

RESRAD-OFFSITE

A Tool for Waste Disposal Facilities Performance Assessment

Charley Yu, PhD, CHP
Environmental Science Division
Argonne National Laboratory

August 30, 2012

Presented at NRC Workshop on Performance Assessment of Near-Surface
Disposal Facilities - Codes Roundtable Discussion

Recent Developments in RESRAD-OFFSITE

- Added a new source term model
 - Derivation of analytical formulations based on the DUST-MS code for the releases to three media (air, runoff, and infiltration) and the vertical profile within the contaminated zone for release to groundwater
- The new source term model considers
 - Mass balance
 - Radionuclide database: ICRP 38 and ICRP 107 and cut-off half-life
 - Backward compatibility (older versions compatibility)
 - Uncontained (soil) and containerized (waste) contamination
 - Sensitivity and probabilistic analyses



Draft NUREG/CR on the New Source Term Model

- Describes three source release options (Feb. 2012)
 - First order release (with transport)
 - Equilibrium desorption (rinse) release
 - Uniform release (constant dissolution)
- Documents verification testing
- Benchmarks the new source term model



NUREG/CR-XXXX
ANL/EVS/TM/11-5

New Source Term Model for the RESRAD-OFFSITE Code Version 3

Manuscript Completed: September 2011
Date Published: February 2012

Prepared by
C. Yu, E.K. Gnanapragasam, J.-J. Cheng, S. Kamboj, and S.Y. Chen

Argonne National Laboratory
9700 South Cass Avenue
Argonne, IL 60439

John Randall, NRC Project Manager

NRC Job Code N6731

Office of Nuclear Regulatory Research

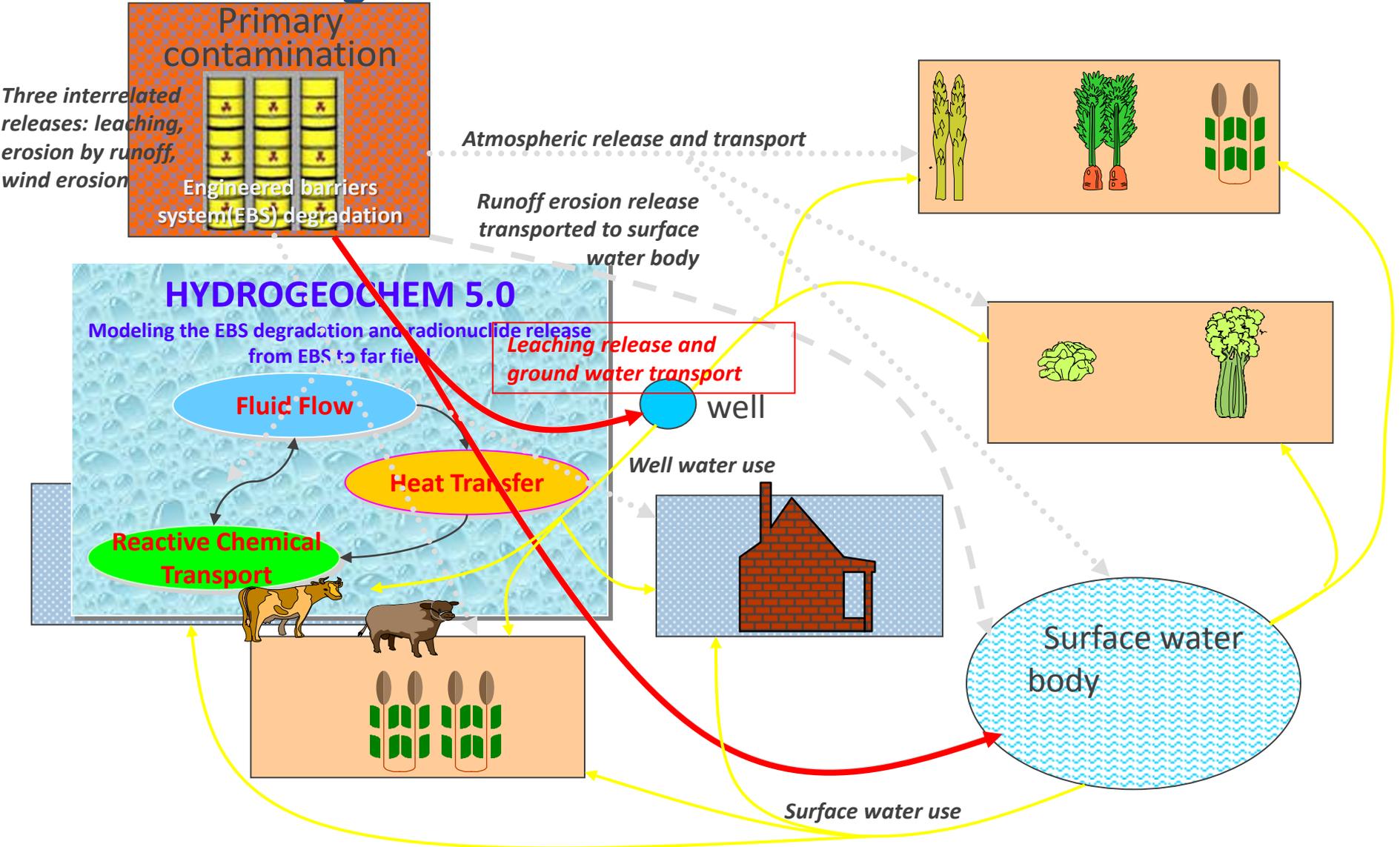


Upcoming Developments in RESRAD-OFFSITE

- Add delay time in the source release options
- Output area factors (for MARSSIM applications)
- Improve the RESRAD-OFFSITE flux and concentration input options:
 - Flux to ground water
 - Flux to atmosphere
 - Flux to surface water
 - Concentrations in surface water and well water
 - Inventory remaining in the primary contamination and mixing layers
- Link to other codes



Linking RESRAD-OFFSITE and HYDROGEOCHEM



HYDROGEOCHEM 5.0 is a flexible and comprehensive package (Yeh et al., 2004)

3-D thermo-hydro-chemical transport

