The RESRAD-BIOTA Code for Application in Biota Dose Evaluation: *Providing Screening and Organism-Specific Assessment Capabilities for Use Within an Environmental Protection Framework*

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Abstract

The RESRAD-BIOTA code was developed through a partnership among U.S. Department of Energy, the U.S. Environmental Protection Agency, and the U.S. Nuclear Regulatory Commission. RESRAD-BIOTA provides a full spectrum of analysis capabilities, from cost-effective conservative screening methods (using biota concentration guides) to realistic, organism-specific dose assessment. A beta version of the RESRAD-BIOTA code is currently available for use and testing. Continued coordination and partnerships with U.S. agencies and international organizations is providing opportunities for the inclusion of additional evaluation approaches and capabilities, such as (1) development of biota concentration guides for additional radionuclides, (2) additional flexibility for specifiying and expanding organism options, (3) improvements to parameter datasets of environmental transfer factors, (4) inclusion of additional "reference organism geometries" (e.g., dose conversion factors for ellipsoids of appropriate size and shielding properties for different sized organisms, appropriate for specific ecosystem types), and (5) the capability to perform sensitivity and uncertainty analyses for calculated dose estimates.

Introduction

The U.S. Department of Energy (DOE) has developed standardized screening and analysis methods [1], provided within a graded approach, for evaluating radiation doses to biota. These methods were made available through a DOE Technical Standard document and a series of electronic spreadsheets termed the RAD-BCG Calculator. The methodology provides limiting (dose/risk-acceptable) concentrations of radionuclides, termed biota concentration guides (BCGs), for use in screening water,

sediment, and soil media to determine whether user-specified dose limits for biota are exceeded. As the graded approach methodology received increasing interest from other U.S. agencies and from international organizations, it became apparent that a more robust and sophisticated software platform was needed to support the refinements and additional capabilities desired by this broader community of users. The RESRAD (RESidual RADioactivity) software platform was used to convert the RAD-BCG Calculator as the basis for a new PC code, "RESRAD-BIOTA". The code was developed through a partnership among DOE, the U.S. Environmental Protection Agency (EPA), and the U.S. Nuclear Regulatory Commission (NRC).

RESRAD Family of Codes

The RESRAD family of codes [2], developed at Argonne National Laboratory, is a suite of dose/risk assessment tools designed to evaluate radiological and chemical contamination in the environment. The RESRAD family of codes, shown in Figure 1, include (1) RESRAD, which evaluates doses and related risks to human health and the environment resulting from exposure to radiologically contaminated soils, (2) RESRAD-CHEM, which assesses chemical risk from soil contamination, (3) RESRAD-ECORISK, which estimates the risk from chemical contaminants to ecological receptors, (4) RESRAD-BUILD, which evaluates potential health impacts in buildings contaminated with radioactive materials, (5) RESRAD-RECYCLE, which estimates radiation doses to various receptors resulting from the recycle and/or reuse of radioactively contaminated materials and equipment, (6) RESRAD-BASELINE, which performs baseline risk assessments following EPA's human health risk assessment guidelines, (7) RESRAD-OFFSITE, which extends the RESRAD (onsite) model to evaluate dose/risk to receptors located at offsite locations, and (8) RESRAD-BIOTA, which uses a graded approach in assessing biota dose for radionuclides. All of the RESRAD codes are easy to install, have user-friendly interfaces, and provide on-line help messages. They can be used for different applications and are maintained and updated regularly; comprehensive documents are available to support their operation and application.

