Statistics on the Traffic of Radioactive Material, and the Resulting Radiation Exposures, in the European Union and Applicant Countries

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1. INTRODUCTION

Radioactive materials of natural or artificial origin are of widespread use across the world and are transported within and between countries. A wide range of materials are transported, from small quantities of radiopharmaceuticals for medical use to highly radioactive spent nuclear fuel and vitrified wastes arising from the nuclear fuel cycle. The handling and transport of these radioactive materials can give rise to radiation exposure of workers, and of members of the public. Statistical information on the transport of radioactive material and the radiation doses arising from these operations are important to:

- demonstrate the efficacy of the IAEA Transport Regulations [1],
- provide support for the continuous review and revision process of the IAEA Transport Regulations [1],
- provide guidance and support to national, regional and international transport regulatory activities,
- support and guide compliance assurance,
- provide data for assessing and evaluating the doses and risks to workers and to members of the public,
- identify needs and trends in national and international transport activities, and
- provide factual information to assist in addressing public concern on these issues.

A study has been carried out on behalf of the European Commission [2] in 2001/ 2002 by expert organisations in five EU Member States with two main objectives:

- To collect and compile information on the type, volume and radiological characteristic of, and the doses from radioactive material shipments in the European Union (EU) and in the countries applying for accession to the EU, and
- To perform statistical analyses on the traffic of radioactive material shipments in EU Member States and in the applicant countries, where possible, by: type of package, type of transport, radiation exposures of workers and members of the public, and, use of radioactive material.

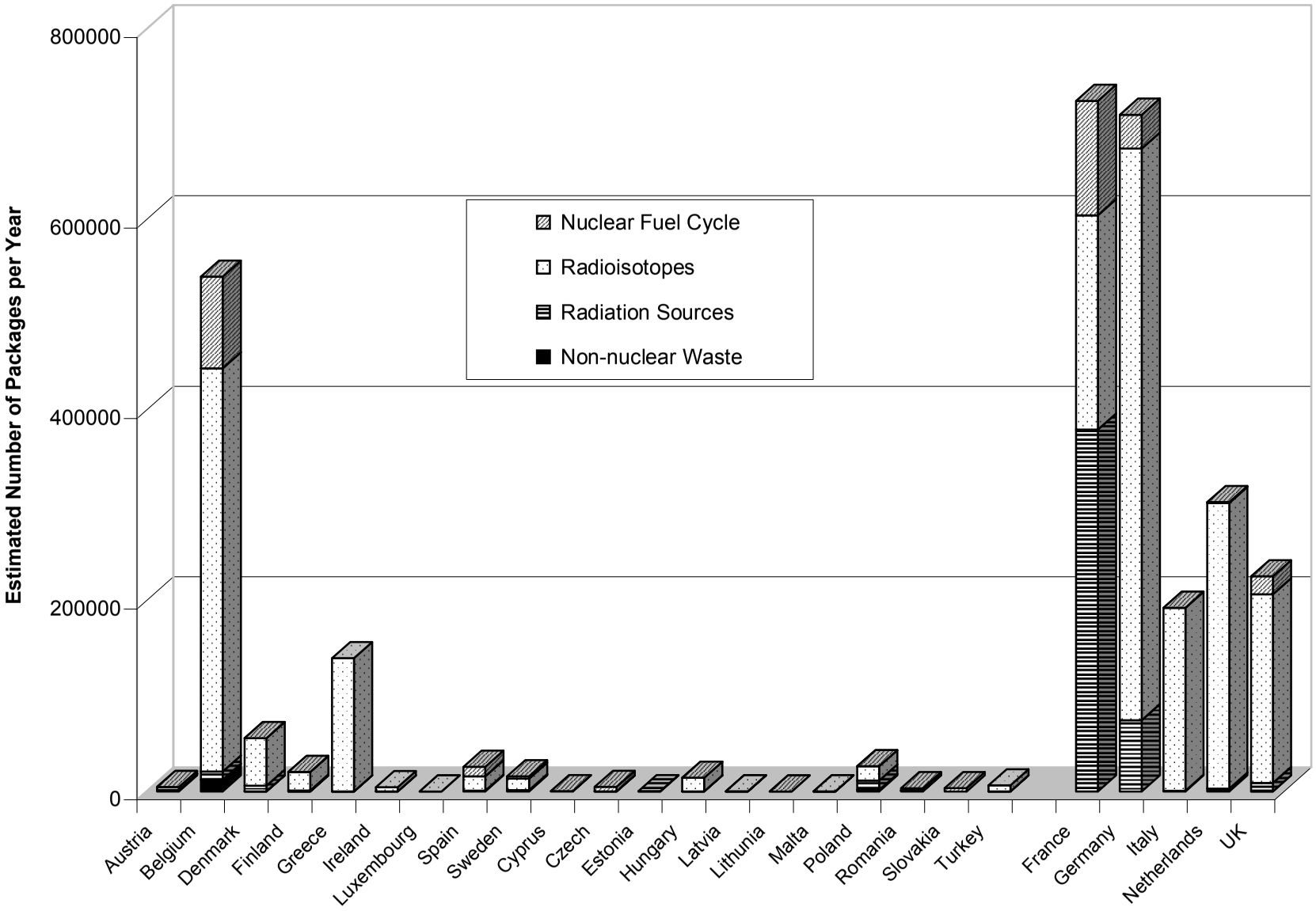
This paper summarises the methods and principal findings of that study.

