



# RESRAD-OFFSITE

## A Tool for Evaluating Radiation Doses and Risks to Humans



### 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. This Information Brief 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
- Contacts for information and assistance

### 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, and 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, with support from the U.S. Nuclear Regulatory Commission. It was developed by Argonne National Laboratory (Argonne). Code and version control are currently maintained by DOE through Argonne.

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

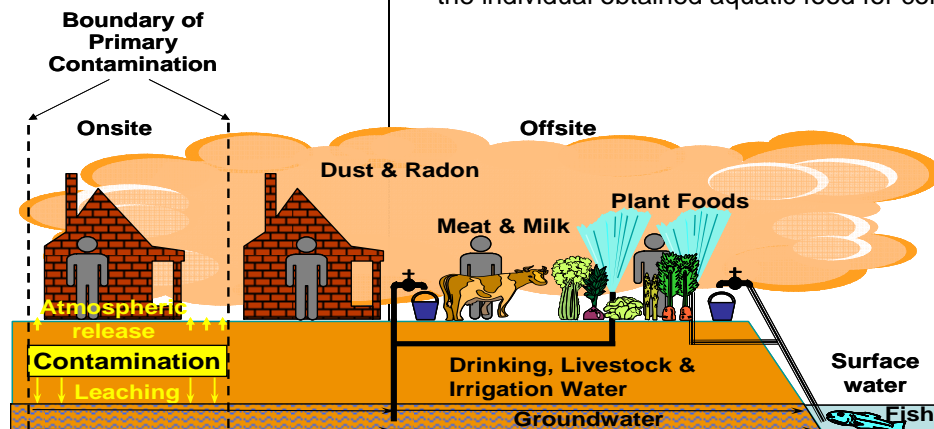
RESRAD-OFFSITE considers initial radiological contamination in soil in settings ranging from a clean cover layer on top of it to up to five partially saturated layers below it. The code has a capability to model the radiation exposure of an individual who spends time directly above the primary contamination (onsite) and in the vicinity of the primary contamination (offsite).

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

By selecting different pathways, RESRAD-OFFSITE can be used to simulate various exposure scenarios, including Rural Resident Farmer, Urban Resident, Worker, and Recreationist.

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

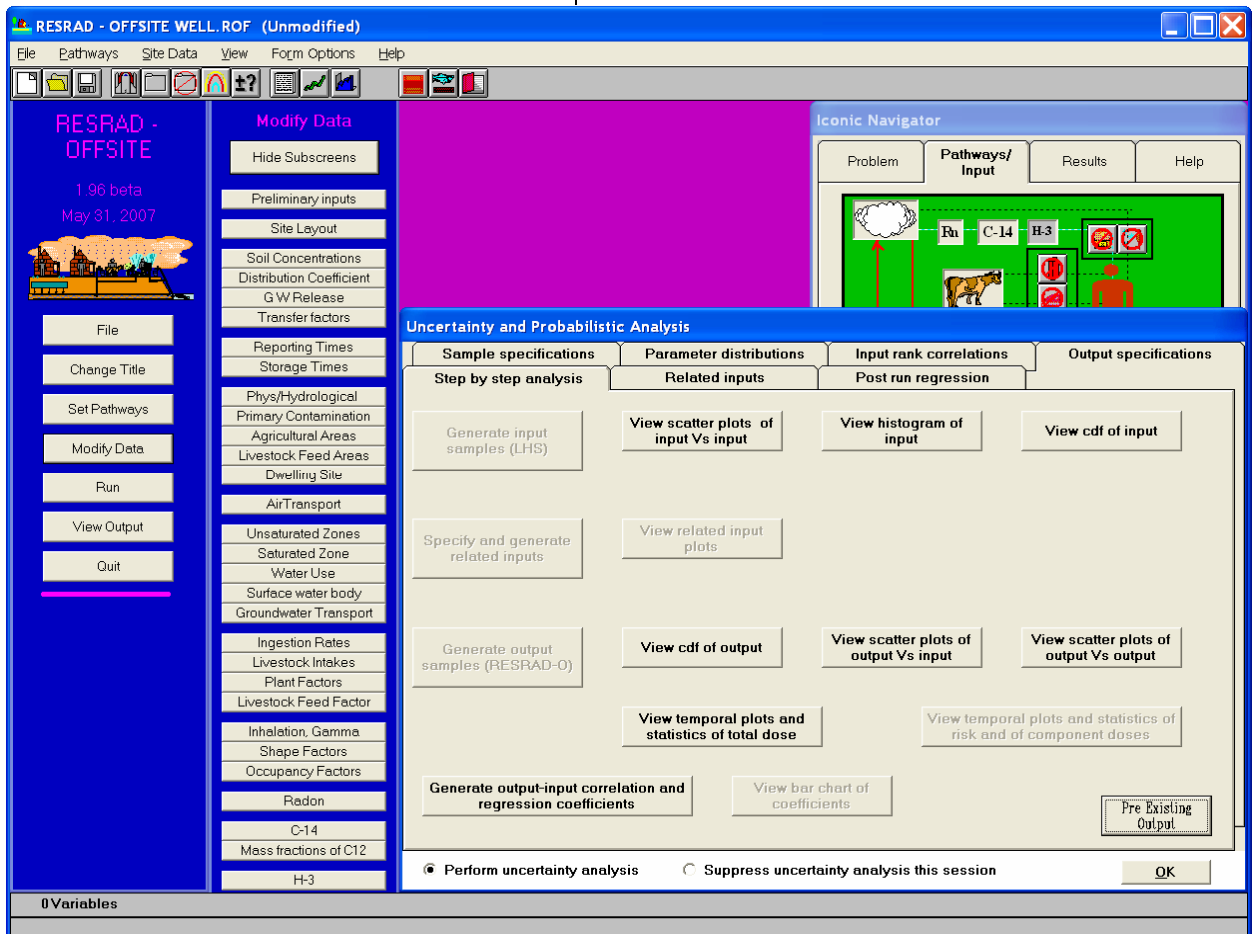


**WHAT ARE THE MAIN FEATURES OF THE RESRAD-OFFSITE CODE?**

- 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.
- Uses the ICRP38 (International Commission on Radiological Protection Publication 38) database of radionuclides.
- 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.

