Radiation Doses Arising From the Air Transport of Radioactive Materials

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INTRODUCTION

There is a compelling need for the transport of radioactive material by air because of the requirement by hospitals throughout the world for urgent delivery for medical purposes. Many countries have no radionuclide-producing capabilities and depend on imports: a range of such products is supplied from the United Kingdom. Many of these are short lived, which explains the need for urgent delivery. The only satisfactory method of delivery on a particular day to a particular destination is often by the use of scheduled passenger air service.

The International Civil Aviation Organisation's Technical Instructions for the Safe Transport of Dangerous Goods by Air (ICAO 1987-1988), prescribe the detailed requirements applicable to the international transport of dangerous goods by air. Radioactive materials are required to be separated from persons and from undeveloped photographic films or plates: minimum distances as a function of the total sum of transport indexes are given in the Instructions.

A study, which included the measurement and assessment of the radiation doses resulting from the transport of radioactive materials by air from the UK, has been performed by the National Radiological Protection Board (NRPB) on behalf of the Civil Aviation Authority (CAA) and the Department of Transport (DTp).

PACKAGE MOVEMENTS

In the UK, packages of radioactive materials for export or import by air are generally sent through London Heathrow (LHR). It is estimated (ACTRAM 1987) that some 150,000 packages annually are despatched worldwide by air from LHR on about 7,200 flights: most imports come from North America or mainland Europe and the number of packages is estimated to be less than 5% of the number exported. Within the UK one manufacturer is responsible for the majority of consignments and, although these are carried by a number of airlines, one major airline takes about 30% of packages exported.

In passenger aircraft, radioactive material was found to be carried usually in one or two of several cargo compartments below the passenger cabin deck. Cargo for long-haul aircraft is carried in unit-load devices (ULD) with radioactive material stowed at the base. Short-haul aircraft have compartments too shallow for ULDs, so cargo is manually loaded, with packages of radioactive materials being placed on the floor where it is held in position by netting. Freighter aircraft can carry substantial numbers of packages on pallets.

QUESTIONNAIRES AND SURVEYS

Questionnaires were sent to 150 out of 300 airlines licensed by CAA to carry radioactive materials requesting details of their transport arrangements, such as annual number of flights with radioactive materials compared to all flights, crew numbers, flight frequency and annual hours flown. The carriers were selected mainly from major airlines with regular flights to countries with major hospital facilities.

Visits were made to the principal carriers and radiation surveys were performed on six types of aircraft undertaking long-haul or short-haul flights. The radiation surveys occurred after the packages of radioactive materials had been loaded but before passengers were allowed onto the aircraft.

RADIATION DOSE RATES

Several radiation surveys at LHR were carried out on Boeing 757 and 747 aircraft. In addition, single surveys were made of an Airbus A-310 carrying imported radioactive material, of a Lockhead Tristar and of a Boeing 747 Combi. Two surveys were made of a Boeing 737 F freighter. The flights selected for the radiation surveys were those with the highest values of total transport indexes.

In passenger aircraft, radiation dose rates were measured at seat level on the passenger deck and on the flight deck. On all surveys, dose rates on the flight deck were very close to natural background radiation levels. On the passenger deck, the maximum dose rate was determined and readings also taken throughout the deck. Table 1 gives details of the maximum dose rates measured for different aircraft types together with the sum of transport indexes in the cargo compartments.

Table 1: Maximum dose rates at seat level in occupied areas

Aircraft type	Sum of transport indexes	Maximum dose rate ($\mu Sv\ h^{-1}$)
757	5	7
747	9	2
A-310	8	5
Tristar	8	6
747 Combi	6	0.2
737 F	90	0.2

The dose rates in occupied areas are determined largely by the sum of transport indexes, the separation of the packages from deck areas and the intervening shielding provided by other cargo. The Boeing 757 has shallower compartments than those on the other passenger aircraft surveyed. Dose rates fell off rapidly with distance on the passenger decks and were reduced by an order of magnitude within a few rows of seats.

DOSE ASSESSMENT FOR AIRCREW

The dose rates measured on flight decks were very close to natural background radiation levels and the radiation doses to flight deck crew, due to the transport of radioactive materials, are therefore negligible. Cabin crew work in various areas of the passenger deck and could experience dose rates upto the maximum measured values.

Short-haul flights from the UK are generally airborne for between 1 and 3 hours and the cabin crew could travel on between 1 and 5 flights a day. On long-haul routes, flights take from 5 to 22 hours, but the permitted duty hours for cabin crew restrict the average time that can be spent on board to about 7 hours. The average annual radiation dose to a member of the cabin crew is estimated as the product of the average dose rate, the number of flights taken per year when radioactive materials are carried, and the number of hours of exposure per flight. This latter parameter includes exposure before takeoff and after landing. Table 2 gives values of these parameters for short-haul and long-haul flights.

