

TSD-DOSE: A RADIOLOGICAL DOSE ASSESSMENT MODEL FOR TREATMENT, STORAGE, AND DISPOSAL FACILITIES

M. Pfingston, J. Arnish, S.Y. Chen, and D. LePoire
Argonne National Laboratory
Argonne, Illinois

H. Himpler and G. Vazquez
U.S. Department of Energy
1000 Independence Avenue, S.W.
Washington, D.C.

ABSTRACT

In May 1991, the U.S. Department of Energy (DOE), Office of Waste Operations stopped shipment of waste not meeting the authorized release provisions from DOE facilities to commercial treatment, storage, and disposal (TSD) facilities. Studies were subsequently conducted to evaluate the radiological impacts associated with DOE's prior shipments through DOE's authorized release process under DOE Order 5400.5. Detailed radiological assessments were performed for eight commercial hazardous waste TSD facilities. Based on these detailed assessments (case-by-case), a radiological assessment computer code — TSD-DOSE (Version 1.1)—was developed and issued by DOE in 1997. It was designed to utilize waste-specific and site-specific data to estimate potential radiological doses to on-site workers and the off-site public from waste handling operations at a TSD facility. The code has since been released for use by DOE field offices and was recently used by DOE to evaluate the release of septic waste containing low levels of residual radioactive material to a TSD facility permitted under the Resource Conservation and Recovery Act.

Revisions to the code were initiated in 1997 to incorporate comments received from users and to increase TSD-DOSE's capability, accuracy, and flexibility. These updates included incorporation of the method used to estimate external radiation doses from DOE's RESRAD model and expansion of the source term to include 85 radionuclides. In addition, a detailed verification and benchmarking analysis was performed.

INTRODUCTION

In May 1991, U.S. Department of Energy (DOE) Headquarters learned that past practices at DOE field facilities may not have met its authorized release provisions. These hazardous wastes had been shipped to various commercial treatment, storage, and disposal (TSD) facilities not licensed to receive radioactive materials. As a result of these

shipments, DOE Headquarters stopped off-site shipment of hazardous wastes until procedures could be established to ensure that only hazardous waste would be shipped.

To determine the radiation exposures, if any for commercial hazardous waste workers and the off-site public resulting from previous contaminated shipments, detailed radiological dose assessments were performed for eight TSD facilities. Doses at these eight facilities were assessed on an annual basis rather than shipment by shipment basis. Worker doses ranged from 2×10^{-6} mrem to 7×10^{-2} mrem annually. Annual doses to the maximally exposed off-site individual were between 1×10^{-7} mrem and 1×10^{-3} mrem. Off-site population doses were between 4×10^{-7} person-rem and 3×10^{-1} person-rem. These doses are small compared with background doses and are well within regulatory limits. Typical individual background radiation doses from terrestrial and cosmic sources range from 50 mrem to 200 mrem annually (1). The dose assessments for these eight facilities indicated that it is highly unlikely that the previous shipments resulted in significant radiological health impacts to the workers or the public.

Because the detailed dose assessments indicated extremely small doses, the benefits of conducting additional dose assessments using this level of detail did not outweigh the resources required to perform them. In March 1997, a radiological assessment computer code—TSD-DOSE (Version 1.1) — was developed to utilize waste-specific and site-specific data to estimate potential radiological doses to these on-site workers and the off-site public from waste-handling operations at a TSD facility; this code was documented in Reference (2). The code was based on the detailed assessments of potential radiological exposures and doses at eight commercial hazardous waste TSD facilities. The code was developed to provide both DOE and commercial TSD facilities with a rapid and cost-effective method for assessing potential human radiological impacts from processing (at commercial facilities) chemical wastes contaminated with trace amounts of radionuclides. The model provides information that can be used by DOE, regulators, facility operators, and others in their decision-making process. The model has been described in References (3) through (6).

