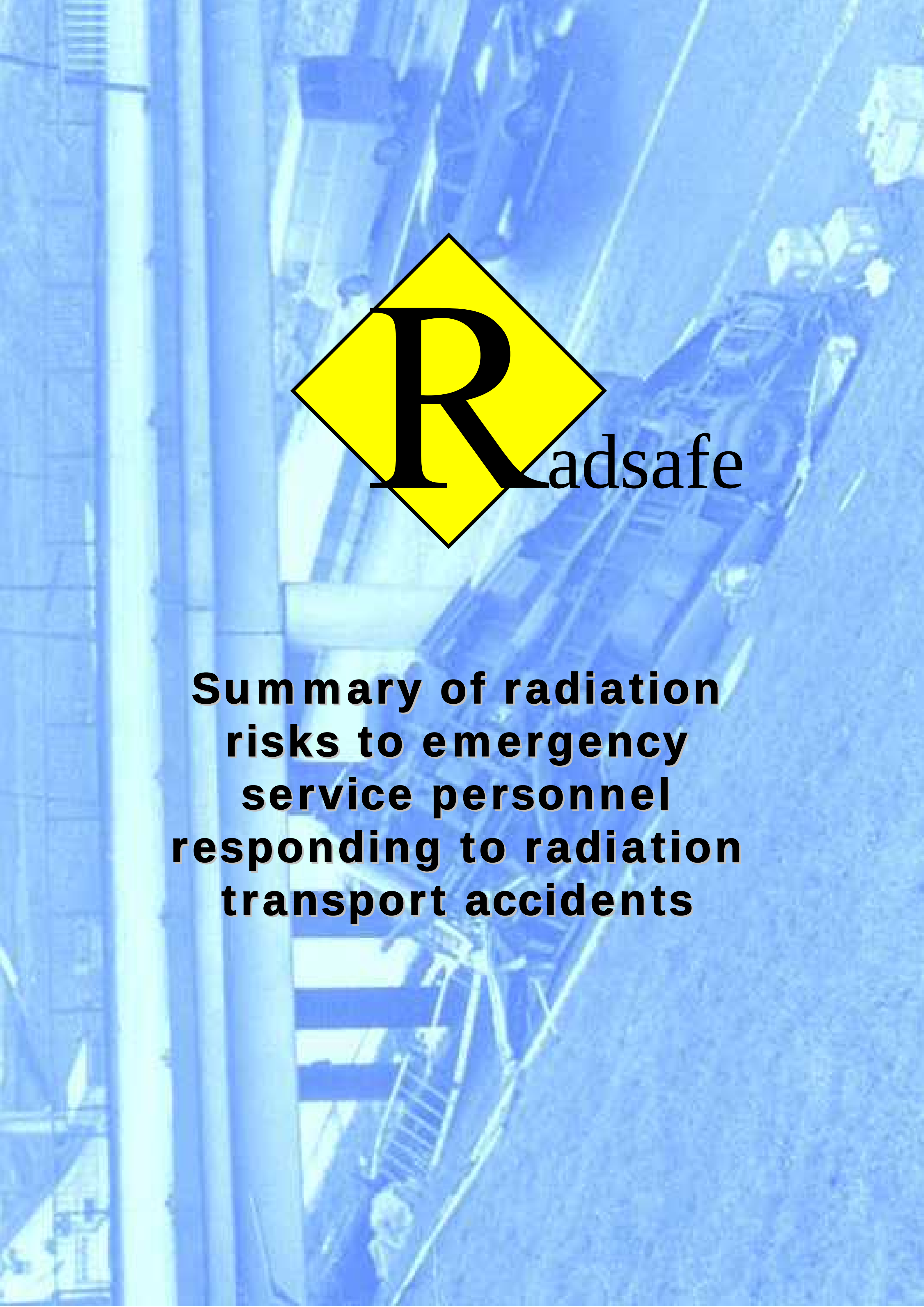

Radsafe

Summary of radiation risks to emergency service personnel responding to radiation transport accidents

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Summary of radiation risks to emergency service personnel responding to radiation transport accidents

P Kruse, NP McColl and SL Prosser

Abstract

This report summarises the work originally presented in NRPB memorandum M1044, "Radiation risks to emergency service personnel responding to nuclear and radiation accidents". This report presents assessments of the risks arising from radiation exposure incurred by emergency service personnel involved in the response to accidents associated with the transport of radioactive materials under RADSAFE.