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



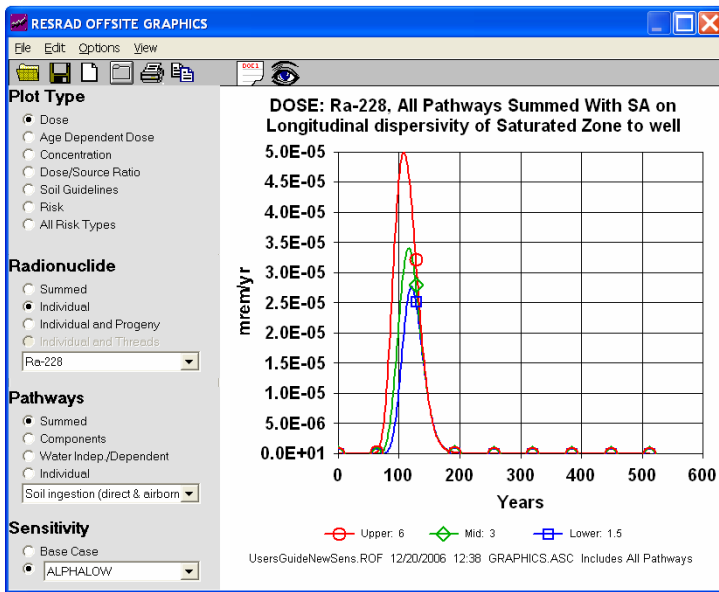


Figure 3. RESRAD-OFFSITE sensitivity analysis results

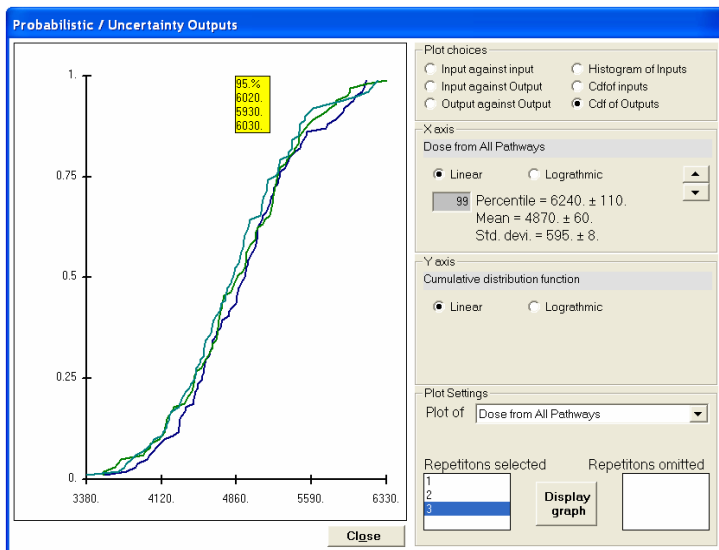


Figure 4. RESRAD-OFFSITE probabilistic analysis results

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

- 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 rate-controlled release is used to model the quantity of contaminants that are removed by water that flows down through the primary contamination (leaching). 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. Accumulation of radionuclides at the offsite locations are considered through deposition and irrigation.

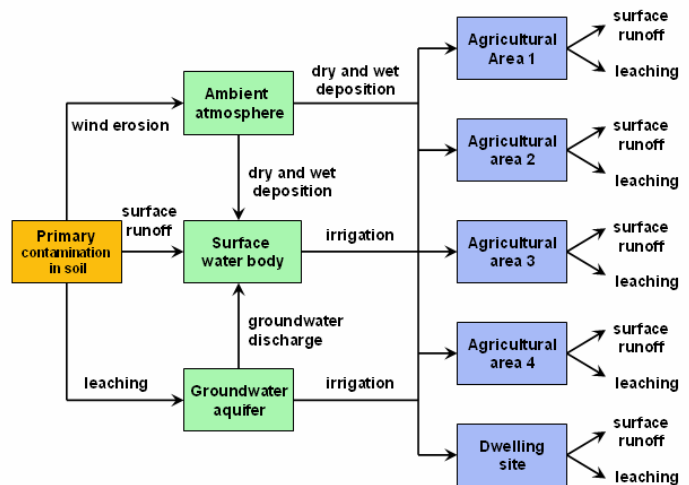


Figure 5. Environmental transport considered in RESRAD-OFFSITE

## 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 original RESRAD (onsite) code is the industry standard for calculating site cleanup criteria, and is widely applied within DOE, other Federal agencies, and the commercial nuclear industry. Use of the code in deriving site cleanup criteria has resulted in significant cost savings to the Department.

The RESRAD-OFFSITE code provides expanded state-of-the-art capabilities for conducting probabilistic calculations of radiological doses and risks and for deriving site cleanup criteria. RESRAD-OFFSITE is currently being used as an assessment tool for development of the Department's Greater-than Class-C (GTCC) Waste Environmental Impact Statement, and can potentially be used to support waste disposal performance assessments.

## 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 (EMRAS) programs. Currently the EMRAS Naturally Occurring Radioactive Material working group is using RESRAD-OFFSITE for model comparison study using area source scenarios.

## WHERE TO GET RESRAD-OFFSITE?

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.

## WHO CAN PROVIDE ADDITIONAL INFORMATION?

For additional information on training and assistance, please contact:

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