Review of Events Involving the Transport of Radioactive Materials in the UK, from 1958 to 2004, and their Radiological Consequences

J S Hughes, D Roberts and S J Watson

ABSTRACT

Radioactive materials are widely used in hospitals, industry and research. It is necessary for these materials to be transported from suppliers to customers, and for some radioactive wastes to be returned from customers to suppliers or to waste facilities. All these materials are normally transported by road. Radioactive materials associated with the nuclear industry are mainly moved by rail. Also, exports and imports of radioactive materials are made by sea and air. During these shipments events, or accidents and incidents, can occur. Records of these events are collated and held on the Radioactive Material Transport Event Database (RAMTED). The database contains information on over 800 events that occurred during the period 1958 to 2004. In this study these events were reviewed to examine trends and radiological consequences. The most serious radiological consequences occurred as a result of transporting improperly packaged industrial radiography sources. However, these events are historical, as there has not been such an occurrence for two decades. The analysis of the information in the database provides an overview of the types of events that have featured throughout the period covered.

This work was undertaken under the Environmental Assessments and Emergency Response Group's Quality Management System, which has been approved by Lloyd's Register Quality Assurance to the Quality Management Standards ISO 9001:2000 and TickIT Guide Issue 5, certificate number 956546.

This study was funded by the Department for Transport and the Health and Safety Executive

Approval: May 2006
Publication: July 2006
£14.00
ISBN 0 85951 577 X

EXECUTIVE SUMMARY

Radioactive materials are widely used in hospitals, industry and research. It is necessary for these materials to be transported from suppliers to customers, and for some radioactive wastes to be returned from customers to suppliers or to waste facilities. All these materials are normally transported by road. Radioactive materials associated with the nuclear industry are mainly moved by rail. Also, exports and imports of radioactive materials are made by sea and air. Up to half a million packages are transported in the UK annually, and during these shipments events can occur. Packages that are damaged, or poorly prepared, resulting in increased dose rates around the package, or releases of radioactive material from a damaged package, can have the potential for radiological consequences for workers and members of the public in the vicinity. The collection of information and lessons learned on such events can provide feedback to the regulatory process, or to local operational procedures, to improve safety in the transport of radioactive materials.

The types of events range from those that are serious enough to require statutory reporting to less serious events. The latter are often reported to the Department for Transport on an informal basis. Information on all these events are kept on official files at the Department for Transport (DfT), the Health and Safety Executive (HSE) and other bodies such as the Civil Aviation Authority (CAA). The details of these events have been entered into a database, known as the Radioactive Material Transport Event Database (RAMTED). The database was first compiled in the 1980s, and since 1989 annual reports have been published, giving brief descriptions and analyses of each year's events. RAMTED contains the details of 806 events that occurred from the earliest recorded in 1958 up to and including the year 2004.

The present study is a review of all the recorded events in the database to examine trends and radiological consequences. The most serious radiological consequences occurred as a result of transporting improperly packaged industrial radiography sources. However, there has not been such an occurrence for two decades, largely because of better training of radiographers. Individual whole-body doses over 1 mSv, or extremity doses over 50 mSv, were received in 19 (2.3%) events out of the total of 806. Almost all of those events occurred in the earlier years of the period, only two having occurred since the mid 1980s. In 65% of the events no doses were received above that expected for normal transport conditions.

The analysis of the information in the database provides an overview of the types of events that have featured throughout the period covered. For example, there was an increase in occurrences of excess contamination on flasks and rail wagons used to transport irradiated nuclear fuel (INF) from the late 1990s to the early 2000s. The occurrence of these events was reduced by improved conditions in power station storage ponds and more thorough cleaning and monitoring of INF flasks. During the 1970s there were many events involving packages being damaged at airport cargo centres, but their occurrence was greatly reduced by improvements in handling procedures. In the later years of the period covered events involving contaminated items and lost sources being discovered in scrap metal were included in the database.

Accidents and incidents that happen during the transport of radioactive materials, as in the transport of other types of materials, inevitably occur from time to time. However, the frequency of occurrence of such events, and their effects, can be reduced by the establishment of comprehensive radiation protection programmes and emergency procedures. Appropriate training of workers involved in these transport operations must always be a priority.

CONTENTS

1 INTRODUCTION

Radioactive materials are widely used in hospitals, industry and research. These materials are transported from suppliers to customers, and some radioactive wastes are returned from customers to suppliers or to waste disposal facilities. Also, radioactive materials associated with the nuclear industry are transported between nuclear sites. During these shipments accidents and incidents can occur, which are referred to in this report as events. Packages that are damaged, or poorly prepared, resulting in increased dose rates around the package, or releases of radioactive material from a damaged package, could result in the radiation exposure of workers and members of the public in the vicinity. The collection of information and lessons learned on such events can provide useful feedback to the regulatory process, or to local operational procedures, to improve safety in the transport of radioactive materials.

The UK Department for Transport (DfT), together with the Health and Safety Executive (HSE) have supported work to compile, analyse and report on events that occur during the transport of radioactive materials. The details of these events are recorded in the Radioactive Material Transport Event Database (RAMTED), which is maintained by the Radiation Protection Division of the Health Protection Agency (HPA-RPD) on behalf of DfT and HSE. Periodic reviews of these event data have been carried out over the last two decades (Gelder et al, 1986; Shaw et al, 1989; Hughes and Shaw, 1996b; Warner Jones et al, 2002b). Since 1989 annual reviews have been carried out (Hughes and Shaw, 1990-1999; Hughes et al, 2001a, 2001b; Warner Jones et al, 2002a; Warner Jones and Jones, 2004; Watson and Jones, 2004, Roberts et al, 2005).

The objectives of those annual reviews were:

- to assess the radiological impact of events involving the transport of radioactive materials on both workers and members of the public over the period of study;
- to comment on transport practices;
- to provide information pertinent to future legislation and codes of practice;
- to produce and maintain a database of events covering the period of study.

The main objective of the present study is to review and analyse all the events recorded in the database, which currently covers the period 1958 to 2004.

Much of the information in RAMTED is stored in a coded format, which allows the data to be retrieved and analysed, and for the results to be presented concisely. A comprehensive review was carried out of events that occurred in the period from 1958 to 1994 (Hughes and Shaw, 1996b). A further analysis of all events to the year 2000 was presented at the Sixth International Conference on Radioactive Materials Transport (Warner Jones et al, 2002b). The coding systems and the structure of the database were reviewed and revised in 2004 (Watson, 2004). The current coding systems are described in Section 3, and in the Appendices.

2 TRANSPORT OF RADIOACTIVE MATERIALS IN THE UK

2.1 Movements and types of radioactive materials

A few hundred thousand packages are transported in the UK annually (Watson et al, 2005). Many hospitals, in particular those with nuclear medicine departments, receive packages containing radionuclides from suppliers on a weekly, or even daily basis. These shipments are of a range of radionuclides for a variety of diagnostic, or therapeutic, uses. One of the most widely used radionuclides is ^{99m}Tc, which has a short half life and is derived from a small unit which contains the parent radionuclide, ^{99}Mo. These technetium generators need to be replaced on a regular basis and used generators are returned to the manufacturer. Technetium generators and other medical radionuclides are produced by a manufacturer in the UK that also exports thousands of such items annually. These items are shipped in packages by road to UK hospitals or airport cargo centres for export. Many of the radioactive materials used by hospitals are in liquid form.

One of the commonest uses of radioactive materials in industry is in gauges used for automatic measurement of the thickness of materials on a production line, or of the level of a material in a hopper or other type of container. These sources are transported to their site of use, and replaced periodically. Another type of gauge is used in the measurement of the surface being applied during road construction, and these gauges are transported from site to site. Other uses include industrial radiography, which can make use of a radioactive source to examine welds, castings and other objects for defects. These sources are carried in shielded containers and are transported from site to site, usually in small vans. The radioactive materials used in industry are usually in “special form”; that is, the material is enclosed in a small high-integrity capsule. In this form the material is very unlikely to be dispersed during an accident. This type of material must meet standards of mechanical and thermal integrity specified in the regulations (IAEA, 2005). Other types of radioactive material are known as “non-special form”, for example liquids or powders, and these have the potential for dispersal following a severe accident.

Radioactive materials are also transported by the nuclear industry. Nuclear power stations require regular supplies of new fuel, which is delivered by road. Spent fuel, after storage for a period at the power station, is transported in robust containers referred to in this report as irradiated nuclear fuel (INF) flasks. These are taken from the power stations by rail to a reprocessing/ storage site. A number of nuclear power stations are undergoing decommissioning and wastes from those sites are taken by road or rail to a waste processing and disposal facility. The raw material for nuclear fuel, uranium ore concentrate (UOC), is imported in drums by sea and transported to a fuel manufacturing site by road. During fuel enrichment uranium hexafluoride (UF_6) is manufactured which is transported into and out of the UK by road and sea in large cylinders. Uranium dioxide (UO_2) in powder and pellet form is also transported by road and sea.

2.2 Packages

The International Atomic Energy Agency (IAEA) defines various categories of packages to be used for the transport of radioactive materials in the latest edition of the IAEA regulations for the safe transport of radioactive materials (IAEA, 2005). These categories of packages were defined in previous editions of those regulations and have changed little over the period covered by this report. The types of packages regularly used in the UK are briefly described below.

2.2.1 Excepted

These packages are for low hazard materials, with activities below specified levels. The packages are of simple design and used mainly to transport the low activity materials used for medical diagnostic tests. If severely damaged it is assumed that most of the material might be lost from the package, but it would represent a low hazard to workers dealing with the package debris.

2.2.2 Industrial

These packages normally consist of steel drums or freight containers used to transport bulk materials such as wastes or mineral ores. UOC is normally transported in these packages.

2.2.3 Type A

These packages are widely used to transport industrial and medical materials. The IAEA regulations (IAEA, 2005) specify a limit on the activity content, depending on the radionuclide being carried. This limit ensures that in a typical mechanical accident in which the package is severely damaged the hazard from released material is restricted. The regulations also specify certain mechanical tests that the design of such packages must meet for normal, accident-free, transport. This ensures that the package will retain its contents after minor mechanical damage. However, Type A packages are not required to withstand fire, and a severe fire might result in the total loss of the contents.

2.2.4 Type B

For activities that exceed the Type A limits the more robust Type B package must be used. These packages are required to withstand mechanical tests that are more severe than the Type A tests. Further, Type B packages are required to withstand a severe fire. The IAEA specifies that they should withstand a temperature of 800°C for 30 minutes in a fully engulfing fire. These packages are most unlikely to be breached during any foreseeable event. Type B packages are used to carry high activity materials such as irradiated nuclear fuel and high-activity industrial radiography sources.