- Include variably saturated-unsaturated fluid flow, heat transfer, and reactive biogeochemical transport;

Effect of precipitation/dissolution on the pore size

- Incorporate the effect of precipitation/dissolution on the change of pore sizes, hydraulic conductivity, and diffusion/dispersion;

Deal with equilibrium and kinetic reactions

- Equilibrium (aqueous complexation, precipitation-dissolution, adsorption/desorption, ion-exchange, redox, and acid-base reactions) and kinetic reactions including decay chain;

Heterogeneous and anisotropic

- Treat heterogeneous and anisotropic media;

Sources/sinks

- Consider spatially and temporally distributed sources/sinks as well as point sources/sinks;

Steady-state/transient-state variables

- Deal with simulation of steady-state and prescribed transient state-variables (pressure head and/or temperature and/or Chemical concentrations) distributed over a dirichlet boundary;

Time-dependent fluxes boundary

- Handle time-dependent fluxes over variable boundaries;

Off-diagonal tensor coefficients

- Include the off-diagonal tensor coefficients in the governing equation for dealing without principal directions of the tensor;

Provide three options for numerical approximations

- Conventional finite element method (FEM), hybrid lagrangian-eulerian FEM, or hybrid lagrangian-eulerian FEM for interior nodes plus FEM for boundary nodes;





RESRAD-OFFSITE

A Tool for Waste Disposal Facilities Performance Assessment



SYNOPSIS

RESRAD-OFFSITE is an assistance tool that provides technically sound, cost-effective, and user-friendly methods for evaluating human radiation doses and risks associated with exposure to radiological contamination. A new source term model was recently added to allow evaluation of waste disposal facilities performance assessment. This Fact Sheet on RESRAD-OFFSITE summarizes:

- RESRAD-OFFSITE features and capabilities
- Exposure locations and pathways considered
- Types of releases from primary contamination
- Conceptual model applied for groundwater transport
- Code QA/QC and benchmarking
- Where to get a copy of RESRAD-OFFSITE

WHAT IS RESRAD-OFFSITE?

