INTERTRAN 2: A Computer Code for Transportation Risk Assessment

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INTRODUCTION

This paper presents the work of the IAEA's Coordinated Research Programme (CRP) on the Probabilistic Safety Techniques Related to the Safe Transport of Radioactive Materials.

The paper gives information about the different parts included in the INTERTRAN 2 package for risk assessment on transportation of radioactive material and gives a summary of the main document "The Advisory Material" that will be delivered together with the INTERTRAN2 package. The package is a result of the work within the above mentioned IAEA Coordinated Research Programme.

The following countries have been participating in the work;

Canada, Egypt, Finland, France, Germany, India, Japan, Peoples Republic of China, Sweden, the United Kingdom, and the United States

A pre-meeting to this CRP took place in Stockholm 1987, hosted by the Swedish Nuclear Power Inspectorate. At this meeting the experiences with the earlier developed computer program INTERTRAN were discussed. The INTERTRAN computer code have been available since 1983 and it was felt that all experiences gained from using the code should be taken into account and that the time for updating the code was appropriate. The meeting in Stockholm in 1987 led to the upstart of this CRP.

This Coordinating Research Programme started in 1989 with a first meeting hosted by the Sandia National Laboratories in Albuquerque, New Mexico, USA. After that meetings have been held in Vienna 1990 hosted by the IAEA, in Paris 1991 hosted by Institut de Protection et de Sureté Nucléaire (IPSN), in Cologne 1993 hosted by the Gesellschaft fur Reaktorsicherheit GmbH, and 1994 in Canada hosted by the Ontario Hydro.

The main tasks for this CRP have been to improve the INTERTRAN package in accordance with the experienced gained from using the previous version. The new package is called the INTERTRAN 2. The INTERTRAN 2 model, however does not contain anything from the older INTERTRAN but are completely built around independent parts that have been modified and linked together for this purpose.

The INTERTRAN 2 package contains a base for risk assessment, the RADTRAN 4 computer code modified for international purposes and PC use. The RADTRAN 4 computer code has been made available and modified in accordance with the recommendations of the CRP by the Sandia National Laboratories, Albuquerque, NM, USA. The INTERTRAN 2 package also contains an atmospheric dispersion model made available and modified for this purpose by Institut de Protection et Sureté Nucléaire (IPSN), France. The pre-processor developed by the AMC konsult AB, Sweden, under contract with the Swedish Nuclear Power Inspectorate was included after request from member states to get a tool which could facilitate for less experienced users to create their input data files for the program.

In addition, two independent programs have been submitted by the Sandia National Laboratories, one dealing with calculation of individual doses (TICLD) and one dealing with sensitivity analysis (LHS).

The risk assessment computer codes RADTRAN 4 and the TICLD are also installed on the TRANSNET network at Sandia National Laboratories in the United States. The installation on TRANSNET is using a different preprocessor than the PC version Other codes, including TRANSAT; several domestic databases; and a number of sample RADTRAN files are also available on this network. TRANSNET is accessible via the INTERNET.

During the work within the CRP all participants have been testing the different parts of the program and given valuable input for the modifications that have been made. The final package is therefore a product jointly produced by all participants of the CRP.

The INTERTRAN 2 package contains the following computer programs and documents;

Computer Programs:

The Pre-Processor
The RADTRAN4 computer code (PC version)
The TRANSAT atmospheric dispersion model
Code for calculating individual doses
Code for Sensitivity Analysis (on request)

Documentation:

- Advisory Material
- Technical documentation, Programmer´s Manual and User´s Guide for each of the programmes.
- QA documentation for the models

The INTERTRAN2 package is delivered on two 3 1/2" diskettes. The first diskette contains all codes and batch files needed to run the code from DOS, (RADTRAN4 requires that Windows is installed on the machine). The second diskette contains the files necessary for running all applications from Windows.

It is possible to run all programs from the DOS prompt, but the Radtran4 program requires that Windows is installed on the machine.

The documentation of the INTERTRAN2 Package has been written by different authors from participating countries. The documentation for each of the included programs have been written by the organization submitting the programs. The Advisory document is a jointly written document.

The INTERTRAN 2 package is a computer code system for the assessment of radiological consequences and risks for the transport of radioactive material. It allows study of incident-free and accident conditions of transport separately. It is applicable to all modes of transport, in particular to multimodal shipments, and it can deal with nuclear material and industrial material as well as radiopharmaceuticals.

Under normal conditions of transport (incident-free case) the expected dose to workers and to different members of the public along the transport route can be calculated as a collective dose also taking into account handling operations. This incident-free case exposure of persons results from the external radiation originating from the radioactive material within the package during shipment. In addition to the collective dose of different subgroups, the code also computes a hypothetical maximum dose to an individual member of the public who lives beside a highway or a railroad track. Under accident conditions the INTERTRAN 2 package can be used to estimate the resulting external and internal individual and population doses as the consequence of an accident to be analyzed and the corresponding risk.