2.3 Emergency arrangements

For each mode of transport the applicable legislation requires the establishment of emergency arrangements for consignments to limit the effects of the event and to deal with any damaged packages. Also, the Ionising Radiations Regulations 1999 (GB Parliament, 1999) requires all operators to establish contingency plans to deal with emergencies involving radioactive materials. If the police are called to a scene of an accident involving the transport of radioactive materials, they may seek assistance from the National Arrangements for Incidents Involving Radioactivity (NAIR). This will summon assistance from a radiation expert to assess the extent of any hazard, and further assistance can be obtained through this scheme to deal with the clean up of contaminated debris. However, this is a background scheme and the primary responsibilities for emergency response rest with the consignor and carrier.

3 DATA REPORTING AND RECORDING

3.1 Reporting of events

The transport of radioactive materials covers a range of activities, including the preparation of the package by the consignor, and loading onto a vehicle, followed by the shipment phase by carriers using various modes of transport. The shipment phase may involve a number of loading and unloading operations between different modes of transport, before final delivery to the consignee. Events can occur at each of these stages of transport. For each mode of transport there are regulatory requirements to report such events, if they satisfy certain criteria. During 2004 the main relevant legislation was:

- Road – The Radioactive Material (Road Transport) (Great Britain) Regulations (GB Parliament, 2002a), 2003 Amendment (GB Parliament, 2003) and EC Agreement (UNECE, 2003);
- Rail – The Packaging, Labelling and Carriage of Radioactive Material by Rail Regulations 2002 (GB Parliament, 2002b), The Carriage of Dangerous Goods and Transportable Pressure Equipment Regulations 2004 (GB Parliament, 2004), and EC Regulations (DfT, 2003);
- Sea – The Merchant Shipping (Dangerous Goods and Maritime Pollutants) Regulations 1997 (GB Parliament, 1997), Merchant Shipping Notice MSN 1772 (MCA, 2003), and international Code (IMO, 2002);
- Air – The Air Navigation (Dangerous Goods) Regulations 1994 (GB Parliament, 1994), 2002 Amendment (GB Parliament, 2002c) and international Technical Instructions (ICAO, 2003).

For transport by road in Great Britain (GB), the regulations (GB Parliament, 2002a, 2003) require the driver of a vehicle transporting radioactive material to report a notifiable event to the police, fire brigade and consignor. A notifiable event is an event in which:

a) radioactive material is lost, escapes or is unlawfully removed from the vehicle carrying the material;

b) any package carried in or on a vehicle is opened or otherwise damaged (whether or not the package is still in or on the vehicle);

c) the vehicle carrying the radioactive material overturns (including being turned on its side) or suffers serious damage or is involved in a fire; or

d) a radiological emergency occurs;

e) there is an imminent risk of loss of product;

f) a person has suffered personal injury;

g) material damage or environmental damage has occurred, or

h) the authorities are involved.

Following this, the carrier must report the event to the police (if the driver has not already done so), the consignor and the Secretary of State for Transport. The notification of the latter is fulfilled by informing the Competent Authority; that is, the Dangerous Goods Division of the DfT.

In practice, many other less serious events are reported voluntarily by consignors, carriers and consignees. Other types of events that are relevant to the transport of radioactive materials may also be reported by others, such as the police, suppliers and manufacturers. There have also been a few instances where members of the public have found lost packages, and informed the police.

A system has been established to rate events that occur in the nuclear industry, by the International Atomic Energy Agency (IAEA) and the Nuclear Energy Agency (NEA) of the Organisation for Economic Co-operation and Development (OECD), and is known as the International Nuclear Event Scale (INES) (IAEA & NEA, 2001). This system enables a rating, from Level 0 to Level 7, to be applied to an event so as to give a prompt and consistent indication of the severity of the event to the media and members of the public. Level 7 refers to the most severe type of accident and Level 0 refers to an event with no safety consequences. The INES scale has been extended to cover other events, including events involving the transport of radioactive materials. Significant events are reported to the IAEA and the details are distributed, and made publicly available. The UK, in common with most other countries, only reports events that are rated at Level 2 or above.

Following the annual compilation of UK events, all but the most minor events are reported to the IAEA for inclusion in the IAEA's EVTRAM database, which is used to collect international data on transport events.

3.2 Data collection and recording

3.2.1 Event Information

Information on events has been obtained from a number of sources. Most of the information was obtained from official files at the Department for Transport (DfT) and the Health and Safety Executive (HSE). Information has also been obtained from other sources, such as the Civil Aviation Authority (CAA), the Department of the Environment in Northern Ireland and individual Radiation Protection Advisers (RPA). Other sources of information include events occasionally reported to the Environment Agency (EA) and records of events reported under the National Arrangements for Incidents involving Radioactivity (NAIR). Under the NAIR scheme, the police attending an incident involving radioactive material can summon assistance from a health physics expert in the region. However, only occasionally do these NAIR events directly involve the transport of radioactive materials.

The most significant accidents and incidents that are included in these reviews are those that give rise to increased radiation exposures during transport. In addition to these, events are included that had the potential for increased radiation exposures. There are some events in this group that may seem trivial, such as those involving administrative errors. However, experience has shown that in some circumstances such errors can have serious consequences. In practice, all but the most trivial of reported events are included in RAMTED. Events involving shipments from the UK are also included if the event was as a result of a failing in the UK. However, events occurring within consignors and consignees' premises, i.e. “on-site”, are not included unless they are relevant to transport in public areas or result in an occurrence during transit.

Incidents involving the transport of dangerous goods by rail are subject to standard reporting procedures. This system can result in quite minor events being reported very efficiently. Each year during the transport of irradiated nuclear fuel (INF) flasks there are a number of incidents where the train has been stopped following the detection of overheated axles or brakes. The detectors activate at temperature levels that do not pose a threat to the integrity of the INF flask. However, on occasions the overheating can result in smoke production and fires in the axle or brake areas. The criterion for including such events in RAMTED is whether smoke is apparent.

INF flasks are mainly loaded and unloaded underwater in ponds at nuclear power stations and reprocessing plants. The water in these ponds tends to be contaminated with radioactive material, and this contamination may become attached to the flask surfaces. Before transport, the flasks are thoroughly cleaned and monitored. The level of non-fixed contamination by radionuclides must be below the regulatory limit of 4 Bq cm^{-2} for beta emitters (and low toxicity alpha emitters) and 0.4 Bq cm^{-2} for alpha emitters (IAEA, 2005). For non-fixed contamination, the operational quantities used in industry related to these values are termed derived working levels (DWLs). Reports of excess levels of contamination on INF flasks are included in RAMTED if at any point on the surface the level is 10 DWLs or above. This criterion separates out those events where the regulatory limit is likely to have been exceeded.

Information is stored in RAMTED using descriptive text and coding systems for each feature of an event, as briefly described below. The information is of two types: the factual information gathered on the event, and the codes relating to how that event is classified within the system. Detailed descriptions of these features are given in Appendix A.

3.2.2 Factual information

The basic information on an event may consist of letters from consignors or carriers sent to DfT, or HSE, as formal notification of the occurrence. Other records may consist of notes of information sent by telephone or email. Incidents that have been the subject of an investigation by a Radiation Protection Advisor, or under the NAIR scheme, will normally be recorded in a short report. Each event is given a unique identification number which consists of the year of occurrence and a sequential number. The basic details recorded are:

- date of occurrence
- location of occurrence
- mode of transport
- type of material involved
- type of packages being carried
- the consignor, carrier and consignee
- radionuclides and activities carried
- Transport Index of packages
- source of the event information

The mode of transport and material category are further sub-divided into specific types. The record of the event includes a brief description of what happened, or the nature of the irregularity. Other information such as the consignor, carrier and consignee are included. Depending on the type of event, details of any emergency action are recorded, and information on any assessed doses received as a result of the event. The full list of items that can be recorded is given in Appendix A.

3.2.3 Event types

Most of the information on an event is coded using a system of codes that facilitate the analysis of the event data. The codes indicate what type of event it is and what its consequences were. When the database was first established abnormal occurrences (or events) during any phase of transport were divided into accidents, incidents and contamination events. Accidents and incidents were then further divided into those occurring in either the transport phase or the handling phase. Within the international, and national, system of legislation there are a number of definitions of accident and incident, which generally refer to the degree of severity of an occurrence, but are not necessarily consistent from definition to definition. To avoid any misunderstanding or further inconsistency, within the context of these studies the terms accident and incident are replaced by event. The description of the severity of an event is implicit within the detailed coding system described below. However, the division of the events into those occurring during handling or transport phase, and those involving contamination, has been retained.

Thus there are three broad types:

a) a transport event, which occurs during the movement phase of transport;

b) a handling event, which occurs during the preparation of the package, or subsequent loading, unloading or stowage operations; and

c) a contamination event, which involves excess radioactive contamination either outside or inside a package or conveyance.

The first two types separate out the physical or administrative irregularities into the main phases of transport operations. The third type is identified separately because contamination can arise in the absence of a physical or administrative event. These three overall classifications are separate from the detailed event definitions described below. They have been retained from the original system of classification, as they give a useful overview of the types and trends of all the events.

In addition to the simple division into the three types above, a more detailed classification system has been developed. This system is described briefly below, and is set out in detail in Appendix B. The system gives information for each event on three features: a definition (or classification) giving the type of event, the effects on the package and the radiological consequences.

3.2.4 Event classification

Events are divided into those involving administrative irregularities and those involving physical occurrences. The latter are further divided into those involving INF flasks and those involving other types of shipments. INF flasks are considered separately as they are subject to particular types of transport operations and therefore the occurrences tend to be unique to INF shipments. Events in these three areas are further divided into those involving the consignment or the conveyance, as shown in Appendix B, Table B1. The administrative category has a further subdivision of general events, which includes training, documentation and false alarms. All events are assigned a main or first priority classification. If an event has additional causes or features of non-compliance, further classifications can be applied as second or third priorities.

3.2.4.1 Administrative

These events consist mainly of breaches of the regulations concerning the consignor's certificate or other shipping documents, or training. Also included are incorrect or absent labels on packages, and vehicle placards. Although such events may be regarded as minor, they have the potential to have serious consequences if the presence of radioactive material is not indicated.

3.2.4.2 General shipments

These events include all the physical occurrences involving packages and conveyances (apart from INF flasks). It includes traffic events, lost or damaged packages and incorrectly prepared packages.

3.2.4.3 Irradiated Nuclear Fuel (INF) flasks

These events include all the physical occurrences and contamination events involving INF flasks, or the conveyances used to transport them. Any administrative irregularities involving INF flasks are grouped in the 'Administrative' area.

3.2.5 Physical consequences and effect on the package

Following an event involving the transport of radioactive material, the subsequent hazard to workers and members of the public from that material depends on the performance of the packaging. If the package is breached there could be a release of the material or a loss of the shielding provided by the package. Therefore it is important to record the effect of the event on the package. The possible effects are given in Appendix B, Table B2, ranging from cases where there is no package or no damage, to cases of severe damage with loss of containment, or loss of shielding. Incorrectly prepared packages are also included, as these are potentially serious if there is insufficient shielding. The range of possible effects also includes contamination of the package and/ or conveyance.

