

A REVIEW OF 10 YEARS RADIOACTIVE MATERIAL TRANSPORT INCIDENTS AND ACCIDENTS EXPERIENCE IN GERMANY

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ABSTRACT

This paper describes the work undertaken to establish a national radioactive material transport event review and analysis system and presents the findings and conclusions of a comprehensive assessment and evaluation of abnormal occurrences and irregularities involving radioactive material shipments which occurred in the 10-year reporting period from about 1995 - 2006 in Germany. The 10-year transport event review results provide evidence that implementation and application of the existing national and international regulatory controls and operational performance requirements ensure a high level of protection and safety in transport of radioactive material.

INTRODUCTION

Every year approximately 700.000 radioactive material packages (consumer goods excluded) are transported within, into and out of Germany by all modes of transport, i.e. on land and water and by air. The transport involves many types of nuclear and non-nuclear radioactive materials and radiation sources for applications in research, medicine, manufacturing industry, agriculture, hydrology, geology, education and nuclear power production in quantities ranging from miniscule amounts to very large quantities of radioactivity of some 100.000 Tera-Becquerel. The great majority of these radioactive material shipments consist of relatively small quantities of radiopharmaceuticals, labelled compounds, radioactive samples, test and gauging sources, radioactive residuals and waste materials and other commodities containing radioactive substances which serve our daily lives, while large quantity shipments of radioactive material such as spent nuclear fuel or high-level radioactive vitrified waste account for only a small proportion of the national transport volume.

The transport operations vary considerably in size and complexity and may involve numerous individuals and organizations, e.g. consignors, shipping agents, carriers, and consignees. Road and air are the predominant modes of transport. A significant fraction of these radioactive material shipments are transboundary (international) shipments of packaged radioactive material.

THE NEED FOR EXPERIENCE FEEDBACK

For a long time it has been recognized that radioactive material shipments present a unique (radiological and non-radiological) hazard during transport. The transport of radioactive material in the public domain is therefore subject to stringent regulations and safety requirements agreed

upon internationally and compliance with these regulatory requirements is generally found to be very good. However, in spite of all measures taken to ensure compliance with all applicable regulatory requirements and operational performance standards, practical experience shows that non-compliances and abnormal occurrences, i.e. deviations from normal performance and operation conditions by systems and personnel including incidents and accidents - hereinafter referred to as events - can and do occur during transport and handling of radioactive material shipments.

Such events may occur for a number of reasons with different outcomes and safety implications ranging from minor irregularities with insignificant radiological and non-radiological consequences - if any at all - to serious events involving radiation exposures of workers and members of the public in the vicinity and are thus consistently a matter of concern to operators, competent authorities, the media and the general public. It is therefore important to learn from any such event so that - as far as possible - appropriate corrective actions can be taken and implemented by both operators and/or competent authorities to (i) prevent their recurrence, (ii) limit the likelihood and - where relevant - the consequences of events (e.g. the potentially adverse radiological or non-radiological consequences) and (iii) enhance compliance with the relevant regulatory and performance requirements for transport.

In order to allow full use to be made of any lessons learned from events requires a systematic and comprehensive approach to be applied and is generally achieved through the establishment, application and maintenance of an appropriately designed system of reporting, compilation, analysis and evaluation of the type, nature, effect, cause and safety significance of such events. The collection and analysis of events can also provide useful information feedback (experience feedback) to the regulatory process, or to local operational procedures, to improve protection and safety in transport and is believed to be a reasonable and pertinent (proactive) approach in driving good operational performance and minimizing non-compliances and human errors. Feedback of experience also increases knowledge of the operation conditions and performance trends and provides useful data and guidance for emergency preparedness and response planning and for qualitative and quantitative safety analysis.