Table 2: Values of parameters used in cabin crew dose estimation

Parameter	Value of parameter	
	Short-haul	Long-haul
Average dose rate (μSv h^{-1})	0.07	0.02
Average no. of flights y^{-1} coincident with radioactive materials	17	3
Average no. of hours of exposure per flight	3	7

The average dose rate for the passenger deck is some two orders of magnitude below the maximum value measured on the relevant aircraft during this study. Dose rates will vary owing to differences in transport indexes carried and also to shielding effects caused by other cargo. The average dose rates are, however, considered to be reasonable values: on most flights the sum of transport indexes is considerably less than that used for the measurements but this may be balanced, in a few cases, by less cargo providing less shielding between passengers and radioactive materials. The number of flights per year carrying radioactive materials from LHR was estimated for individual cabin crew members from data supplied by relevant airlines, as was the number of hours per flight. The average annual doses to individual members of cabin crew are estimated as the products of the relevant values from Table 2: they are 0.42 μSv for long-haul and 3.6 μSv for short-haul.

With equal total numbers of cabin crew in a year on all long-haul and short-haul flights, an average annual dose of 2 μSv may be used in the estimation of collective dose. Annual collective dose to cabin crew may be estimated as the product of the total number of cabin crew and their average annual dose. The number of UK aircrew is approximately 20,000 (Hughes et al 1989): this leads to a straightforward estimate of collective dose of 0.04 man Sv. A more detailed assessment, as part of this study, taking account of actual cabin crew numbers on the various flights, has produced a better estimate of 0.06 man Sv.

DOSE ASSESSMENT FOR PASSENGERS

The number of passenger hours flown in UK aircraft was about 1.3 10^8

in 1986 (Hughes et al 1989). A conservative estimate is that 1 in 10 of all flights carry radioactive materials: an analysis of airline data has shown that very different ratios apply to short-haul and long-haul flights with values for domestic, continental and other international flights ranging from some 1 in 30 to 1 in 8. The mean dose rate on aircraft carrying radioactive materials, taken as the mean of short-haul and long-haul values, is 0.045 μSv h^{-1}.

A straightforward estimate of the collective dose to passengers is the product of the number of passenger hours, the factor of 1 in 10 for the fraction of flights carrying radioactive materials, and the mean dose rate: this gives 0.59 man Sv. A more detailed assessment, during this study, taking account of flights on different aircraft and comprehensive passenger data gives a better estimate at 0.5 man Sv.

In the assessment of individual doses for passengers, it is necessary to consider their frequency of flying. Couriers were found to be the critical group of high-frequency passengers. They travel on various short-haul flights to mainland Europe, with an average of 400 flights a year, half of the departures being from LHR. One particular route, with flight times of 3 hours each way in a Boeing 757, resulted in an annual flying time of 1200 hours. This same route was used for twice-weekly consignments of radioactive material, and courier and consignment coincided on up to 80 flights in a year. The annual radiation dose to a courier on this route can be estimated as the product of the short-haul average dose rate (0.07 μSv h^{-1}) and the number of hours per year flown in conjunction with radioactive material (240 hours): this gives a simple estimate of 17 μSv. It is not considered likely for a courier always to be seated at the maximum dose rate on every flight. However, such a coincidence may occur on a number of flights and it is possible that a courier could receive an annual dose upto an order of magnitude higher than 17 μSv: it is also known that two cargo compartments are often loaded with radioactive materials on these flights. A detailed appraisal, during this study, of courier work schedules on European routes has shown that the maximum annual individual dose is 420 μSv.

SUMMARY AND DISCUSSION OF RADIATION DOSES

Individual and collective doses for aircrew and passengers have been estimated in this study. In some cases, straightforward values have been estimated to complement the more detailed assessments. A summary of the estimated individual and collective doses are given in Table 3.

Table 3: Individual and collective doses

Persons	Average annual individual dose (μSv)	Collective dose (man Sv)
Flight deck crew	Background levels	-
Cabin crew (short-haul)	3.6	0.06
Cabin crew (long-haul)	0.42	
Passengers (general)	Background levels	0.5
Passengers (couriers)	17 (420 maximum)	

Surface dose rates of up to 2 mSv h^{-1} are allowed for packages of radioactive materials in cargo compartments of aircraft. Current radiation doses to aircrew are low because many of the packages have low external radiation levels and are generally surrounded by other cargo affording shielding for the passenger and crew decks. Future changes in operational procedures and in the nature of the packages carried will affect radiation doses. Periodic radiation surveys and dose assessments are therefore necessary.

The estimated doses are low compared to doses received from cosmic radiation during flight: on average, members of crew receive about 2 mSv per annum (Hughes et al 1989).

CONCLUSIONS AND RECOMMENDATIONS

The doses to passengers and crew are generally low, although traffic in radioactive materials is steadily increasing. The low doses demonstrate that individual radiation monitoring of aircrew is not necessary. It is recommended, however, that the situation be reviewed at intervals of a few years.

The average annual radiation doses received on board aircraft are below 0.01 mSv for individual members of the crew. They are below

0.5 mSv for the critical group of passengers, namely the couriers. The doses from cargo may be compared to the average annual dose from natural radiation, which is about 2 mSv on land and an additional 2 mSv from cosmic radiation for aircrew.

The Segregation Tables in the ICAO Technical Instructions (ICAO 1987-1988) are based on cautious values of the important parameters and they are robust in nature; consequently they are still adequate for segregating radioactive materials on board aircraft from passengers and crew.

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