RADTRAN 5 - A Computer Code for Transportation Risk Analysis*

K. S. Neuhauser[1] and F. L. Kanipe[2]

[1]Sandia National Laboratories**, Albuquerque, New Mexico, United States of America
[2]GRAM, Inc., Albuquerque, New Mexico, United States of America

Introduction

RADTRAN 5 is a computer code developed at Sandia National Laboratories (SNL) in Albuquerque, NM, to estimate radiological and nonradiological risks of radioactive materials transportation. RADTRAN 5 is written in ANSI Standard FORTRAN 77 and contains significant advances in the methodology for route-specific analysis first developed by SNL for RADTRAN 4 (Neuhauser and Kanipe, 1992). In RADTRAN I through III, a route had to be divided into three population-density zones per run (usually labelled rural, suburban, and urban), and multiple runs of the code were required to examine any breakdown of a route into more than three such zones (Taylor and Daniel, 1977; Madsen et al., 1983; Madsen et al., 1986). This methodology was retained as a user option in RADTRAN 4 for the sake of continuity; it has been removed from RADTRAN 5. The new methodology is discussed in this paper. The code also includes several improved and/or updated numerical models. RADTRAN 5 will be released after benchmarking and other quality assurance tests are complete.

Like the previous RADTRAN codes, RADTRAN 5 contains two major modules for incident-free and accident risk analysis, respectively. All commercially important transportation modes may be analyzed with RADTRAN 5: highway by combination truck; highway by light-duty vehicle; rail; barge; ocean-going ship; cargo air; and passenger air.

Incident-Free Module

The incident-free module contains a series of numerical models that describe relevant infrastructure features of each transportation mode and roadway type (the latter for highway modes only) such as minimum distance to "offlink" population (i.e., population adjacent to transportation link). The models are simplified as much as possible, partly by neglecting features that, if considered, would reduce the consequence and risk estimates. For example, the buffer zone that generally is present between lanes in each direction on interstate highways in the United States is omitted because including it would reduce the estimated incident-free risk.

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The numerical models for the various types of stops (e.g., truck stop, inspection stop) have been modified. Stop parameters are now included in the array of user-defined route-specific parameters in the LINK subroutine, which is described below.

Accident Module

RADTRAN 5 permits the user great flexibility in accident risk analysis. Parameter values that were formerly fixed within the code may now be user-defined (Table 1). For example, the time of groundshine exposure prior to emergency response action was formerly fixed at the very conservative value of 24 hours. In recognition of the fact that public evacuations can often be accomplished in far shorter time periods, this parameter is now user-definable. All parameters in the optional economic model are initialized at zero, and most default values have been removed. RADTRAN 5 users are provided, instead, with a number of sample input data sets for various types of shipments. These data sets may be edited by the user to tailor them to the user's problem, and, of course, the user may still construct entirely new data sets.

Table 1
RADTRAN 5 Parameters with Formerly Fixed Values

Parameters	Value(s)
Number of handlers	2 (intermediate packages) 5 (large packages)
Handling time	15 min (intermediate packages) 30 min (large packages)
Handler distance	1 m (all packages)
Minimum groundshine exposure time	24 hr
Interdiction level	40X clean-up action level
All economic parameters	various; now initialized at zero

The health-effect and dispersion models, which are used in the accident risk calculations, have been modified. The changes in these models are discussed under their separate headings below. In addition, a new numerical model that calculates dispersion-related doses to individuals located at specified downwind distances has been added to RADTRAN 5.

Health-Effects Model

Several health-effects models have been published since the 1986 Hiroshima-Nagasaki dosimetry reassessment (e.g., ICRP 60, 1990; BEIR V, 1990; UNSCEAR 1988; and NRC 1989). While similar, they are not identical, and various governmental entities in the United States and around the world have expressed preferences for one or the other. This has resulted in a need for new flexibility in the health-effects calculations in RADTRAN 5. Therefore, conversion factors in RADTRAN now can be modified by the user to conform with any of the cited health-effects models.