The INTERTRAN 2 package provides a tool for

- specific shipment studies,
- national assessments,
- comparison of shipment options, and
- supporting decisionmaking processes and optimization of transport concepts and technologies from the viewpoint of radioactive protection safety.

The computer code system allows the user to adjust the analysis to the specific problem being analyzed, but the resolution of an analysis may be limited by the quality of available data. Taking this into account, the scope of the INTERTRAN 2 package and the accuracy of the results are mainly limited by the availability and quality of the data which are necessary to represent the specific transport situation to be analyzed.

RADTRAN 4

RADTRAN 4 is not intended for the performance of site-specific consequence or risk analyses. In a site-specific analysis, the consequences and risk associated with events or operations at specific locations are estimated. Many of the analytical methodologies in RADTRAN 4 differ mathematically from those used with fixed locations because RADTRAN 4 is used to analyze the effects of radioactive transport involving a source moving through a constantly variating landscape and potentially stopped at virtually any location along a route in the same landscape. To address this difficulty, populations along route segments are modeled as being uniformly distributed. Different population densities may be assigned to different route segments, but the distribution is always treated as uniform.

At fixed locations, wind-direction data (wind rise) from weather stations in the same area are often used in risk analyses. Wind-rose data are not used in the dispersal accident analysis in RADTRAN 4. Wind-rose data are used to distinguish between differences in potential population exposures according to wind direction, but with a uniformly distributed population model, all wind directions would give the same results. Further, weatherstations are absent on most links of any transportation route, and detailed meteorological data are not available for those links. The RADTRAN 4 calculational strategy for dispersal intentionally precludes the need for such unobtainable data. The possibility exists of extrapolating from weather data at a few locations and applying these data to the surrounding region (so called "mesoscale" weather), but meteorologists have not yet developed reliable methods of doing this. Much broader national-average data have been used for analyses of cross-country transportation, however. If particular locations along potential routes are of special interest, then detailed site-specific consequence analyses may be performed to complement a RADTRAN 4 risk analysis. Further, in many codes used for stationary facilities that have been in operation for years, chronic releases are modeled. Releases of this type cannot be analyzed with RADTRAN 4.

Chemical hazards analyses necessary in assessing the consequences and risks of shipping hazardous substances such as uranium hexafluoride are also not performed by RADTRAN 4. In addition, RADTRAN 4 does not address radiological consequences to emergency response personnel.

Another limitation of RADTRAN 4 is that the internal health effects model is out of date and should not be used. Results should be obtained as dose-risks; and current conversion factors from CRP-60 or other source should be applied to the dose-risk values to yield health-effects risks.

Users cannot apply separate sets of meteorological data to individual route segments in the LINK option. Segment-level data are seldom available in the United States, and conservative values are routinely used anyway because the latter approach is preferred for the most common type of RADTRAN 4 applications in the United States, the preparation of environmental impact statements (EIS's) and environmental assessments (EA's) under U.S. Federal law (National Environmental Policy Act). However, this may be a limitation to persons with detailed meteorological data who wish to use them in a RADTRAN analysis. The only method to employ such data is to perform a separate run of the code for every segment(s) with distinct meteorological characteristics.

Groundscatter is not directly accounted for in the code, but the curve-fitting coefficients for gamma and neutron radiation may be altered to account for scatter if the user has data to support the change. Since the nature of the ground surface (albedo, roughness, etc.) may vary widely as a conveyance traverses a route, it is virtually impossible to accurately account for this effect within a numerical model. It is probably best accounted for by means of uncertainty analysis. In addition, the inherent conservatism of the basic point- and line-source models generally encompasses the scatter contributions. Therefore, the user should benchmark against actual measurements, if possible, before changing the default coefficients.

TRANSAT

The TRANSAT atmospheric dispersion code is founded on the widely used Gaussian model with standard deviations expressed according to the PASQUILL categorization scheme of weather conditions. Moreover, the time-integration of the downwind concentrations relies on the analytical bi-Gaussian approximation.

The basic hypotheses associated to this Gaussian model implementation are:

- point source release,
- open downwind surface (no obstacles),
- no gravitational effects, and
- constant meteorological conditions.

It should be noted that gravitational effects are essentially important in the case of cryogenic gas transportation and thus of limited interest in the specific case of radioactive material transportation.

The point source hypothesis is also of minor importance in the case of transportation releases where involved quantities are generally much lower than in releases from fixed plants.

Regarding the open downwind hypothesis, this assumption is obviously not well suited in the case of accidental release in an urban area. Nevertheless, one should admit that alternative 3-dimensional models and related data collection are out of the scope for a generic probabilistic transportation safety assessment.

Finally, the constant meteorological conditions hypothesis (PASQUILL's weather category and wind direction) could be a problem in situations where the duration of the exposure or the duration of the wind transportation to the downwind observation point are well beyond a commonly accepted limit of 2 hours (ca 10 km for A and F PASQUILL weather categories).

