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RADIOLOGICAL IMPACT OF TRANSPORT ACCIDENTS AND INCIDENTS IN THE UNITED KINGDOM OVER A TWENTY YEAR PERIOD

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Abstract

RADIOLOGICAL IMPACT OF TRANSPORT ACCIDENTS AND INCIDENTS IN THE UNITED KINGDOM OVER A TWENTY YEAR PERIOD.

A review has been performed in the United Kingdom (UK) of the radiological impact resulting from accidents and incidents occurring during transport over the period 1964 to 1983. This work was jointly commissioned by the UK Health and Safety Executive and the Department of Transport. The materials transported consisted of nuclear fuel cycle materials, and radionuclides for medicine and industrial use. The modes of transport studied were road, rail, sea and air. Information in this paper should be used with caution because the database is likely to be incomplete and selective owing to the difficulties of data collation for the review. These difficulties arise because information is sparse as a result of the low frequency of occurrence of such events and to the lack of published information on their impact. In the 20 year period a total of about 330 events were recorded for an estimated 720 000 shipments. Of these events only 42 had the potential to exceed or did exceed the radiological impact associated with normal transport conditions. Over 98% of the total collective dose of about 5 man·Sv may be attributed to 15 events. It is in part due to regulatory control that there has never been a serious accident involving the dispersal of radioactivity during transport in the UK. The regulations are directed to ensuring that safeguards appropriate to the nature and quantity are built into the design of the package in which the material is to be transported. A review extending over a twenty year period cannot be used to derive the probability of occurrence of severe accidents which have very low probabilities. The review has demonstrated that the majority of significant events in the UK are related to procedural and quality assurance failures. These failures are aspects which should be addressed in a comprehensive assessment of the radiological impact of transport operations.

Introduction

The UK Health and Safety Executive, jointly with the Department of Transport, commissioned the National Radiological Protection Board to carry out a study of accidents and incidents arising from the transport of radioactive materials, in the UK, covering the period 1964 to 1983.

It was important from the start of the study to specify the events to be covered. Events were classified as occurring either during the moving phase of transport or during handling prior to, during, or subsequent to the movement. Further, the events were categorised either as accidents or as incidents. The former involved significant damage to the transport or package whilst the latter dealt with other events, for example, theft, incorrect procedures, delays and incorrect packaging prior to shipping. The term 'significant damage' was limited to the situation where the load was subject to potential disruption: it excluded situations of trivial damage with negligible risk to packages.

Formal reporting of accidents was not required until 1970, when formal requirements were introduced for reporting to the appropriate authority [1,2]. The formal reports were brief, giving few details and, where the radiological impact was low, commenting little or only that dose limits were not exceeded. Few data were available on the exposure of members of the public.

Methodology

Investigation of the formal reports yielded limited data on some 200 events during the 20 year period. In addition, the Board held files on transport incidents and accidents involving radioactive materials under the NAIR scheme (National Arrangements for Incidents involving Radioactivity). Many of these reports referred to transport accidents or incidents but, again, held only limited data because the radiological consequences were always low.

Board assistance had been requested from time to time in evaluating substantial doses to radiographers travelling from remote locations to their headquarters with a gamma radiography source out of its shielded container. This group of events - transport incidents involving incorrect procedures prior to commencing a journey - was included in the report.

A questionnaire was prepared and distributed to all major transporters of radioactive material, explaining the classification and requesting data on relevant events. Once data had been collated from all readily available sources, site visits were made in order to extend the database and to expand the information on known events.

As the study progressed it became clear that few companies had retained data for more than 5 to 10 years previously, since the majority of all events were radiologically trivial and company archives are often cleared at regular intervals in order to retain only significant information for long-term record purposes. Thus for the early years of this study, data were sparse, but sufficient for the overall purposes of this report.

It is believed that no significant events have been overlooked or not recorded for the period of the study.

Materials and their modes of transport

From within the UK, radioactive materials are transported by road, rail, sea and air - about 37 000 shipments (containing various numbers of packages) in 1981/82 [2] and, because of limited data from earlier years, this same value is applied without modification to the earlier years of this study.

Materials transported were considered under three broad headings (with sub-divisions where appropriate), namely non-irradiated nuclear fuel cycle material, irradiated spent nuclear fuel plus waste products arising and radioisotopes. Consideration was given to their physical and chemical form - whether solid or liquid, sealed and encapsulated or in the form of drums of chemical powders, in order that allowances could be made for whether the radiological hazards were external or included the potential for internal exposure. Criticality has been considered where relevant.

During the period under study, road transport accounted for 68% of movements, air transport 21%, rail transport 8% and sea transport 3%.

As can be seen from Table I, radioisotopes used for radiography constitute the largest single number of annual shipments with other general radioisotopes the next largest group.