3.2.6 Radiological consequences

An event in which a package is damaged could result in leakage of its contents, or a loss of shielding. This could then give rise to elevated exposures of persons in the vicinity, by direct external radiation, or from intakes of the released material. Similarly a package prepared with insufficient shielding would give rise to excess exposures, especially to workers handling the package. Contaminated packages and conveyances also represent a potential radiological hazard as the radioactive material could be inadvertently ingested or inhaled. In some cases of inadequate, or loss of, shielding excess doses to workers in the vicinity have been recorded on personal dosimeters. If no dosimeter information is available an estimate of the accidental dose received can be made if the details of the exposure conditions are known. Such an accident will usually be subject to an investigation, and a report, from which exposure data can be obtained.

A simple grading system is used to categorise the possible radiological consequences, which is shown in Appendix B, Table B3. The lowest category is for events where there were no consequences (N). If there was an exposure that was likely to be slightly above that expected from normal transport, but no formal assessment was made, it is graded as “extremely low” (E). For more significant exposures for which an assessment of dose was made, the category is either “lower” (L) for doses below 1 mSv, or “upper” (U) for doses above 1 mSv. For extremity doses the boundary between the upper and lower categories is set at 50 mSv.

4 ANALYSIS OF EVENT DATA

4.1 Event type

As described above, events may be divided into three broad types: those occurring during the transport phase, those occurring during handling operations and contamination events. Up to the end of 2004 the database contained 806 events, of which 380 (47%) occurred during transport, 327 (41%) during handling operations, and 99 events (12%) involved contamination. Figure 1 shows the trend in these types of events; a feature of the trend is a peak in the number of handling events in the 1970s. These were mostly events involving damaged packages at airport cargo centres. Packages being moved on pallets carried by fork lift trucks would sometimes fall from the pallet and be crushed under the wheels of the truck. The frequency of these occurrences was greatly reduced by introducing better techniques to secure the packages during these movements. However this type of event still occurs occasionally. With these events removed from the data the trend in all other events is shown in Figure 2.

When the database was first compiled in the mid-1980s, the data on events was obtained from contemporary and archived files covering mainly the previous two decades. During those years the details of the events were not comprehensively recorded and it is probable that some events were not reported or recorded. The annual number of events for the earlier years is therefore

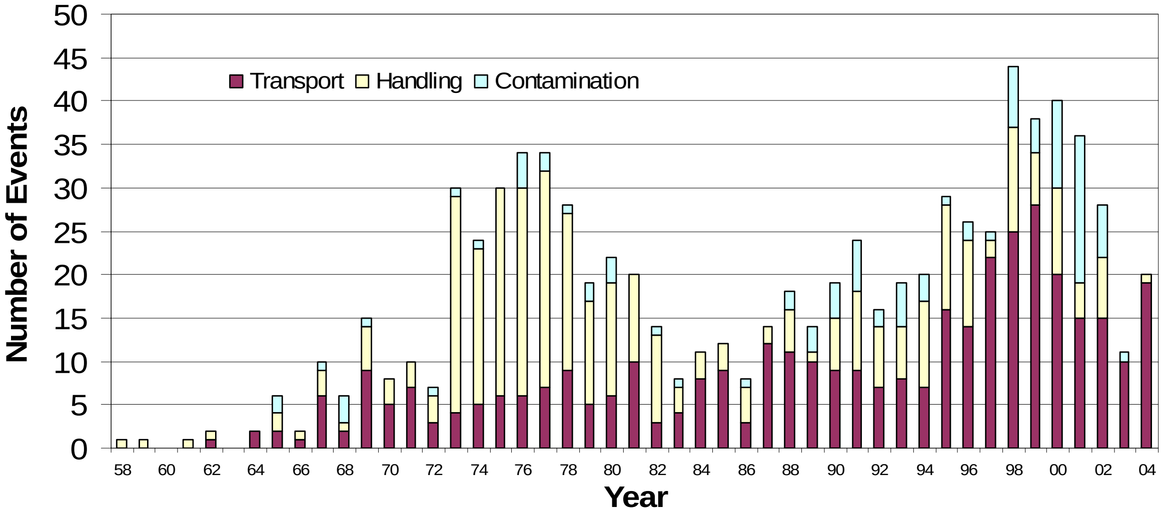

Figure 1 Annual trend in number of events by event type

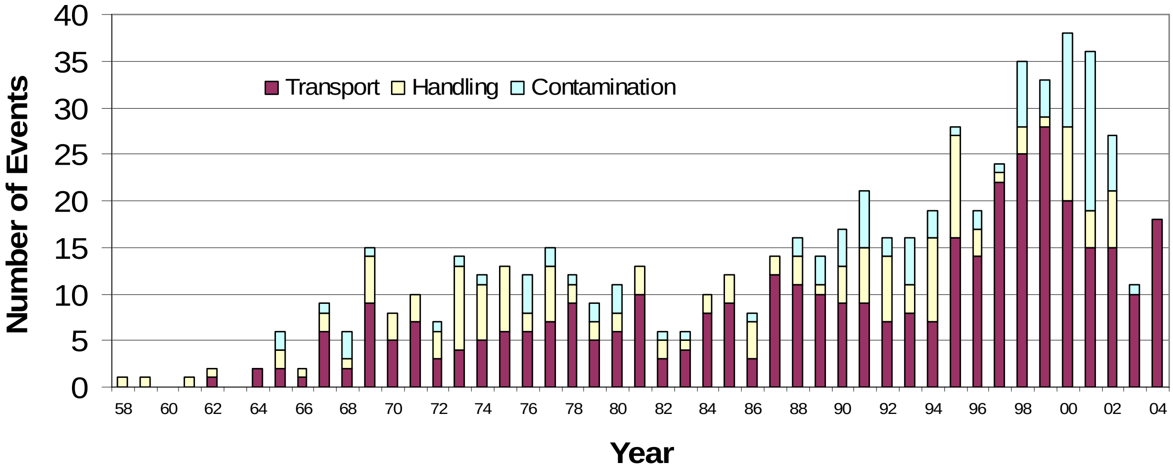

Figure 2 Annual trend in number of events by event type, excluding packages damaged at airport cargo terminals

likely to be underestimated. From soon after the establishment of the database, data has been collated on an annual basis. This is likely to have contributed to an increased collection efficiency that may partly account for the higher annual numbers during the 1990s. The annual number of events shown in Figure 2 displays a peak between the years 1995 and 2002. The rise in the annual number of events in the late 1990s is partly accounted for by the inclusion of new types of events such as contaminated scrap metal arriving at scrap yards. The increase in annual numbers of events in the late 1990s is further examined in Section 4.5. A further reason for this rise is the increased occurrence of cases of excess contamination on INF flasks. During 2003 and 2004 the annual number of events decreased to the level of that reported before the peak of the late 1990s.

4.2 Analysis by type of material

The type of material classifications used in the database (see Section A7) is an indication of their uses. For example, M01 to M05 are almost all associated with the nuclear industry, and M07 to M11 are associated with general industry and medical uses. Category M06 (radioactive wastes) can apply to both nuclear and non nuclear operations.

Table 1 gives an analysis of all the events by the type of material being carried. The events are divided into the three main categories: administrative, general shipments and INF flask shipments. There were 132 (16.4%) administrative events, 487 (60.4%) general shipment events, and 187 (23.2%) INF flask events. Medical and industrial isotopes (M07) had the highest number of events at 376 (47%). Material type M05 (residues) consists almost entirely of discharged INF flasks. The total number of this type and of those involving loaded INF flasks was 212 (26%). There were 33 (4%) events involving uranium ore concentrate, which were mainly damaged drums with some loss of contents. However, most of these occurred before the mid-1970s. Since then these drums have tended to be transported in freight containers which has virtually eliminated this type of event. There were 78 (9.7%) events involving the transport of industrial radiography sources, and many of these led to significant radiological consequences, as discussed in Section 4.7.

An analysis by material type and second priority classification is given in Table 2, and shows that 42 events were given a second classification. The largest single group consist of inappropriate stowage conditions of drums containing uranium ore concentrate. In these cases, this was determined to be the cause of the damaged drums, which was the primary classification.

Table 1 Analysis of events by material category and first priority classification

Material code	Material type	Administrative			General (non-INF) shipments		INF flask shipments		Totals
		Conveyance	General	Package	Conveyance	Package	Conveyance	Package	
M01	Uranium ore concentrate	0	3	1	4	25	0	0	33
M02	Pre-fuel material	0	1	1	10	10	0	0	22
M03	New fuel	0	1	2	1	3	0	0	7
M04	Irradiated fuel	0	12	0	0	0	36	53	101
M05	Residues[1]	0	7	1	1	4	57	41	111
M06	Radioactive wastes	0	13	1	11	38	0	0	63
M07	Medical & industrial isotopes	6	32	14	44	280	0	0	376
M08	Radiography sources	3	10	12	9	44	0	0	78
M09	No radioactive material	3	6	2	0	1	0	0	12
M10/ 11	Consumer products/ other	0	1	0	0	2	0	0	3
	Totals	12	86	34	80	407	93	94	806

[1]Including discharged INF flasks.

Table 2 Analysis of events by material category and second priority classification

Material code	Material type	Administrative			General (non-INF) shipments		INF flask shipments		Totals
		Conveyance	General	Package	Conveyance	Package	Conveyance	Package	
M01	Uranium ore concentrate	0	1	0	11	0	0	0	12
M02	Pre-fuel material	0	0	0	1	0	0	0	1
M03	New fuel	0	0	0	0	1	0	0	1
M05	Residues[1]	0	1	0	0	0	3	1	5
M06	Radioactive wastes	0	1	0	0	2	0	0	3
M07	Medical & industrial isotopes	1	4	5	3	0	0	0	13
M08	Radiography sources	0	1	4	0	1	0	0	6
M10/ 11	Consumer products/ other	0	1	0	0	0	0	0	1
	Totals	1	9	9	15	4	3	1	42

[1]Including discharged INF flasks.

Table 3. Analysis of events by mode of transport and primary classification

Mode code	Mode type	Administrative			General (non-INF) shipments		INF flask shipments		Totals
		Conveyance	General	Package	Conveyance	Package	Conveyance	Package	
V01	Rail	0	16	2	3	8	85	83	197
V02	Air	1	28	17	15	42	0	0	103
V03	Sea	1	7	4	3	37	0	3	55
V04	Road, Lorry > 1.5 t	2	19	6	29	55	8	4	123
V05	Road, Van < 1.5 t	8	12	4	27	53	0	0	104
V06	Road, Car	0	2	0	3	21	0	0	26
V07	Road, Unknown	0	0	1	0	4	0	0	5
V08	Fork-lift Truck	0	1	0	0	176	0	0	177
V09	Other	0	0	0	0	0	0	3	3
V10	Road and Sea	0	1	0	0	5	0	0	6
V11	Road and Rail	0	0	0	0	0	0	1	1
V12	Road and Air	0	0	0	0	6	0	0	6
	Totals	12	86	34	80	407	93	94	806

[1]Including discharged INF flasks.