In this later case, the downwind integrated concentrations are generally overestimated. Source limitations more specific to the TRANSAT implementation are associated to both the standard deviation formulation and to the release hight, boundary layer, and deposition modeling.

The TRANSAT code does not include any modeling of plume rise. The user must thus add the plume rise effect, when appropriate, to the physical release height to obtain the effective release height to be used in TRANSAT.

The reflections due to the ground and to the mixing layer are taken into account by a multiple image source model.

A complete reflection of the plume is assumed.

The depletion of the cloud by dry deposition on the ground surface is actually accounted for by the internal INTERTRAN calculations and, thus, is not considered in the 1.6 TRANSAT version.

The depletion of the cloud by rain is modeled through a user input wet removal rate directly proportional to the rain intensity. This simple modeling assumes a uniform vertical wash-out of the cloud and a constant rain-fall along the dispersion path.

DATA COLLECTION

The limited number of accidents that have occurred during transport of radioactive materials do not provide a large enough database for examining the effects of all potential transport conditions. Assessment of risk from transportation programs, therefore, depends on calculations using a database for a larger group of transports (e.g., all-vehicle or all-truck). The frequencies of a range of transportation accident scenarios are estimated. These frequencies are combined with estimates of accident consequences in terms of the amount of radioactive material released, and the corresponding potential radiation doses, to give the risk.

The risk calculations are carried out by the code INTERTRAN2. The user has to supply input data, including basic accident rates and severity probabilities, appropriate to their particular case. Some default data are provided with the preprocessor. However, users are advised to generate their own input data in order to provide meaningful results. The default data should be resorted to only when there is no avenue available for generating the required input data.

In many cases data will be generated from statistical databases or by considering similar operations. However, where results are critical, or in certain particular situations (for example, when modeling an intermodal transfer such as ship to truck), it will be necessary to observe how the operations are carried out, to follow shipments, and to conduct timing and other studies.

Generation of input data can be a formidable task. In the incident-free case, much of the effort can be saved by carrying out a sensitivity analysis using first cut, or approximate, data. The INTERTRAN2 output lists the input parameters required for incident-free conditions in the order of their importance. On the basis of this listing, effort on data refinement can concentrate on the more important parameters.

The PRE-PROCESSOR

The first version of the pre-processor was introduced at the Coordinated Research meeting in Paris 1991. Since then, the software has been tested by the participants in the CRP and been up-dated in accordance with comments received.

One of the reasons for developing a pre-processor was that the INTERTRAN 2 tool should be used also by IAEA Member States not so experienced in the area of risk assessment. The pre-processor should facilitate the creation of input data files needed by the risk assessment program.

The pre-processor is a tool which assists the user in the preparation of input data files. It contains a database handling system where the user can store data for different package types, package contents, PASQUILL data, accident data, link data, etc.

The pre-processor will help the user creating input data files by asking questions and presenting alternatives. The pre-processor also makes checks on the combination of data to see if chosen combinations are applicable. The pre-processor can also be a valuable tool to an expert user if the databases contains information on different routes, link segments, modes, and packages. These data could easily be combined in any way to analyze different problems, just by selecting different records in the databases. It is also possible to make changes of default data to country specific data from the pre-processor instead of from within the code.

The pre-processor is a menu driven program, and the creation of the input file is done interactively. The program contains on-line help functions and pop-up windows showing the available choices and explanations where applicable. It is possible to combine available data sets, "impossible combinations" are, however, recognized by the program and the user is warned.

The pre-processor is written in Clipper 5.2. It is built around a number of databases which are used to put together the input data block. By deciding whether the calculations should be made for incident-free and/or accident case and whether population dose calculations or health effect calculations shall be made the possibility of choosing a set of data (one record) from each of the databases is given. The user can also chose to modify an earlier studied case as all previously studied cases, are stored in a special database.

The pre-processor is based on several databases which gives the user opportunity to create an input data file for RADTRAN4. The different databases contains data that are logically grouped. By selecting different data sets (records in the database files), the user should be able to create an input data file.

After making selections of data sets in the different databases the program makes a quality control to check for inconsistencies in the selection of data. If there are any errors the program will alert the user. After the quality control the program adjusts all data and copies the result into a database. The result is presented to the user on the screen, and the user can make manual adjustments if necessary. If the user is satisfied the selections made can be saved into databases available for this purpose. Then it is possible to save the result to an ASCII file, which can be used as an input file for RADTRAN4.

To be able to keep track of previously saved data selections the program uses several databases. The main database is MAIN.DBF. This database contains the basic selections for each saved case. Multiple selections of data, like different packages, links, and modes, are saved in the databases MAINPACK.DBF, MAINLINK.DBF, and MAINNORM.DBF. These databases are connected to the MAIN.DBF database.

When saving a case, selecting an old case, or deleting a case, several of the databases are updated.