ASSESSMENT
OF THE RADIological IMPACT
OF THE TRANSPORT
OF RADIOACTIVE MATERIALS
ASSESSMENT OF THE RADIOLOGICAL IMPACT
OF THE TRANSPORT OF RADIOACTIVE MATERIALS
IAEA, VIENNA, 1986
IAEA-TECDOC-398

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The transport of radioactive materials is an activity which involves large quantities and diverse forms of materials, many packages, all modes of transport and a very large number of persons -- both transport workers and members of the public. For example, as the result of a study performed by the International Atomic Energy Agency (IAEA), with the cooperation of 35 of its Member States, it has been estimated that from 18 to 38 million package shipments of radioactive material were made annually, worldwide, in the early 1980's. It is expected that as the use of radioactive materials continues to expand, the numbers and types of shipments will also grow.

The radiological impact of these activities on workers and members of the public is important. Indeed, the IAEA Regulations for the Safe Transport of Radioactive Material, Safety Series No. 6, both the 1985 Edition and earlier editions, contain a provision requiring that assessments or surveys of radiation exposures resulting from the transport of radioactive materials be periodically undertaken.

The results of such assessments or surveys provide essential inputs in many areas: e.g., in evaluating the adequacy of the existing transport regulations and practices, in studies of the optimization of radiation protection in the transport of radioactive material, in guiding the design and development of radioactive material transport packages, in the development of segregation tables used by modal transport authorities to control exposures during transport, in risk assessment studies, and in the preparation of general assessment documents such as the document on "Ionizing Radiation: Sources and Biological Effects" which is periodically produced by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).

In order to facilitate the assessment of the radiological impact of transport, and to guide the collection of data for future assessments, the IAEA convened a technical committee (The Technical Committee on the Assessment of the Radiological Impact from the Transport of Radioactive Materials; TC-556) in Vienna, Austria on 21-25 October 1985. The Terms of Reference called for this committee "to collect and assess data on the radiation exposure of workers and the public during the transport of radioactive
material, and to develop a summary statement, reflecting current practice and current state of knowledge, on the radiological impact of transport." This technical document provides the summary statement developed by TC-556. The statement should be viewed as an interim assessment since it utilized only data then available, or made available, to the committee.

This document consists of three Sections:

Section I - Background Information to the Summary Statement (prepared by the Secretariat);

Section II - The Summary Statement on the Radiological Impact of the Transport of Radioactive Materials (developed by TC-556); and

Section III - Recommendations for Future Assessments (a summary of statements and conclusions provided in the TC-556 Chairman's Report).

Comments on this document from interested parties are welcome and should be addressed to:

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Division of Nuclear Safety
International Atomic Energy Agency
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A-1400 Vienna, Austria

EDITORIAL NOTE

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The International Atomic Energy -- with the extensive help and guidance of many experts worldwide -- completed in 1985 the revision of Safety Series No. 6, the Regulations for the Safe Transport of Radioactive Material. The new edition fully reflects the Basic Safety Standards for Radiation Protection (Safety Series No. 9, 1982 Edition) in controlling transport operations involving radioactive materials. Initial guidance to the transport community on how to optimize for radiation protection during transport has been provided in IAEA-TECDOC-374, "Discussion of and Guidance on the Optimization of Radiation Protection in the Transport of Radioactive Material", 1986. However, it is also necessary to provide assessments of the radiological impact of transport to serve as a basis for judging the adequacy of the current packaging requirements, derived dose rate limits, etc., and for recommending possible future changes to such requirements.

Furthermore, the United Nations Scientific Committee on the Effects of Atomic Radiation -- commonly known as "UNSCEAR" -- periodically issues a report on "Ionizing Radiation: Sources and Biological Effects". The last report of this nature was issued in 1982. It only contains an assessment for the transport of radioactive materials related to nuclear power production, and that assessment is limited to the transport of spent fuel.

The Technical Committee Meeting on the Assessment of the Radiological Impact from the Transport of Radioactive Materials, TC-556, was convened in Vienna, Austria, 21-25 October 1985 to provide an initial, and as up-to-date as possible, statement on the exposures of workers and members of the public which result from the transport of radioactive materials. TC-556 also provided guidance to the Agency on the utility and accuracy of the computer code INTERTRAN and on changes which should be made thereto; but this guidance is not addressed in this document.