2. DATA COLLECTION

The five organisations that performed this work are from EU Member States that have substantial transport operations concerned with the use of radioactive materials in medicine, research, general industry and the nuclear fuel cycle. These Member States also have different structures of licensing and surveillance, and transport data on normal operations are collected in different formats.

The scope, level of detail and frequency of collection and analysis of statistical transport and exposure data vary widely depending on the type of radioactive material and mode of transport and the nationally existing institutional and regulatory requirements. Data on the shipment of other radioactive materials are not always easily available in the various countries for different reasons. For example, the absence of legally binding provisions to collect such data or difficulties in collecting and processing of the data due to a lack of resources or the confidentiality of the relevant information. Some countries that have a statutory system of notification or authorisation of radioactive material shipments are facilitated in collecting data by the operators and have organised a system to manage those data. Other countries that do not have such systems collect data generally through consignors or carriers that provide those data on a voluntary basis.

Figure 1: Radioactive material transport in EU Member States and Applicant Countries (1990s/early 2000)



Occupational and public exposure data are generally not being collected, reported and published by transport operators and Competent Authorities on a routine basis. Therefore other collection and analysis methods have been employed for the purposes of this study.

Collection and compilation of radioactive material transport data in Applicant Countries and EU Member States other than those involved in the project were based on a questionnaire survey. The relevant questionnaire forms covering transport and exposure data were developed within the project. A guidance note was included with the questionnaire to assist the respondents in providing data in a consistent format. Nonetheless, the shipment data from each country were collected and supplied in different ways making inter-comparisons sometimes difficult. Care was needed in the use and interpretation of some of the data. One particular source of difficulty in making comparisons is in the different understanding of the term "shipment". Guidance on the term was given with the questionnaire, but interpretation was sometimes different for different types of movements in each country.

Data was received from 25 countries and, apart from the difficulties of collecting data noted above, the level of reported operations in each country are influenced by factors such as whether there is a major nuclear industry, or a major producer or supplier of radioisotopes. Annual data was requested and were mainly supplied for the year 2001. In some countries data for other years were reported depending on whether annual data is routinely collected, and whether a dedicated survey had been carried out in recent years.

3. PACKAGE NUMBERS AND TRENDS

The data on package numbers are generally well known for nuclear fuel cycle operations but in most cases can only be estimated for other transport operations. The data presented in Figure 1 are taken from the information supplied by countries for this survey. There are many reasons for the differences in package numbers between countries. Some countries have a large in-transit component, some have nuclear fuel cycle operations and some have major suppliers of radionuclides. The five countries that took part in the study are among those with the largest volumes of shipment.

