TRITIUM RELEASES TO THE ATMOSPHERE
ADJACENT TO AN ARID WASTE-DISPOSAL SITE

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(Garcia et al. 2009, in press, Vadose Zone Journal)
Desert Soil-Plant-Atmosphere Interactions

- Strongly influence subsurface water movement (liquid & vapor) (Gee et al. 1994; Andraski 1997)
- Little known about
  - Effect on release of water-borne contaminants to atmosphere
  - Remediation potential of native plants

Objective

- Estimate the magnitude and spatio-temporal variability of tritium transport from the shallow unsaturated zone to the atmosphere
EXPERIMENTAL APPROACH

Tritium flux to the atmosphere ...

Product of tritium concentrations and ET fluxes

- Tritium measured in
  - Soil – vapor extraction
  - Plants – toluene extraction

- ET partitioned into bare-soil E and plant T
**EXPERIMENTAL APPROACH**

- **Tritium Concentrations**
  - Sampled quarterly
  - August 2003–05
  - Spatially extrapolated
  - 0.76 km² study area
  - Base map May 2001 (Andraski et al. 2005)
  - Temporally interpolated
  - Converted to mass fraction (X)
Continuous ET partitioned: $ET = E + T$

- **ET**: measured eddy-covariance
- **$E = E_s \times \% soil \ cover$**
  - **$E_s$**: Chamber measurements
    - Priestley-Taylor model
- **$T$**: computed as $ET - E$

- % soil cover interpolated from quarterly plant-&-soil transect data
RESULTS – Tritium Concentrations

Spatial Distributions

- Measured Concentrations
  - Decrease from sub-root zone to canopy
  - Decrease with distance from facility
  - Background at >300 m

Air Std. (15% RH) off chart
Public: $4 	imes 10^7$ Bq/L
Occupational: $3 	imes 10^8$ Bq/L

(Garcia et al. 2009, in press)
RESULTS – Tritium Concentrations

Spatial Distributions

- Concentration Distributions
  - Reflect measurements
  - Pattern consistent for all quarters

(Garcia et al. 2009, in press)
RESULTS – Tritium Concentrations
Temporal Changes

- Sub-root-zone gravel
  - Long-term decrease near facility
  - Indicate plume movement with time

- Root-zone
  - Similar to sub-root zone
  - Short-term variations

- Plants
  - No long-term trends
  - Variation generally follows inverse of change in soil moisture

(Garcia et al. 2009, in press)
RESULTS – Partitioned Evapotranspiration

- **ET**
  - Similar to total precipitation
  - Lack of seasonality
  - Large increases with precipitation
  - Year 2 = twice year 1

- Average E:T = 70:30 %

- Proportion of T increased in year 2

(Garcia et al. 2009, in press)
RESULTS – Tritium Flux
Temporal Variability

- Magnitude of tritium flux affected by changes in
  - Soil & plant concentrations
  - Proportioning between soil E & plant T

- Tritium flux on average:
  - 85% attributed to E
  - 15% attributed to T

- Both short- & long-term variations
  - Annual tritium flux: Year-1 was 15% > Year-2

(Garcia et al. 2009, in press)
RESULTS – Tritium Flux
Spatial Variability – 2-Year Distribution

- Two “hotspots”
  - Represent 20% of study area
  - Contribute 90% of 2-year tritium flux

- Total mass of tritium released = 1.5 mg
  (8×10^{10} Bq; 2×10^{12} pCi)
  - 0.002% of the residual disposed tritium

(Garcia et al. 2009, in press)
IMPLICATIONS – Remediation

- 2-year flux (1.5 mg) ~ 0.002% of disposed tritium
  - Extrapolate into the future
    - 13 mg of tritium over 40 yrs (7×10^{11} Bq; 2×10^{13} pCi)
    - ~0.05% of remaining tritium
    - Total mass of tritium in atmospheric reservoir (Aug. 03 on)
      - Reaches a maximum of 5.6 mg in 2021 (3×10^{11} Bq; 8×10^{12} pCi)

- Plume movement
  - Concentrations nearest the source have reached peak values and are declining
  - Contaminant plumes advancing but decaying

(Garcia et al. 2009, in press)
IMPLICATIONS – Waste Disposal

- Devegetated soil covers
  - Enhanced accumulation of precipitation
    - Increases potential for downward tritium transport
    - Hinders upward vapor transport of contaminants
      - May play a role in unexplained long distance, lateral migration of contaminants (Andraski et al. 2005; Mayers et al. 2005)

- Arid site waste isolation – high ET / low precipitation
  - Diminished with
    - Precipitation and runoff into open trenches
    - Disposal of liquid contaminants in unlined trenches

(Garcia et al. 2009, in press)
CONCLUSIONS

- Complex soil-plant-atmosphere interactions control tritium release to the atmosphere

- Remediation through desert ET removed 1.5 mg (8×10^{10} Bq; 2×10^{12} pCi) of tritium from the 0.76 km² study area in 2 years

- Results improve understanding of near-surface processes controlling subsurface transport and release of contaminants to the atmosphere

(Garcia et al. 2009, in press)