The Technical Committee consisted of the following:

Mr. B.G. Pettersson, Sweden -- Chairman
Mr. R.B. Pope, IAEA - Scientific Secretary
Mr. A.L. Biaggio, Argentina
Mr. J. Neubauer, Austria
Mr. N.L. Meldonian, Brazil
Ms. T.F. Kempe, Canada
Mr. G.B. Johnston, Canada
Mr. A. Hurda, Canada
Mr. E. Tomachevsky, France
Mr. J. Hamard, France
Mr. C. Ringot, France
Ms. C. Fasten, German Democratic Republic
Mr. F. Lange, Federal Republic of Germany
Mr. C. Faloci, Italy
Mr. L. Bramati, Italy
Mr. A. Orsini, Italy
Ms. S. Piermattei, Italy
Mr. J. Akaishi, Japan
Mr. T. Suzuki, Japan
Mr. J.H. Wiesenhaan, Netherlands
Ms. B. Svahn, Sweden
Mr. C. Ospina, Switzerland
Ms. N. Ozlüoglu, Turkey
Mr. R. O'Sullivan, UK
Mr. J.H. Mairs, UK
Mr. D.R. Poulter, UK
Mr. B.Y. Underwood, UK
Mr. J.R. Cook, USA
Ms. S. Neuhauser, USA
Mr. G. Gouvras, CEC
Mr. A. Marchal, CEC
Mr. G. Silini, UNSCEAR
Mr. H. Knauthe, UPU
Mr. H. Koponen, IAEA

At TC-556, a working group, led by Mr. R. O'Sullivan, UK, prepared a summary statement on the radiological impact of transporting radioactive materials. The full committee then reviewed and adopted the statement, referring it to the Agency's Standing Advisory Group on the Safe Transport of Radioactive Materials (SAGSTRAM). SAGSTRAM reviewed an updated version of the statement in March 1986, and recommended that it be published as a TECDOC by the IAEA. The updated statement is provided in Section II.
Data were made available for the preparation of the statement either as "open-literature" documents or as "Working Papers" provided by Member States to the committee.

For Normal Transport, radiation exposure data were available from 14 countries as summarized in Table I.1.

For Transport Accidents and Incidents, exposure data are very limited, and data only from the USA and the UK were available.

The Summary Statement, Section II, is the Committee's interpretation of the data provided.
<table>
<thead>
<tr>
<th>Country</th>
<th>Fuel Cycle Materials</th>
<th>Other than Fuel Cycle Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time Period</td>
<td>Basis</td>
</tr>
<tr>
<td>Argentina</td>
<td>1982, 1985</td>
<td>Calculation &amp; Measurement</td>
</tr>
<tr>
<td>Austria</td>
<td>1982 to 1985</td>
<td>Measurement</td>
</tr>
<tr>
<td>Canada</td>
<td>1983</td>
<td>Calculation</td>
</tr>
<tr>
<td>Finland</td>
<td>1981</td>
<td>Calculation &amp; Measurement</td>
</tr>
<tr>
<td>France</td>
<td>1984</td>
<td>Measurement</td>
</tr>
<tr>
<td>GDR</td>
<td>1982</td>
<td>Calculation</td>
</tr>
<tr>
<td>FRG</td>
<td>1985</td>
<td>Calculation</td>
</tr>
<tr>
<td>India</td>
<td>1982</td>
<td>Calculation</td>
</tr>
<tr>
<td>Italy</td>
<td>1981</td>
<td>Calculation &amp; Measurement</td>
</tr>
<tr>
<td>Japan</td>
<td>1984</td>
<td>Measurement</td>
</tr>
<tr>
<td>Sweden</td>
<td>1975 to 1985</td>
<td>Calculation &amp; Measurement</td>
</tr>
<tr>
<td>Turkey</td>
<td>1984</td>
<td>Calculation &amp; Measurement</td>
</tr>
<tr>
<td>UK</td>
<td>1985</td>
<td>Calculation &amp; Measurement</td>
</tr>
<tr>
<td>USA</td>
<td>1985*</td>
<td>Calculation &amp; Measurement</td>
</tr>
</tbody>
</table>

* Based upon projections and calculations made in 1977
II.1. INTRODUCTION

II.1.1. Definition of terms

For the purposes of this summary statement from the Technical Committee on the Assessment of the Radiological Impact from the Transport of Radioactive Material, the radiological impact is defined in terms of radiation exposure. No attempt has been made to express the radiological impact in terms of health detriment.

The individual exposure from sources of external penetrating radiation is expressed in terms of effective dose equivalent in units of milli-Sievert (mSv). Collective exposure from sources of external penetrating radiation are expressed in terms of collective effective dose equivalent in units of Man-Sievert (Man-Sv).

In the case of the incorporation of radionuclides into the body of an individual, it would be appropriate to express the exposures in terms of the committed effective dose equivalent to that individual (mSv). In the case of radionuclides released to the environment the appropriate term for the expression of collective exposure is the collective effective dose equivalent commitment (Man-Sv).

