity and chemistry of water contacting waste packages and waste forms
  - DOE models consider temporal variation in chemistry more completely than NRC models.
  - Dripping models are different, but both are speculative.
  - DOE has mechanistic models of dripping at the drift scale (but outside of TSPA code).
  - DOE model provides more credit for water removal and diversion by capillary forces.
  - DOE model also has several likely conservatisms for dripping and chemistry.

Major Differences Between DOE and NRC Models for Seepage and Release (Cont'd)

- Colloid release and transport
  - DOE models consider colloid release and transport.
  - As an alternative conceptual model, NRC emulated transport of colloids as dissolved transport, but with zero retardation.
- Cladding - DOE takes substantial credit for cladding protection (up to 98.75% for 100,000 years). NRC takes no credit for base case.
- Water/Fuel Contact
  - DOE model assumes available water contacts fuel and saturates the fuel rind.
  - NRC assumes either a Bathtub or Flow-through model. For bathtub, water available determined by volume of water filling WP. For Flow-through model, water volume generally set to small fraction of WP volume.

Major Differences Between DOE and NRC Models for Seepage and Release (Cont'd)

- Waste-form Dissolution Model

  - DOE relies primarily on fuel-dissolution data with pure carbonate waters.
  - NRC relies on data for waters containing silica and calcium.

- Surface Area Model for Spent Fuel

  - DOE uses UO_2 grain size (about 10 micron diameter) model ⇒ more surface area
  - NRC uses UO_2 particle size (about 1 millimeter diameter) model

- Solubilities

  - DOE has revised solubility of Np downward by 2 orders of magnitude

- Glass Waste Form

  - DOE takes glass waste form into account. NRC's TPA analysis did not.

Major Differences Between DOE and NRC Models for Seepage and Release (Cont'd)

- Near-field transport
  - DOE has a reactive transport model AREST-CT for off-line calculation of release behavior of spent fuel in the near-field.
  - NRC has schoepite dissolution model within TPA 3.2 code for considerations of secondary minerals of the spent-fuel waste form.
  - Both NRC and DOE have models of near-field transport through the invert. Most flow bypasses invert in NRC model because of low permeability assumed.

- Diffusional Release
  - DOE considers release of radionuclides from waste package by diffusion when advective flow is small.
  - NRC's model no longer considers diffusional releases.

Features of DOE Models of Drift-Scale Seepage and Release for the VA

- DOE model uses mechanistic (offline) simulation to estimate the fraction of percolating water flux that infiltrates the drifts.
- Seepage flux is represented in TSPA-VA as an analytic function of percolation flux.
- Waste package represented as an area 5m x 5m, approximately length of WP and width of drift. DOE did not consider potential diversion after entering drift by flow along drift wall, or runoff from waste package.
- Seepage calculated separately for each of 6 subareas, but perfectly correlated among subareas in a single realization.

Comparison of DOE and NRC Flow Rates per Waste Package

- At drift scale, seepage fraction getting into waste packages considerably higher in DOE's model.

- DOE model has higher plan area per waste package (25 M^2 versus 10 M^2)