The code has since been released for use by DOE field offices and was recently used by DOE to evaluate the release of septic waste containing residual radioactive material to a TSD facility permitted under the Resource Conservation and Recovery Act.

In December 1997, DOE initiated revisions to the TSD-DOSE code (Version 2.0) to incorporate comments received from users and to add new features. Improvements were made to increase the capability, accuracy, and flexibility of TSD-DOSE. This paper gives an overview of TSD-DOSE and describes these enhancements. The applicability of the code and recent uses of the code by DOE field offices are also discussed.

TSD-DOSE: A BRIEF OVERVIEW

The TSD-DOSE model was developed in four basic stages: (a) identification of major operations and major receptors, (b) selection of isotopes and pathways, (c) development of dose calculations and (d) development of a graphical user interface. These stages are described below.

Identification of Major Operations and Receptors

Seven reference operations that might contribute to radiation exposures for TSD facility workers and the public were developed on the basis of information gathered from the eight previously analyzed TSD facilities. Each operation was subdivided into a series of steps. Key parameters and ranges of their values were chosen on the basis of observations made during site visits to the eight TSD facilities. Each reference operation is treated as an individual module. Facilities are modeled by combining the applicable reference operations or modules. Operations are carried out in the same sequence as those for waste processing, including the following:

- Transport of wastes from DOE generator sites and if necessary, transport of incineration residues off-site;
- Acceptance of waste at TSD facility—including unloading, sampling, check-in, and storage;
- Waste incineration, which involves incineration, transport of incineration residues on-site, and incinerator maintenance;
- On-site landfilling of incineration residues.

The TSD-DOSE model estimates doses to workers and the off-site public from treatment, storage, and disposal of waste contaminated with small quantities of radionuclides. The on-site TSD facility receptors include drivers, receiving workers, incinerator workers, landfill workers, and the collective worker population. Off-site receptors are analyzed for both individuals and populations living within 50 miles of the TSD facility.

Selection of Isotopes and Pathways

Eighty-five isotopes were selected for dose calculations in the model on the basis of previous TSD facility dose assessments; a survey of DOE waste streams; *Code of Federal Regulations*, Title 10, Part 61 (10 CFR 61); and similar dose calculation codes. To extend the model to a broader range of radionuclides and site conditions, simplified groundshine and ingestion pathways were added to the plume-based inhalation.

Development and Use of Dose Calculations

Mathematical models were developed to calculate doses to on-site workers and the off-site public for each reference operation. Through use of conservative parameter values

derived from the eight TSD facilities, bounding dose calculations were performed on the basis of unit activity. Methods were then developed, where necessary, to adjust the bounding doses to achieve more accurate values by using actual facility parameters. The calculations are discussed in detail in Reference (2).

Development and Use of a Graphical User Interface

TSD-DOSE is a PC-based program that runs on any IBM-compatible computer (80386 or higher). To make the model easy to understand and apply to future shipments, a Windows -based, point and click graphical user interface (GUI) was created. The approach has been summarized in References (2). Conservative default values are provided for most input parameters, although site-specific values can be used if data are available. The model contains detailed help screens to aid the user. The model is operated by (a) choosing one or more reference operations to describe waste processing at the facility of interest, and (b) defining the source term by choosing from the list of 85 radionuclides and entering the activity levels. The code output includes a list of all input parameters and detailed assessment results. The main screen of TSD-DOSE is shown in Figure 1.

The model is intended to be used in an iterative fashion. The first step is to enter the radionuclide activities and toggle the operations icons at the left side of the user interface to match the TSD facility being assessed. This step will give a bounding dose for the shipment. Site-specific values for the adjustable parameters can then be entered as necessary to refine the dose calculation and to make the calculated dose more accurate for the specific site. An example of an adjustable parameters screen for TSD-DOSE is shown in Figure 2.

MODIFICATION TO TSD-DOSE

Updates to TSD-DOSE Version 2.0 and above include (a) inclusion of the RESRAD external model, (b) inclusion of 85 radionuclides, (c) verification and benchmarking, and (d) other modifications.