Normal transport is defined as operations which occur without unusual delay, loss of, or damage to the package, or an accident involving the conveyance. Events in which the shipment is not timely or the package or conveyance is damaged or the contents of the package are lost or destroyed are considered to be defined as transport accidents or incidents.
II.1.2. Terms of reference

The terms of reference, relative to the development of this statement, were to collect and collate data on the radiation exposure of workers and the public during the transport of radioactive materials and to develop a summary statement on the radiological impact of such transport.

II.1.3. Scope of Transport Dose Assessment

The IAEA Regulations (Safety Series No. 6 – 1985 Edition, paragraph 103) define transport as "Transport shall be deemed to comprise all operations and conditions associated with and involved in the movement of radioactive material; these include the design, fabrication and maintenance of packaging, and the preparation, consigning, handling, carriage, storage in transit and receipt at final destination of packages. Transport includes normal and accident conditions encountered in carriage and in storage."

From this definition it could be inferred that doses resulting from the many operations required to prepare the package until it is ready for carriage are "transport doses". However, it is realized that most of the available data include only doses incurred by workers or the public during the loading and unloading of vehicles, carriage, storage in transit and, in some cases, delivery. Furthermore, in many cases it appears to be difficult to exactly define at what stage "preparation" begins. Moreover it is noted that the doses incurred by workers during preparation of the packages are recorded as occupational doses to the workers employed in the facility and that this could lead to double counting when global collection of dose data is carried out, for example by UNSCEAR. For these reasons each footnote to the tables of dose data presented in subsection II.2 will include an indication of whether doses incurred during preparation were not taken into account and if possible, to what extent.

II.1.4. Aims of the statement

The aims of this document are to assist Member States in assessing the adequacy of their procedures and to assist the Agency in focussing its resources on key issues in the transport area; and also to provide an up-to-date input to other international studies such as UNSCEAR's Ionizing Radiation: Sources and Biological Effects periodical report.
II.1.5. Outline of the structure of the statement

It was decided to present separately information about normal transport on one side and the considerations about transport accidents and incidents on the other side. It seemed that most countries would be able to submit information concerning normal transport; accidents and incidents however can only be treated and evaluated on the basis of experience and historical investigations. According to the reasons laid down in II.1.4, information for fuel cycle materials and other radioactive materials are presented separately. A distinction was made between "occupational exposure" and "public exposure"; a subdivision was provided between collective and individual exposures.

The information from all countries which were represented at the TC-556 meeting and were able to furnish the data concerned are included in Tables II.1 and II.2.

II.1.6. Statement of confidence

With reference to data summarized in Tables II.1 and II.2, it is stressed that the figures do not share the same level of validity. Doses incurred by the most exposed transport workers were usually taken from individual monitoring and have a high level of confidence, though it is noted that they are expressed in an "operational" quantity and an additional effort is required to present the results as effective dose equivalent, a more suitable quantity for UNSCEAR purposes. Doses evaluated from measurements in conjunction with exposure models could have, in most cases, a reasonable level of confidence. Doses evaluated from mathematical models, for instance the INTERTRAN code, are in most cases based on somewhat idealized and often cautious assumptions which could lead to quite significant overestimations.

II.2. NORMAL TRANSPORT

II.2.1. Introduction

The data presented in Tables II.1 and II.2 which are referred to in this section are for exposures due to normal transport of radioactive materials. They have been obtained through the Member State representatives at the
Technical Committee meeting or by direct enquiries to Member States not represented. Only those countries are shown for which data were available for the transport of nuclear fuel cycle materials and/or for the transport of radioisotopes. Where data are not complete or were not immediately available, entries for these countries have nevertheless been included as far as possible to indicate needs for data.

In the case of individual occupational exposures separate values have been included, as far as possible, for both mean and maximum exposures. This was considered useful to enable these doses to be put into appropriate perspective.

The means by which individual values of exposure were obtained have been indicated in the Tables by affixing the letters M, I or A in parentheses, signifying respectively measurement (M), INTERTRAN calculation (I), other assessment method (A). Combinations of these means have been indicated by appropriate combination of those letters.

Footnotes have been provided for each set of Member State data, to give information on the shipments to which they provide a basis for comparison between them. The facts listed below have been included in the footnotes, using the same numbers as in the list.