4.3 Analysis by mode of transport

An analysis of the events by mode of transport and primary classification is shown in Table 3. The frequencies for each mode of transport are: road 32%, rail 24%, fork lift truck 22%, air 13%, sea 7% and the remainder 2%. The remainder includes 13 events that occurred during a combination of road transport with other modes, and 3 events involving crane operations. The analysis shows that events occurring with road shipments are the most frequent. However, a direct comparison of the numbers of events can be misleading, since, for example, events occurring on the railway tend to be much more efficiently reported than events occurring during road transport. Low speed derailments of wagons carrying INF flasks by rail are efficiently reported while a deflated tyre on a van carrying packages for medical uses is unlikely to be reported. Another major factor is the overall volume of shipments made of each material type. There are far more shipments made by road than by rail, and therefore a greater number of road events may be expected, compared to rail. An analysis by second classification shows the largest group of these to be the uranium ore shipments by sea, as noted in Section 4.2.

4.4 Analysis by primary event classification

The event classifications are listed in Table 4, along with the number of events that were given that classification as the primary classification.

4.4.1 Administrative events

Of the 132 administrative events reported in RAMTED the largest group included 33 (25%) events involving incorrect or absent package labels (AP111-AP131). The other main groups of events were, in decreasing order:

- incorrect or absent shipping documents (AG211-AG231) (24%);
- suspected event but not found (false alarms) (AG411) (21%);
- undeclared material (AG241) (14%) and,
- incorrect or absent vehicle placards (AC111-AC112) (8%).

Among the remainder were 4 cases of apparent loss of package resulting from an accounting error, which are similar to false alarms.

4.4.2 General shipment events

Of the 487 general shipment events (not including INF flask events), 80 (16%) involved the conveyance and 407 (84%) involved the package. The largest group of these were 231 (47%) events involving damaged packages (SP311 - SP351). The other main groups were, in decreasing order:

- incorrectly prepared, including contaminated, packages (SP111-SP171) (16%)
- lost and stolen packages (SP211-SP232) (14%);
- collisions involving the conveyance (SC511-SC611) (11%), and
- radioactive material in scrap metal, and inappropriate disposal (SP241-SP251) (6%).

Table 4 Numbers of events in each classification

Event code	Event description	Number of Events
Administrative		
AC111	Correct vehicle placards not displayed	7
AC112	Placards displayed but no sources carried	3
AC211	Excessive TI on conveyance or in stowage hold	2
AG111	Insufficient worker training	2
AG211	Consignor's certificate incorrect or absent	11
AG221	Other shipment documents incorrect or absent	19
AG231	Correct documents, but wrongly described in documents	2
AG241	Material undeclared as being radioactive	18
AG251	Accounting error, i.e. apparent loss of package	4
AG311	Administrative difficulty or error, returned to consignor or re-consigned	2
AG411	Suspected incident but none found	28
AP111	Insufficient or incorrect package labels	24
AP112	Labels on empty package	2
AP121	Incorrect TI on package label	5
AP131	Incorrect radionuclide or activity on package label	2
AP211	Package type unmarked or wrongly marked	1
Shipments, general (non irradiated fuel)		
SC111	Excessive load on conveyance	2
SC211	Faulty conveyance, or mechanical failure	4
SC311	Locks or security devices: insecure, insufficient or defective	1
SC411	Tie-downs or similar devices: insufficient or defective	5
SC511	Collisions and other accidents, without fire	49
SC611	Collisions and other accidents, with fire	7
SC711	Spontaneous fire on conveyance	5
SC811	Inappropriate stowage conditions	7
SP111	Poor standard of packaging or containment	15
SP121	Incomplete package, insecure inner container	4
SP131	Incomplete package, insufficient shielding	23
SP141	Incorrect contents or package type	13
SP151	Material in supposedly empty package	9
SP161	Contamination inside package	10
SP171	Contamination outside package	5
SP211	Stolen, and recovered	15
SP212	Stolen, not recovered	5
SP221	Lost, found, temporary loss, wrong destination or wrong conveyance	27
SP222	Lost, not recovered	14
SP231	Lost at sea and recovered	2
SP232	Lost at sea not recovered	6
SP241	Inappropriate disposal	11
SP251	Radioactive material in scrap metal	17

Event code	Event description	Number of Events
SP311	Spontaneous mechanical failure of package, including leakage	9
SP321	Deliberate damage or interference	1
SP331	Damaged by falling from or within conveyance, or by falling object, or by external object	24
SP341	Damaged during cargo handling	195
SP351	Damaged due to broken or loose tie-downs	2
Flasks (irradiated nuclear fuel)		
FC111	Wagon or HGV problem e.g. buffers, brakes, canopy not correct, including significant overheating of wheel or axle	20
FC211	Collision	16
FC221	Derailment during low speed marshalling	29
FC241	Fire on the conveyance	3
FC311	Wagon or HGV contaminated above 10 DWL	25
FP111	Shock absorber damaged or unsatisfactory	1
FP121	Tie-down bolts insufficient or defective	2
FP131	Lid, defective or loose bolts	4
FP132	Lid seal unapproved or obsolete	2
FP141	Water level valve defective	3
FP151	Discharged flask containing fuel rod, excessive deposit or other incorrect contents	6
FP161	Faulty test procedures	2
FP171	Fuel not fully covered by water	2
FP181	Other minor preparation error	1
FP211	Mishandled during loading or unloading	3
FP221	Venting system or valve problem	4
FP311	Contamination of surface above 10 DWL	62
FP321	Other: poor standard of decontamination	2
Total		806

The remainder mainly consist of faults involving the conveyance. Of the 69 (14%) packages lost or stolen, 20 were not recovered.

4.4.3 INF flask events

There were 187 events during the shipment of INF flasks, involving flasks and conveyances in almost equal numbers. The largest group of these involved 62 (33%) occurrences of excess contamination on the surface of the flask (FP311). The other main groups of events were, in decreasing order:

- collisions and low speed derailments of the conveyance (FC211-FC221) (24%);
- flask preparation faults, and loading/ unloading faults (FP121-FP221) (16%);
- excess contamination of conveyance (FC311) (13%), and
- faults involving the conveyance (FC111) (11%).

The remainder included 3 cases involving fire on the locomotive (FC241), but in each case the flasks were not affected.

4.5 Trends by event classification

Figure 3, which shows the annual number of administration events, indicates a general increase in the annual numbers of administrative events since the mid-1980s. It is likely that this is due to the higher efficiency of event reporting and recording throughout this period (see Section 4.1). The majority of these events are in the "general" category, which includes irregularities in shipping documents and false alarms. These are all minor in nature but proper documentation is essential for the safe transport of radioactive materials.

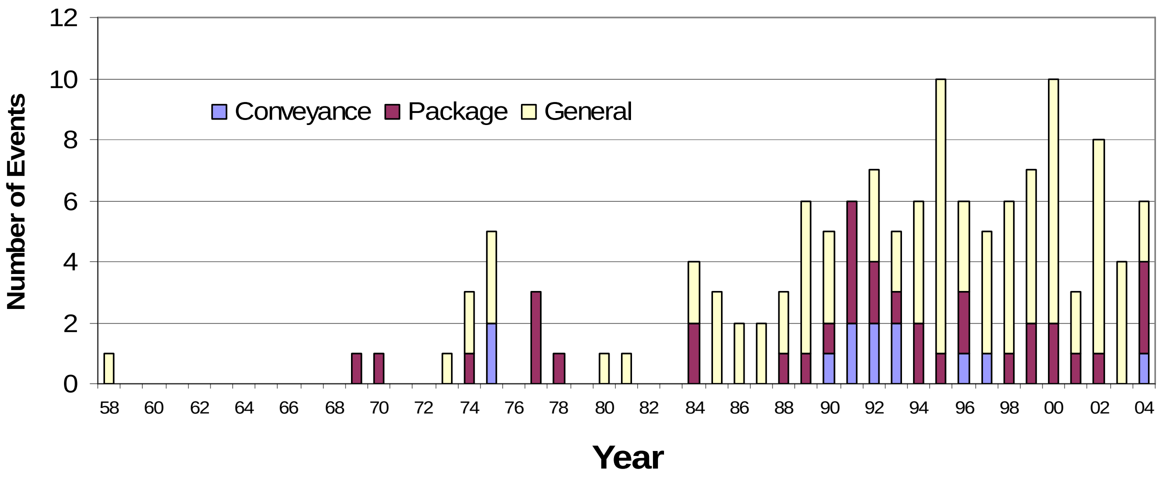

Figure 3 Annual trend in numbers of administration events, by conveyance, package and general subcategories

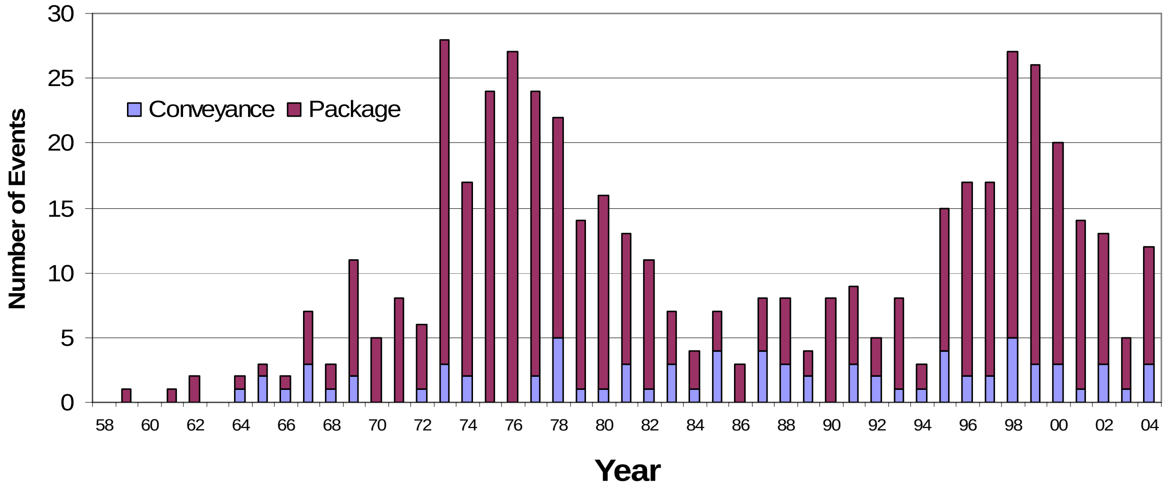

Figure 4 Annual trend in numbers of non-INF events, by package and conveyance subcategories

Figure 4, which shows the annual number of events of the general shipment type, displays two peaks. The first, in the 1970s, includes the packages damaged at airports, discussed earlier in Section 4.1. The second occurs between the years 1995 and 2004. An analysis of these events shows that within this period there was an excess of lost and stolen packages (SP211-SP222), and an excess of instances of packages poorly prepared for transport (SP111-SP171). Some events involving packages damaged at airports also contributed to this peak in the annual number of events during the late 1990s. It is unclear if this represents a genuine deterioration of safety standards or is due to more thorough reporting. Also, from 1995 new types of event started to be recorded, such as radioactive material being discovered at scrap metal yards and subsequently transported without the necessary requirements. The development of this trend will be monitored in future annual and periodic reviews of transport events.