Reports received

Some 330 events have been reported out of nearly three quarters of a million transport shipments in the twenty year period of this study. Events were randomly distributed around the UK with a slight emphasis on nuclear materials in Lancashire and Cumbria in the later 1960s and early 1970s because of a combination of the presence of ports, chemical and reprocessing plants and particular operations in those areas. The nuclear material principally concerned was uranium ore concentrate (UOC) carried in industrial drums. Events during unloading of vessels at ports (10 reports) and road accidents (4 reports) led to spills of UOC, with consequential

Table I
MATERIALS AND TRANSPORT MODE (1981/82)

Numbers of consignments carried annually

	Non-irradiated	Irradiated	Isotope General use	Isotope Radiography
Road	3 000	1 000 (flasks) 1 000 (wastes)	9 000	12 000
Rail	Nil	1 100	1 600	260
Air	Negligible	Nil	8 000	Negligible
Sea	1 000	<50	200	Negligible

The table shows numbers of consignments with the majority representing single packages except for radioisotopes and low-level wastes. For radioisotopes, a typical road consignment could contain 300 packages. For low-level wastes, typically up to 100 drums could be carried as a single load by road.

light contamination, low internal and external exposure of drivers and members of the public resulting in low radiological consequences, and with no exposure exceeding 2 mSv for dock workers or drivers and 0.01 mSv for a member of the public. Containerisation of these drums since 1978 has resulted in no further releases being reported.

Radioisotopes are transported throughout the UK with radiography isotope movements concentrating around industrial centres and the edges of cities. Some of these latter movements have taken place with unshielded sources, either by accident or by improper procedure prior to the transport movement. Thus, in addition to radiation doses to the radiographers (who also transport these sources), members of the general public have also been exposed but again it is estimated that none of this latter group have exceeded a radiation dose of 2 mSv arising from any single event.

Nearly half the reports (140) related to events occurring in the cargo area of the principal UK airport. With more than one daily road delivery of medical isotopes intended for world-wide export by air, several hundred individual packages are handled daily (70 000 per annum) [2]. Typical of many bulk-cargo handling depots, packages were moved within the cargo area stacked loose on pallets mounted on lift trucks. This has resulted in packages falling from the front of the pallet, not being noticed by the driver and being run over by the lift truck or other vehicles making collections or deliveries to the airport cargo centre. In only a single event was the inner capsule, containing a radioactive liquid, broken, releasing its contents and resulting in minor contamination of the aircraft and two handlers loading the plane. One other event with a broken capsule occurred after the incorporation of absorbers in packages and so no release resulted.

In none of the other 138 events was there any damage to the inner capsules. Loose stacking has been reduced in recent years and is reflected in a reduction in airport incidents reported.

Rail transport of spent nuclear fuel and discharged fuel flasks has resulted in reports of nearly 40 incidents, mostly involving low speed collisions or derailments, principally at marshalling yards. In none of these events has there been any radiological consequences, either from external or internal exposure, nor has any irradiated nuclear fuel flask suffered any damage.

Some 20 reports of contamination on irradiated nuclear fuel flasks or their associated flatrol transporters occurred evenly over the study period. Most of these reports arise from reactor cooling pond water being contaminated, and this contamination being preferentially absorbed in painted flask surfaces. Despite subsequent decontamination, the contaminating isotopes - principally caesium-137 and caesium-134 with lesser amounts of strontium-90 - have not proved entirely removable. Adverse conditions lead to later release of these materials from the surfaces and four reports refer to the transfer of contamination from flasks to protective gloves worn by British Rail staff handling the flasks to and from their flatrols. No contamination of persons has been reported.

The contamination reports led to a further investigation of the consignor's reports. Only Magnox fuel flask data were available and these showed a frequent low level of flask contamination, largely below the derived working limit. On theoretical considerations, with all flasks assumed to be uniformly contaminated at the working level and this contamination released completely throughout a transport movement, calculations showed that doses arising from inhalation of this material resulted in wholly trivial annual doses to individual members of the public or individual transport workers.

About a third of reports associated with irradiated nuclear fuel flasks refer to incorrect procedures. None of these events led to any reported additional exposure of transport workers or members of the public.

Package and transport failures

Package failures resulting in breaches of the containment have occurred and been noted during this study. However, almost without exception, these have been subject to stresses greatly in excess of test limits.

Large industrial packages, subject to a drop test, containing 300 kg UOC have failed after 10 m drops or 50 km/h speeds, when thrown from lorries. Small industrial packages used for radiopharmaceuticals are subject to a compression test. Such packages have failed twice in 140 events, mainly as a result of compressions estimated to be one hundred to one thousand times the package weight.

Steel pressure cylinders used for the transport of uranium hexafluoride were twice involved in severe accidents, once in a road crash, once at sea. In both instances the cylinders were dislodged or torn from their mountings, and were thrown onto the road surface or vessel decking and suffered no other damage. No leakage and no contamination occurred.

An early despatch of new fuel involved in a road accident was spilt onto the road when the steel chest burst on impact. No radiation doses were recorded but these were subsequently estimated to be trivial - below 0.1 mSv.

There have been few transport failures reported in the period of the study - twenty two colliding or crashing road vehicles, two vehicle fires, some twenty derailments of railway rolling stock and two aircraft crashes but no sea-vessel failures.