1. Year in which shipment(s) took place
2. Kind of product
3. Number of shipments and packages studied
4. Mode(s) of transport
5. Fraction or segment of shipment concerned
6. Whether preparation for transport is included
7. Reference(s)*

Some of the references are denoted, for example, as "WP27 for TC-556", which indicates the reference was Working Paper No. 27 for the Technical Committee meeting TC-556; such references are available from the Radiation Protection Section of the IAEA upon request.
II.2.2. Radiation exposure associated with the normal transport of radioactive materials

Table II.1 presents data on radiation exposure associated with the normal transport of nuclear fuel cycle materials.

Table II.2 presents data on radiation exposure associated with the normal transport of non-nuclear fuel cycle materials.

II.2.3. Discussion of Findings for Normal Transport

The data presented in Tables II.1 and II.2 are incomplete in so far as they do not represent a global set and are restricted in some cases to only part of the transport field in the Member State concerned. Moreover, they are not always supported by full information on the shipments studied nor on the accuracy of the measurements or assessments carried out. Because of this it is not possible to base any truly global conclusion on them.

The indications from the data that are available are nevertheless that exposures due to normal conditions of transport are low. Only in a few cases do transport workers receive doses which are more than a significant fraction of the applicable dose limits. Furthermore at least in the case of the data from the USA and the UK it can be inferred that the fuel-cycle materials are significantly lesser contributors to transport workers' exposure than are the non-fuel cycle materials.

The technical committee found it difficult to carry out an effective comparison of the exposure data because of the short time available in which to assess it, the many gaps in the supporting information and the differences in basis of many of the individual values. In the view of the technical committee it is premature to try to make extrapolations or to draw conclusions from the data currently available. It would be valuable however to try to obtain more complete and comparable data; the Agency could usefully provide guidance on the kind of data that are needed and the supporting information which should be supplied with it in order to promote better coherence for the purpose of future assessment and comparison. The facts tabulated in the footnotes to Tables II.1 and II.2 (see II.2.1 above) are, it is suggested, the minimum which should be provided with data, supplemented by details of the
journeys with the populations and distances and activities involved in addition to the doses obtained and an indication of their accuracy.

In relation to public exposures, although it would appear that both collective and individual doses are low, there is a particular scarcity of data and therefore a consequent need to develop more information. Apart from the intrinsic desirability of assuring the adequacy of the regulatory standards, and of their implementation in practice, this could help to provide an effective response to concerns in some Member States and useful information for international organizations such as UNSCEAR.
### Table II.1 Radiation exposure associated with the normal transport of nuclear fuel cycle materials

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>OCCUPATIONAL EXPOSURE</th>
<th>PUBLIC EXPOSURE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Collective Man Sv</td>
<td>Individual mSv (Max)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Individual mSv (Mean)</td>
</tr>
<tr>
<td>Argentina</td>
<td>Not available</td>
<td>Not available</td>
</tr>
<tr>
<td>Austria</td>
<td>Not available</td>
<td>Not available</td>
</tr>
<tr>
<td>Canada</td>
<td>Occupational doses arising during the transport phase have not been compiled separately from measured doses received during all nuclear activities.</td>
<td>Assessments have mainly been concerned with conceptual future programmes. There is currently no large scale programme of transport of irradiated fuel, although low and medium level wastes and other materials are transported.</td>
</tr>
<tr>
<td>FRG</td>
<td>0.018 (I)</td>
<td>0.06 (I)</td>
</tr>
<tr>
<td>Finland</td>
<td>0.4 to 1.0 x 10⁻³ (I,A)</td>
<td>0.7* (M)</td>
</tr>
<tr>
<td></td>
<td>0.6 to 1.4 x 10⁻³ (I,A)</td>
<td></td>
</tr>
</tbody>
</table>

#### FRG

1. * 1983
2. For the nuclear cycle materials (fresh and spent fuel, UF₆, ores and wastes)
3. 740 shipments
4. Rail
5. All transport by rail
6. Not included
7. WP27 for TC-556

#### Finland

1. 1982, 1985
2. Spent fuel
3. 1 shipment, 4 packages/year
4. Road and rail
5. Road 13 km, rail 230 km
6. Included in measured data
7. WP7 for TC-556

* Doses mainly in result of handling operations. Maximum dose during transport is less than 0.1 mSv (registration limit).