Dispersion Model

RADTRAN 5, like its predecessors, contains no internal dispersion model. Dispersion is highly dependent on physical-chemical properties of the material being shipped and can vary from flow scenarios (liquids and heavier-than-air gases) to explosive dispersal. Therefore, RADTRAN 5 allows the user to enter input data obtained from any of a large number of suitable dispersion codes. The data must be entered in the form of tables of downwind isodose areas (isopleths) and associated time-integrated concentrations. For the user's convenience, default data from a Gaussian puff dispersion model (for a ground-level, small diameter, instantaneous release) calculated either with average U.S. meteorological factors or with Pasquill atmospheric stability categories A through F are provided. To use the latter, one must enter a frequency value for each category. Puff models are usually used in transportation accident applications, and dispersion codes that model continuous releases are almost always unsuitable.

A second, closely related code modification concerns aerosol deposition velocities. In RADTRAN 4, deposition velocity was a variable on the isotope level, but since aerosol particulates are generally made up of mixtures of isotopes reflective of the makeup of the original material, the location of this parameter in the logic flow was inappropriate. In RADTRAN 5, deposition velocity has been placed among parameters defined at the physical-chemical group level.

The tables of meteorological input data also have been modified to permit optional entry of a third column of values for maximum downwind distance in each isopleth. If these optional values are entered, they are included in the output in the tables of downwind dose data, which permits the user to correlate dispersion-related doses with distance from release point. The expected dose to an individual in each isodose area also is calculated and printed. If no values for this parameter are entered, then a "no entry" message appears in the output. In the past, these individual doses could only be estimated by performing a calculation external to the code, and the calculation simply has been incorporated into RADTRAN for the convenience of the user. These values are of interest to persons who must demonstrate compliance with International Commission on Radiation Protection recommendations and/or U.S. Environmental Protection Agency regulations that address individual as well as population doses.

Route-Specific Analysis and the LINK Subroutine

Route-related parameters are entered separately for each user-defined route segment in the LINK subroutine. In LINK, a route segment can be created that represents either (a) an actual segment of a route or (b) an aggregate of route segments that have the same characteristics. The latter application renders the three-zone method used in RADTRAN I through III redundant. Coding for the three-zone method has been removed from RADTRAN 5. However, the user must still indicate segment type (i.e., whether a segment is rural, suburban, or urban in character). This designation controls selection of building shielding factor and calculation of ingestion pathway dose (rural areas).

The segment-specific variables have been expanded over those in RADTRAN 4 to include designators for land under cultivation (rural segments) and for selection of dispersion conditions (can select from several user-defined dispersion data tables). The user-defined parameters for each route segment are given in Table 2.

Because conveyance stops may vary considerably in character, RADTRAN 5 allows the user to define stops along a route by use of what are termed "stop links" in the LINK subroutine. To accomplish this, the LINK subroutine was modified to allow the user to enter stop-specific variables formerly entered in the NORMAL array in RADTRAN 4. When the user enters a "zero" for segment-length parameter, that segment is then modelled by RADTRAN 5 as a stop. Parameters for that segment that do not relate to stops are either set to fixed values or replaced by distinct parameters. The parameters for a stop in the LINK subroutine are shown in Table 2.

Table 2
Comparison of LINK Parameters for Route Segments and Stops

Route Segment	Stop Link
mode	mode
distance (km)	[set to zero]
vehicle speed (km/hr)	stop time [hr]
offlink population density (person/km^2)	surrounding population density (person/km^2)
vehicle density on-link (vehicles/hr)	population at stop
accident rate (acc/km)	[set to zero]
segment type	stop type
road type	near-field (number of persons)
fraction of land in agricultural use	near-field (time; hr)
dispersion conditions	near-field (distance; m)

In RADTRAN 5, persons at stops are modelled as three separate populations occupying annular areas around the shipment (Figure 1). This approach was used to model rail stops and loss-of-shielding accidents in RADTRAN 4 and now models stops in all modes in RADTRAN 5. The population density of the area surrounding the stop is analogous to the offlink population for a travelling shipment and replaces the latter parameter in a stop link.