Inclusion of RESRAD External Model

For analysis of the worker dose, the new version (2.22) of TSD-DOSE uses the latest U.S. Environmental Protection Agency (EPA) external dose conversion factors from Federal Guidance Report No. 12 (7) in combination with the Monte Carlo N-Particle (MCNP) transport code (8). The calculations include dose contributions from both gamma and beta radiation. TSD-DOSE uses these dose conversion factors for rotational exposure as reference points. The methodology described in Reference (9) for corrections due to the finite size was extended to included differences in source configuration. This external model in TSD-DOSE provides the unique feature of allowing users to choose geometry parameters on-line. This feature permits users to construct their tailored scenarios for volume-contaminated sources.

This model maintains consistency with the RESRAD computer code (10), which also incorporates the external gamma dose model based on FGR-12. RESRAD is the computer code used in implementing DOE's residual radioactive material guidelines.

Inclusion of 85 Radionuclides

One of the most substantial improvements to TSD-DOSE has been the expansion from 20 radionuclides to a total of 85 radionuclides. Decay product radionuclides that have half-lives of less than 30 days are also included to maintain consistency with RESRAD. Expanding the source term to 85 radionuclides also maintains consistency with PNL-9405 (11), for which an extensive study was conducted of the radionuclides present in waste streams of various DOE facilities.

Verification and Benchmarking of TSD-DOSE Model

TSD-DOSE has been validated against spreadsheet calculations to ensure that the worker doses are being computed correctly. The external model has been benchmarked against MCNP to ensure proper code execution for similarly shaped sources having similar material types. In addition, the off-site models have been benchmarked against the CAP88-PC computer code (12). Details of verification and benchmarking process and results are given in Reference (2). Results of this process have confirmed that the code is performing as expected and the results are consistent with the results obtained using MCNP (9).

Other Modifications

Radionuclide-specific release fractions have been added to TSD-DOSE Version 2.0 and above. The user may accept the default release fractions or may enter site-specific information (if available) into TSD-DOSE. Also, radionuclide food transfer factors have been updated for each new radionuclide added to TSD-DOSE. The food transfer factors are derived from vegetable/soil transfer factors and meat and milk transfer factors obtained from the RESRAD code and documented in Reference (13).

APPLICABILITY OF TSD-DOSE ASSESSMENT MODEL

The TSD-DOSE assessment model can be applied in situations that meet both of the following criteria:

- The TSD facility being evaluated processes waste in a manner that can be modeled by using the reference operations incorporated in the TSD-DOSE modules.
- The shipment being assessed contains one or more of the radionuclides included in TSD-DOSE (Version 2.0 and above).

The purpose of the model is to enable TSD facilities, site managers, and others to calculate possible radiological doses from processing DOE waste shipments and to assess the risks involved.

TSD-DOSE was used by DOE to evaluate the release of septic waste containing residual radioactive material to a TSD facility permitted under the Resource Conservation and Recovery Act (14). The operational activities modeled in the dose assessment included: transport of the septic waste to the TSD facility, receiving and sampling of the waste, interim storage, incineration of the waste, incinerator maintenance, transport to an off-site landfill, and disposal at an off-site landfill. Results of the dose assessment using TSD-DOSE indicated that no worker would receive a radiation dose of more than 0.02 mrem for the entire quantity of waste. A maximally exposed member of the public was estimated to receive a radiation dose of approximately 3.1×10^{-4} mrem from all incineration and landfill activities. These estimated doses are well below the U.S. Nuclear Regulatory Commission (NRC) and DOE's basic dose limit of 100 mrem per year for nonradiation workers.