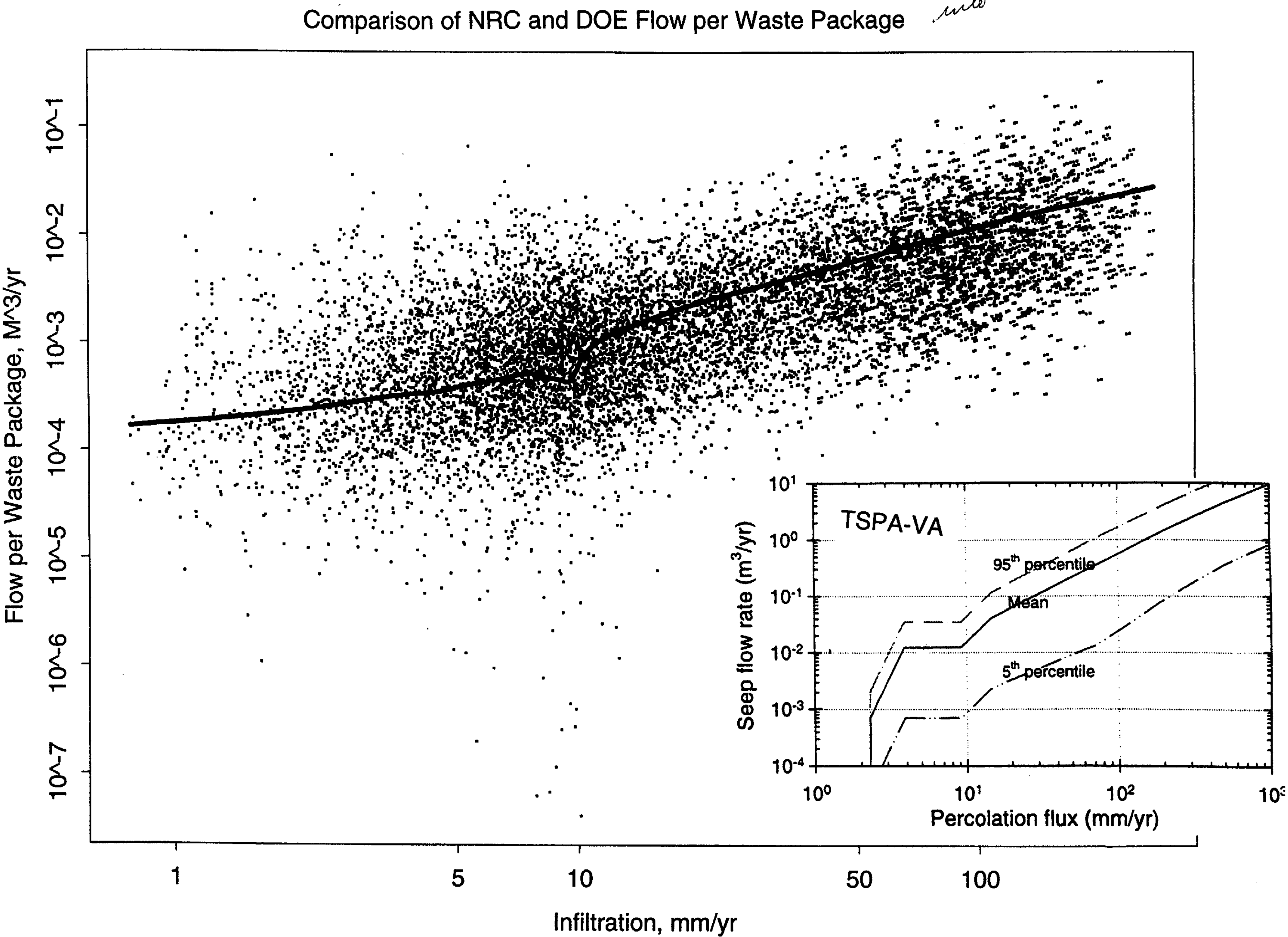
- DOE has no diversion from failed waste package.

- NRC model has diversion factor (0.01 to 0.2, lognormal) for fraction shed from waste package. fraction getting into WP

- NRC model has wetting fraction and diversion factors chosen once per run, and fixed for all time.

- DOE model allows number of WPs to change during run.

