Workers monitor spent-fuel shipping flasks for rail transport. (Credit: BNFL)

Worker exposures: How much in the UK?

An NRPB study assesses radiological safety

by Ken B. Shaw

In the United Kingdom, most radioactive materials travel by road, and even materials carried by rail, air, and sea usually include a road journey at the start or end of their movements. Total road miles covered per year is several million, compared with some hundred thousand for rail.

*Basically, four categories of workers are involved with transport operations: handlers, drivers, health physics monitoring staff, and supervisory staff. In 1984, the National Radiological Protection Board (NRPB) published results of a study covering all four of these worker categories, all types of radioactive material, and all modes of transport used in the United Kingdom. The study covered occupationally related exposure during all normal transport operations of radioactive materials, but did not cover potential consequences of accidents.**

Although mainly concerned with exposure of workers, the study included the exposure of the public from the transport of irradiated Magnox fuel from the first generation of nuclear power stations. The current evaluation – based on measurements as distinct from earlier assessments which were theoretical estimates – shows that the public exposure is much lower than the calculated maximum based on pessimistic assumptions.

*For workers, the study concluded that the annual collective dose from the transport of all radioactive materials in the UK is approximately 1 man-sievert.*** This compares with an annual collective dose estimated at 500 man-sievert from all occupational exposure to ionizing radiation in the UK.*

Following is Mr Shaw's review of the study's main findings, by specific categories.

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* The study is entitled *Radiation Exposure Resulting from the Normal Transport of Radioactive Materials within the United Kingdom,* by R. Gelder, J.S. Hughes, J.H. Mairs, and K.B.Shaw.

** The sievert is the unit used to measure the dose-equivalent of a given exposure, taking into account the differing biological effects of different types of radiation. One sievert (Sv) corresponds to 100 rem. *Collective dose* is an abbreviated form of collective effective dose-equivalent and is the sum of the doses to all the relevant workers.

Transport of radioisotopes

The movement of radioisotopes within the UK is extensive. Approximately 1000 packaged isotopes are transported daily, in quantities ranging from individual packages to several hundred packages. The majority is moved by road, but about 1% by rail.

One important operation is the transport of technetium generators. These contain molybdenum-99, which undergoes radioactive decay to produce the short-lived nuclide technetium-99m. This is separated from the molybdenum at hospitals and, attached to various chemicals, injected into patients to assist in diagnosis of cancers of the bone, liver, brain, etc. The success of this technique has led to its use on a substantial scale in the UK and overseas so that regular supplies of the generators are required.

Technetium generators for hospital use produce some of the highest radiation levels external to the package during transportation. Typical dose rates at one metre from these packages are 0.02 to 0.05 millisievert per hour (mSv/h). Dose rates from other packages are often insignificant in comparison to those from generators. The number of generators transported and the dose rates outside the packages are such that some workers involved with them receive the highest radiation doses from an identified type of transport. Nonetheless, doses to these workers remain within the dose limits.

There are many other commonly used radionuclides in medicine, some of which are gamma emitters with short half-lives necessitating regular movements between producers and hospitals. Radioactive materials are also widely used in industry and frequent transportation may be required. The radiation exposure of site radiographers was given particular consideration since this group of workers regularly transport radiography sources as part of their operations.

The annual occupational collective doses involved are estimated at 0.48 man-sievert for technetium generators; 0.18 man-sievert for medical isotopes; and 0.2 man-sievert for industrial and research isotopes. Individual annual occupational doses range up to 0.02 sievert, although very few workers approach the top end of this range.

In perspective: dose limits

Currently limited data are available from a few IAEA Member States on estimates of collective doses, supported by actual measurements, from the transport of radioactive materials. Based on the data available, IAEA has tentatively concluded that the collective doses are low. Work on optimization of protection, however, in the transport of radioactive material will continue in the Agency and should continue in the Member States to assure that data and methodology are developed.

The 1985 edition of IAEA's *Regulations for the Safe Transport of Radioactive Materials, Safety Series No.6,* which emphasizes these facts, has incorporated recommendations on general principles for radiation protection that are consistent with current international optimization requirements.* In essence, these state that "all exposures should be kept as low as reasonably achievable, economic and social factors being taken into account".

Regarding the limitation of individual doses, the 1985 edition notes that:

- Neither special work patterns nor detailed monitoring or assessment of radiation doses shall be required for individual occupationally-exposed workers, where it is determined that the dose received is most unlikely to exceed 5 millisievert (500 millirem) per year.
- Periodic (as necessary) environmental monitoring and assessments of radiation exposure levels in work areas (including in conveyances) shall be conducted for individual occupationally-exposed workers, where it is determined that the dose received is likely to be between 5 millisievert (500 millirem) and 15 millisievert (1500 millirem) per year.
- Individual radiation exposure monitoring programmes and special health supervision shall be required for individual occupationally-exposed workers, where it is determined that the dose received is likely to be between 15 millisievert (1500 millirem) and 50 millisievert (5000 millirem) per year.