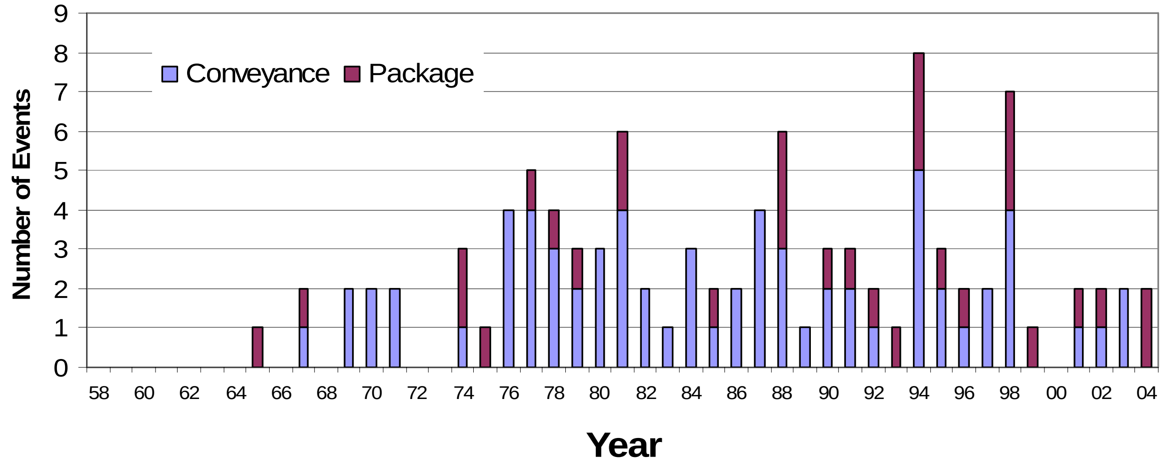

Figure 5 Annual trend in numbers of INF events, by package and conveyance subcategories (excluding contamination events)

Figure 5 shows the numbers of events involving INF flasks, but excluding contamination events. There are fluctuations in the annual number, with no strong indication of a trend up to the turn of the century. However, the annual numbers in the last few years have been consistently low.

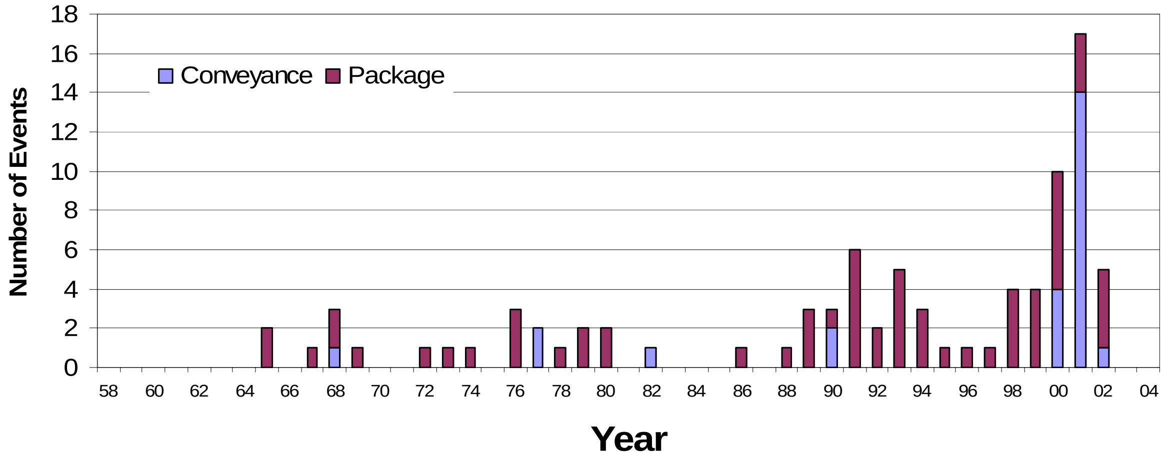

Figure 6 Annual trend in numbers of INF events involving contamination, by package and conveyance subcategories

Figure 6 displays the annual number of events involving excess contamination on INF flasks and their conveyances. In the last few years, in particular in 2000 and 2001, there was a significant increase in the occurrence of excess contamination of flasks and rail wagons. These events have their origin in the increase in the ^{137}Cs concentration of some of the cooling ponds of nuclear power stations. The flasks are lowered into these ponds to be loaded and during this time ^{137}Cs is adsorbed into the paintwork and crevices of the flasks. Although there is extensive decontamination of the flasks after their removal from the ponds, some fixed contamination can leach from the surface. This non-fixed contamination may be detected when the flask is checked on arrival at the consignee's site. Also, during carriage on the rail wagon some of this non-fixed contamination can be washed, e.g. by rain, onto the surfaces of the wagon. A campaign to reduce the pond concentrations of ^{137}Cs was undertaken, with more thorough decontamination procedures. This led to a sharp reduction in the numbers of these events in 2002. There were no such events in 2003 or 2004.

4.6 Analysis of package effects and deficiencies

The record of each event contains a description of what happened, if anything, to the package, or whether there was some fault in the package that gave rise to the event. Table B2 in Appendix B gives the descriptions of these effects, and some examples of the type of event. Table 5 gives an analysis of these effects on the package according to type of package. In some events only one package was involved, whereas in some events many packages may have been involved, for example if a van carrying many packages overturns. In other events only one of a number of packages being carried may have been deficient in some respect. The type of package noted in Table 5 refers to the affected package or to the main type of package in the shipment involved in the event.

Table 5 Nature of package deficiency by package type

Package deficiency code and description		Package type						Total
		B	A	E	IP	O	Con	
D01	No package	0	0	1	0	23	0	24
D02	Contaminated conveyance	7	0	0	0	0	18	25
D03	No damage or threat of damage to package	68	52	23	18	4	0	165
D04	No report of damage/inc. dose rate. Potential for damage (lower category)	67	26	8	9	0	0	110
D05	No report of damage/inc. dose rate. Potential for damage (upper category)	7	41	14	11	5	0	78
D06	Defective/Poor condition. No increase in dose rate or loss of containment	17	9	0	2	2	0	30
D07	Minor damage. No increase in dose rate or loss of containment	7	95	9	8	5	0	124
D08	Severe damage. No increase in dose rate or loss of containment	3	60	9	0	14	0	86
D09	Damaged. Increase in dose rate. No loss of containment (Shielding loss only)	0	7	0	0	0	0	7
D10	Damaged with loss of containment	0	11	5	23	1	0	40
D11	Contamination inside package	6	3	1	1	1	0	12
D12	Contamination outside package	65	0	0	2	4	0	71
D13	Improper package with loss of shielding or containment – inappropriate contents	3	3	0	2	0	0	8
D14	Improper package with loss of shielding or containment – inadequate shielding	7	16	0	3	0	0	26
	Totals	257	323	70	79	59	18	806
Key: B – Type B, A – Type A, E – Excepted, IP – Industrial, O – Other, Con – Contaminated conveyance only								

The analysis shows that the proportions involving the main package types were: Type A, 40%, Type B, 32%, Industrial packages, 10%, Excepted, 9%. The remainder consisted of contaminated conveyances only (2%), and events involving other types of package or material that was not packaged (7%).

Of the total of 806 events, 63% involved packages that were either not damaged or suffered only minor damage, with no loss of contents or increase in package surface dose rate (D03-D07). In a further 11% of the events the package was severely damaged but there was no loss of contents or increase in surface dose rate (D08). Only in 6% of cases was there some increase in dose rate or loss of contents as a result of the event (D09-D10). Packages were contaminated in 10% of the events (D11-D12). Packages improperly prepared for transport (D13-D14) accounted for only 4% of the events, but many of these events resulted in the highest radiological consequences, as noted in the following section. The remaining 6% of events consisted of contaminated conveyances only, or items that were not packaged such as depleted uranium weights, or contaminated items that were transported to and from scrap metal yards (D01-D02).

Not all the records of events specify the radionuclides being carried, but the information on package contents gives a cross section of the radionuclides being shipped. Events can involve the carriage of just one package, or several packages. An analysis was carried out of the radionuclides being carried in each package for which there was this information. The numbers of packages carrying specified radionuclides were listed in ranges as shown in Table 6. For example ^{110m}Ag was noted in very few packages (4 or less). The large volume of packages containing ^{131}I being shipped to hospitals is reflected in the number of these packages involved in events (50 - 99 range). Similarly ^{192}Ir used for industrial radiography features significantly in the recorded events. The events involving INF flasks (noted as containing fission products) appear as the largest single material. This predominance is partly due to the very efficient reporting of these events as discussed in Section 4.3.

Table 6 Radionuclide contents of packages

Number of packages	Radionuclides recorded
0-4	^{110m}Ag, ^{198}Au, ^{133}Ba, ^{10}Be, ^{7}Be, ^{82}Br, ^{41}Ca, ^{45}Ca, ^{252}Cf, ^{36}Cl, ^{152}Eu, ^{154}Eu, ^{55}Fe, ^{67}Ga, ^{203}Hg, ^{123}I, ^{132}I, ^{111}In, ^{85}Kr, ^{54}Mn, ^{24}Na, ^{63}Ni, ^{33}P, ^{210}Pb, ^{147}Pm, ^{238}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu, ^{224}Ra, ^{225}Ra, ^{86}Rb, ^{35}S, ^{124}Sb, ^{85}Sr, ^{87m}Sr, ^{178}Ta, ^{99}Tc, ^{99m}Tc, Th(nat), ^{228}Th, ^{232}Th, ^{204}Tl, ^{234}U, ^{88}Y, ^{90}Y, ^{65}Zn, ^{95}Zr
5-9	^{57}Co, ^{51}Cr, ^{22}Na, ^{210}Po, ^{239}Pu, ^{201}Tl, ^{133}Xe
10-19	^{241}Am/Be, ^{99}Mo, ^{32}P, ^{226}Ra, ^{75}Se, ^{90}Sr, U (dep)
20-49	^{241}Am, ^{14}C, ^{60}Co, ^{137}Cs, ^{125}I, T(^{3}H), U (nat), ^{238}U
50-99	^{131}I, ^{192}Ir
100-149	Unknown
>149	Fission products (mainly INF flasks)

4.7 Analysis of radiological consequences

Since in 90% of the events there was no containment loss or reduced shielding, the potential for any appreciable radiological consequences is rare. The events were analysed by material type and radiological consequences using the system of grading set out in Table B3 of Appendix B. Table 7 gives this analysis and shows that in 527 events (66%) there were no consequences, and a further 241 events (30%) any consequences were extremely low. Within this latter category are included all the cases of excess contamination of INF flasks, since with contamination above the statutory level it is deemed that there is potential for exposures slightly above that for normal transport conditions.