CONCLUSIONS

TSD-DOSE was developed to provide DOE with a simple, easy-to-use tool for estimating radiological doses to workers and the surrounding public at a commercial treatment, storage, and disposal (TSD) facility for hazardous waste as a result of processing waste slightly contaminated with radionuclides. This model requires only a few key parameters and is generally applicable to a TSD site with similar waste treatment operations to those incorporated into the model modules. Improvements made in Version 2.0 and above increase the capability, accuracy, and flexibility of TSD-DOSE. Recent application of the code by DOE to evaluate the release of septic waste containing residual radioactive material indicated that doses to workers and members of the public are well below the NRC and DOE basic dose limit of 100 mrem per year for nonradiation workers.

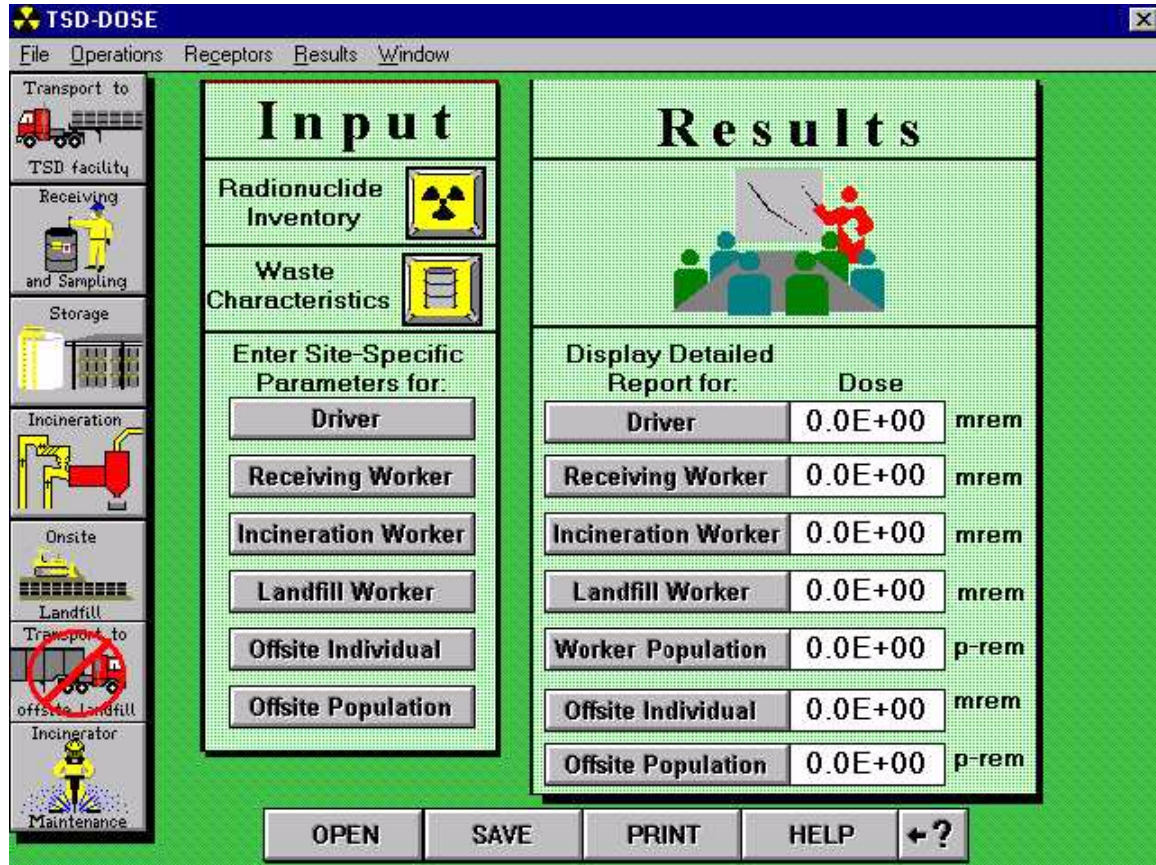


Figure 1. Main Screen of TSD-DOSE

Transport to TSD Facility

Waste Density **D** 0.7 g/cc # of crew **D** 1 **+ ?**

Cargo Dimensions

Length **D** 18.4 feet
Width **D** 7.3 feet
Height **D** 2.8 feet

**Step A
Load and Secure Shipment**

Time **D** 5 hours
Shielding **D** 0.0625 inches
Distance **D** 3 feet

**Step B
Drive**

Time **D** 28 hours
Shielding **D** 0.125 inches
Distance **D** 7 feet

**Step C
Rest**

Time **D** 16 hours
Shielding **D** 0.125 inches
Distance **D** 2 feet

**Step D
In Route Maintenance**

Time **D** 2 hours
Shielding **D** 0.0625 inches
Distance **D** 3 feet

Close

Figure 2. Adjustable Parameters Screen for Transport to TSD Facility

REFERENCES

1. National Council on Radiation Protection and Measurements, "Exposure of the Population in the United States and Canada from Natural Background Radiation," NCRP Report No. 94 (1987).
2. M. PFINGSTON et al., "TSD-DOSE: A Radiological Dose Assessment Model for Treatment, Storage, and Disposal Facilities," ANL/EAD/LD-4 (Rev. 1), Argonne National Laboratory (1998).
3. L.E. STEVENS et al., "Issues related to Estimating Potential Radiological Doses from Treatment, Storage, and Disposal Facilities Handling Waste Containing Trace Amounts of Radioactive Material," Environmental Restoration Conference, Denver, Colo. (1995).