RESRAD-OFFSITE is an extension of the RESRAD (onsite) computer code that was developed to estimate the radiological consequences to a receptor located onsite or outside the area of primary contamination. It calculates radiological dose and excess lifetime cancer risk with the predicted radionuclide concentrations in the environment. For contaminated-soil sources, it derives soil cleanup guidelines corresponding to a specified dose limit.

The code is sponsored by DOE's Office of Health, Safety and Security, and the Office of Environmental Management, as well as the U.S. Nuclear Regulatory Commission. It was developed by Argonne National Laboratory (Argonne).

WHAT EXPOSURE LOCATIONS, PATHWAYS, AND SCENARIOS ARE CONSIDERED IN RESRAD-OFFSITE?

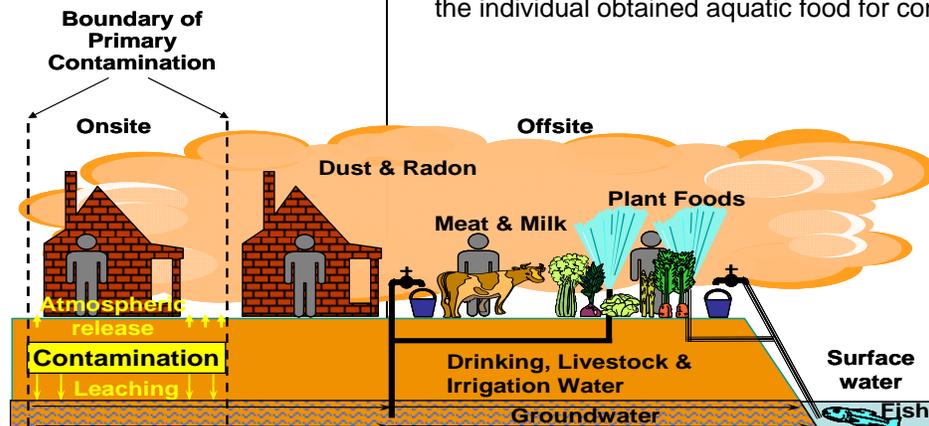
RESRAD-OFFSITE can be applied to estimate release rates of radionuclides from underground sources in different waste forms, including soils. It simulates the environmental fate and transport of released radionuclides and the subsequent human exposures. The settings of the underground sources can range from a clean cover layer on top and up to five partially saturated layers below. The individual receptor can spend time directly above the primary contamination (onsite) or in the vicinity of the primary contamination (offsite), or both.

Nine exposure pathways are considered in RESRAD-OFFSITE: direct external radiation, inhalation of particulates and radon, and ingestion of plant foods, meat, milk, aquatic foods, water, and soil. The conceptual model is presented in Figure 1.

Various exposure scenarios, including Rural Resident Farmer, Urban Resident, Worker, and Recreationist can be analyzed by selecting applicable pathways.

For example, the code enables a user to evaluate a scenario where an individual might spend some time in buildings that are located either onsite or offsite. That individual could consume plant- and animal-based foods that are grown onsite or derived from offsite agricultural fields that are contaminated by material from the primary contamination. The water the individual drinks and uses can be drawn from a well or a surface water body located onsite or offsite. For a surface water body, it can also be the source where the individual obtained aquatic food for consumption.