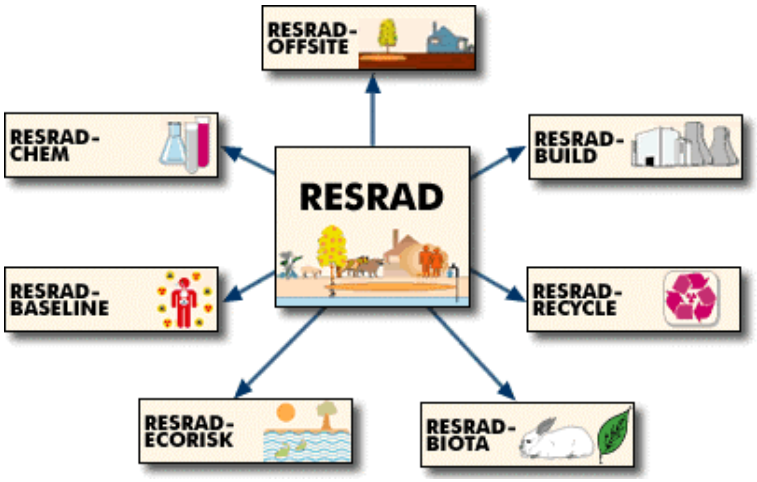

FIG. 1. RESRAD Family of Codes

Development of RESRAD-BIOTA

The development of RESRAD-BIOTA was initiated by DOE in June 2000. RESRAD-BIOTA is DOE's "next generation" dose/risk assessment tool for biota dose evaluation. The Microsoft Excel-

based RAD-BCG Calculator continues to meet DOE's needs but is approaching the limits of its software platform capabilities. The RESRAD platform was selected because it has a highly regarded record of quality assurance (QA) and validation studies and it is widely recognized and implemented within DOE, other U.S. Federal and State agencies, and the U.S. nuclear industry. It provides the software architecture and degree of sophistication needed for expanding upon DOE's biota methods and capabilities.

The RAD-BCG Calculator was successfully converted into a beta version of RESRAD-BIOTA in 2001. The beta version was reviewed by DOE's Biota Dose Asssessment Committee.
In May 2001, through an interagency partnership, EPA and NRC provided funding and staff commitment to work with DOE's Biota Dose Assessment Committee to further develop the RESRAD-BIOTA code. In December 2001, an improved version of RESRAD-BIOTA was developed. Some features of this version of RESRAD-BIOTA are described in the following section.

Features of RESRAD-BIOTA

RESRAD-BIOTA is freely distributed at http://www.ead.anl.gov/resrad. It is easy to install and user-friendly. The main window of the application is shown in Figure 2.

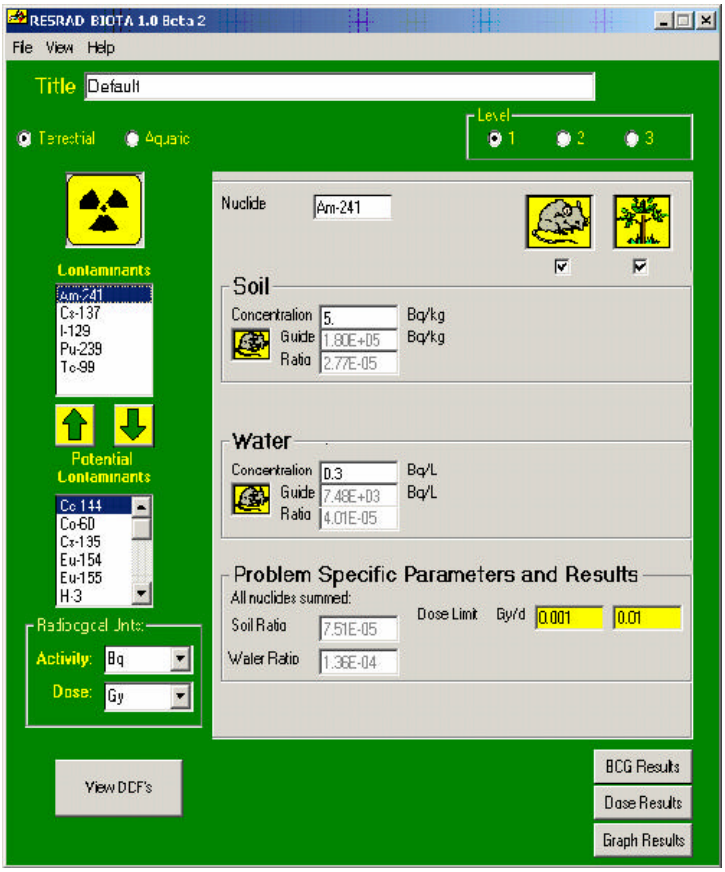

FIG. 2. RESRAD-BIOTA Main Window, Level 1

Three levels of assumptions are available, ranging from Level 1, for which conservative assumptions are made but few inputs are required, to Level 3, for which fewer assumptions are made but more