* For description of notes, see Section II.2.1.
Table II.1  Radiation exposure associated with the normal transport of nuclear fuel cycle materials (continued)

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>OCCUPATIONAL EXPOSURE</th>
<th>PUBLIC EXPOSURE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Collective Man Sv</td>
<td>Individual mSv</td>
</tr>
<tr>
<td></td>
<td>(Max) (Mean)</td>
<td>(Max) (Mean)</td>
</tr>
<tr>
<td>France</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1) Irrad. fuels</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) 1982</td>
<td>0.7 x 10^-2 (M)</td>
<td>0.5 (M)</td>
</tr>
<tr>
<td>b) 1983</td>
<td>2.6 x 10^-2 (M)</td>
<td>4.2 (M)</td>
</tr>
<tr>
<td>c) 1984</td>
<td>1.5 x 10^-2 (M)</td>
<td>5.8 (M)</td>
</tr>
<tr>
<td>d) 1985</td>
<td>2.3 x 10^-2 (M)</td>
<td>7.2 (M)</td>
</tr>
<tr>
<td>2) Wastes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) 1982</td>
<td>4.4 x 10^-2 (M)</td>
<td>3.7 (M)</td>
</tr>
<tr>
<td>b) 1983</td>
<td>4.1 x 10^-2 (M)</td>
<td>5.6 (M)</td>
</tr>
<tr>
<td>c) 1984</td>
<td>4.0 x 10^-2 (M)</td>
<td>6.8 (M)</td>
</tr>
<tr>
<td>d) 1985</td>
<td>4.7 x 10^-2 (M)</td>
<td>7.6 (M)</td>
</tr>
<tr>
<td>3) Plutonium and Enriched Uranium</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) 1982</td>
<td>1.6 x 10^-2 (M)</td>
<td>1.3 (M)</td>
</tr>
<tr>
<td>b) 1983</td>
<td>0.7 x 10^-2 (M)</td>
<td>0.3 (M)</td>
</tr>
<tr>
<td>c) 1985</td>
<td>1.8 x 10^-2 (M)</td>
<td>1.5 (M)</td>
</tr>
<tr>
<td>4) Other</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) 1982</td>
<td>1.6 x 10^-3 (M)</td>
<td>0.27 (M)</td>
</tr>
<tr>
<td>b) 1983</td>
<td>7.4 x 10^-2 (M)</td>
<td>2.6 (M)</td>
</tr>
<tr>
<td>c) 1984</td>
<td>9.3 x 10^-2 (M)</td>
<td>2.7 (M)</td>
</tr>
<tr>
<td>d) 1985</td>
<td>5.0 x 10^-3 (M)</td>
<td>0.25 (M)</td>
</tr>
</tbody>
</table>

1) 1. 1982 to 1985
2. Irradiated fuels
3. All transported in France
4. Road
5. From plant to station, station to plant
6. Not included
7. PATRAM '83 (1982 data)
8. PATRAM '86 (1983-1985 data)

2) 1. 1982 to 1985
2. Low level wastes
3. Unknown
4. Road
5. Complete Transport
6. Not included
7. PATRAM '83 (1982 data)
8. PATRAM '86 (1983-1985 data)

3) 1. 1983 to 1985
2. Plutonium & Enriched Uranium
3. Unknown
4. Road
5. Complete transport
6. Not included
7. PATRAM '86
8. PATRAM '86 (1983-1985 data)

4) Data refer to other radioactive materials (natural uranium, Pu nitrates, others)
1. 1982 to 1985
2. Other radioactive materials
3. Unknown
4. Road
5. Complete transport
6. Handling included
7. PATRAM '86 (1982 data)
8. PATRAM '86 (1983-1985 data)
Table II.1 Radiation exposure associated with the normal transport of nuclear fuel cycle materials (continued)

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>OCCUPATIONAL EXPOSURE</th>
<th>PUBLIC EXPOSURE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Collective Man Sv</td>
<td>Individual mSv</td>
</tr>
<tr>
<td></td>
<td>(Max)</td>
<td>(Mean)</td>
</tr>
<tr>
<td>GDR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>India</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Italy</td>
<td>0.01 (M)</td>
<td>0.06 (M)</td>
</tr>
<tr>
<td>Japan</td>
<td>-</td>
<td>&lt; 1.5 (M)</td>
</tr>
<tr>
<td>Sweden</td>
<td>2 x 10^{-3} (M,A)</td>
<td>0.7 (M)</td>
</tr>
<tr>
<td>Turkey</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Not available</td>
<td></td>
</tr>
</tbody>
</table>

**Italy**

1. 1981
2. Fuel elements PWR
3. 7
4. Road
5. Transport from Trino Vercellese to Anrio port - 700 km
6. Included
7. WP11 for TC-556 - IAEA Research Agreement 2837/CF

**Japan**

1. 1984
2. Fresh and spent fuel, high enriched uranium, etc.
3. Unknown
4. Road
5. Main six carriers
6. Not included
7. Communications to IAEA from Scientific and Technology Agency, Japan, 10 January 1986 and 7 July 1986. For the Individual Maximum Occupational Exposure, the individual exposure was from a non-detected level (less than 0.1 mSv) in every measurement by film badge, and the film badges were changed and measured 15 times per year. For the Individual Mean Occupational Exposure, all individual exposures were from non-detected level (less than 0.1 mSv) in every measurement by film badge, and the mean number of film badge changes and measurements was 6.1 times per year.