Figure 1. Graphic representation of RESRAD-OFFSITE conceptual model

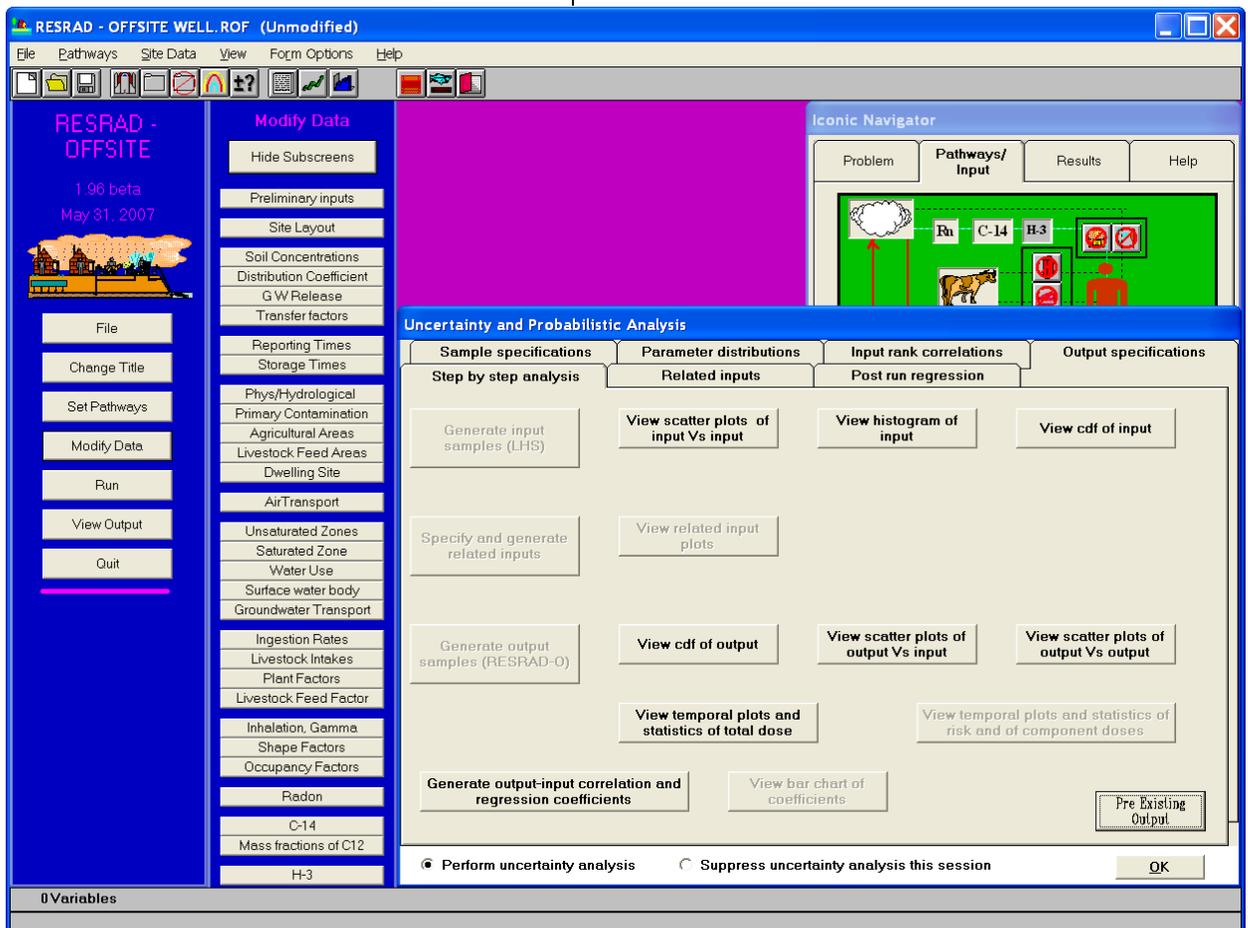


WHAT ARE THE MAIN FEATURES OF THE RESRAD-OFFSITE CODE?