Estimates of individual doses were made in 38 events, of which 19 (2%) were less than 1 mSv. Ten of these 19 events involved the transport of industrial and medical radionuclides. In a further 19 events (2%) an assessment of exposure indicated received doses over 1 mSv. In some of these the doses were appreciable. All the high dose events involved industrial radiography sources that were transported without being properly returned into their containers. In most of these events, which occurred mainly in the 1970s, the radiographer received a radiation dose from the partly shielded source while carrying the equipment away after its use. The most serious of these events occurred in 1968 and resulted in an individual dose estimated as up to 2 Sv. The estimated dose to a hypothetical member of the public was up to 2 mSv. That particular incident was due to a malfunctioning radiography container and probably caused by poor maintenance. These types of events have not occurred in the past two decades as better training of the radiographers has made them aware of the need to check that the source has been properly returned into its container before onward transport. The events involving the shipment of INF flasks, or other nuclear materials, did not give rise to any exposures over 1 mSv.

Table 7 Radiological consequences by material category

Material Code	Material Type	None	Not Assessed, Extremely Low	Assessed, Lower Category (<1mSv)	Assessed, Upper Category (>1mSv)	Total
M01	Uranium ore concentrate	14	18	1	0	33
M02	Pre-fuel material	20	2	0	0	22
M03	New fuel	4	2	1	0	7
M04	Irradiated fuel	69	32	0	0	101
M05	Residues (inc discharged INF flasks)	42	68	1	0	111
M06	Radioactive wastes	35	23	4	1	63
M07	Med & Industrial Radioisotopes	282	81	10	3	376
M08	Radiography sources	48	13	2	15	78
M09	No radioactive material	11	1	0	0	12
M10 & M11	Consumer products/ other	2	1	0	0	3
	Totals	527	241	19	19	806

Table 8 gives a brief description of all the significant events involving workers or members of the public. The last significant event involving a radiography source, as described above, was in 1985 and gave rise to an individual dose of about 600 mSv. In the past two decades elevated exposures from transport events have been very rare. In 1996 a worker incorrectly removed some ^{241}Am sources from some equipment and damaged them. The sources were transported to a waste reception site in a van which resulted in the contamination of the inside of the vehicle. The worker's clothes were also contaminated, and another worker was also contaminated. Furthermore, the wife of the worker was exposed to the contamination from that clothing. The two workers were estimated to have received 20 mSv and 2 mSv from intakes of ^{241}Am; the wife of the worker was estimated to have received less than 1 mSv.

In 1996 a driver carried a contaminated lid spacer from an INF flask in his cab for several hours. The operators failed to check the item for contamination and provide appropriate packaging. However, the driver received only a very low dose of a few microsieverts. In 1997 an imported technetium generator containing 0.23 TBq of ^{99}Mo/^{99m}Tc was discovered to have surface dose rates more than five times the legal maximum of 2 mSv h^{-1}. It was found that some material had leaked internally outside the shielding, but there was no external leakage. The package had been imported by air and it was estimated that the maximum dose to a passenger and a crew member would have been about 0.6 mSv and 0.4 mSv respectively. The maximum dose to a loading worker was estimated at about 0.3 mSv.

An event occurred in 2002 that had the potential for serious radiological consequences. However, since it was the subject of a prosecution, the details were only made public while this report was being compiled, and therefore are not included in this review. A

Type B container was being used to transport a 129 TBq ^{60}Co radiotherapy source and on arrival it was found that a shielding plug was not in place. This resulted in a high dose rate beam which emerged from the container during its transport. Fortunately the beam was directed vertically downwards to the road surface and it is estimated that the radiological consequences were very low. The details of this event will be described in the next annual report of events, for the year 2005.

Table 8 Events resulting in excess exposures of workers and members of the public

Year	Material category	Brief description of event	Worker dose, mSv		Public dose, mSv
			Extremity	Whole-body	Maximum individual
1967	Radioisotopes	Cylinder containing 18 GBq ^{137}Cs sources on deck of ship were damaged in a storm and shielding was lost	-	<1	-
1967	Uranium Ore Concentrate (UOC)	UOC drum fell from a lorry, with some spillage of contents	-	0.02	-
1968	Radiography source	^{192}Ir source fell out of container due to failure of retaining bolt	730 410 73	2,380 510 52	2
1969	Radiography source	Detached source placed in a van was exposed during journey	2 x 1,000	460 510	0.17
1969	Radioisotopes	Neutron source modified, shield drilled through partially exposing source	1.8	0.3	-
1969	Radiography source	Deliberate exposure to ^{192}Ir source. Vehicle driver exposed	-	500	0.13
1970	Radiography source	Two customs officers opened unlabelled suspect package and held ^{147}Pm source with bare hands.	2 x 78	-	-
1971	Radioisotopes	Source filed to fit collimator. Widespread ^{137}Cs contamination	-	6 x 1	-
1972	Radiography source	^{192}Ir source partially exposed. No monitoring carried out	-	2 x 150	-
1973	Radiography source	^{192}Ir source left out of container during transport and left in van overnight unshielded	-	84 62 6	-
1974	Radioisotopes	Package crushed by fork lift truck then continued journey to Germany. Widespread ^{90}Y contamination.	-	2 x 0.14	-
1975	Radioisotopes	Attempt to repair soil density gauge in field. ^{137}Cs fell out and was repeatedly handled	10 5	2 x 0.1	-
1975	Radiography source	Source shutter open during journey. ^{192}Ir source exposed	-	2 x 15	-
1975	Radiography source	^{192}Ir source fell from guide tube during use. Exposed during subsequent journey	-	200 2 x 10	0.8
1975	Radiography source	Container supposed to be empty. Loose lid fell off exposing two ^{192}Ir sources	5,000	4	-

Year	Material category	Brief description of event	Worker dose, mSv		Public dose, mSv
			Extremity	Whole-body	Maximum individual
1976	Radioisotopes	^{192}Ir source partly exposed during transport	-	55	0.05
1977	Radiography source	Shielding container faulty. No labelling, driver unaware of cargo contents	-	2 x 100	0.2
1979	Radioisotopes	Three packages fell and ^{60}Co source was exposed. Driver took no action and continued journey.	0.05	0.002 0.02	-
1979	Radiography source	Incorrectly shielded container used and not monitored prior to journey	2.4	2 x 8 2	-
1979	Radioisotopes	Aircrash followed by fire. Release of activity in cargo bay area	-	4 x 0.1	-
1980	Radioisotopes	Technetium generator leaked internally, with increase in dose rates. No escape of material	0.12	0.21	-
1981	Radiography source	^{192}Ir source incorrectly packaged leading to excessive dose rates	-	12 5	-
1981	Radioisotopes	Technetium generator leaked internally, with increase in dose rates. No escape of material	0.07	0.01	-
1982	Radioisotopes	Damaged wooden crate containing ^{137}Cs source taken for repair	-	0.1	-
1982	Radiography source	Wrong container used for ^{192}Ir source	-	4 x 19	-
1983	Radiography source	Source retaining screw failed leading to exposure of ^{192}Ir source	14	14 7 x 1	-
1985	Radiography source	^{192}Ir source exposed in guide tube in van. Driver failed to monitor and drove for about 1 hour.	-	600	-
1992	Radioisotopes	A laboratory ordered 74 MBq of ^{32}P but received 74 GBq, due to an error. Technician received excessive hand dose	200	-	-
1996	Residues	A contaminated flask lid spacer carried in a vehicle cab. The driver and another worker received low doses.	0.052 0.070	0.0065	-
1996	Radioisotopes	Four 3.7 GBq ^{241}Am damaged sources transported in van. The driver, another worker and a member of the public were exposed to contamination.	-	20 2	<1
1997	Radioisotopes	Technetium generator leaked internally. Increased dose rates on aircraft caused low exposure of loading worker, crew and passengers.	-	0.3 0.4	0.6

5 DISCUSSION AND CONCLUSIONS

The RAMTED database of transport events currently covers the period from 1958 to 2004, and contains information on 806 events. Considering the large number of shipments of packages containing radioactive material in the UK, the annual number of events is very small. The great majority of these events have resulted in either trivial or no radiological consequences. Analyses of these data are useful in tracking trends, giving factual information on specific types of events and learning lessons. There are limitations on the use of the data as many records, particularly for the earlier years, do not contain all the necessary details. The efficiency of reporting and recording is improved in later years, when information was gathered annually. While some minor events may have not been reported in earlier years, all the major events since the 1960s are included.

Within the period covered there are examples of some events featuring more significantly. In the 1960s and early 1970s there were many instances of drums of UOC being damaged either in cargo holds of ships or on docksides during unloading operations. These events were virtually eliminated by transporting the drums in freight containers, from about the mid-1970s onwards. During the 1970s there were many packages damaged at airport cargo centres, while being moved by fork lift trucks. Better handling techniques reduced the annual number of these occurrences. However, these are still likely to occur and a number of these events contributed to a rise in the overall annual number of events in the late 1990s. There were a number of events, mainly during the 1970s, involving the transport of unshielded industrial radiography sources, which led to the most significant radiological consequences of all transport events. Better training of radiographers virtually eliminated these events since the 1980s. During the late 1990s and early 2000s there was a significant increase in occurrences of excess contamination on INF flasks and rail wagons. The number of these occurrences has decreased as a result of improvements in the cleaning and monitoring of INF flasks, and reductions in the radionuclide concentrations of the cooling ponds at some nuclear power stations. During the later years of the period there were increases in events involving shipments of decommissioning wastes, and new types of events were included which involved contaminated scrap metal and sources discovered at scrap yards.

There was no evidence that packages prepared according to the standards specified by the IAEA transport regulations (IAEA, 2005 edition and previous editions) under-performed in any of the events. In particular there was no event involving a properly prepared and maintained Type B package where any of the contents were lost.

In the period since the previous review (Hughes and Shaw, 1996b) there has only been one event that resulted in an appreciable dose to a worker. That event resulted in a maximum dose of 20 mSv from intakes of ^{241}Am from some damaged sources. Before that the most radiologically significant events were those involving incorrectly shielded industrial radiography sources. An examination of the events listed in Table 8 show that almost all could have been prevented by properly monitoring the package before transport, and in that sense the basic causes of these events were human error and lack of appropriate training. The reduction of serious events in the last 20 years shows that this situation has improved.

