Radiation Doses Arising from the Sea Transport of Radioactive Materials

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INTRODUCTION

For both economic and geographic reasons a wide variety of radioactive materials is transported to and from the United Kingdom (UK) by sea. These materials include those associated with the nuclear fuel cycle such as uranium ore concentrate (UOC) and irradiated nuclear fuel and also radioisotopes used in medicine and industry.

The international carriage of radioactive materials by sea is governed by the requirements of the International Maritime Organisation's International Maritime Dangerous Goods Code (IMDG Code), (IMO 1988). This requires the segregation of radioactive materials from persons and undeveloped photographic film. The appropriate separation distances are given in tables and nomographs in the Code.

A study to investigate the UK practices associated with the carriage of radioactive materials by sea and to assess the radiation doses to passengers and crew has been performed by the National Radiological Protection Board (NRPB) on behalf of the UK Department of Transport. The Segregation Tables in the IMDG Code were reviewed and the implications of a revised quality factor for neutrons assessed (ICRU 1986).

COLLECTION OF DATA

A small number of companies are involved with the majority of exports and imports of radioactive material. These were approached to provide details of consignments. Then, with the co-operation of ships officers and crew, arrangements were made to visit the ports and to take measurements of radiation levels on board vessels carrying a representative sample of the consignments.

Radiation dose rates were measured in the regularly occupied areas such as crews' living quarters and the bridge and also at locations close to the cargo (1 - 2 m) and (3 - 6m). Where relevant both gamma and neutron dose rates were measured.

Questionnaires were sent to the operators of UK registered ships to seek information on manning and working arrangements on board their vessels. This information was followed up by discussion with ships officers and ratings and established the existence of broad patterns of work common to certain vessel types.

TRAFFIC AND WORK PATTERNS

Because a significant proportion of the doses could be received during work close to the cargoes of radioactive material actual exposure times at different locations on board vessels were estimated from work patterns.

The vessels involved in the carriage of radioactive material were classified into four categories: ferries; container ships; off-shore support vessels; and dedicated vessels.

Ferries. These are generally about 120m in length and carry both cargo and passengers between Europe and the UK. The relatively short voyages across the North Sea and English Channel take between 1 and 24 hours.

The cargo, of say a lorry trailer of uranium hexafluoride cylinders, or a box van carrying medical radioisotopes is stowed on the lower vehicle deck against the side wall either at the bow or stern of the vessel. This provides the maximum separation between the radioactive material and the areas regularly occupied by crew and passengers.

Work close to the radioactive material for about 15 minutes is undertaken during the voyage by the duty watch keeper who makes visual inspections of the cargo; and during docking by 3 or 4 crew members who prepare the exit ramp for the off loading of vehicles. Maintenance is held over until port is reached.

Container ships. These are generally 150 - 300m in length and take up to 14 days to cross the Atlantic and 40 days to cross the Pacific, calling at UK cargo ports for loading, unloading or transhipment.

Cargoes mainly consist of non-irradiated nuclear fuel cycle materials such as UOC in standard 6 or 12m containers. These are located above and below the main deck about ½ - ⅓ of the vessel length away from the regularly occupied areas.

Cargo inspection is made daily by the deck officers. These duties involve the traversing of all decks and making a visual inspection of container restraints and tie-downs. Inspections close to cargoes of radioactive materials can take from 10 to 30 minutes a day. In addition, other duties require the ship's bosun to traverse the deck daily, passing close to such cargo. Maintenance, in the general area adjacent to these cargoes, is carried out for a few hours during each voyage and is common to all container vessels.

Off-Shore Support Vessels. The supply vessels for the oil and gas rigs around the UK are about 50 - 70m long and undertake journeys of 10 - 100 hours duration travelling from the Scottish east coast ports such as Aberdeen to the North Sea or from Great Yarmouth to the gas rigs. They generally carry a single box holding well-logging and/or the occasional radiography source together with smaller callibration sources. This box is stowed at the mid point or stern of the loading platform. The regularly occupied area of the vessel is in the bow.

Exposures for a few minutes occur very close to the box during its loading and unloading, and at a distance of a few metres during the loading/unloading of adjacent cargo. No routine maintenance or close inspection of the cargo is undertaken during the voyage.

Dedicated Vessels. Although mentioned here for completeness the ships dedicated to the carriage of irradiated nuclear fuel are very much a special case and the work patterns of their crews differ markedly from those observed in the three other vessel types. The radiological protection of the crew is achieved not by the application of segregation tables but by having purpose built vessels and full radiological supervision throughout the voyage.

RADIATION LEVEL MEASUREMENTS AND ASSESSED DOSES

Table 1 gives details of the dose rates associated with certain cargoes of radioactive materials. The lowest radiation levels (A) are associated with cargoes of small numbers of containers of unirradiated nuclear fuel cycle material, or radiotherapy sources or a single spent fuel flask containing low burn-up fuel.

The medium radiation levels (B) arise from larger numbers of containers of unirradiated nuclear fuel cycle material and from most medical radioisotope shipments, and the highest radiation level (C) arises a few times a year from consignments of medical radioisotopes.

Table 1 Gamma Dose Rates

	Dose rates from cargoes ($uSvh^{-1}$)		
Distance from Cargo	Low (A)	Medium (B)	High (C)
1 - 2 m	5	20	150+
3 - 6 m	1	5	20
Regularly occupied areas	BG*	BG*	0.2

+ This is the average of measurements which were made at 1.5 m, they were less than 100 $uSvh^{-1}$ at 2 m

* BG Background 0.1 $uSvh^{-1}$

Typical neutron dose rates are given in Table 2. They have been encountered only around nuclear fuel flasks and well-logging sources.

Table 2 Neutron Dose Rates

	Typical dose rates from cargoes ($uSvh^{-1}$)		
Distance from Cargo	Single Flask low burn-up fuel	Single Flask High burn-up fuel	Well-logging source
Close to package surface	6	15	60
1 m	Not detectable	5	10
Regularly occupied areas	Not detectable	1.3	0.23

Assessments of maximum doses to passengers and crew were made using the measured radiation levels, estimated exposure times during the voyage and number of voyages undertaken per year. The results are given in Table 3.

Table 3 Assessed radiation doses to the most exposed crew member and passenger

		Annual number of Voyages with RAM		Annual Dose mSv	
Type of Vessel	Typical Cargo	Crew	Passenger	Crew	Passenger
Ferry	Medical Isotopes	45	10	0.39	0.006
Container Vessel	Containers UOC	1	1	0.3	0.05
Off-shore Support Vessels	Well-logging sources	10	0	0.25	-

DISCUSSION AND CONCLUSIONS

Although for some crew members between one half and two thirds of the dose arises from work close to the cargoes rather than in regularly occupied areas the Segregation Tables in the IMDG Code are sufficiently robust and conservative such that their application provides adequate protection for both crew and passengers.

Quality Factors (QF) are currently under review by international groups. An ICRP/ICRU Task Group (ICRU 1986) has suggested an approximation which would mean for neutrons an increase by factor of 2.5 on the current value of QF. Discussions are continuing and ICRP has not yet made formal recommendations. The implications of an increase in QF for neutrons by factors of 2 or 3 would not be severe with regard to radiation doses.

The annual radiation doses likely to be received on board non-dedicated vessels are below 0.05mSv for passengers and 0.5mSv for crew. These values may be compared to the average annual doses from natural background radiation which are about 2mSv on land and 0.7mSv at sea.

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