- Contains user-friendly interface with context-specific help (see Figure 2).
- Includes all the exposure models in RESRAD (onsite). Extends these models to offsite locations to consider offsite exposure.
- Allows users to model different exposure scenarios by activating or suppressing pathways and by modifying usage and occupancy parameters.
- Performs sensitivity and probabilistic analysis (Figure 2) to study the influence of input parameters and generates graphic results for the analysis (Figures 3 and 4).
- Includes the FGR11 (Federal Guidance Report No.11), FGR12, and ICRP72 age specific dose factors, as well as FGR13 and HEAST2001 (Health Effects Assessment Summary Tables) morbidity or mortality slope factors in its database. Allows users to choose dose and risk factors or to set up their own dose/risk library.

- Uses numerical methods to compute media concentration, dose, and risk over time.
- Accepts input of temporal data of (1) radionuclide concentrations in the primary contaminated zone and the mixing layer, (2) radionuclide fluxes to the groundwater, to the surface runoff, and to the atmosphere, (3) the dimensions of the cover, mixing layer, and primary contamination, and (4) the eroded soil mass.
- Incorporates a map interface that allows the primary contamination and the offsite areas to be specified and displayed on a map of the region of interest.
- Generates text reports following each run, providing a listing of all input parameters, the environmental media concentrations, the maximum dose, and the minimum soil guidelines.
- Generates temporal plots of dose, risk, soil guideline, concentration, and dose/source ratio.
- Contains a new source term model that can be used to simulate radionuclides breaching and leaching from waste disposal sites.