The assessments cover accident scenarios involving a range of radioactive materials that are transported in Type A and B and industrial packages under the RADSAFE scheme.

The primary risk from radiation exposure at the assessed levels is a very small addition to the normal lifetime risk of developing cancer.

Generic risk assessments are presented for a range of accidents scenarios. These are intended to be compatible in structure and format with other risk assessments developed by the emergency services to meet the requirements of the Management of Health and Safety at Work Regulations 1992.

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CONTENTS

1 INTRODUCTION

This report summarises the work originally presented in NRPB memorandum M1044, "Radiation risks to emergency service personnel responding to nuclear and radiation accidents". NRPB was contracted by BNFL and British Energy to carry out assessments of the risks arising from radiation exposure that might be incurred by emergency service personnel in a variety of potential accident scenarios. This included the response to accidents associated with the transport of radioactive materials under RADSAFE. A full description of the assessments carried out can be found in McColl and Prosser (1999).

Assessing risks is a general requirement of the Management of Health and Safety at Work Regulations (HMSO 1992). By assessing the risk of a particular activity in the workplace, informed decisions can be made regarding the control of that risk. The emergency services (primarily police, ambulance, fire and rescue) are required to have risk assessments in place for activities they carry out, including those that form part of their emergency response function.

The risk arising from radiation exposure is quantified by assessing the effective dose (ICRP 1990) received by notional individuals in the various scenarios considered.

In each of the scenarios considered, the doses assessed are solely those that arise as a direct consequence of the accident under consideration. Doses exclude contributions from natural background and regulated direct radiation that may be emitted from any nearby packages or facilities.

2 TRANSPORT ACCIDENT SCENARIOS

A wide range of consignments of packages containing radioactive material are transported every year under the RADSAFE scheme. In order to provide a basis for assessing risks to emergency service personnel involved in the response to accidents involving such consignments, a set of representative but fairly pessimistic accident scenarios was developed by the authors and the customers for use in this study.

The customers (private communications 1998/99) provided additional information about accident scenarios, release conditions, representative off-site duties and protective measures that would be taken by the emergency services in the event of an accident involving consignments of radioactive material transported in Type A or B or industrial packages under RADSAFE.

Simple models were used to represent external radiation (from exposed sources and airborne radionuclides) and the local dilution of radionuclides released to air (McColl et al 1993). These models were used to generate gamma dose rates and airborne concentrations of radionuclides. These quantities were combined with information about the representative duties and dosimetric information to calculate effective radiation doses to notional individuals performing representative duties.

2.1 Release scenarios

Three accident scenarios were considered for Type A packages. They cover a range of radionuclides and physical properties of source types that are routinely transported. The scenarios encompass beta/gamma and alpha emitting sources. They encompass sources that do not have great physical integrity (“non-special form”) as well as more intense (higher activity) sources that are designed and manufactured to be able to withstand significant environmental stresses (“special-form”). The three scenarios were:

- 0.4 TBq* of Cobalt-60 (^{60}Co) special form - source fully exposed, no environmental release
- 2.0 TBq Iodine-125 (^{125}I) non-special form - source fully exposed complete airborne release over 1 hour
- 2 10^{-4} TBq Amercium-241 (^{241}Am) non-special form - source fully exposed 10% airborne release over 1 hour

A single Type B package scenario was considered. This accident involves a transport flask containing spent Magnox fuel. It was assumed that a very small quantity of the contents (0.035%) is released uniformly to atmosphere over period of 84 hours.

