Accidents and Incidents in the Transport of Radioactive Material—An Analysis of 37 Years of Experience

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INTRODUCTION

The regulations for the safe transport of radioactive material (IAEA 1990)are formulated on the basis that accidents, even severe ones, can and do occur in transport. It is fundamental that safety is built into the design of the packages and that packaging should be appropriate to the potential hazard of the contents. An analysis of the radiological consequences of the accidents which have occurred provides a means of assessing the effectiveness of these regulations. Where compliance issues are raised it enables enforcing authorities to focus resources on areas of greatest concern.

With this in mind, in 1983 the UK Department of Transport in conjunction with the Health and Safety Executive asked the National Radiological Protection Board to assess the radiological impact of transport accidents and incidents which had occurred over a 20- year period. The results of the study, published in 1984 (Gelder et al. 1984) were felt to be sufficiently useful for it to be revised and updated in 1990 (Shaw et al. 1990a) and for annual updates to be published thereafter (Hughes and Shaw 1990-1995). Some details of the database together with preliminary results were published in 1990 (Shaw et al. 1990b). A further revision and consolidation, using a different system of classification, took place in 1995 covering the period 1958 to 1994 and is described below.

The database on which transport events are registered has developed and changed over time. The information recorded, and the number of ways in which it can be analysed, has improved. The method of classification of events has evolved to reflect the experience gained of the types of event which reoccur. Both the computer software and hardware have been progressively improved following the rapid changes in these areas over the last decade. The number of events recorded has risen from around 300 over 20 years in 1984 to more than 500 for the 37 years at present . The time period covered by the database has been extended as new events happened and earlier, overlooked, events came to light.

ORIGINS AND PURPOSE

The transport of radioactive material has always had a high media profile, particularly when the material transported is part of the nuclear fuel cycle. Because of this it has always been necessary to

brief politicians and prepare for media enquiries, often even for events having little or no radiological significance. Reporting, therefore, has always gone beyond the formal reporting of events required by the various modal statutes. However, the details associated with these events, particularly the earlier ones, is sometimes sparse.

Prior to 1983, reports existed in some abundance but were uncollated and no formal assessment of their significance existed. In particular, no view on the overall radiological impact of accidents and incidents could be taken. A large number of reports involving the transport of irradiated nuclear fuel by rail existed, but these seemed merely to reflect the more severe reporting requirements of that particular mode of transport. Similarly, larger companies particularly the nuclear ones, aware of their public image and the need for early media and political briefing, have tended to be more conscientious in reporting than, for example, hospitals or site radiographers. Up to the early 1980s trends or repetitive types of accident could not be identified with any confidence, and it was not easy to learn from past experiences or to determine how effective were the regulations.

The 1983 study had three main purposes. Firstly, it would assess the radiological impact of accidents and incidents in the transport of radioactive material in terms of the individual doses to workers and members of the public, and the contribution they make to the collective dose to the population. Secondly, it would comment on compliance, or lack of compliance, with the regulations and the contribution this made to the radiological impact; this would enable enforcement activities to be focussed on areas of greatest concern. Finally, the report would make recommendations regarding lessons learned. If deficiencies in the existing regulations were to be revealed, recommendations for future regulations could be made.

No attempt was made, in 1983 or later studies, to provide information for probabilistic risk assessments. Although this is a possible use of accident studies, compatible shipment data are also required and it is probably best dealt with in its own right..

CLASSIFICATION SYSTEMS PRIOR TO 1995

Transport accidents and incidents have many recordable attributes and it is possible to classify and analyse them in many different ways. Some attributes, such as the number and type of packages involved or the mode of transport, are fairly obvious although for the latter it was quickly recognised that incidents involving fork lift trucks were worthy of separate treatment. How usefully to classify the types of material transported is less obvious but the division of both fuel cycle material and radioisotopes into a number of different categories according to use has proved beneficial. Some instances, attributes, particularly the causes of events, have sometimes been difficult to identify uniquely, and individual judgement plays an important part. It is important to bear this in mind whenever comparisons or international compilations are made.