into WP



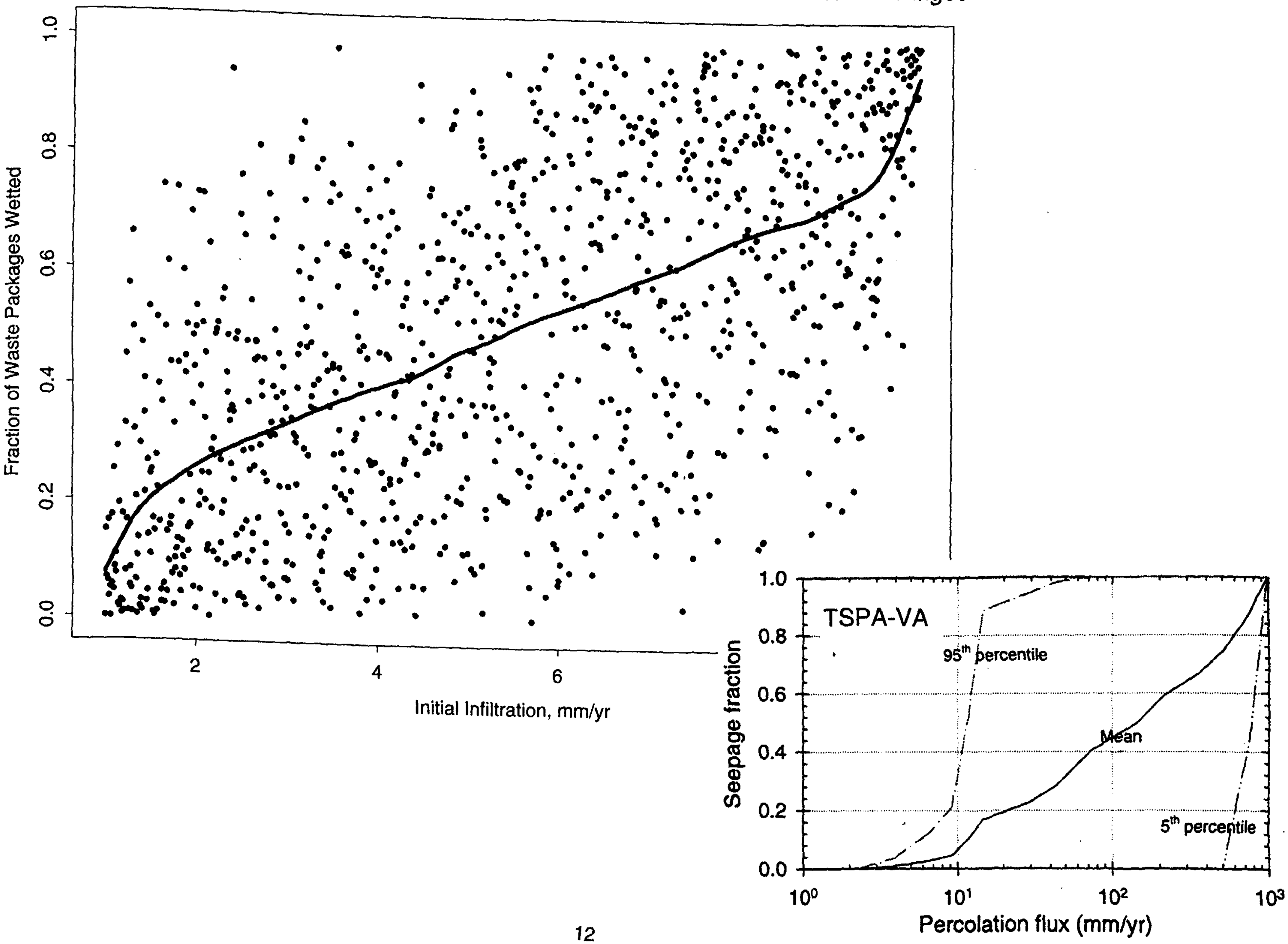
Comparison of NRC and DOE Flow per Waste Package
Flow per Waste Package, M^3/yr
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
10^-7
1
5
10
50
100
Infiltration, mm/yr
TSPA-VA
Seep flow rate (m^3/yr)
95th percentile
Mean
5th percentile
Percolation flux (mm/yr)

Comparison of DOE and NRC WP Wetting Fractions

- DOE wetting model has much smaller fraction of WP wet fraction than NRC.

  At 10 mm initial infiltration, DOE = 0.07, NRC = about 1.0 (Mean Values)

Comparison of NRC and DOE Fraction of Wetted Waste Packages



Relationship between Seepage and WP Wetting

- DOE's model had perfect correlation between fraction of WPs wetted and seepage flux.

- NRC's model had statistical correlation between fraction of WPs wetted and seepage flux (-0.631), and TS_w matrix permeability (-0.623).

- DOE's model does not calculate thermal recirculation.

- NRC's model calculated and uses thermal recirculation for releases from early failures of WPs.