**Sweden**

1. 1975-1985 for measured data
2. Spent fuel, fresh fuel, low level waste
3. Unknown
4. Road
5. Part of nuclear fuel cycle
6. Preparation is not included
7. Private communication
Table II.1 Radiation exposure associated with the normal transport of nuclear fuel cycle materials (continued)

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>OCCUPATIONAL EXPOSURE</th>
<th>PUBLIC EXPOSURE</th>
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<tbody>
<tr>
<td></td>
<td>Collective Man Sv</td>
<td>Individual mSv</td>
</tr>
<tr>
<td></td>
<td>(Max)</td>
<td>(Mean)</td>
</tr>
<tr>
<td>UK</td>
<td>0.14 (MA)</td>
<td>1.2 (M)</td>
</tr>
<tr>
<td>USA</td>
<td>19 (M,A)</td>
<td>9 (M)</td>
</tr>
</tbody>
</table>

UK
(a)
1. 1981
2. All radioactive materials in the nuclear fuel cycle
3. Approximately 6,000 journeys
4. Variable number of packages
5. Road and rail
6. Not included

(b) These assessments are for the transport of irradiated fuel.

USA
1. 1985 (data projected in 1977)
2. All radioactive materials in the nuclear fuel cycle
3. Details provided in Appendix A of NUREG 0170
4. All modes of transport
5. Whole country
6. Not included
7. NUREG 0170. Assessments based on cautious assumptions.
Table II.2 Radiation exposure associated with the normal transport of radioisotopes for medical, industrial and research use

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>OCCUPATIONAL EXPOSURE</th>
<th>PUBLIC EXPOSURE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Collective Man Sv</td>
<td>Individual mSv (Max)</td>
</tr>
<tr>
<td>Argentina</td>
<td>0.12 (M)</td>
<td>24 (M)</td>
</tr>
<tr>
<td>Austria</td>
<td>0.07 (I)</td>
<td>0.36 (M)</td>
</tr>
<tr>
<td>Canada</td>
<td>0.029 (M)</td>
<td>11.1 (M)</td>
</tr>
</tbody>
</table>

Argentina
1. 1984
2. Radioactive materials for medicine and research
3. About 12,000 packages
4. Road
5. For 60% of packages the whole transport and for the remainder only a fraction
6. Not included
7. WP23 for TC-556

Austria
1. 1984
2. Ir-192, Mo-99, Co-60, I-123, I-131, Xe-133
3. ~ 10,500 shipments/ ~ 12,000 packages
4. Air, road and rail
5. Whole country
6. Not included
7. Austrian research centre, Seibersdorf, data provided to TC-556 (not published)

Canada
1. 1984
2. Industrial isotopes, radiopharmaceuticals, wastes
3. 9000
4. Road followed by air and/or sea
5. (Atomic Energy of Canada Ltd. – Radiochemical Company). Due to the 8 persons involved in the shipping and transport of activity. About 4000 packages containing 15 million Ci of activity to customers. Note: 1% of packages account for over 90% of activity.
6. Included
7. WP30 for TC-556
Table II.2 Radiation exposure associated with the normal transport of radioisotopes for medical, industrial and research use (continued)

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>OCCUPATIONAL EXPOSURE</th>
<th>PUBLIC EXPOSURE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Collective</td>
<td>Individual</td>
</tr>
<tr>
<td></td>
<td>Man Sv (Max)</td>
<td>mSv (Mean)</td>
</tr>
<tr>
<td>FRG</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finland</td>
<td></td>
<td></td>
</tr>
<tr>
<td>France</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) 1981</td>
<td>0.12 (M)</td>
<td>30 (M)</td>
</tr>
<tr>
<td>b) 1984</td>
<td>0.30 (M)*</td>
<td>19 (M)</td>
</tr>
<tr>
<td>GDR</td>
<td>0.07 (M)(a)</td>
<td>8.5 (M)(a)</td>
</tr>
<tr>
<td>India</td>
<td>0.014 (M)</td>
<td>-</td>
</tr>
</tbody>
</table>

FRG
1. 1983
2. Radioisotopes
3. - 18,000 shipments
4. Rail
5. All transport by rail
6. Not included
7. WPZ7 for TC-556