Based on this understanding and consistent with the safety requirements and good practices agreed upon internationally (cf. IAEA Safety Standards Series No. GS-R-1, 2000 and the Convention of Nuclear Safety, Article 19), the national regulatory agencies concerned, i.e. the Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) and the Federal Office for Radiation Protection (BfS), have supported work with the objective:

- To collect, compile, analyze, evaluate and document information on abnormal events that occur during the transport of radioactive material
- To draw conclusions and elaborate recommendations to further enhance safety and security of radioactive material shipments

GERMAN RADIOACTIVE MATERIAL TRANSPORT EVENT REVIEW AND ANALYSIS SYSTEM

Work has been performed with the objective to collect, compile, analyze, evaluate and present information on events that occur during the transport of radioactive material in Germany. The work performed covered all modes, i.e. road, rail, air, sea and inland waterways, and has resulted in the establishment of a computerized national database on events involving radioactive material shipments. The national transport event database is operated and maintained by Gesellschaft fuer Anlagen- und Reaktorsicherheit (GRS) mbH, Cologne (Germany), on behalf of the competent authority and has since 1995 periodically updated and reviewed, cf. Sentuc and Schwarz 2007.

Radioactive material transport operations involve usually a wide range of activities and operations including, for example, preparation of the radioactive material package by the

consignor, loading/unloading operations, carriage in the public domain, in-transit storage, intra-/intermodal transfer and delivery of loads of radioactive material packages to the consignee at the final destination. Abnormal occurrences and irregularities (events) can occur at each of these stages of transport. The radioactive material transport event database developed covers consequently all modes and stages of transport for the reporting period from approximately 1995 through 2006 (2006 data preliminary). Transport event information excluded from the computerized event database includes: i) defence related shipments, ii) transport events within fixed establishments, iii) transport events involving consumer goods containing small quantities of radioactive substances, and iv) excess surface contamination events involving either the package or the transport vehicle of irradiated nuclear fuel shipments.

The scope and detail of event information reported or available differs usually significantly. The event details recorded in the computerized national database are broadly compatible with the IAEA Transport Event Database EVTRAM and include - where available - generally the following information:

- date of event
- location of event or event discovery
- mode of transport
- type of material involved
- stage of transport
- description of the event
- type and severity of the adverse consequences
- primary cause of the event
- emergency response activities

SOURCES OF EVENT INFORMATION

Information on events involving radioactive material packages and shipments has been obtained and derived from a wide number of sources of information. For each mode of transport there are specific regulatory requirements to report transport events to the competent authority if they meet certain criteria or result in serious consequences, e.g. human injuries or fatalities. In practice it has been noted that abnormal transport event data are also frequently provided and reported on a voluntary basis by consignors, carriers, consignees, emergency responders, police etc. to competent authorities and by the media.

The main sources of factual information available and used for the compilation and review of transport events in this study included inter alia: i) event information provided by national regulatory agencies (competent authorities) for the transport of dangerous goods including Class 7 material, and ii) compilations of events associated with the use and handling of radioactive material and radiation sources. The information available was generally provided in an anonymous form. In a few cases the basic information available was derived and complemented by event data taken from event occurrence reports and public media.

EVENT CLASSIFICATION

For the purpose of the review and analysis the characterization and description of the type and nature of transport events involving radioactive material has been based on the classification scheme developed for the IAEA Transport Event Database EVTRAM, cf. IAEA 1997. The IAEA's EVTRAM database divides abnormal occurrences and irregularities during transport in seven broad categories including the following:

- Unlawful interference: theft, malevolent acts (e.g. sabotage)
- Documents, marking, labelling: improper/absent documents etc.

- Preparation for shipment: undeclared material, wrong package etc.
- Handling during transport: package dropped, package crushed, package damaged, wet package etc.
- Loss of control of package: package lost, package misdirected etc.
- External influences: conveyance in accident, fire
- Unspecified unknown, others

EVENT SIGNIFICANCE CLASSIFICATION

Assessment and rating of the severity and safety significance of transport events within the German radioactive material transport event review and analysis system has essentially been based on the severity scale for radioactive material transport developed for the IAEA's Transport Event Database EVTRAM. The EVTRAM severity scale categorizes transport events according to the type and magnitude of the radiological consequences and level of degradation of the safety provisions (defence in depth) and/or the effort required to restore control, if it has been lost (e.g. through recovery/remedial measures), into seven broad severity classes (level 1 - 7):