TPA CALCULATIONS WITH TSPA-VA DATA

Seepage and flow into WP

Areal avg. mean annual infiltration at start	constant: 10 [mm/yr]
FowFactor	lognormal: .054555, 0.054556
FmultFactor	lognormal: 1.0, 1.00001
SubAreaWetFraction	uniform: 0.9999, 1.0

Release rate modification

TPA dissolution model	user-specified
User leach rate	constant: 7.e-3 [kg/yr/m2]
Initial radius of SF particle	constant: 1.e-3 [m]
SF wetted fraction	uniform: 0.49, 0.51

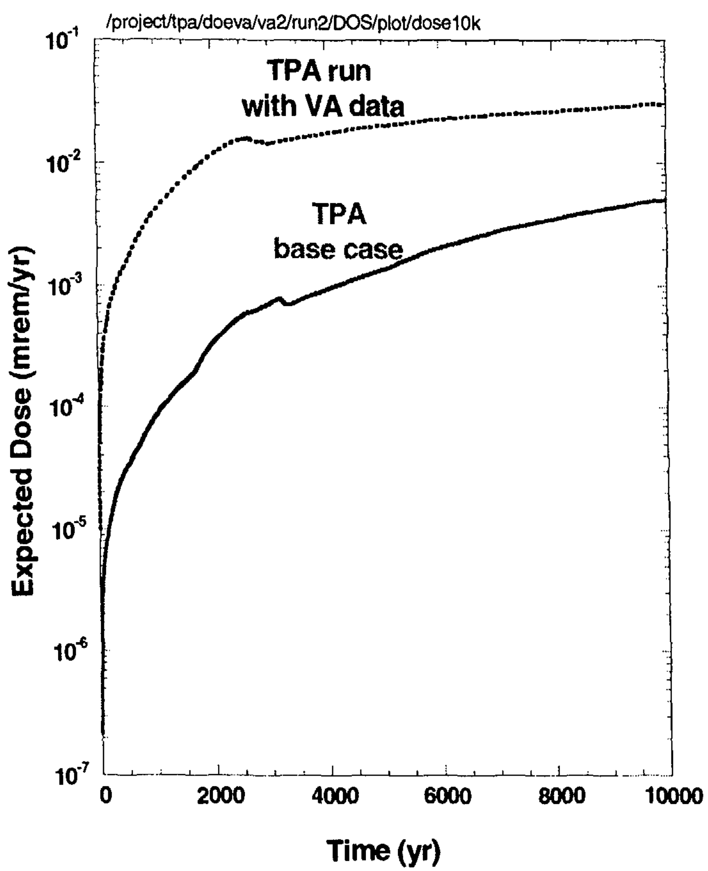
(Reflux model was turned off)
Flow into WP = 0.098 m3/yr/WP