France
1. a) 1981, b) 1984
2. Radiopharmaceuticals - TC gen.
3. a) 57,000, b) 106,000
4. a) Road, b) Road
5. a) From plant to station or airports, b) From plant to user site
6. a) Not included, b) Included
7. PATRAM '83 (1981 data), PATRAM '86 (1984 data)

*The collective dose includes the dose resulting from the preparation of the package

GDR
(a)
1. 1975-1984
2. Radioisotopes
3. Unknown
4. Road
5. Most exposed group
6. Not included
7. GDR working paper for TC-556

(b)
1. 1980
2. Radioisotopes
3. 35,000
4. Road, rail, air
5. Whole country
6. Not included
7. GDR working paper for TC-556

India
1. 1982
2. Radioisotopes (sources and radiopharmaceuticals)
3. 11,000
4. Road/Air
5. From plant to user site
6. Included
Table II.2 Radiation exposure associated with the normal transport of radioisotopes for medical, industrial and research use (continued)

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>OCCUPATIONAL EXPOSURE</th>
<th>PUBLIC EXPOSURE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Collective</td>
<td>Individual</td>
</tr>
<tr>
<td></td>
<td>Man Sv</td>
<td>(Max)</td>
</tr>
<tr>
<td></td>
<td>(Mean)</td>
<td>(Mean)</td>
</tr>
<tr>
<td>Italy</td>
<td>0.80 (I)</td>
<td>0.12 (M)</td>
</tr>
<tr>
<td>Japan</td>
<td>-</td>
<td>1.08 (M)</td>
</tr>
<tr>
<td>Sweden</td>
<td>-</td>
<td>0.091 (M)</td>
</tr>
<tr>
<td>Turkey</td>
<td>0.667 (I)</td>
<td>-</td>
</tr>
</tbody>
</table>

**Italy**
1. 1982
2. Radioisotopes for medical use
3. 50 000 packages
4. Road (truck)
5. Average km per package - 200 km
6. Not included
7. WP10 for WP10 for TC-556 - IAEA Research Contract 2837/R1/CF

**Japan**
1. 1984
2. Radioisotopes for medical, industrial and research use
3. Unknown
4. Road
5. Main four carriers
6. Not included
7. Communication to IAEA from Scientific and Technology Agency, Japan, 10 January 1986

**Turkey**
1. 1984
2. Ir-192, Co-60, I-131, Tc-99m, Cs-137, Am-241 (Medical, industrial)
3. 166 shipments per year, 1448 packages per year
4. Road (truck, p. van) pass, air, cargo air
5. From customs to companies
6. Not included
7. Inventory of the licensing department of Radiological Safety of Turkish Atomic Energy Authority, WP34 for TC-556
Table II.2 Radiation exposure associated with the normal transport of radioisotopes for medical, industrial and research use (continued)

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>OCCUPATIONAL EXPOSURE</th>
<th>PUBLIC EXPOSURE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Collective Man Sv</td>
<td>Individual mSv</td>
</tr>
<tr>
<td></td>
<td>(Max)</td>
<td>(Mean)</td>
</tr>
<tr>
<td>UK</td>
<td>0.92 (MA)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>20 (M)&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>USA</td>
<td>~100 (M,A)</td>
<td>9 (M)</td>
</tr>
</tbody>
</table>

UK

(a)
1. 1982
2. Radioisotopes
3. 20,000 journeys (a variable number of packages are transported in a journey)
4. Principal mode is road
5. Whole country
6. Not included
7. NRPB-R155. WP29 for TC-556

(b) This information refers only to the major "primary" movements of radioisotopes

USA

1. 1985 (projected data)
2. All radioactive materials
3. Details provided in Appendix A of NUREG 0170
4. All modes of transport
5. Whole country
6. Not included
7. NUREG 0170 (assessments are based on cautious assumptions)
II.3. TRANSPORT ACCIDENTS AND INCIDENTS

II.3.1. Introduction

Several countries have begun to consider the difficult topic of assessing the radiological impact arising from potential accidents and incidents involving the transport of radioactive materials. Very few countries are currently in a position to present information in this field.

The technical committee was provided with information which suggests that mathematical risk assessment models (including INTERTRAN) in their present form, may not be the best tools for handling the potential accident situation and, because parameters, data, and modelling are so uncertain, it is believed to be premature to use these models for the assessment of the radiological impact from accidents. In view of these difficulties it was decided that it would be unwise to make a summary statement on the potential radiological impact of transport using risk assessment techniques. The application of risk assessment techniques to transport operations is particularly difficult for many reasons, such as the location of a potential release of radioactive material is not known, the wide variety of package types, package contents and types of conveyance used in transport.