4. L.E. STEVENS et al., "A Simplified Model to Estimate Radiological Doses from Incineration of Radioactive Waste," 14th International Symposium on Thermal Treatment Technologies: Incineration Conference, Bellevue, Wash. (1995).
5. S.Y. CHEN et al., "A Waste-Clearance Strategy for DOE Waste Processed at Commercial Facilities," 1996 Annual Meeting of the American Nuclear Society, Reno, Nev. (1996).
6. L.E. STEVENS et al., "Potential Waste Clearance Strategy for U.S. Department of Energy Waste Processed at Treatment Storage, and Disposal Facilities," WM '96 Conference, Tucson, Ariz. (1996).
7. K.F. ECKERMAN and J.C. RYMAN, "External Exposure to Radionuclides in Air, Water, and Soil, Exposure-to-Dose Coefficients for General Application, Based on the 1987 Federal Radiation Protection Guidance," EPA 402-R-93-081, Federal Guidance Report No. 12, Oak Ridge National Laboratory (1993).
8. J.F. BRIESMEISTER, "MCNP—A General Monte Carlo N-Particle Transport Code, Version 4A," LA-12625, Los Alamos National Laboratory (1993).
9. S. KAMBOJ et al., "External Exposure Model Used in the RESRAD Code for Various Geometries of Contaminated Soil," ANL/EAD/TM-84, Argonne National Laboratory (1998).
10. C. YU et al., "Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD, Version 5.0," ANL/EAD/LD-2, Argonne National Laboratory (1993).

REFERENCES (cont.)

11. R.L. AABERG et al., "Radiation Dose Assessment Methodology and Preliminary Dose Estimates to Support U.S. Department of Energy Radiation Control Criteria for Regulated Treatment and Disposal of Hazardous Wastes and Materials," PNL-9405/UC-610, Pacific Northwest Laboratories (1995).
12. U.S. ENVIRONMENTAL PROTECTION AGENCY, "User's Guide for CAP88-PC, Version 1.0," EPA-402-B-92-001, Office of Radiation Programs, Las Vegas, Nev. (1992).
13. Y.-Y. WANG et al., "A Compilation of Radionuclide Transfer Factors for the Plant, Meat, Milk and Aquatic Food Pathways and the Suggested Default Values for the RESRAD Code," ANL/EAIS/TM-103, Argonne National Laboratory (1993).
14. J.J. ARNISH, unpublished information, Argonne National Laboratory (1997).