input data are required. Analysis can start at a lower level and proceed to higher levels if the assumptions in the lower levels are too conservative.

At all levels, the user can choose which type of ecological system, terrestrial or aquatic, to assess (Terrestrial or Aquatic button, top left, Fig. 2). The layout of an aquatic assessment is almost identical to that of a terrestrial assessment (shown in Figure 2). The only differences in the forms are the default organisms considered and the ability to specify a distribution coefficient if only one of the two media concentrations (soil or water) is known.

After a contaminant (radionuclide) is added to the Contaminants list box (left, Fig. 2), its characteristics are shown in the corresponding boxes. Once selected, the characteristics of the contaminant can be modified. The dose limits of each organism also can be modified. The values for all of the ratios and limits are updated immediately upon data entry.

The organism icons in the media frames reflect the organism(s) that are responsible for the limiting dose of the selected contaminant. For example, a raccoon icon indicates that this terrestrial animal is responsible for the limiting dose. A results window can be accessed by clicking on the BCG Results button. This results window lists the concentrations, BCG values, and ratios for each individual contaminant, as well as the summed ratios. The dose associated with each organism is accessed by clicking on the Dose Results button. Examples of the BCG Results and Dose Results windows are shown in Figure 3. The results can also be shown in graphics (bar charts). For example, Figure 4 is a bar chart of calculated doses.