The intention of this section of the report is to very briefly review work that has been published regarding the collation of historical data on accidents and incidents involving the transport of radioactive materials. Information on transport accidents and incidents involving radioactive materials is sparse due to the low frequency of occurrence of such events and due to the lack of published data on their impact.

II.3.2. A review of the radiological impact from accidents and incidents involving the transport of radioactive materials

There have been a number of reviews of accidents and incidents involving the transport of radioactive materials. In the United States statistics have been collated by Grella, McClure, Emerson, Jefferson, and in NUREG 0170. NUREG 0170 has attempted to use statistics of transport accidents and incidents to produce an assessment of radiological impact. Appendix F of NUREG 0170 provides information of incidents reported to the US
Department of Transportation involving radioactive material from 1971 through 1974. The methodology and results of a study of the impacts of transport accidents based on a risk assessment using this statistical analysis together with projections of accident data is given in Chapter 5 of NUREG 0170.

In the United Kingdom a review of accidents and incidents occurring during transport over the last 20 years has been performed by the NRPB. Statistics were gathered for analyses by mode of transport and category of material transported. Tentative estimations of resultant doses to transport personnel and members of the public were made. The results of this work are to be published and a summary of this work was presented to the meeting in Working Paper No. 29.

II.3.3. Discussion of Findings for Transport Accidents and Incidents

Reviews of the available historical data have shown that there has never been a serious incident involving the dispersal of radioactive material. This is, in part, due to regulatory control. The regulations are directed to ensuring that safety measures appropriate to the nature and quantity are built into the design of the package in which the material is to be transported.

The review conducted in the UK has demonstrated that the majority of significant events in the UK are related to procedural and quality assurance failures. This is an aspect that should be addressed in a comprehensive assessment of radiological impact from the transport of radioactive materials.

The information available suggests that there has never been an accident or incident involving radioactive material transport which has led to the significant exposure of a member of the public.

There is a need for information on accidents and incidents involving the transport of radioactive materials to be recorded on a consistent basis throughout the world. The Agency could play an important role in promoting and co-ordinating this work. The information would provide valuable information in the design of packages, the planning of emergency response procedures and in the development of valid risk assessment techniques.
II.4. CONCLUSIONS

As has been pointed out in Sections II.2 and II.3 there is at present an inadequate amount of data on exposures in Member States on which to base a full assessment of the radiological impact due to the transport of radioactive materials. This is particularly true in regard to doses to the population, in the case of transport in normal conditions, and generally, in relation to accidents.

The specific needs for the obtaining and collection of more complete data have been identified in Sections II.2 and II.3. Comprehensive assessments of transport operations can be well served by a diverse range of study techniques. Assessments using mathematical techniques have an important role to play but are only one of the available techniques.

As an overall view, from the information currently available, it can be reasonably asserted that exposures of most workers and of the public in normal transport are low. Only in a few cases do transport workers receive doses which are more than a significant fraction of applicable limits. It is also believed, and this is confirmed by experience to date, that the risks to workers and the public due to potential accidents and incidents in transport are also low.

While there is a need for more data to provide confirmation of these views, it is therefore necessary to achieve an appropriate balance between the acquisition of data and the possible expenditure of excessive resources.
SECTION III

RECOMMENDATIONS FOR FUTURE ASSESSMENTS

As a result of the review made by TC-556 of the exposures to workers and members of the public resulting from the transport of radioactive materials, the following general recommendations can be made relative to future assessments:

1) Further efforts are needed to provide a more complete data base for the assessment of the radiological impact of the normal transport of radioactive material. Table I.1 indicates the very limited nature of the data used in the summary statement. Attention needs to be given especially to collecting additional data for the air and sea modes of transport. Specifically, more comprehensive and consistent data on exposures to workers and the public, and on the risks due to potential accidents and incidents, are necessary to form the basis of a meaningful statement on the radiological impact due to the transport of radioactive materials.

2) Further efforts are also required to provide a more complete data base for the assessment of the radiological impact of transport accidents or incidents. At the TC-556 meeting, such data were only available from two countries.

3) High priority should be given to properly normalizing future data from transportation assessments. Data should be provided to allow normalization to appropriate, system-related factors such as (mSv/GWh), etc. The quantities used should also be standardized to the SI system of units.

4) The particular types of exposures which should be considered as involved in transportation should be clearly defined. For example, are exposures associated with preparing a package for shipment to be counted as transportation exposure? Also, the number of packages, shipment distances, persons exposed, distances at exposure etc. should be known.
5) Exposures due to QA failures can be substantial. Data which relate to QA failures should be identified separately from accident-related data: this would aid efforts in identifying specific needs for establishing or enhancing effective QA training, and administrative and procedural programmes.
REFERENCES