Release rate with cladding

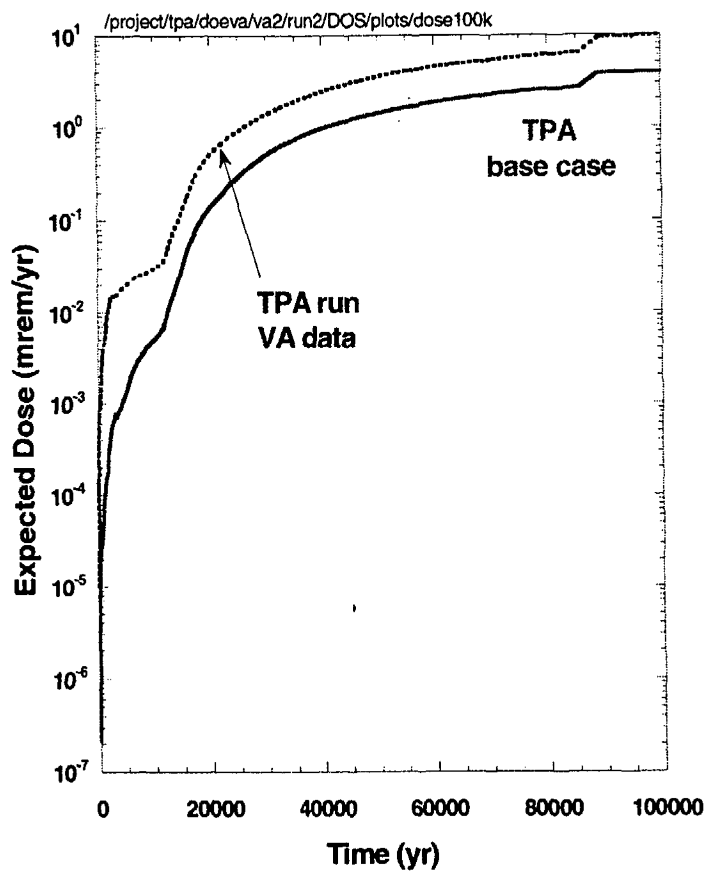
Same as release rate modifications plus

Cladding Correction Factor	constant: 0.0125

TPA RUN WITH TSPA-VA SEEPAGE DATA

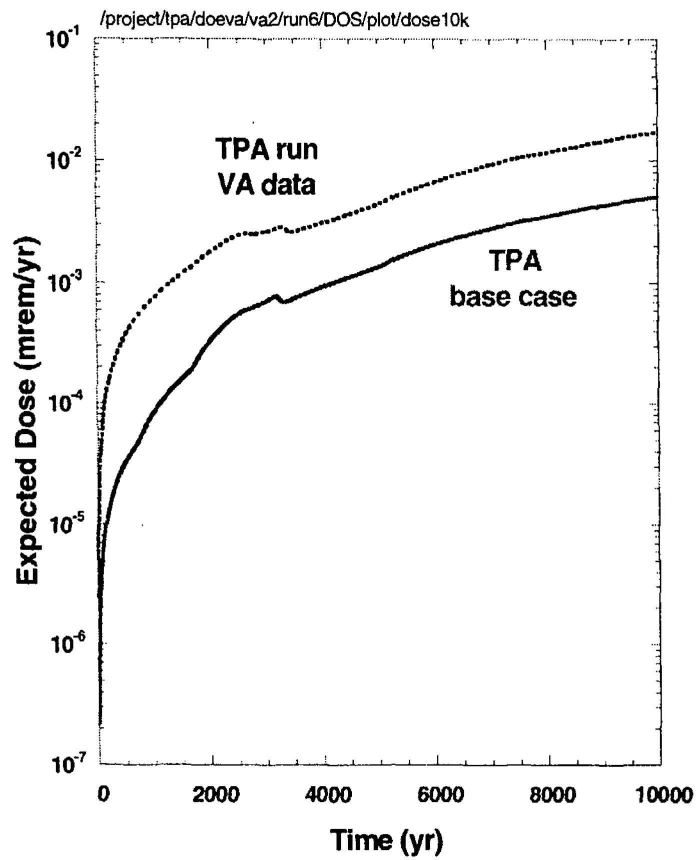


10,000 yr run

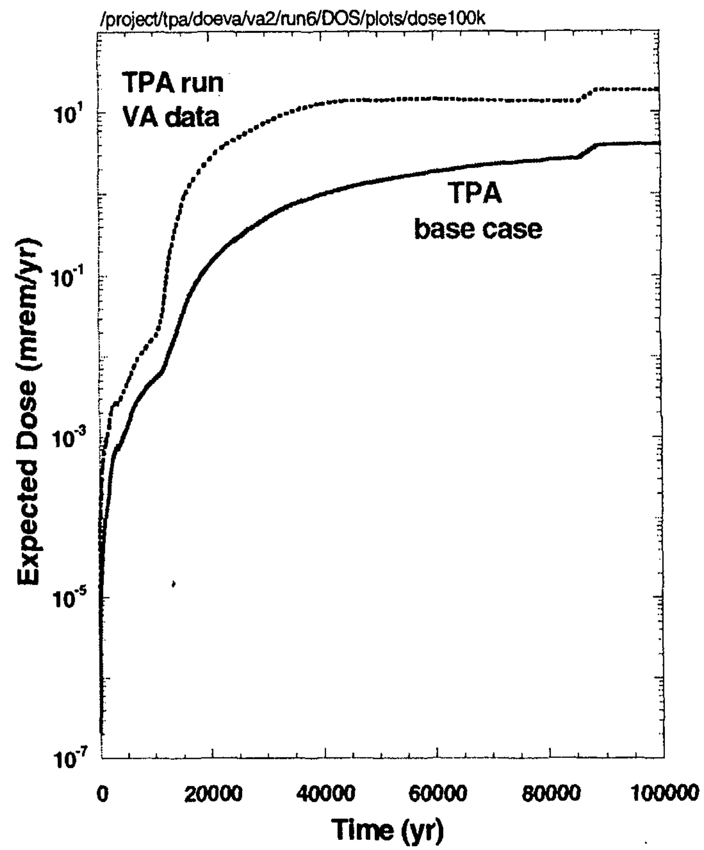


100,000 yr run

TPA RUN WITH TSPA-VA RELEASE RATE DATA