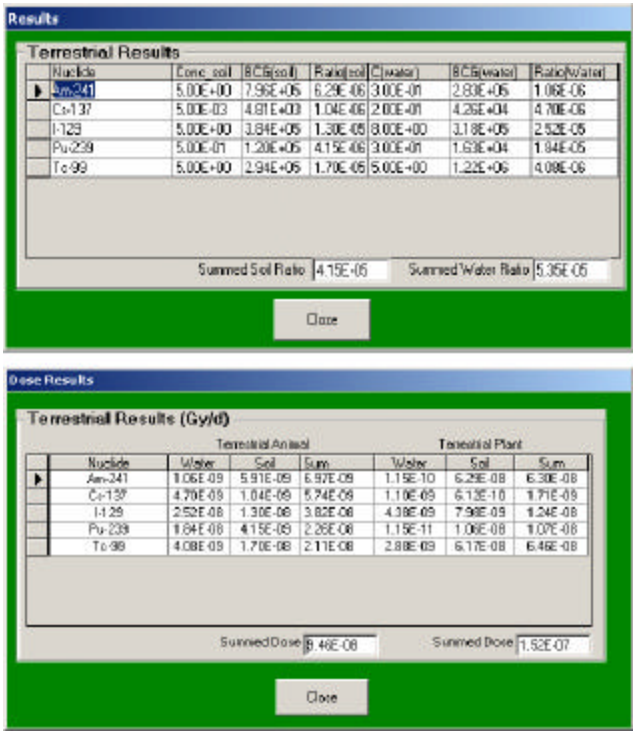

FIG. 3. Text Results

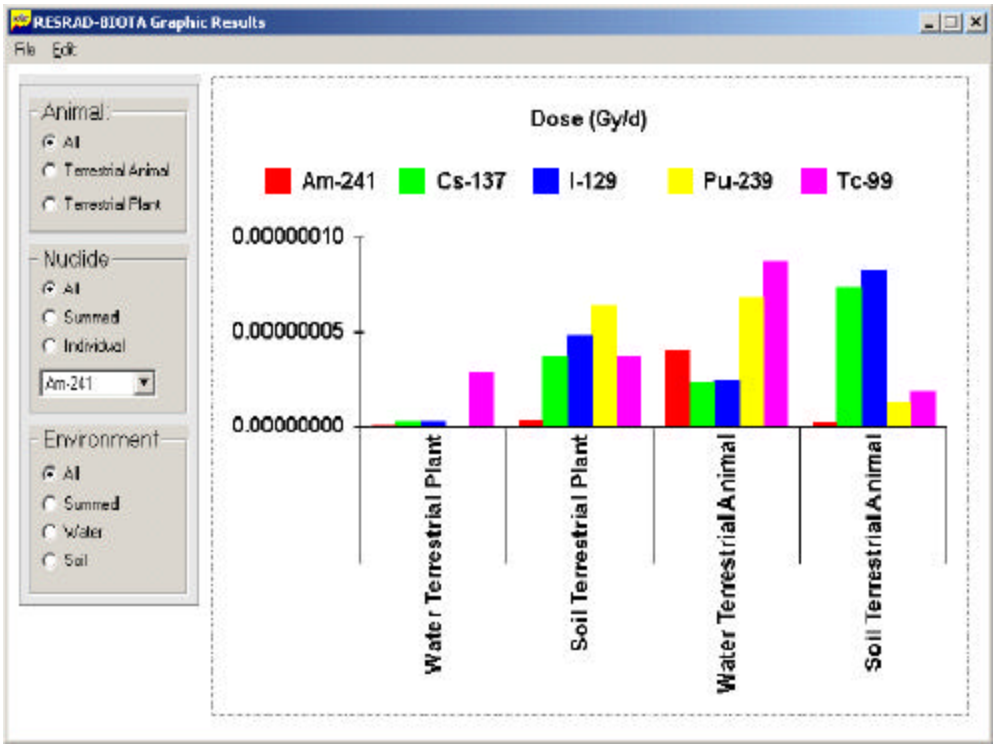

FIG. 4. Graphic Results

The layout of the Level 2 form is shown in Figure 5. In Level 2 more extensive data entry options are offered through the form than in Level 1. The additional data requirements for a Level 2 assessment include the following: a check box that allows inclusion of progeny radionuclides (if applicable) in the internal dose conversion factors, a radiation weighting factor for alpha radiation, a B-value for each contaminant and organism, specification of an area factor for each organism, and a dose conversion factor for each radionuclide selected.