In France, a survey found that in 1997, 345,000 packages were transported in 31,000 shipments. However, the number of shipments of industrial radiography containers, gamma density gauges and lead analysers were underestimated. According to a survey carried out in 2002, the total number of packages transported could now be about 700,000, carried in about 410,000 shipments. That work revealed that a significant number of other users of packages for civil industries had been overlooked in the 1997 survey. A recent building regulation has introduced a requirement to check for the presence of lead in paint in dwellings being sold to a new occupier. The lead analysers used for this are carried as Excepted packages and there are an estimated 260,000 movements of these each year.

The total annual number of radioactive material shipments in Germany is approximately 500,000, carrying about 700,000 individual packages, by all modes of transport, i.e. road, rail, air and sea. A major fraction of these radioactive material shipments are transboundary shipments. Road transport represents the most dominant shipping mode with an annual volume of about 600,000 shipped packages. Transportation by air ranks second with a total of approximately 100,000 shipped packages annually. The annual number of radioactive material shipments by rail and sea represents only a very small fraction of the national shipping volume.

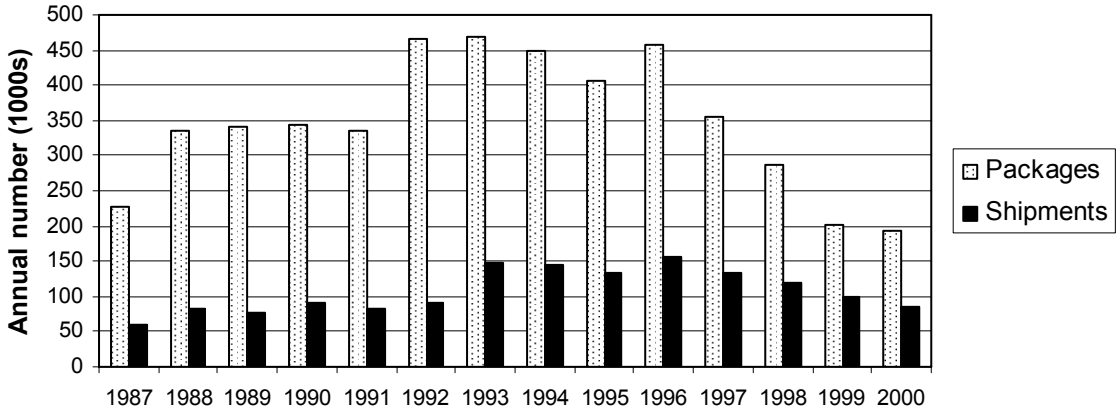
In the UK some 230,000 packages are transported, 86% for the supply and distribution of medical radionuclides, 8% by the nuclear industry, 5% are gauges and industrial radiography sources, and 1% are consumer products. Apart from a relatively small number of fuel flasks that are transported by rail, all packages are transported by road, for at least part of the journey.

In the Netherlands almost 300,000 packages are shipped annually, and more than 95% of these contain radiopharmaceuticals. About 2000 packages are from nuclear industry operations, containing uranium hexafluoride (UF_6) and radioactive wastes. A further 3000 contain wastes from the non-nuclear industry. Shipments in the non-nuclear sector are made by two main consignors. One consignor ships about 220,000 packages annually, of which 55,000 are technetium generators in Type A packages. The packages shipped by this consignor are almost all exported to other European countries. The second consignor imports about 30,000 and about 60% of these are distributed within the Netherlands, the rest being exported.

The volume of shipments of packages is considered to have been at these levels for a number of years, but with annual changes reflecting medical developments or changes in the nuclear industry over time. Most countries do not have sufficient shipment data to establish trends for all categories of radioactive material. However Italy has such data for a major fraction of the national traffic of radioactive material shipments over a 14-year period. The analyses of shipment data from Italy are for shipments carried out during the period 1987 - 2000 by authorised carriers. The results of the analysis of data are based both on direct analyses and also by sampling data. Trend analyses have been carried out of transport flows. The data regarding the number of shipments and number of packages transported during the period analysed are summarised in Figure 2.