Although there is rarely enough information to specify the root cause of each event, almost all of the administrative events, as well as events involving poor preparation and maintenance of packages, are likely to be due to human error or poor training. An examination of the numbers of events which were very likely to have been due to human error, poor training or poor procedures (see Table 4) shows that these comprise roughly half of all the events in the database. The 1996 edition of the IAEA transport regulations (IAEA, 1996) introduced the requirement for radiation protection programmes, and this requirement entered UK legislation in 2002 (GB Parliament, 2002a). The adoption of these programmes by UK operators should further improve safety in the transport of radioactive materials and make training a priority.

6 REFERENCES

DfT (2003). Department for Transport. Convention concerning the International Carriage of Dangerous Goods by Rail (COTIF) Appendix B. Uniform rules concerning the contract for the International Carriage of Goods by Rail (CIM) Annex 1, Regulations concerning the International Carriage of Dangerous Goods by Rail (RID) (Class 7) (2003).

GB Parliament (1994). The Air Navigation (Dangerous Goods) Regulations, 1994, SI 1994 No 3187. London, HMSO.

GB Parliament (1997). The Merchant Shipping (Dangerous Goods and Maritime Pollutants) Regulations 1997, SI 1997 No 2367. London, HMSO.

GB Parliament (1999). The Ionising Radiations Regulations, 1999, SI 1999: 3232, London, HMSO.

GB Parliament (2002a). The Radioactive Material (Road Transport) (Great Britain) Regulations, SI 2002 No 1093. London, HMSO.

GB Parliament (2002b). The Packaging, Labelling and Carriage of Radioactive Material by Rail Regulations, SI 2002 No 2099. London, HMSO.

GB Parliament (2002c). The Air Navigation (Dangerous Goods) Amendment Regulations 2002, SI 2002 No 2786. London, HMSO.

GB Parliament (2003). The Radioactive Material (Road Transport) (Amendment) Regulations 2003, SI 2003 No 1867. London, HMSO.

GB Parliament (2004). The Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2004, SI 2004 No 568. London, HMSO.

Gelder, R, Mairs, J H, and Shaw, K B (1986). Radiological impact of transport accidents and incidents in the United Kingdom over a twenty-year period. IN Proceedings of the International Symposium on the Packaging and Transportation of Radioactive Materials, PATRAM ‘86, Davos, June 1986.

Hughes, J S, and Shaw, K B (1990). Radiological consequences resulting from accidents and incidents involving the transport of radioactive materials in the UK - 1989 Review. Chilton, NRPB-M230.

Hughes, J S, and Shaw, K B (1991). Radiological consequences resulting from accidents and incidents involving the transport of radioactive materials in the UK - 1990 Review. Chilton, NRPB-M310.

Hughes, J S, and Shaw, K B (1992). Radiological consequences resulting from accidents and incidents involving the transport of radioactive materials in the UK - 1991 Review. Chilton, NRPB-M364.

Hughes, J S, and Shaw, K B (1993). Radiological consequences resulting from accidents and incidents involving the transport of radioactive materials in the UK - 1992 Review. Chilton, NRPB-M437.

Hughes, J S, and Shaw, K B (1994). Radiological consequences resulting from accidents and incidents involving the transport of radioactive materials in the UK - 1993 Review. Chilton, NRPB-M475.

Hughes, J S, and Shaw, K B (1995). Radiological consequences resulting from accidents and incidents involving the transport of radioactive materials in the UK - 1994 Review. Chilton, NRPB-M549.

Hughes, J S, and Shaw, K B (1996a). Radiological consequences resulting from accidents and incidents involving the transport of radioactive materials in the UK - 1995 Review. Chilton, NRPB-M662.

Hughes, J S, and Shaw, K B (1996b). Accidents and incidents involving the transport of radioactive materials in the UK, from 1958 to 1994, and their radiological consequences. Chilton, NRPB-R282 (London, HMSO).

Hughes, J S, and Shaw, K B (1997). Radiological consequences resulting from accidents and incidents involving the transport of radioactive materials in the UK - 1996 Review. Chilton, NRPB-M862.

Hughes, J S, and Shaw, K B (1998). Radiological consequences resulting from accidents and incidents involving the transport of radioactive materials in the UK - 1997 Review. Chilton, NRPB-M964.

Hughes, J S, and Shaw, K B (1999). Radiological consequences resulting from accidents and incidents involving the transport of radioactive materials in the UK - 1998 Review. Chilton, NRPB-M1082.

Hughes, J S, Warner Jones, S M and Shaw, K B (2001a). Radiological consequences resulting from accidents and incidents involving the transport of radioactive materials in the UK - 1999 Review. Chilton, NRPB-M1256.

Hughes, J S, Warner Jones, S M and Shaw, K B (2001b). Radiological consequences resulting from accidents and incidents involving the transport of radioactive materials in the UK - 2000 Review. Chilton, NRPB-M1320.

IAEA (1996). Regulations for the Safe Transport of Radioactive Material, 1996 Edition. No. ST-1, IAEA, Vienna.

IAEA (2005). Regulations for the Safe Transport of Radioactive Material, 2005 Edition. No. TS-R-1, IAEA, Vienna.

IAEA & NEA (2001). The International Nuclear Event Scale (INES). User's Manual, 2001 Edition. IAEA & OECD/ NEA. IAEA-INES-2001.

ICAO (2003). International Civil Aviation Organisation. Technical Instructions for the Safe Transport of Dangerous Goods by Air (Class 7) (2003-2004 Edition).

IMO (2002). International Maritime Organisation. Dangerous Goods Code (IMDG Code) (Class 7).

MCA (2003). Maritime and Coastguard Agency. The Carriage of Dangerous Goods and Marine Pollutants in Packaged Form - Amendment 31-02 to the International Maritime Dangerous Goods Code. Merchant Shipping Notice MSN 1772 (M) (2003).

Roberts, D, Watson, S J, Jones, A L and Hughes, J S. (2005). Radiological consequences resulting from accidents and incidents involving the transport of radioactive materials in the UK – 2004 Review. HPA-RPD-007.

Shaw, K B, Hughes, J S, Gooding, T D, and McDonough, L (1989). Review of the radiological consequences resulting from accidents and incidents involving the transport of radioactive materials in the UK from 1964 to 1988. Chilton, NRPB-M206.

UNECE (2003). United Nations Economic Commission for Europe. European Agreement concerning the international carriage of dangerous Goods by Road (ADR) (Class 7).

Warner Jones, S M, Hughes, J S, and Shaw, K B (2002a). Radiological Consequences Resulting from Accidents and Incidents Involving the Transport of Radioactive Materials in the UK – 2001 Review, Chilton, NRPB-W29.

Warner Jones, S M, Hughes, J S, and Shaw, K B (2002b). Experience in the Analysis of Accidents and Incidents involving the Transport of Radioactive Materials, RAMTRANS, Vol. 13, No. 3-4, 2002 pp 371-376.

Warner Jones, S M and Jones, A L (2004). Radiological consequences resulting from accidents and incidents involving the transport of radioactive materials in the UK – 2002 Review. NRPB-W53.

Watson, S (2004). Review of the content and structure of the RAMTED Database. NRPB-EA/1/2004.

Watson, S J and Jones, A L (2004). Radiological consequences resulting from accidents and incidents involving the transport of radioactive materials in the UK – 2003 Review. NRPB-W64.

APPENDIX A Information System Used in the Database of Reported Events of Accidents and Incidents Involving the Transport of Radioactive Material

The details of each event are stored in a computer database by the use of descriptive text and alphanumeric coding systems that are described below.

A1 EVENT ID

The events are numbered using a 7 digit identifier with the format YYYYXXX, where YYYY is the year of the event, and XXX is a sequential figure.

A2 DATE

The date is recorded in the format DD/MM/YYYY

A3 SOURCE

Information regarding events is obtained from the following sources: Civil Aviation Authority, Dangerous Goods Division of the Department for Transport, HPA-RPD, National Arrangements for Incidents involving Radioactivity, Environment Agency, Health & Safety Executive and others. The source of the information is given for each event, together with the event identifier used by the source organisation.

A4 TYPE OF EVENT

This coding gives the broad type of event, classified as occurring either during the moving phase of transport operations or during handling before or after movement. Furthermore, events occurring during either the moving or handling phases are categorised either as accidents or as incidents. Alternatively, events may be classified as contamination events. To avoid inconsistencies with other definitions of accident and incident the general term event is used in published material. However the RAMTED definitions are retained in the database for internal use.

TA – transport accidents

A transport accident is defined as any event during the carriage of a consignment of radioactive material that causes damage to the consignment or significant damage to the conveyance so that the conveyance could not continue its journey.

TI – transport incidents

A transport incident is defined as any event, other than an accident, occurring before or during the carriage of a consignment of radioactive material which caused, or might have caused, damage to or loss of the consignment or unforeseen radiation exposure of workers or members of the public.

HA – handling accidents

A handling accident is defined as an event during the loading, trans-shipping, storing or unloading of a consignment of radioactive material and which caused damage to the consignment, e.g. a package falling from a fork-lift truck and subsequently being run over or a package being dropped owing to crane failure during handling.

HI – handling incidents

A handling incident is defined as an event, other than an accident, during the loading, trans-shipping, storing or unloading of a consignment of radioactive material which caused, or could have caused, damage to or loss of the consignment or unforeseen exposure of workers or members of the public.

C - contamination

A contamination event is defined as an event where radioactive contamination is found on the surface of the package or conveyance in excess of the regulatory limit.

A5 REGIONAL LOCATION OF EVENT

The location at which the event occurred is given, if known, together with a code assigning the location to one of a number of defined geographical regions.

A6 MODE OF TRANSPORT

The mode of transport is given for each event, coded as follows:

V00 unknown,
V01 rail,
V02 air,
V03 sea,
V04 road – lorry > 1.5 t,
V05 road – van < 1.5 t,
V06 road – car,
V07 road – unknown,
V08 fork-lift truck,
V09 other (including crane).
V10 road and sea
V11 road and rail
V12 road and air

A7 CATEGORY OF MATERIAL

The type of material is given for each event, coded as follows:

M00 unknown,
M01 uranium ore concentrate (UOC),
M02 pre-fuel material,
M03 new fuel,
M04 irradiated fuel,
M05 residues including discharged nuclear fuel flasks,
M06 radioactive wastes,
M07 medical and industrial radioisotopes,
M08 radiography sources,
M09 no radioactive material,
M10 consumer products,
M11 other.

A8 CONSIGNOR

The name and address of the company/organisation that despatched the shipment is given for each event, if known.

A9 CONSIGNEE

The name and address of the destination company/organisation is given for each event, if known.

A10 CARRIER

The name and address of the carrier (and sub-carrier, if appropriate) is given for each event, if known.

A11 DESCRIPTION OF EVENT

A brief description of the event is given in words.

A12 ACTIVITY RELEASE

The activity, in TBq, of any radioactive material released into the environment is given for each event.

A13 WORKER DOSES

The maximum dose received by workers from an event is given in mSv, if known.