Figure 2. RESRAD-OFFSITE data and probabilistic analysis input screen



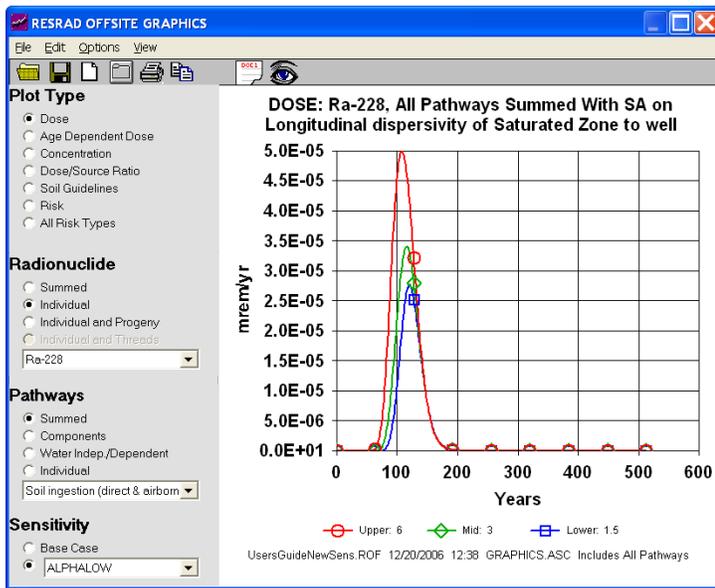


Figure 3. RESRAD-OFFSITE sensitivity analysis results

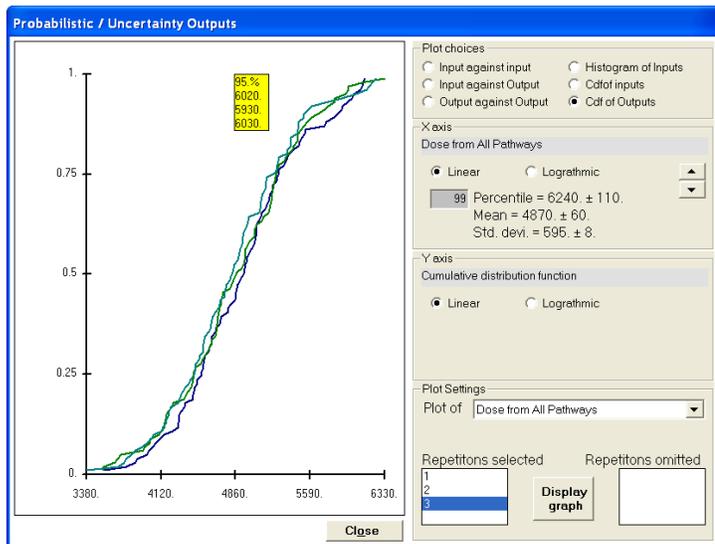


Figure 4. RESRAD-OFFSITE probabilistic analysis results

WHAT NEW MODELS AND MAJOR IMPROVEMENTS ARE IN RESRAD-OFFSITE?

- A new source term model to simulate release of radionuclides from different types of waste materials (in addition to contaminated soil).
- Air dispersion (Gaussian Plume) model to calculate concentrations at downwind locations.
- Groundwater transport model includes consideration of dispersion horizontally and

vertically to calculate concentration at a down gradient off-site location.

- Off-site accumulation of radionuclides in soil from irrigation and in surface water from runoff.
- Graphical map interface for specification of receptor and agricultural field locations.
- Choice of two dwelling locations (onsite, offsite).
- Choice of four agriculture fields at different locations.
- Well and surface water body can be located off the centerline of the groundwater plume.
- Improved user interface for both deterministic and probabilistic analysis.

WHAT TYPES OF RELEASES FROM PRIMARY CONTAMINATION ARE CONSIDERED?

The code considers three types of releases that lead to the contamination of the offsite locations (Figure 5). A dust release-equilibrium model is used for the atmospheric release. The material that is eroded by surface runoff is modeled as a release to the surface water body. The atmospheric and runoff releases are effective once the surface soil layer becomes contaminated. Leaching release caused by water flowing through the primary contamination can be simulated with one of the three release options (first order release, equilibrium desorption release, and uniform release) provided by the new source term model to consider release from different waste forms. Accumulation of radionuclides at the offsite locations are considered through deposition and irrigation.

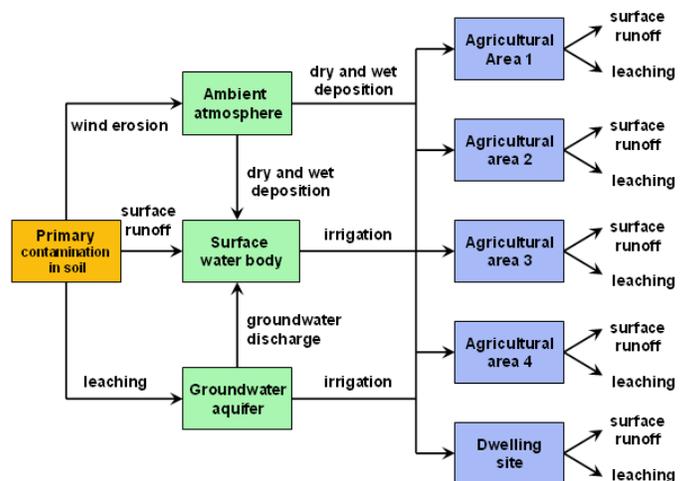


Figure 5. Environmental transport considered in RESRAD-OFFSITE

The new source term model has been benchmarked with DUST-MS and GoldSim (RT module). The leaching release rates agreed well among the three codes (Fig.6).