Currently, an annual effective dose-equivalent limit for workers at 50 millisievert is established in IAEA's *Basic Safety Standards for Radiation Protection, Safety Series No.9.*

* These are consistent with the standards previously specified in IAEA's *Basic Safety Standards for Radiation Protection, Safety Series No.9,* published in 1982.

Transport of irradiated fuel by rail

The major movements of irradiated nuclear fuel are by rail, from commercial nuclear power stations to the reprocessing plant. Considerable media attention has been focused on these movements and they were therefore investigated in some depth.

This study was conducted in association with the rail carrier. Work patterns were observed and radiation surveys performed on the radioactive consignments. Dose rates were recorded close to all accessible flask surfaces and at distances around the flask at a height of 1.5 metres. Radiation levels in the drivers' cabs and guards' vans were also monitored. Tests for removable contamination on the flasks, flask wagons, and other accessory equipment were made.

This assessment has demonstrated that the annual collective dose received by rail staff in the course of their duties is small, about 0.005 man-sievert. Most of the dose accrues at the railheads where the loading staff work in close proximity to the flask while it is being loaded. A loading staff member at the busiest railhead is unlikely to exceed an annual dose of 0.1 millisievert. The dose rates in areas normally occupied by the train crew were not detectable above background.

Transport of low-level radioactive waste

Low-level radioactive wastes have been transported by road and rail to disposal sites and to the docks for disposal in the deep Atlantic Ocean. For the sea disposal operation, low-level wastes are moved by rail from various processing stations to the port for loading onto the ship.

Summary of NRPB study results — transport worker exposures

Transport activity	Annual dose	
	Collective (man-sievert)	*Maximum individual* (millisievert)
Radioisotopes for medical use		
Technetium generators	0.48	
Other medical isotopes	0.18	20
Radioisotopes for industry and research	0.20	
Irradiated fuel by rail	0.005	less than 0.10
Radioactive waste		
Rail workers	0.0012	less than 0.50
Dock workers	0.0096	1.2
Irradiated fuel and radioactive wastes by road	0.091	Not available
Non-irradiated fuel cycle material	0.036	Not available
Nuclear power plant transport workers	0.020	1.2
Total	1.02	

Common cargo: technetium generators for hospitals. (Credit: AECL)

This assessment has shown that the annual collective dose received by rail staff at the loading points for radioactive waste to be transported to the dock is small, about 0.0012 man-sievert. The highest annual individual dose received by a rail employee is unlikely to exceed 0.5 millisievert. Radiation levels in the drivers cabs were not detectable above background dose rates.

Dock workers load the ship with radioactive waste at the docks. The collective dose to this group of workers from the 1982 sea-disposal operation was 0.0096 man-sievert. The maximum annual individual dose was 1.2 millisievert.

Other nuclear fuel-cycle movements

Ores are generally transported by road and occasionally by rail. New fuel assemblies are generally moved by road and it is estimated some 40 drivers are involved regularly with the transport of new reactor fuel. Their annual collective dose is about 0.036 man-sievert.

Fuel residues and wastes arise as a result of the nuclear fuel cycle and many of these items are carried by road from the reactor site for processing or disposal. Radiation exposures are low for the drivers involved, the annual collective dose being estimated at 0.097 man-sievert.

The data returned by the major operator of commercial nuclear power stations for the staff employed on transport duties provided the following information. A staff of 986 men were involved whose total estimated collective dose per annum was 0.02 man-sievert. The average annual dose was 0.02 millisievert and the maximum annual dose was 1.2 millisievert. Care was taken in the study to separate doses resulting from transport duties from those received due to other duties.

Survey in India

A recent study in India, partially supported by an IAEA research contract, provided measurements of exposure to transport workers associated with the transport of radioisotopes for medical, industry, and research purposes. A survey performed in the early part of the study showed the transport of these types of materials to be the single most significant source of transport worker exposure in India.

The largest exposures were found with transport workers at the Bombay airport through which these packages are directed for distribution. The maximum annual occupational doses were found to be between 1.8 and 2.0 millisievert, assuming only four men handle all of the packages throughout the year.

Furthermore, it was found that the surface transport of these materials in the Bombay area results in an estimated maximum annual collective dose to the public of only 0.1 man-sievert. It was further noted that this collective dose results not from high radiation levels, but from the high population density in the Bombay area.

The individual exposures compare very favourably with the lowest category set forth in the IAEA's 1985 edition of *Safety Series No.6* where "neither special work patterns nor detailed monitoring or assessment of radiation doses shall be required"; and they are well below the limit of 50 millisievert for the annual effective dose-equivalent for workers established in the Agency's *Basic Safety Standards for Radiation Protection.*