The collection and analysis of accident data in 1983 was new for the United Kingdom and there was some concern at the time that the tabulation of around 300 events would undermine the view that the transport of radioactive material was a safe practice. It was therefore important that events, particularly those of little radiological importance, should be seen in their proper perspective. Events were therefore categorised as "accidents" or "incidents" and further subdivided into those which occurred during transport (transport events) and those which occurred during loading, unloading or storage (handling events). Accidents covered events such as crashes and crane failures, while incidents covered events such as incorrect procedures and administrative failures. Unfortunately, real events do not always fall neatly into pre-ordained categories and judgement is

sometimes required as to whether a particular event should be classified as an accident or an incident.

From the very beginning of the work information was coded and put on a commercial computer database (Superfile system, Southdata Ltd. London), on a microcomputer. Almost 30 fields were coded identifying the consignor, carrier, consignee, location, date, mode of transport, package type, and up to five types and activities of the radionuclides involved. Most importantly, several fields were provided for descriptive text such as a package description and narrative of the event. Some information was double coded in both alphanumeric fields and numeric fields; the former being more descriptive but the latter being quicker when searching.

By the time of the 1990 review, computers had become more sophisticated and the database responded by becoming more complex. New software was used (dBASE 1.1, Ashton Tate Corporation, California.) and several additional fields were added to accommodate subcategories of the original classification and to allow package damage to be coded. In addition, extra fields were needed to renumber existing records when earlier events came to light in order to reference the old record numbers for comparison purposes.

By this time some patterns in the recorded events were emerging and the database was modified to make use of this. In order to provide more analyses, transport accidents were divided into nine subcategories; transport incidents into eight subcategories; handling accidents into two subcategories; and handling incidents into four subcategories. Incidents could be subcategorised on the basis of radiological consequences such as increased dose rate, and similar types of transport accidents such as those involving fires could be grouped together. The database was able to be interrogated for such initiating events as improper procedures and it could identify those events which led to an increase in dose rate. Losses or thefts of packages either during transport or during handling could also be identified separately.

The 1989 report analysed events by their effects on packages. The analysis in terms of loss of shielding and/or containment was instructive. It showed that faulty package preparation was the cause of more occasions of loss of containment or shielding than damage to the packages. Indeed, the resistance of correctly prepared packaging to damage was excellent. On the occasions when packages were damaged there was no loss of containment from any of the Type B packages or from about 90% of the lower grades of package. Over the period of this study, the weak link in the transport chain was people not packaging.

THE 1995 CLASSIFICATION SYSTEM

By the time of the 1995 report, 500 events were recorded on dBASE IV (Borland, California) and an entirely new classification system had been introduced. It is retrospective and pragmatic rather than prospective and theoretical and is based upon the experience of previous analyses and takes into account recurring types of event. Events are divided into broad areas which are further subdivided into subjects, items, and two event codes. Extra fields have been introduced to accommodate this and to provide for a second similar coding for events in which there was a subsidiary cause or deficiency. A further code for the extent of radiological consequences has been introduced along with a separate coding of package damage. Additionally, the 1983 classification of transport accidents and incidents and handling accidents and incidents has been retained. The number of fields has risen to 52.

The first of the broad areas concerns administrative events leading to breaches of the regulations. This area is broken down into three subjects according to the nature of the breach. The subjects may concern the conveyance (e.g. placarding offences), the package (marking and labelling), or they may be more general concerning documentation, delivery, or training, or they may be false alarms. In this way individual types of events can be broken down and classified in terms of an alpha-numeric string. For example, an event where the wrong label was on a package would be: area - administrative (A), subject - package (P), item - labels (1), event codes - insufficient or incorrect package labels (1,1).

The second area concerns those events which relate to the transport of irradiated nuclear fuel (INF). In the UK these have many features found only in the transport of this type of material. As a consequence the types of events recorded have tended to be different from the types of events involving other radioactive material. INF has a high public profile and is transported in controlled and well-defined circumstances. Since it travels mainly by rail, even minor incidents are very efficiently reported. This area is broken down into two subjects: those events primarily concerning the conveyance, and those primarily concerning the packages. Rail vehicles are prone to overheating axle boxes, or low-speed derailments during marshalling operations. Serious collisions, however, are rare and collisions followed by fires are very rare indeed. The packages are large, robust Type Bs, and the events tend to be instances of poor preparation or mechanical difficulties.

The third area concerns events related to shipments of other radioactive material This too is broken down into two subjects according to whether the event is primarily related to the conveyance (crashes, for example) or the package. Road transport is the predominant mode. Vehicles have been involved in collisions, with or without subsequent fires. and packages have been lost or stolen.

RESULTS

Table 1: Classification of Events by Mode of Transport.