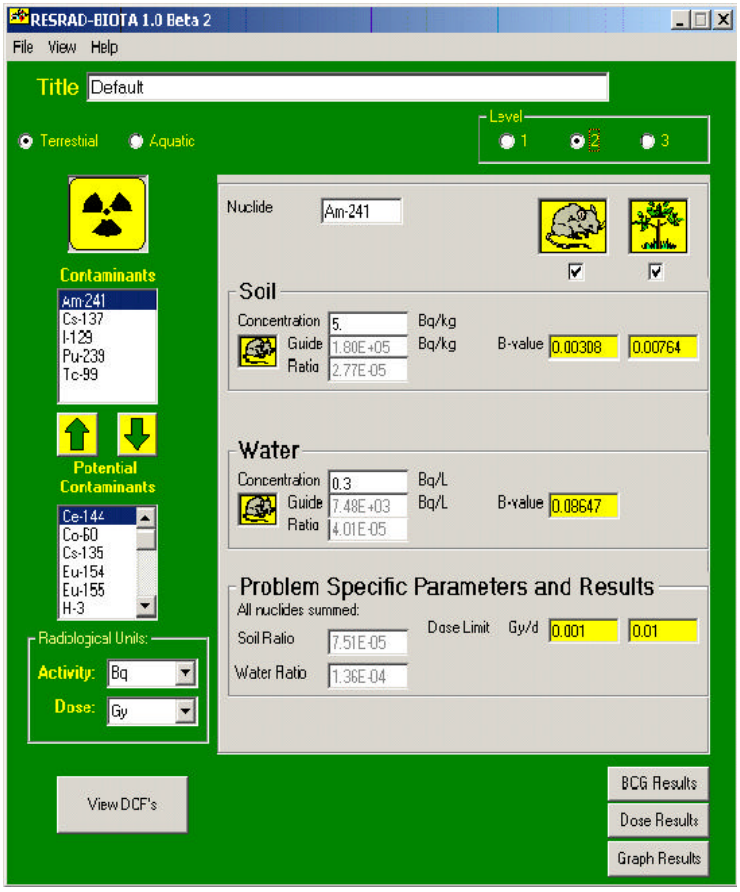

FIG. 5.Main Window, Level 2

Parameters used to calculate the dose conversion factors can also be modified by including data for the internal and external dose conversion factor. Figure 6 provides an example of the Dose Conversion Factor input window. The dose conversion factors will be calculated and displayed on the bottom of the window in the frame titled Calculated Dose Conversion Factors.

As in Level 1, the background color of the results exceeding the limits will turn red. The user can then move to the final level (Level 3) and perform an assessment at the greatest level of detail currently supported by RESRAD-BIOTA.

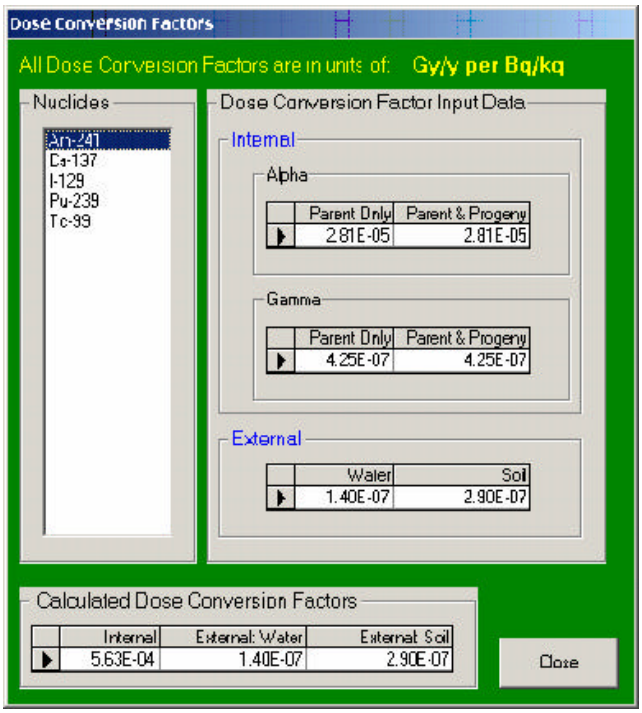

FIG. 6. Dose Conversion Factor Input Window

The layout of Level 3 is shown in Figure 7. The key feature of Level3 is the Allometric Parameters window (upper right in figure), which allows specification of parmeters specific to the riparian or terrestrial animal, including weight, ratio of active to basal metabolic rate, fraction of energy ingested that is assimilated and oxidized, caloric value of food, fraction of soil in diet, and airborne dust loading. Organism- and nuclide-specific parameters that can be manipulated are fraction of intake retained (f1), the constant (a) and exponent (b) of the biological decay constant, and an adjustment for inhalation relative to ingestion (PT/IT). After all of the data have been specified the summed ratios will be updated accordingly.