Level	Description
7	Major accident
6	Severe accident
5	Accident with significant radiological consequences
4	Accident with appreciable radiological consequences
3	Accident with limited radiological consequences
2	Incident with complications, affecting safety function but no release
1	Incident resulting in some disruption of normal transport, without affecting safety functions
(0)	Non-incident (e.g. "false alarm")

For the purpose of the review and analysis of abnormal transport occurrences and irregularities presented herein the EVTRAM event classification system was arbitrarily expanded by an additional significance class (level 0) to account for (frequently) reported non-incidents or false alarms, i.e. events that were originally reported to be a problem but on investigation nothing was found to be in error. For example, occasionally a package is reported to be leaking but closer examination identified that the liquid was rainwater.

TRANSPORT EVENT REVIEW AND ANALYSIS RESULTS

The nationwide survey and analysis of abnormal occurrences and irregularities involving radioactive material shipments identified a total of 495 transport events which occurred in the 10-year reporting period from approximately 1995 through 2006 in Germany and where sufficient details for each transport event were reported and available (2006 data preliminary). The annual number of transport events identified and analyzed is given in Table 1 for each mode of transport, i.e. road, rail, air, and sea/inland waterways. The retrievability and availability of detailed information for transport events in the mid and late 1990s was limited. It is, however, believed that the event database contains as a result of intensified data collection procedures essentially all significant transport events since about 2000.

The type, nature and number of reported events for each mode of transport varied widely and included, for example, numerous non-events (false alarms) and minor non-compliances (e.g. irregularities in shipping documents) as well as transport accidents with limited radiological consequences resulting from an accidental radionuclide release into the environment. However, in the 10-year review and analysis period there were no reported transport incidents or accidents

having resulted in serious exposures to ionizing radiation of people (workers, members of the public) or major human health effects (physical injuries, fatalities) attributable to the radiological material properties.

No readily discernable and meaningful trends over the 10-year reporting period were identified in the number of transport events for each mode presented in Table 1. It is, however, of interest to note that the numbers of reported events differ significantly between the modes considered and that the numbers reported are disproportionate to the volume of radioactive material shipments for the respective mode of transport. This observation reflects primarily the existing event reporting criteria and practices for the various transport modes at the time being rather than different performance and safety standards of the various transport modes. Airlines, for example, have a longstanding tradition of reporting events while systematic event reporting for other modes is a fairly new feature and regulatory requirement.

Table 1. Reported Transport Events in Germany by Mode of Transport

Mode	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Total
Road	--	--	--	5	3	8	3	3	3	0	0	4	29
Rail	9	3	3	6	4	0	0	0	1	+	+	9	35
Air	--	--	--	--	--	46	17	50	118	97	27	60	415
Sea	--	--	--	--	--	--	2	1	1	--	1	1	6
Unknown							5	1		3	1		10
Total	9	3	3	11	7	54	27	55	123	100	29	74	495
--) Event information unavailable													
+) Exact number of transport events unavailable, but involved primarily improper marking and labelling of packages													

Analysis by type of event

The event information generally available permitted analysis of the type and nature of the reported transport events. The result of this analysis is shown in Figure 1 (top). The figure indicates that the vast majority of reported transport events (66%) is attributable to handling failures giving rise to some kind of package damage (e.g. package dropped, crushed, run over, wet package etc.) during loading/unloading, stowage, transfer and loss of control of radioactive material packages (package lost, package misdirected etc.). These were frequently events which occurred during package handling at airport cargo center. Improper documentation and breaches of certain technical and administrative regulatory requirements (e.g. elevated package radiation levels, undocumented contents, absent/improper labels, lack of prior notification etc.) represent with 25 percent the next largest group of transport events and irregularities in the 10-year reporting period and are likely to be related to poor preparation, lack of information and human carelessness.