A single industrial package scenario was considered. This accident involves a container carrying low specific activity waste packaged within steel drums. A wide range of low specific activity material or surface contaminated objects materials are transported in Industrial Packages. The accident characteristics used here are based on information provided by RADSAFE. The accident considered involves a consignment of low specific activity radioactive waste transported in an Industrial Package. The waste is held in metal drums within a standard full height ISO container. It is assumed that a total of 8.4 x 10^{-4} TBq of beta/gamma emitting fission products (represented by Ruthenium-106/Rhodium-106) are released to atmosphere over a period of 2 hours.

* TBq, or terabecquerel, is a measure of activity. One terabecquerel equals 10^{12}Bq.

2.2 Emergency Service Duties

Early generic advice provided to the emergency services specifies that, in an accident involving the transport of radioactive material, following the initial response, a 45 metres cordon is set up around the affected package. A copy of the generic advice is provided in Appendix D.

For the purpose of these assessments, the following three representative duties were considered:

- an initial responder - assumed to be at a distance of 10 metres from the affected package for 10 minutes with no special protection.
- an individual outside the cordon - assumed to be at the cordon distance of 45 metres for 1 hour with no special protection.
- an individual within the cordon - assumed to be at a distance of 10 metres from the affected package for 1 hour wearing full chemical protection suit and breathing apparatus.

2.3 Radiological Assessments

Assessments of the radiation doses received by personnel were made by considering the locations and times at which an individual is present during the accident, as described above.

Environmental radiological quantities (gamma dose rates and concentrations of radionuclides in air) were calculated for those locations and times based on the appropriate accident parameters.

The following pathways were considered:

- inhalation of radioactive material
- external irradiation

Effective doses were calculated from the inhalation of locally diluted radionuclides released to air and from external gamma radiation from an exposed or released source.

For duties in which chemical protection suits and breathing apparatus are worn, it was assumed that these provided complete protection against the inhalation pathway but have no effect on doses from external radiation.

For accidents involving Type A packages, external gamma irradiation from airborne radionuclides was ignored since for all cases considered it is very small compared with other direct or inhalation exposure pathways.

For accidents involving Type B or industrial packages, external irradiation from airborne radionuclides was represented by 5 minutes worth of airborne release acting as a point source at a distance of half the separation of the individual and the release point.

3 DOSES AND RISKS

At the levels of radiation exposure assessed here, it is considered appropriate to assume that there is a linear no-threshold relationship between radiation dose, as expressed by the quantity effective dose, and the additional lifetime risk of developing a fatal or serious non-fatal cancer as a consequence of that dose (ICRP 1990). The recommended risk factor for cancer induction in a working population is 4.8 % per Sievert of effective dose (ICRP 1990).

Effective doses for each accident scenario are shown in Table 1. The additional lifetime risk of cancer arising from the radiation exposure is also presented. All doses and risks are presented to a single digit of precision.

TABLE 1 Summary of doses and risks

Scenario	Effective Dose (mSv)	Additional lifetime risk		Equivalent period of typical background radiation
Type A package	1	$5\ 10^{-5}$	About 1 in 20,000	A few months
Type B package	0.00001	$5\ 10^{-10}$	About 1 in 2,000,000,000	Less than 1 day
Industrial package	0.0002	$1\ 10^{-8}$	About 1 in 100,000,000	Less than 1 day

The assessed doses are placed into context by broadly equating each to an appropriate period of exposure to normal natural and man-made background radiation sources. The average annual dose to a member of the UK population from all radiation sources (Hughes and O'Riordan 1993) is approximately 2.6 mSv, most of which arises from sources of natural origin.