In other countries, consistent long-term data are generally only available for shipments of nuclear fuel. In the UK, flask shipments have been around 700 each year with no significant trends. Information on commercial reactor spent nuclear fuel movements in Germany over the last two decades showed that the annual volume of shipments has been consistently in the range of about 60 - 100 shipments. During 1999 and 2000 these shipments in Germany were stopped following concern over contamination of rail wagons.

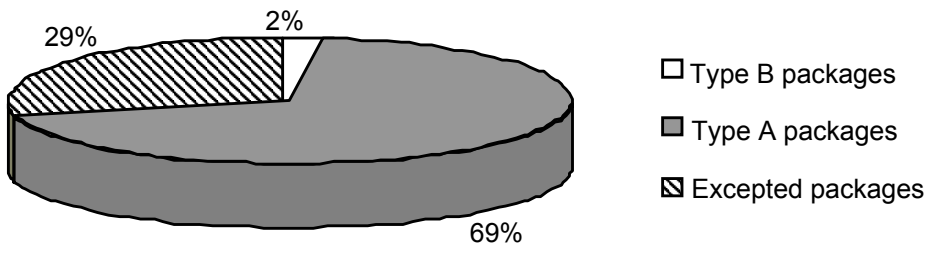
Figure 2: Trends in Italy



4. PACKAGE TYPES

The most comprehensive shipment data is that of package type. In most countries Excepted and Type A packages are the most frequently transported packages. Figure 3 shows the distribution of the total number of packages in all responding countries by package type. Shipment data are not complete since not all countries provided data on all package types.

Figure 3: Distribution of packages by type



There was considerable variation between countries, depending on the types of industries and operators. In Italy, the data show that Type A packages (56.4%) and Excepted packages (42.8%) are most frequently transported, whereas Type B packages represent only 0.2% and are related in large part to the transport of radiographic devices for non destructive testing. In France, 30% were Type A packages, 14% were Industrial Packages, 46% were Excepted packages, and 7% were Type B packages. In 0.4% of cases, the package type was not specified. In these countries the remainder consisted of bulk shipments of other types of packages.

5. ACTIVITY CONTENT

Type A and Excepted packages used for carrying materials for industrial and medical purposes generally contain much less than the maximum allowable activity, but in almost all countries, records of activity content are not comprehensive. However, in Italy the data collection system allows such data to be analysed. Data for the year 2000 is shown in Table 1 for Type A and Excepted packages. These materials are mainly radiopharmaceuticals in liquid or solid non-special form. The activity contents are expressed as fraction of the relevant A_2 value for the radionuclide being carried. Similar shipment data have been found to prevail in other EU Member States [3].

Table 1. Activity of the contents in Type A and Excepted packages

Activity (fraction of A_2)	Type A packages (%)	Excepted packages (%)
1 to 10^{-1}	11	-
10^{-1} to 10^{-3}	24	-
10^{-3} to 10^{-5}	41	19
10^{-5} to 10^{-6}	4	16
< 10^{-6}	20	65

In Italy, only 11% of Type A packages carried activities over 10% of A_2. About two-thirds of Excepted packages are used to carry very low activities (<10^{-6} A_2). In Italy there has been an increase in the percentage of packages of Category II-Yellow and III-Yellow shipped in the period 1997–2000. The reasons for this increase and for the increase of the total TI shipped are that there has been an increase in the average activity transported in a single package and an increase in the use of radionuclides with more penetrating radiations, for example ^{99m}Tc for medical diagnostic use.