Transport accidents and fires involving radioactive material packages and conveyances giving rise to some personal and/or material damage account for 3,4% and 0,2% of the reported events, respectively, in the 10-year review period up to the end of 2006 and are thereby relatively rare abnormal physical occurrences. The transport accidents involved - consistent with the large national transport volume by road - primarily road shipments except one which occurred on an inland waterway (ship collision). Among the remainder events were 4 (0,8%) malevolent acts (e.g. tampering of a railcar, intentional stop of a waste shipment by rail) and 2 (0,4%) cases of theft involving radioactive material packages and/or conveyances. However, none of the latter events resulted in adverse radiological consequences to people, property or the environment.

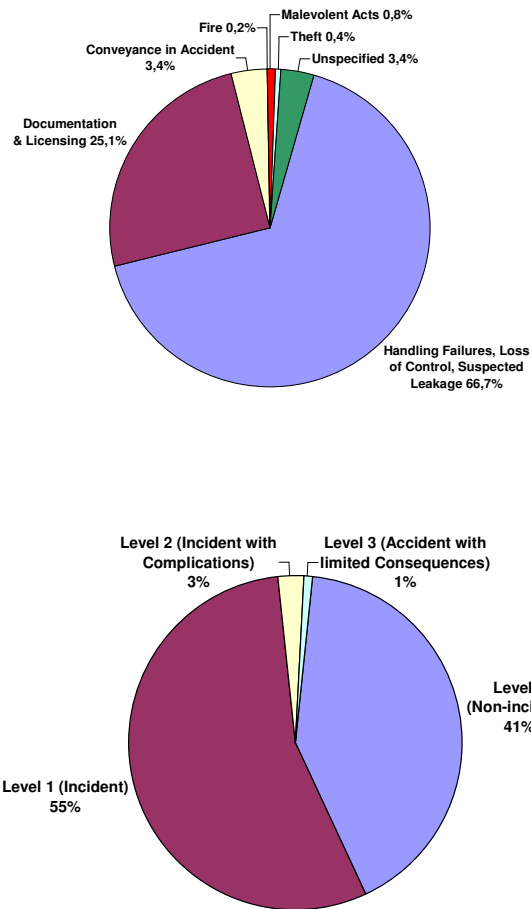


Figure 1. Analysis of Transport Events by Type of Event (top) and Safety Significance (bottom) in the Reporting Period from 1995 - 2006 in Germany

Analysis by safety significance of events

The analysis of the reported abnormal transport occurrences and irregularities by safety significance of the event is shown in Figure 1 (bottom) for the 10-year reporting period. As described above the available events were divided in eight broad safety significance categories based on the actual or potential for radiological consequences and level of degradation of defence in depth with level 0 (non-incidents) and level 1 (incident) representing the two lowest significance ratings where there were no radiological consequences. 205 (41%) non-incidents/false alarms and 273 (55%) incidents with some disruption of normal transport conditions (without affecting the package safety functions) were found to make up the largest group of reported transport events with limited or no implications on safety, although it is recognized that, for example, certain technical and administrative requirements (e.g. proper documentation, labelling) are essential for the safe transport of radioactive material.

13 (3%) events were rated as level 2 incidents with complications (but no package contents release) based on the severity of the level of degradation of defence in depth (i.e. deterioration of the safety functions available) and the magnitude of the attendant radiological hazard (e.g. elevated exposures) and/or loss of control of packages (temporary/permanent loss of packages). Four (1%) reported transport events qualified as level 3 incidents with limited radiological

consequences in the 10-year review period based on the principal feature of having resulted in elevated personal exposures and/or environmental contamination during transport but with doses remaining within permissible limits. These were generally events and physical occurrences involving damaged packages and the subsequent environmental release of the package contents and several cases of inadequate, or loss of, shielding giving rise to elevated doses to people in close proximity to the damaged radioactive material package shipment or environmental contamination. Packages being moved on pallets or handled for loading fall occasionally from the pallet or are dropped and are thereby vulnerable to be crushed or run over.