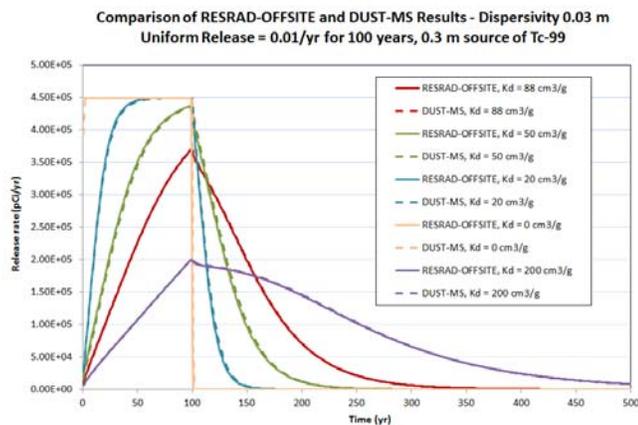


Figure 6. Benchmarking results between RESRAD-OFFSITE and DUST-MS

WHAT ARE THE MAIN FEATURES OF THE ATMOSPHERIC TRANSPORT MODEL?

- Gaussian plume model based on area source release was incorporated to calculate air concentrations at offsite locations.
- Plume-rise model was employed to estimate the buoyancy-induced rise.
- Standard Pasquill-Gifford dispersion coefficients or the Briggs dispersion coefficients are accepted.
- Dry and wet depositions of the plume content are considered for vapor or particulate radionuclides.
- Spatial integration over the area of consideration is performed via the use of spacing grids to obtain the average air concentration.

HOW IS GROUNDWATER TRANSPORT MODELED IN RESRAD-OFFSITE?

In addition to convection and dispersion in the liquid phase, the RESRAD-OFFSITE groundwater transport model also considers the decay of the parent radionuclide, the ingrowth of progeny radionuclide(s), and their respective retardation due to sorption and desorption in the solid phase. Numerical methods were employed to evaluate the analytical solutions to the differential equations that characterize the behavior of radionuclides transport in the unsaturated and saturated zones. To increase the precision of the calculation results, each unsaturated zone and saturated zone can be further divided to smaller sub-layers. The use of sub-layers will increase the precision of the results, but will likely increase the calculation time.

HOW CAN RESRAD-OFFSITE BE USED?

The RESRAD-OFFSITE code provides expanded state-of-the-art capabilities for conducting probabilistic calculations of radiological doses and risks and for applications beyond the typical soil contamination that RESRAD was initially designed for. RESRAD-OFFSITE was used in the preparation of the draft Environmental Impact Statement on disposal of Greater-than Class-C (GTCC) radioactive wastes. It can be used to support performance assessment of radioactive waste disposal facilities.

WHAT QUALITY ASSURANCE AND CONTROL, BENCHMARKING, VERIFICATION, AND VALIDATION IS APPLIED IN MAINTAINING THE CREDIBILITY OF RESRAD-OFFSITE?

RESRAD-OFFSITE was developed following the RESRAD program quality assurance and quality control procedures. RESRAD-OFFSITE and RESRAD (onsite) share the same database and many models and modules. RESRAD-OFFSITE was benchmarked against RESRAD (onsite) code for an on-site residential farmer scenario. Except for surface water concentrations, for which RESRAD-OFFSITE employs more sophisticated model to consider soil erosion, surface runoff and total mass balance, both codes generate consistent results.

The code has been used at the International Atomic Energy Agency's model validation studies such as Biospheric Model Validation Study II and Environmental Modeling for Radiation Safety II (EMRASII) programs. Currently the EMRASII Naturally Occurring Radioactive Material and Legacy Sites working group is using RESRAD-OFFSITE for model comparison study using several real site scenarios.

WHERE TO GET RESRAD-OFFSITE AND WHO CAN PROVIDE ADDITIONAL INFORMATION?

RESRAD-OFFSITE is available free of charge and can be downloaded from the RESRAD web site (<http://www.evs.anl.gov/resrad>). The RESRAD web site contains useful information including the latest version of RESRAD family of codes, training workshop schedules, frequently asked questions, and many supporting documents for download.

For more information, please contact



Charley Yu, PhD, CHP
Environmental Science Division
Argonne National Laboratory
RESRAD@anl.gov
www.evs.anl.gov/resrad