6. TRANSPORT WORKER DOSES

Exposure data were not readily available in some countries. In general most occupational exposures were less than 1 mSv y^{-1} apart from a few handler/drivers delivering radionuclides for medical purposes. Figure 4 shows the average dose (indicated by the horizontal line) and the dose range (indicated by the vertical line) to these workers in 8 countries. Some countries were able to provide data for different types of transport operations so that the maximum annual worker doses for each sector could be compared. Figure 5 gives these comparisons of maximum reported transport worker doses for 7 countries. The data in Figure 5 are for the 1990s to the early 2000s. It should be noted that the maximum of the annual dose scale is at 20 mSv, which is the regulatory dose limit for workers.

There were similar findings from a number of countries on the dose distributions of transport workers. For example in a survey in Germany found 80 to 85 % of workers received annual doses below 1 mSv, while a relatively small number of driver/ handlers carrying medical, research and industrial radioisotopes had maximum annual doses in the range 10 - 14 mSv. This is also the situation in many of the other countries that supplied data. Trends in occupational exposure could be determined from records in some countries. In the UK, classified worker doses are kept on a national database. The data for transport workers for the years 1989 to 2001 shows that there was a significant reduction in the number of workers receiving doses in the higher dose ranges. This indicates that operators have made efforts to improve radiological protection practice. The overall reduction in the number of classified workers in transport is a trend also observed in other practices. One reason is the need to reduce the cost and administrative resources necessary for monitoring and controlling classified workers. The average dose to classified transport workers in the UK fell from 1.6 mSv in 1989 to 0.7 mSv in 2001. However, many transport workers, although not classified, are still monitored on a voluntary basis even though the majority of those workers receive doses below 1 mSv y^{-1}.

Figure 4: Worker maximum, minimum and average doses from road transport of radionuclides

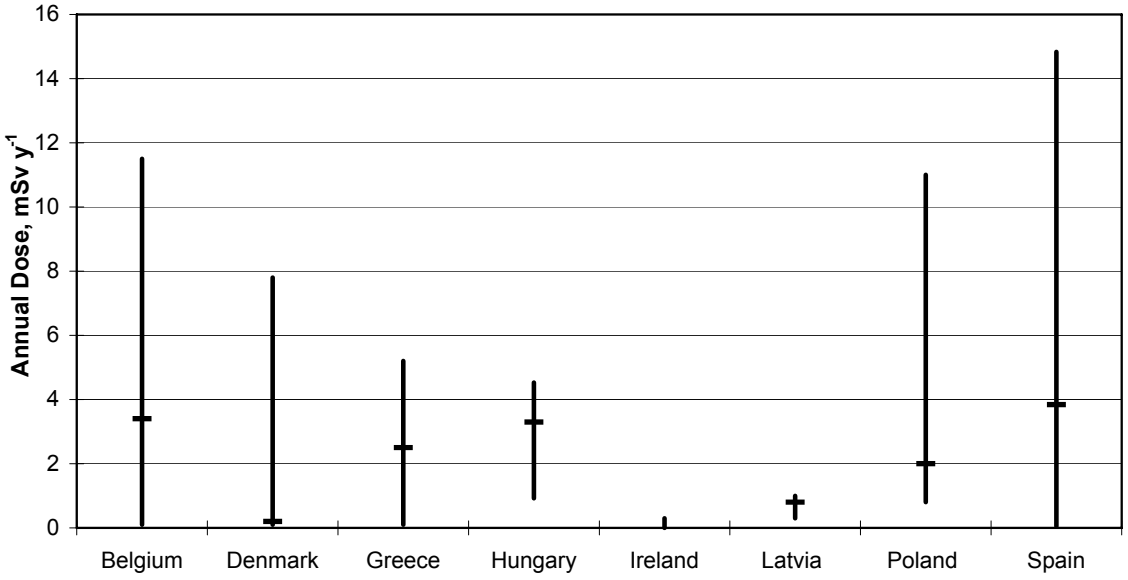
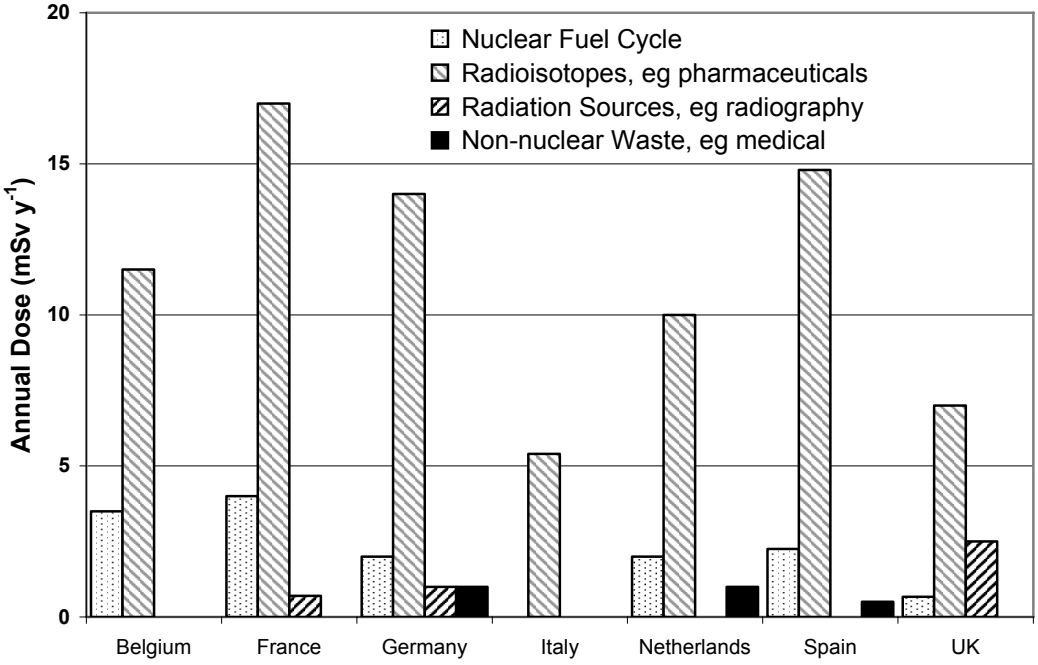