The road vehicle events resulted in external damage to packages but with negligible radiological consequences. The rail reports had no radiological consequences and one of the air crashes resulted in the outer packaging only of a radiography container being destroyed but without breaching of the inner containment. The other air crash with resulting fire resulted in severe damage to about 30 packages with loss of containment, shielding and - for volatile sources - loss of contents. As a result of rapid radiological supervision, the radiological consequences were negligible.

Incorrect procedures

Incorrect procedures have led to the largest radiological consequences encountered in this study. There are 48 reports for radioisotopes and 12 for nuclear fuel cycle materials.

The nuclear fuel cycle reports related mainly to spent fuel flasks (11) with negligible radiological impact.

The 48 reports relate to radioisotopes with 15 of radiological significance, referring to radiography sources. This latter group provided the major radiological impact in this study. Radiography sources, ranging in activity from 0.03 to 1 TBq of iridium-192 (13) caesium-137 (1) and cobalt-60 (1) have been transported out of containers for periods ranging from 1 hour up to 3 days, with overnight parking in public areas in the latter case. The events have generally arisen from operators failing to monitor radiography exposure containers, which also serve as transport containers, at the end of a working day. The unshielded sources have been transported in road vehicles, at distances of 1 to 3 m from the radiographer. In three instances, overnight parking has been with the vehicle either 10 m or 50 m from adjacent housing for 12 hour exposure periods, with an assumed minimum of 200 mm thick brick walls intervening. Individual worker radiation doses ranged from a few millisievert up to 2.4 Sv (measured) individual public radiation doses ranged from 0.1 to 2 mSv (estimated).

The occupational collective dose to approximately 80 workers (all connected with radiography) amounted to 5 man.Sv, whilst the collective dose to the public amounted to 0.02 man.Sv for the same 15 events. The remaining collective occupational and public doses were less than 2% of these values (Table II) for all other events combined.

Contingency planning

For the first ten years of the study, contingency planning for the consignors was broadly limited to the large organisations - the three major groups in the nuclear power industry and the major UK radioisotope producer. These companies had adequate resources and appropriately trained

Table II
OCCUPATIONAL AND PUBLIC COLLECTIVE DOSE

Material transported	Estimated dose (20 year period) Occupational (man.Sv)	Public (man.Sv)
Radiography sources [Ir-192, Cs-137, Co-60]	5	0.02
Nuclear fuel cycle material	0.06	0.0004
Other radionuclides for medical and industrial use	0.003	<0.0001

Footnote. The annual collective dose to the UK population from natural sources is about 105 000 man.Sv.

staff and were able to respond when called to the scenes of accidents and incidents.

Prior to the arrival of these consignors, control was then, and still is, essentially with the police force, who were invariably the first to be called to the scenes of accidents and who secured control of the areas surrounding the events, excluding other persons from entering until radiological supervision could be provided, usually from the NAIR scheme.

The NAIR scheme provides the police with a rapid technical level of support from local professional staff, e.g. hospital or power station health physicists, with supplementary support of a full team if required. This latter facility has seldom been required because few events have yielded any significant radiological impact.

Unfortunately the most significant events - those concerning radiographic sources - have rarely been recognised as events until the equipment has been returned to the consignee. The group of workers most closely involved, namely the site radiographers, are subject to close inspection.

Conclusion

Based on an estimated three quarters of a million transport movements in the 20 year study period, there have been some 330 known events reported, with 15 providing over 98% of the radiological impact.

The major component of both occupational and public doses are directly attributable to the movements of radiography sources. Only a very minor contribution arises from the transport of nuclear fuel cycle materials.

Site radiography is frequently undertaken in conditions which are difficult and hostile, such as construction sites, pipelines, and motorway bridges. These conditions are less conducive to the normal standards of safety associated with nuclear plants, factories and laboratories.

Although early data were sparse, details obscure and, for the earliest years, missing entirely from some archives, it is believed unlikely that any major event has been omitted from this study.

The majority of events are related to procedural and quality assurance failures and improvements in this area would reduce the radiological impact. This is an aspect which should be addressed in a comprehensive assessment of the radiological impact from the transport of radioactive materials. The requirements for packaging and transport have been shown to be generally adequate. Improved reporting is recommended particularly with respect to data relating to emergency personnel.

The occupational collective dose amounted to 5 man.Sv in a 20 year period and the public collective dose in the same period amounted to 0.025 man.Sv. These collective doses are low compared to exposures from the normal transport of radioactive materials and are extremely low compared to exposures from natural sources of radiation.

It is partly due to regulatory control that there has never been a serious incident involving the dispersal of radioactive material during transport in the UK. The regulations are directed to ensuring that safeguards appropriate to the nature and quantity are built into the design of the package in which the material is to be transported.

REFERENCES

[1] Radioactive Substances (Carriage by Road)(Great Britain) Regulations 1970; amended 1974, HMSO, London (1974).

[2] Gelder, R., Hughes, S.J., Mairs, J.H. and Shaw, K.B., Radiation Exposure Resulting from the Normal Transport of Radioactive Materials within the United Kingdom, NRPB-R155, February 1984 (HMSO, London).