One of the most serious level 3-event in the reporting period was a 1998 road transport accident on a motorway in a non-urban area in Germany involving a truck load of 30 Type A packages containing radiopharmaceuticals (primarily Mo99/Tc99, I131, and Tl201). The truck turned over and the load of packages was dispersed on the motorway and some packages were run over by the subsequent traffic. The detailed follow-up investigation of the transport accident revealed complete destruction of about three packages and the release and dispersal of a major fraction of its radioactive contents into the environment at the point of the accident. The accident and the resulting extended ground surface contamination required substantial emergency response activities including the recovery of packages and decontamination and removal of the ground surface in order to mitigate the potential accidental radiological consequences. The accident-related radiation exposures of the transport personal and members of the public were estimated to be negligible.

DISCUSSION

Systems for reporting, compilation and analysis of abnormal transport occurrences and irregularities (events) encountered in the transport and handling of radioactive material shipments are an essential tool to improve the safety and performance of transport operations by learning from such events (experience feedback) and take appropriate corrective actions to prevent their recurrence. A systematic review and analysis of transport event information is also useful and needed for monitoring and judging trends in the adequacy and effectiveness of the regulatory requirements governing the safety and security in the transport and the operational measures and procedures employed by operators to drive performance and minimize non-compliances.

The national radioactive material transport event review and analysis system covers currently the reporting period from about 1995 through 2006 and contains up to the end of 2006 event information for 495 reported transport events including incidents and accidents which occurred during the transport and handling of radioactive material shipments by all modes of transport. Compared to the large number of radioactive material package shipments of about 700.000 packages per year, the number of abnormal transport events is rather small.

The 10-year transport event information available indicates that the type, nature, severity and safety significance of the reported transport events involving radioactive material shipments varies considerably ranging from non-incidents/"false alarms" over minor non-compliances with insignificant consequences - if any at all - to severe transport accidents giving rise to some radiological (and non-radiological) consequences requiring emergency response and recovery activities. The large majority (92%) of reported transport events represent "false alarms" (e.g. suspected leakage), handling failures, loss of control of packages (lost and misdirected packages) and minor non-compliances of a primarily administrative nature (e.g. improper documentation) with no radiological consequences. These types of events are likely to be attributable primarily to poor preparation of shipments, lack of information and human carelessness.

Vehicular transport accidents, fires, theft and malevolent acts involving radioactive material shipments which are generally a particular concern to the media and the public account for

approximately 8 percent of the reported transport events in the 10-year reporting period. The radiological consequences of these events were generally limited in extent and severity. It is, however, of interest to note that the emergency response operations associated with such abnormal transport events may nevertheless be significant in terms of the time and resources required and the cost involved to regain control and to return to normal conditions of transport. Also the impact on public perception on transport operations involving radioactive material can be disastrous.

In the 10-year review and analysis period there were no reported transport events having resulted in excessive radiation exposures of workers and members of the public or major physical injuries or fatalities attributable to the radiological material properties.

From the comprehensive review and analysis of transport event information there is no firm evidence for any significant deficiencies in the existing system of national and international regulatory controls and requirements governing the safe and secure transport of radioactive material. It is, however, believed that there is a potential for improvement of the current safety record by reducing the numerous (minor) administrative non-compliances and handling failures which are likely to be attributable primarily to poor preparation, lack of information and human carelessness through appropriate information and training of the transport personnel involved.

CONCLUSIONS

The comprehensive review and analysis of the 10-year radioactive material transport event database available in Germany provides evidence that implementation and application of the national and international system of controls and requirements for the safe transport of radioactive material ensure a high level of protection and safety of people by minimizing the potentially adverse radiological consequences of transport incidents and accidents to levels deemed to be acceptable. The review of transport events underpins the understanding - given the large number of radioactive material shipments of about 700.000 packages per year in Germany - that transport operators have generally designed their transport programs and operations to comply with the relevant regulatory and performance requirements.

In summary, for more than forty years there have been no reported transport events in Germany with serious human health effects (major physical injuries and fatalities) attributable to the radiological material properties. Nonetheless, there is no room for complacency and monitoring of safety and security trends in transport will remain a continuous challenge for the parties with responsibilities for the safe transport of radioactive material, i.e. competent authorities and transport operators.

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