Figure 5: Maximum reported occupational exposures arising from the transport of radioactive material in some EU Member States



As noted above, in Italy the number of Category II- and III-Yellow packages have been increasing and this has led to higher occupational exposures. The average annual worker dose increased from 0.5 mSv in 1996 to 1.0 mSv in 2000. The comprehensive data from Italy also enables an estimate to be made of the collective dose incurred per Transport Index (TI) [4] transported. In recent years this has been 5 10^{-6} man Sv per TI. In the Netherlands, despite the increase of the number of packages, the collective doses of these handlers have decreased during the last few years due to operational and technical measures. The average collective dose per TI handled has been reduced from 10^{-6} man Sv per TI (1998) to 0.5 10^{-6} man Sv per TI (2001). Also the average collective dose per TI for drivers has been reduced from 0.8 10^{-6} man Sv per TI (1998) to 0.6 10^{-6} man Sv per TI (2001).

7. PUBLIC DOSES

In the five countries involved in the study there have been a number of assessments carried out to estimate doses to members of the public from transport operations. The estimated doses are to members of critical groups, and deliberately conservative assumptions are used to obtain maximum estimated annual doses. In Germany, the highest estimated annual dose was typically less than 0.1 mSv from nuclear fuel shipments. In France, these shipments stopping near buildings gave a maximum estimated annual dose of 0.2 mSv, while radioisotope shipments at a storage facility gave a maximum annual dose of 0.12 mSv. Also in France, shipments of wastes by road could give annual doses up to 0.07 mSv from vehicles waiting at traffic lights. In the Netherlands, the estimated maximum annual dose both from nuclear and non-nuclear shipments was 0.02 mSv. In the UK, 0.02 mSv was the maximum annual dose to sea and air passengers, while scenarios of annual exposures from road and rail transport were both less than 0.01 mSv. Calculations using the INTERTRAN 2 Code [5] in Italy gave a maximum annual dose from shipments of radioactive material for medical use of 0.0012 mSv. All the assessed critical group doses were much less than the annual dose limit of 1 mSv for members of the public.