Mode	Administrative Events			Non-INF Shipments		INF Shipments		Total
	General	Convey-ance	Package	Convey-ance	Package	Convey-ance	Package	
Rail	10	0	0	2	6	52	52	122
Air	11	1	11	4	17	0	0	44
Sea	6	1	3	3	28	0	3	44
Road Lorry	8	1	3	21	19	8	3	63
Road Van	2	6	3	19	32	0	0	62
Road Car	0	0	0	3	16	0	0	19
Fork-lift	1	0	0	0	150	0	0	151
Crane	0	0	0	0	0	0	2	2
Total	38	9	20	52	268	60	60	507

The classification by mode of transport (Table 1) shows a large number of package related events for carriage by fork lift truck. These have occurred mainly in airports throughout the period of the study with a large number happening in the 1970's. The second largest mode is road, reflecting the very large numbers of packages transported this way. Rail is the next largest mode reflecting the high degree of reporting of fairly minor accidents rather than heavy traffic. The rail events for INF are divided equally between conveyance events and package events with the latter largely consisting of instances of contamination with trivial radiological consequences.

The radiological consequences are characterised as: none; extremely low but not assessed; effective dose assessed as being below 1mSv and extremity dose assessed as less than 50mSv ; and effective dose assessed as being above 1mSv or an extremity dose greater than 50mSv. The majority of the higher exposures were due to industrial radiography sources. The radiological consequences due to events involving each type of package are shown in Table 2.

Table 2: Radiological Consequences.

Exposure	Type A	Type B	Excepted	Industrial	None	Total
None	197	105	43	32	5	382
Extremely low: not assessed	16	49	4	21	7	97
Assessed as below 1mSv	9	0	0	1	0	10
Assessed as above 1mSv	13	5	0	0	0	18

An analysis of package damage is shown in Table 3 for each type of package. The damage has been characterised in ascending order of severity as no damage and no potential for damage; no damage but with potential to cause damage; packages damaged but no loss of shielding or containment; packages damaged with loss of shielding; and packages damaged with loss of containment. Incorrectly prepared or poorly maintained packages leading to impairment of shielding or containment are also characterised.

This shows that 38% of the reported events involved neither damaged nor inadequate packages and in a further 39% of the events the packages, although damaged, did not lose containment or shielding. On 170 occasions Type A or excepted packages were damaged without shielding or containment loss, compared to 14 with shielding or containment loss. It is likely, that there is a degree of under-reporting of events involving excepted packages. No type B package lost either shielding or containment in accidents although nine have been transported when inadequately prepared, in five of these cases the shielding was impaired.

Table 3: Package Damage or Deficiency by Package Type

Degree of Damage		Type A	Type B	Excepted	Industrial	None	Total
No damage		30	29	6	9		74
Potential damage	Minor	13	53	3	6		75
	Major	24	7	8	7		46
Damage/Defect-ive package without loss of containment or shielding	Shipped in Poor Condition	1	12	0	2		15
	Minor Damage	87	4	10	8		109
	Severe Damage	54	3	18	0		75
Shielding Loss		4	0	0	0		4
Containment Loss		8	0	2	21		31
Contamination	Contamination inside	1	3	0	1		5
	Contamination outside	0	39	0	0		39
Improper package leading to loss of shielding or containment	Wrong Contents	2	4	0	0		6
	Poor condition and/or defective shielding	11	5	0	0		16
No Package						12	12
Total		235	159	47	54	12	507

CONCLUSIONS

A substantial database exists of accidents and incidents involving the transport of radioactive material in the United Kingdom. The database has developed in line with experience and now holds over 500 records of varying level of detail and importance. On average, about a dozen events occur each year but there has been considerable variation from year to year.

Some trends can be discerned.

- Better handling procedures at airports have greatly reduced the number of accidents at cargo terminals.
- The use of freight containers has almost eliminated spillages from damaged drums.
- Serious exposures arising from incorrectly prepared radiography sources have not occurred since 1985 and the majority of them occurred in the 1970s.
- Human errors rather than inadequate regulatory standards are still the main concern and incorrectly prepared or badly maintained packages feature throughout the period of study.

Incidences of external contamination of packages and conveyances still occur. The radiological impact of this, however, is not significant; 39 recorded events concern irradiated fuel flasks which are not manually handled and the regulatory limits are extremely conservative for these circumstances.

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