A14 PUBLIC DOSES

The maximum dose received by the public from an event is given in mSv, if known.

A15 INES RATINGS

The INES rating assigned to each event is given, if known.

A16 INES CONDITIONS

The INES rating is partly dependent on whether or not certain conditions applied to an event. A record is made of whether these conditions did apply for each event, if this is known.

A17 EVENT IMPLICATIONS

Implications such as worker or public safety implications, or environmental implications are given, if known.

A18 NUCLEAR INDUSTRY AND AIRPORT EVENTS

It is recorded for each event if the event involved the nuclear industry or damage to a package at an airport, if this is known.

A19 EMERGENCY ACTION

It is recorded for each event if emergency action was taken, if this is known.

A20 ADDITIONAL INFORMATION

Any additional information, including photos if appropriate, is recorded for each event.

A21 DESCRIPTION OF PACKAGES

A description of each package is given, if known.

A22 PACKAGE TYPE

For each package, a package type is given, using the following codes.

Type A Package Codes:

A	Type A
AP	Presumed to be Type A
AF	Type A, with fissile material
AFP	Presumed to be Type A, with fissile material

Type B Package Codes:

B	Type B
BP	Presumed to be Type B
BF	Type B, with fissile material
BFP	Presumed to be Type B, with fissile material
BM	Type B(M)
BMP	Presumed to be Type B(M)
BMF	Type B(M), with fissile material
BMFP	Presumed to be Type B(M), with fissile material
BU	Type B(U)
BUP	Presumed to be Type B(U)
BUF	Type B(U), with fissile material
BUFP	Presumed to be Type B(U), with fissile material

Type C Package Codes:

C	Type C
CP	Presumed to be Type C
CF	Type C, with fissile material
CFP	Presumed to be Type C, with fissile material

Excepted Package Codes:

E	Excepted
EP	Presumed to be Excepted

Exempt Package Codes:

X	Exempt
XP	Presumed to be Exempt

Industrial Package Codes:

IP	Industrial Package, any type
IPP	Presumed to be an Industrial Package, any type
IPF	Industrial Package, any type, with fissile material
IPFP	Presumed to be an Industrial Package, any type, with fissile material
IP1	Industrial Package, Type 1 (IP-1)
IP1P	Presumed to be an Industrial Package, Type 1
IP1F	Industrial Package, Type 1, with fissile material
IP1FP	Presumed to be an Industrial Package, Type I, with fissile material
IP2	Industrial Package, Type 2 (IP-2)

IP2P Presumed to be an Industrial Package, Type 2
IP2F Industrial Package, Type 2, with fissile material
IP2FP Presumed to be an Industrial Package, Type 2, with fissile material
IP3 Industrial Package, Type 3 (IP-3)
IP3P Presumed to be an Industrial Package, Type 3
IP3F Industrial Package, Type 3, with fissile material
IP3FP Presumed to be an Industrial Package, Type 3, with fissile material

Other Codes:

CV Contaminated conveyance only
NIL No radioactive material carried
NR Packaged item, but not in recognised package type
SC Item carried within load of scrap
UK Unknown packaging status
UPX Unpackaged item, which should be packaged
UPY Unpackaged item, which is OK to be unpackaged

A23 TRANSPORT INDEX

For each package the Transport Index (TI) is given, if known.

The TI is a number used to provide control over radiation exposure. For packages the TI is the maximum dose rate at 1 m from its surface, in mSv h^{-1}, multiplied by 100.

A24 RADIONUCLIDES

The radionuclides contained in each package are listed by their chemical symbol and mass number, with a record of whether or not each nuclide is a sealed source or a fission product (usually caesium-137.)

A25 ACTIVITY

The activity of each radionuclide is given, in TBq, if known.

A26 EVENT CLASSIFICATION SYSTEMS

The analysis of the database of events is facilitated by the use of classification systems that define the description of the event, the type of package damage or deficiency and the extent of any radiological consequence. These three classification systems are set out in Tables B1, B2 and B3. Each event is characterised by the allocation of the alphanumeric codes shown in Table B1, and the radiological consequences of each event are characterised by the allocation of the codes shown in Table B3. Each package is characterised for damage or deficiency by the codes shown in Table B2.

APPENDIX B Event Classification System

The database uses coding systems for event classifications, package deficiencies and potential radiological exposures. Tables B1 to B3 give details of these classification schemes, showing the coding systems used.

TABLE B1 Classification of reported transport events

Area Subject	Item	Sub-item		Description
A Administrative (all packages)				
G General	1 Training	1	1	Insufficient worker training
	2 Documents	1	1	Consignor's certificate incorrect or absent
		2	1	Other shipment documents incorrect or absent
		3	1	Correct contents but wrongly described in documents
		4	1	Material undeclared as being radioactive
		5	1	Accounting error, i.e. apparent loss of package
	3 Delivery	1	1	Administrative difficulty or error, returned to consignor or re-consigned
	4 False alarm	1	1	Suspected incident but none found
C Conveyance	1 Placards	1	1	Correct vehicle placards not displayed
			2	Placards displayed but no sources carried
	2 Excessive TI	1	1	Excessive TI on conveyance or in stowage hold
P Package	1 Labels	1	1	Insufficient or incorrect package labels
			2	Labels on empty package
		2	1	Incorrect TI on package label
		3	1	Incorrect radionuclide or activity on package label
	2 Marking	1	1	Package type unmarked or wrongly marked
S Shipments, general (not irradiated nuclear fuel flasks)				
C Conveyance	1 Load	1	1	Excessive load on conveyance
	2 Mechanical	1	1	Faulty conveyance, or mechanical failure
	3 Security	1	1	Locks or security devices: insecure, insufficient or defective
	4 Tie-downs	1	1	Tie-downs or similar devices: insufficient or defective
	5 Accidents	1	1	Collisions and other accidents, without fire
	6 Accident/fire	1	1	Collisions and other accidents, with fire
	7 Fire	1	1	Spontaneous fire on conveyance
	8 Stowage	1	1	Inappropriate stowage conditions
P Package	1 Preparation	1	1	Poor standard of packaging or containment
		2	1	Incomplete package, insecure inner container
		3	1	Incomplete package, insufficient shielding
		4	1	Incorrect contents or package type
		5	1	Material in supposedly empty package
		6	1	Contamination inside package
		7	1	Contamination outside package

TABLE B1 Continued Classification of reported transport events

Area Subject	Item	Sub-item		Description
	2 Loss/disposal	1	1	Stolen, and recovered
			2	Stolen, not recovered
		2	1	Lost, found, temporary loss, wrong destination or wrong conveyance
		2	2	Lost, not recovered
		3	1	Lost at sea, and recovered
		3	2	Lost at sea, not recovered
		4	1	Inappropriate disposal
		5	1	Radioactive material in scrap metal
	3 Damage	1	1	Spontaneous mechanical failure of package, including leakage
		2	1	Deliberate damage or interference
		3	1	Damaged by falling from or within conveyance, or by falling object, or by external object
		4	1	Damaged during cargo handling
		5	1	Damaged due to broken or loose tie-downs
F Irradiated nuclear fuel flasks				
C Conveyance	1 Wagon/ HGV	1	1	Wagon or HGV problem e.g. buffers, brakes, canopy not correct, including significant overheating of wheel or axle
	2 Accident	1	1	Collision
		2	1	Derailment during low speed marshalling
		3	1	Inadvertent decoupling
		4	1	Fire on the conveyance
	3 Contamination	1	1	Wagon or HGV contaminated above 10 DWL
		2	1	Fixed-contamination above 5 μSv h^{-1}
P Package	1 Preparation	1	1	Shock absorber damaged or unsatisfactory
		2	1	Tie-down bolts insufficient or defective
		3	1	Lid, defective or loose bolts
			2	Lid seal unapproved or obsolete
		4	1	Water level valve defective
		5	1	Discharged flask containing fuel rod, excessive deposit, or other incorrect contents
		6	1	Faulty test procedures
		7	1	Fuel not fully covered by water
		8	1	Other minor preparation error
	2 Mechanical	1	1	Mishandled during loading or unloading
		2	1	Venting system or valve problem
	3 Contamination	1	1	Contamination of surface above 10 DWL
		2	1	Other: poor standard of decontamination

TABLE B2 Classification of package deficiency associated with the transport event

Deficiency Code	Deficiency	Examples/Comments
D01	No package	No package involved in event.
D02	Contaminated conveyance	Contaminated conveyance only with no package involved.
D03	No damage to package or threat of damage	Administrative errors and false alarms. Inadequate locks and security devices. Inappropriate or wrong contents. Obsolete lid seals.
D04	No report of damage or increase in dose rate, but potential to cause damage to the package. Lower category	Package temporarily lost or mislaid, or wrong destination, or put on wrong conveyance. Low speed derailments and collisions. Wagon decoupling. Faulty conveyance or tie-downs.
D05	No report of damage or increase in dose rate, but potential to cause damage to the package. Upper category	Stolen source. Unretrieved lost package. Inappropriate disposal. Severe collision. Fire on the conveyance.
D06	Defective or poor condition, without increase in dose rate or loss of containment	Package of generally poor standard, corroded or other deterioration. Parts missing or mechanical defect.
D07	Minor damage without increase in dose rate or loss of containment	Damage to outer packaging: knocked, dropped or dented. Conveyance overturned.
D08	Severe damage without increase in dose rate or loss of containment	Severely damaged: crushed. Scorched by fire. Part of container, eg lid, knocked off.
D09	Damaged with increase in dose rate but without loss of containment	Increased dose rate outside package caused by damage or fire en route. Includes internal leakage and other mechanical failure. No loss of material outside package.
D10	Damaged with loss of containment	Leakage out of package caused by damage or fire en route. Includes material or source(s) released from package. Usually accompanied by some increase in dose rate.
D11	Contamination inside package	Unexpected contamination or other residual material found inside package.
D12	Contamination outside package	Fuel flask contamination > 10 DWL. Any other contamination above IAEA limits.
D13	Improper package with loss of shielding or containment – inappropriate contents	Activity unexpectedly high for package, leading to dose rates higher than expected.
D14	Improper package with loss of shielding or containment – inadequate shielding	Package shipped with poor, ineffective or damaged shielding, or source exposed en route.

TABLE B3 Radiological consequences resulting from transport events

Code	Circumstances
N None	No dose rates or contamination above those expected during routine transport. No evidence of exposures having been received.
E Extremely low, not assessed	Some increased exposure above that associated with routine transport but considered to be so low that an assessment was of little value.
L Assessed, and below 1 mSv*	Some increased exposure above that associated with routine transport and considered to be of a magnitude worth investigating, but found to be low.
U Assessed, and above 1 mSv* or exposure to significant contamination	Some increased exposure above that associated with routine transport and considered to be of a magnitude worth investigating. Some exposures found to be appreciable.

Note:

* An effective dose of 1 mSv or an extremity dose of 50 mSv.