8. CONCLUSIONS

Data on shipments of radioactive materials and resulting exposures have been obtained, where possible, for EU Member States and Applicant Countries. The data made available for the study cover 14 EU Member States and 11 Applicant Countries. Currently there are no standard systems for collecting shipment and exposure data. The data collected and briefly summarised in this paper are the first attempt to produce a shipment and exposure database in Europe: there are gaps and differences in the data.

Over 1 million packages of radioactive materials, primarily for use in medicine, research and industry, are transported each year in EU Member States. A major fraction of these radioactive material movements are transboundary shipments. Type A and Excepted packages are the most frequently transported package types, and the highest number of shipments is by road.

A small number of workers (drivers/ handlers) receive doses up to about 15 mSv y^{-1} although most worker doses receive around 1 mSv y^{-1} or less. The highest exposures are associated with the transport of radionuclides for medical, scientific and industrial uses. For members of the public, critical group doses have been estimated to be a small fraction of the dose limit for members of the public.

Overall, the study found that exposures of transport workers are generally low, and exposures of members of the public from these practices are extremely low. The level of safety being achieved in this area is therefore shown to be high. However, this situation could change if radiation protection requirements are not rigorously applied. For example, in 2002 a package with high dose rates was detected in the USA, after being shipped via an airport in France, where it was later found that the handling company had inadequate radiation protection controls. Periodic surveillance of the level of safety in these practices is also required because particular operators may start or cease operations, and there have been trends in the types of operations carried out. Therefore the study concluded that these practices should be kept under review.

9. SUMMARY

The latest available transport and exposure data were sought and generally provided for the late 1990s and early 2000s. The scope and level of detail of transport-related information varied and was generally broader for contractor countries (France, Germany, Italy, Netherlands, UK) than for non-contractor and applicant countries. The transport survey results available clearly indicate that over a million packages of radioactive material have been shipped annually in the recent years in the European Union and its Applicant Countries. The majority of these shipments consist of radiopharmaceuticals and other radionuclides for scientific and general industrial applications.

Fuel cycle shipments represent only a small fraction of the total radioactive material shipments but are generally the largest contribution to the activity transported. Similarly, except for France, radioactive material package shipments taking the form of portable radiographic or gauging radiation sources represent a small proportion of the national volumes of shipments of radioactive materials.

Road transport is the predominant shipping mode for all categories of radioactive materials. A significant fraction of the radioactive materials shipments of the major user and supplier countries are transboundary shipments between EU Member States.

Exposure data available from various countries demonstrate that transport worker exposures are generally low in most transport operations, the majority of doses are around 1 mSv y^{-1} or less. However for drivers/handlers involved with the transport of radionuclides for medical/research uses, a small number of workers receive doses up to a significant fraction of the dose limit. A number of countries reported annual doses of the order of 10 - 15 mSv for these workers. Public radiation exposures received from the transport of radioactive substances in the public domain are typically very low, with most returns stating that doses were below 0.1 mSv y^{-1} for critical groups.

10. ACKNOWLEDGEMENTS

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11. REFERENCES AND NOTES

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3. Assessment of the Radiological Risks of Road Transport Accidents involving Type A Packages, EC Report Contract No. 4.1020/D/96-002, October 1998 (Contributors: GRS: F Lange, H-J Fett, G Schwarz; CEPN: D Raffestin, T Schneider; NRPB: R.Gelder, J S Hughes, K B Shaw; SSI: B. Hedberg, P. Simenstaaad, B Svahn; NRG: J F A van Hienen, R Jansma).

4. The Transport Index (TI) of a package is a number that is used to provide control over radiation exposure, and is defined in the IAEA Transport Regulations [1]. For the packages in this study it is the number obtained by taking the maximum dose rate in mSv h^{-1} at a distance of 1 m from the surface of a package and multiplying this value by 100.

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