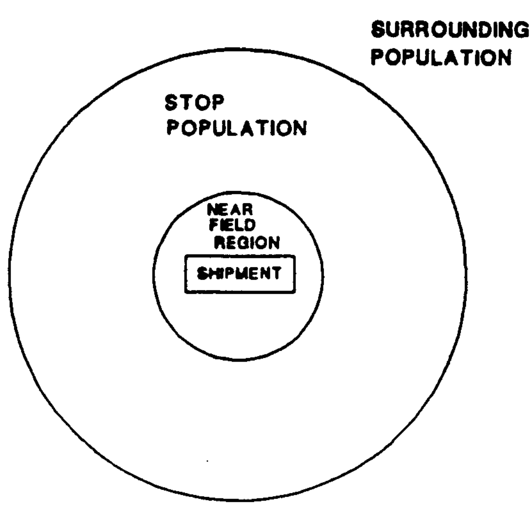

Figure 1. Populations modelled at stops.

The population in the immediate vicinity of a stop is often different from the surrounding population density and may be separately specified by the next parameter, for which the user enters an expected number (not density) of persons within an annular area surrounding the stopped shipment. The annular area extends from a minimum radial distance equal to twice the characteristic package (or shipment) dimension out to a maximum distance of at least 50 m, depending on mode. Persons who are closer are modelled as being in the "near-field," where a line-source model is used to estimate doses. The last three stop parameters are concerned with near-field exposures.

Separate accident rates for stops are not used in RADTRAN 5. Most sources of accident statistics already include accidents that involve stopped conveyances or anchored ships, accidents that occur at roadside locations, etc., and do not identify such accidents separately. These accident subsets may not be easily extracted from the overall statistics.

The stop-type designator allows the user to indicate the nature of the stop—fuel or rest stop, intermodal transfer, inspection stop, etc. In each of these types of stops, persons may come into the near-field range. As noted above, that range is defined as all radial distances equal to or less than twice the effective package dimension. These persons may be facility attendants, handlers, inspectors, etc. For each such stop, the user must enter a set of three variables describing the number of persons, the time they are in the near-field (which may be distinct from the total stop time), and their average distance from the package. In earlier versions of RADTRAN, these values were fixed for a number of scenarios, and the user could not change them.

Output Format

As a result of valuable comments from RADTRAN 4 users, the RADTRAN 5 output has been modified to inform the user when certain calculations have been performed. For example, if the predicted level of ground contamination in a dispersion isopleth exceeds the level at which the area would be interdicted rather than cleaned up (a user-defined parameter), then a message will appear in the output telling the user what downwind isopleths would be interdicted. Another type of message informs the user when an output value is zero because one or more input parameters were initialized at zero. This allows users to distinguish between actual zero-value results and those that appear to be zero-value only because real values were not entered in one or more input fields which contain initial values of zero.

Results are now reported in SI units (person-sieverts and becquerels) as well as in person-rems and curies.

Nonradiological Risks

Nonradiological risk factors have been incorporated to allow users to estimate nonradiological fatalities and injuries that might occur during the transportation event(s) being analyzed. These fatalities include prompt accidental fatalities from mechanical causes. Values of these risk factors for the United States (Neuhauser et al., 1984) have been made available in the code as optional defaults.

Uncertainty Analysis

Work is underway at SNL to develop a special auxiliary code that allows uncertainty analyses to be readily performed with RADTRAN. A functional prototype that uses Latin Hypercube Sampling (LHS) methods (Wheeler et al., unpublished results) has been developed for use with RADTRAN 4, and it is anticipated that this code will be adapted for general use with RADTRAN 5 in the next two years.

Summary

The RADTRAN 5 computer code combines great flexibility with improvements in route-specific analysis capabilities and user friendly output formats. The code and the LHS auxiliary code will be publicly available in 1993.

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