A more detailed breakdown of doses is presented in Table 2. It should be noted that the doses calculated here are indicative and are based on an assessment of a limited number of release and duty scenarios. In practice, a number of factors may result in doses which may be higher or lower than those presented here. In particular, the characteristics of an actual accident may lead to significantly higher or lower quantities of a range of radionuclides being released. However, the release scenarios used here are consistent with the accidents assessment and emergency planing. These accidents are themselves considered to be very unlikely. Accidents significantly more severe than this are considered to have an even lower likelihood of occurring.

A great number and wide range of radioactive packages are transported every year. There are also a wide variety of circumstances in which a transport accident could occur. Thus, doses to emergency service personnel in the event of a transport accident could vary markedly. While the assessments made here cannot be considered to be based on "worst case" scenarios, they are based on generally pessimistic assumptions about the particular radionuclides being transported and the quantities of these radionuclides that are involved in the accident.

4 COMPARISON OF RISKS

It is recognised that comparing risks is always problematic and it is acknowledged that some of the risks described here are voluntary whilst others are involuntary and this can have a large impact on the individual's view of the acceptability of risks. Where possible the report tries to avoid imparting a false precision on the risk estimates. Consequently risks classed as "broadly comparable" mean they are within the same order of magnitude.

Using ICRP recommended risk factors, an effective dose of 1 mSv gives a lifetime fatal cancer risk of about 1 in 20,000 or 5×10^{-5}. The average UK risk of developing fatal cancer is about 1 in 4 or 25%.

A dose of 1 mSv, the highest dose estimated in this study, is broadly equivalent to:

- 1 abdominal X-ray;
- approximately 6 months worth of annual average exposure to natural ionising radiation in the UK. On average a person in the UK receives a dose of 2 mSv every year from natural radiation.

It would be overly simplistic to make such a comparison without recognising the differences between different risks. People are much more likely to accept risks they think as voluntary (such as smoking) compared to the same risk if it was imposed by society or their working conditions. Workers can become familiarised with the usual risks of the job (for example road accident risk for ambulance crews) but may be wary of risks, such as radiation, that they are not familiar with. In addition, Bennett (1998) identifies a number of "fright factors" resulting in risks being seen as less acceptable if perceived:

- to be involuntary
- as inequitably distributed
- as inescapable
- to arise from unfamiliar sources
- to cause hidden and irreversible damage, e.g. through onset of illness many years after exposure
- to pose particular danger to small children or pregnant women or more generally future generations
- to threaten a form of death arousing particular dread

- to damage identifiable rather than anonymous victims
- to be poorly understood by science
- as subject to contradictory statements from responsible sources

These factors relate to an individual's perception of risk. Radiation "scores" for many of these characteristics. It is therefore not surprising that the public may consider radiation risks unacceptable at much lower levels than they tolerate other involuntary risks such as those from smoking or road traffic accidents.

5 SUMMARY RISK ASSESSMENT SHEETS

Summary risk assessment sheets are included in Appendix A-C. A single assessment is provided for Type A (based on the highest doses from the scenarios involving Type A packages). Assessments are provided for both the Type B and industrial package accidents considered. These sheets are presented in a format based on other risk assessments in use by the emergency services.

For each assessment, the summary page presents the hazard, risks and likely consequences of exposure to that hazard. The highest radiation dose assessed to be received by a member of the emergency services undertaking a typical duty in a specified accident scenario is presented. The comparison with a period of typical UK background radiation dose is also presented.

The primary hazard from exposure to radiation at the low levels assessed here is the small additional lifetime risk of developing a fatal or serious non-fatal cancer. The additional risk associated with dose reported for each accident scenario is presented.

The summary table also contains a simple risk estimation expressed as "the likelihood of harm", as specified in the Health and Safety Executive's guidance on Successful Health and Safety Management, HS(G) 65 (HMSO 1993).

In all cases considered here, the likelihood of harm has been attributed as low, namely, where harm will seldom occur.

For a more detailed description of the hazards and assessment and control of risks the original report should be consulted (McColl and Prosser 1993).