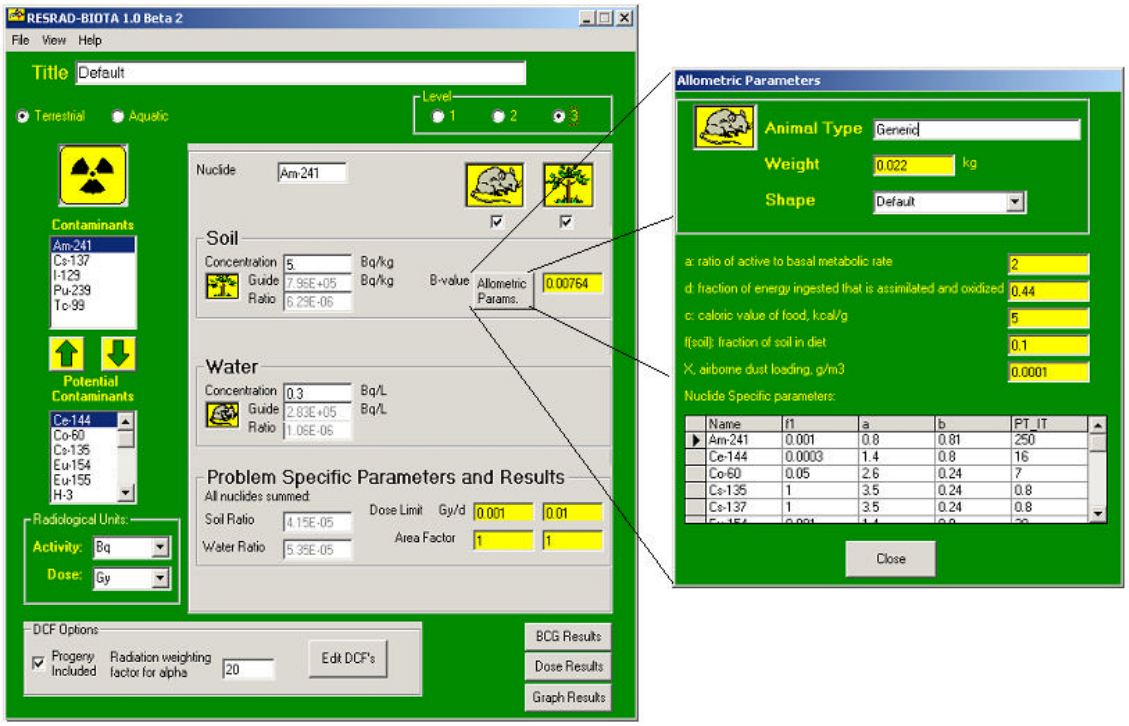

FIG. 7. Main Window, Level 3, with Allometric subform

Future Plans

Coordination and partnerships with U.S. agencies and international organizations will be continued. Such collaboration will provide opportunities for the inclusion of additional evaluation approaches and capabilities, such as (1) development of BCGs for additional radionuclides, (2) additional flexibility for specifiying and expanding organism options, (3) improvements to parameter datasets of environmental transfer factor, (4) inclusion of additional "reference organism geometries" (e.g., dose conversion factors for ellipsoids of appropriate size and shielding properties for different sized organisms, appropriate for specific ecosystem types), and (5) the capability to perform sensitivity and uncertainty analyses for calculated dose estimates. Planned enhancements also include an option that will allow users to transfer radionuclide environmental media concentrations generated from other modeling codes into RESRAD-BIOTA for subsequent biota dose evaluation.

Conclusion

The RESRAD-BIOTA code serves as a cost-effective and flexible tool for conducting biota dose evaluations that can be applied within an international framework for protection of the environment. It can support a variety of environmental assessment needs, including (1) demonstrating compliance of routine facility and site operations with available dose limits for biota, (2) conducting ecological assessments of radiological impact at contaminated sites, (3) estimating doses to biota in an Environmental Impact Statement when coupled with predictive dispersion codes that model a facility's

effluents prior to construction, and (4) predicting future doses to biota when coupled with pathway codes as part of assessing the decommissioning of facilities.

REFERENCES

[1] U.S. Department of Energy, A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota, DOE-STD-XXXX-00, Proposed DOE Standard, June 2000.

[2] Yu, C., RESRAD Family of Codes and Comparison with Other Codes for Decontamination and Restoration of Nuclear Facilities, In: Decommissioning and Restoration of Nuclear Facilities, Edited by M.J. Slobodien, Chapter 11, pp. 207-231. Health Physics Society 1999 Summer School Textbook (1999).