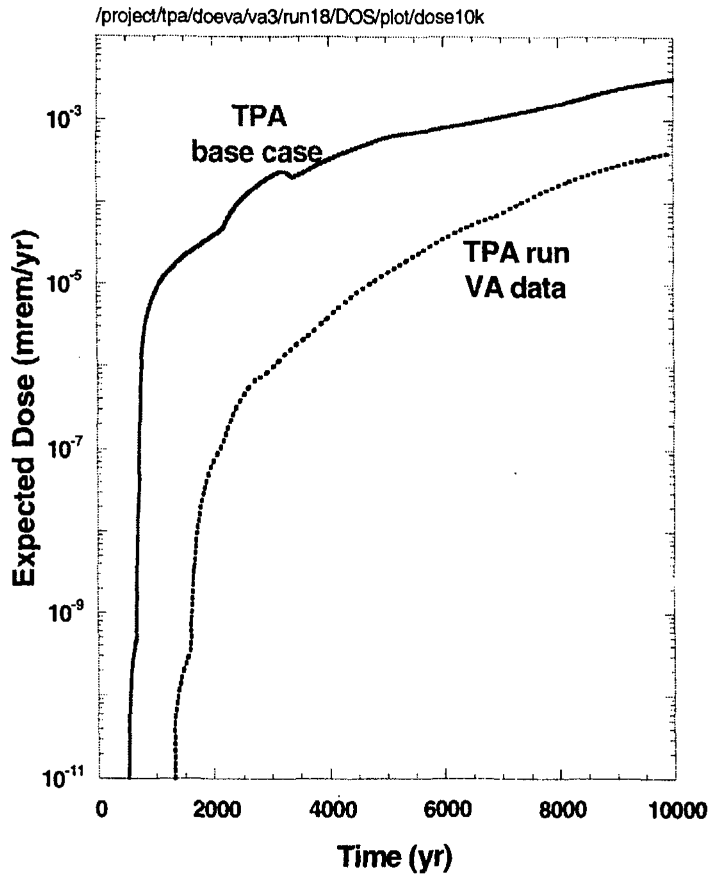


10,000 yr run

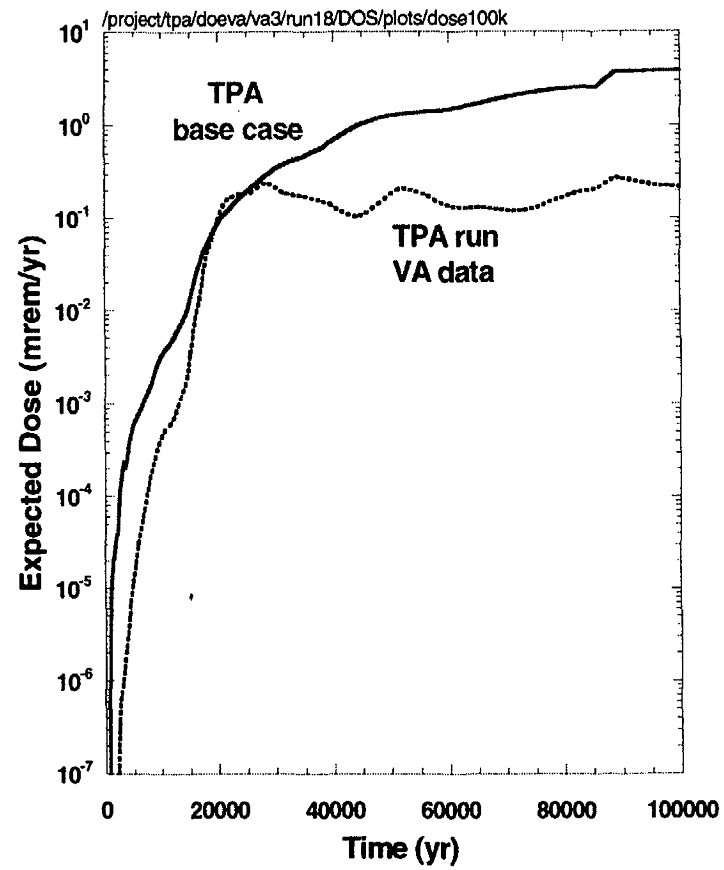


100,000 yr run

TPA RUN WITH TSPA-VA: RELEASE WITH CLADDING CREDIT

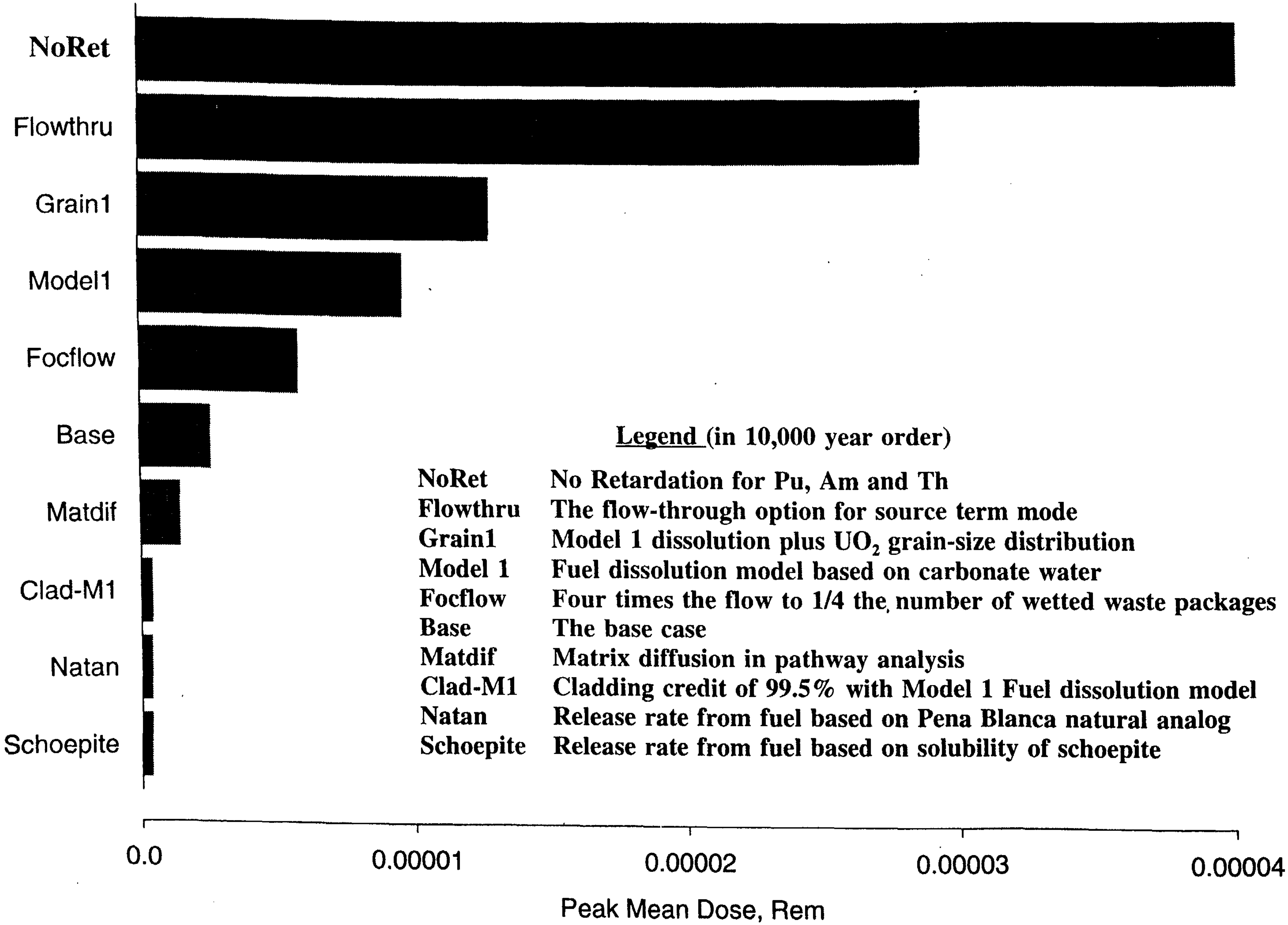


10,000 yr run

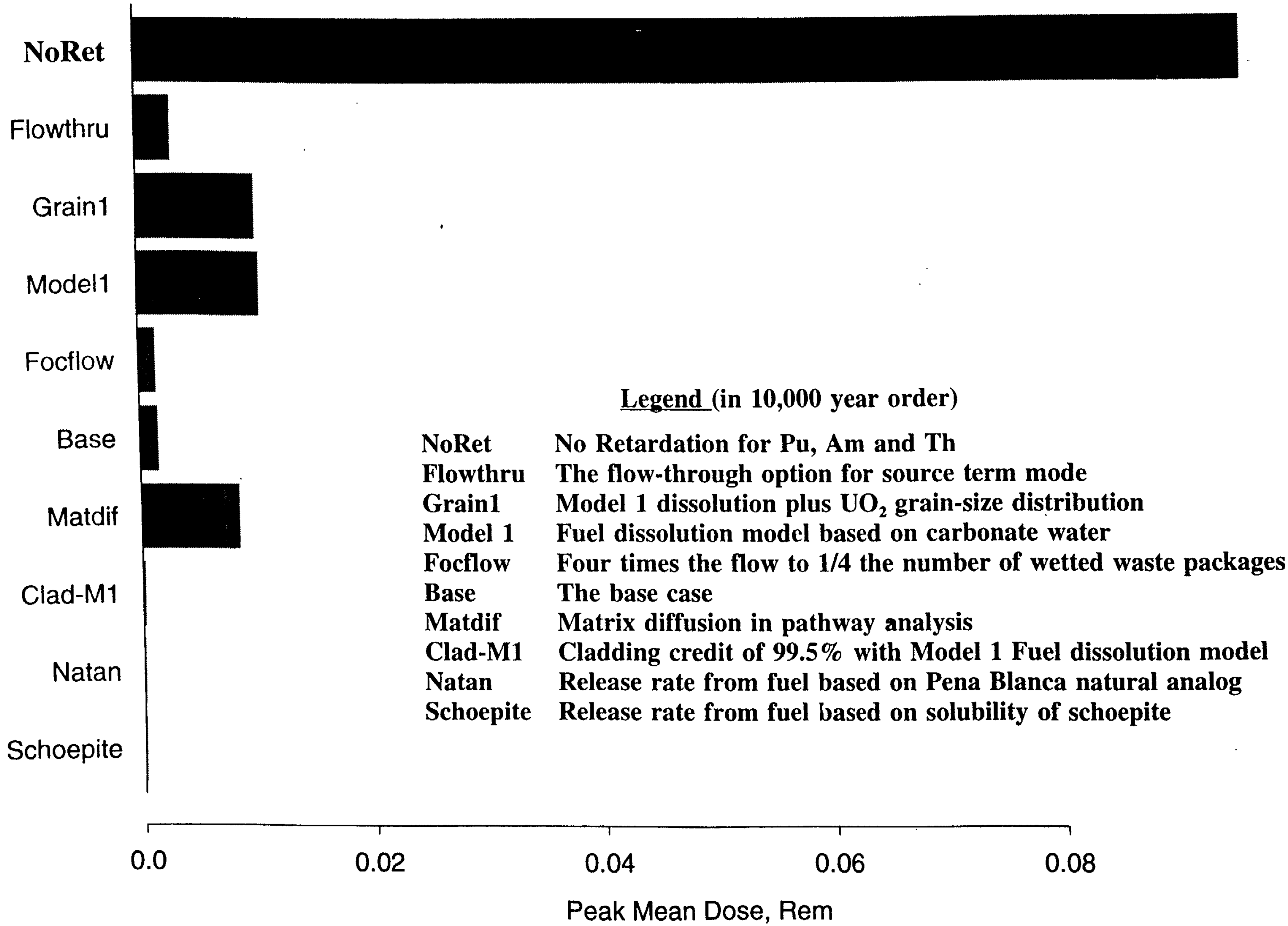


100,000 yr run

Peak Mean Dose for 10,000 Years, Rem



Peak Mean Dose for 50,000 Years, Rem



Summary and Conclusions

Many differences exist between NRC and DOE models of drift seepage and release from the waste packages. Major distinctions for DOE's models are:

- Smaller number of WPs wetted, and variable number within a run.
- Less diversion in drift.
- Attempts mechanistic model for colloid release from glass waste form + spent fuel and transport through geosphere.
- Mechanistic models for wetting and dripping outside of TSPA code.
- Grain-size UO_2 distribution for surface area.
- Carbonate waters for fuel dissolution.
- Much lower Np solubility.
- No use of recirculating water during repository thermal period. → accelerated corrosion by assuming evaporation and change to chemistry