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TABLE 2 Doses and risks

Scenario		Effective Dose (mSv)	Additional lifetime risk		Equivalent period of typical background radiation
Type A package – special form beta/gamma	Initial Responder	0.2	9 10^{-6}	About 1 in 100,000	A few weeks
	Inside Cordon	1	5 10^{-5}	About 1 in 20,000	A few months
	Outer Cordon	0.05	3 10^{-6}	About 1 in 400,000	A few weeks
Type A package – non-special form beta/gamma	Initial Responder	0.2	1 10^{-5}	About 1 in 100,000	A few weeks
	Inside Cordon	0.08	4 10^{-6}	About 1 in 300,000	A few weeks
	Outer Cordon	0.02	8 10^{-7}	About 1 in 1,000,000	A few days
Type A package – non-special form alpha	Initial Responder	0.01	7 10^{-7}	About 1 in 1,000,000	A few days
	Inside Cordon	4 10^{-6}	2 10^{-10}	About 1 in 5,000,000,000	Less than 1 day
	Outer Cordon	0.001	5 10^{-8}	About 1 in 20,000,000	Less than 1 day
Type B package – MAGNOX flask	Initial Responder	1 10^{-5}	5 10^{-10}	About 1 in 2,000,000,000	Less than 1 day
	Inside Cordon	4 10^{-6}	2 10^{-10}	About 1 in 5,000,000,000	Less than 1 day
	Outer Cordon	9 10^{-7}	4 10^{-11}	About 1 in 20,000,000,000	Less than 1 day
Industrial package	Initial Responder	0.0002	1 10^{-8}	About 1 in 100,000,000	Less than 1 day
	Inside Cordon	3 10^{-5}	2 10^{-9}	About 1 in 700,000,000	Less than 1 day
	Outer Cordon	2 10^{-5}	7 10^{-10}	About 1 in 1,000,000,000	Less than 1 day

APPENDIX A GENERIC RISK ASSESSMENT FOR AN ACCIDENT INVOLVING A TYPE A PACKAGE

SUMMARY

GENERIC RISK ASSESSMENT FOR EMERGENCY SERVICE RESPONSE TO INCIDENTS INVOLVING RADIOACTIVE MATERIAL TRANSPORTED IN TYPE A PACKAGES

DATE: April 1999

1. ACTIVITY
Emergency service response following an accident involving radioactive materials transported in Type A packages.

2. GENERIC HAZARD : Radiation

3. PERSONS AT RISK : Emergency service personnel

4. DESCRIPTION OF RISK AND LIKELY CONSEQUENCES
The hazard considered here could lead to risks to emergency service personnel in the form of health effects resulting from a radiation dose. All doses quoted in this document are in the form of effective dose. This is the principal measure of risk associated with radiation exposure.

The highest radiation dose likely to be received by emergency service personnel undertaking representative duties as part of their response to such an accident has been assessed to be approximately **1 mSv** effective dose. In most cases, however, it is expected that the doses would be lower.

This is approximately a few months' worth of the average annual radiation dose of

2.6 mSv that is received every year by people in the UK, most of which arises from sources of natural origin.

The primary hazard from radiation exposure at this level is additional risk of the development of cancer. The additional risk of an individual developing cancer as a result of the radiation exposure assessed here is approximately 5 10^{-5} or

1 in 20,000.

There is a **low** likelihood of harm, as specified in HS(G)65, resulting from undertaking duties as part of the off-site response to the accident considered here.

The radiation doses that might be received by individual personnel could vary markedly according a number of factors including the details of the accident and the duties of the individual.

This assessment was made on the basis of accident information authorised by RADSAFE.

5. PROTECTIVE MEASURES
Following initial response, Chemical Protection Suits (CPS) are assumed to be worn by responders within a 45 m cordon.

6. ASSESSOR : National Radiological Protection Board

APPENDIX B GENERIC RISK ASSESSMENT FOR AN ACCIDENT INVOLVING A TYPE B PACKAGE

SUMMARY

GENERIC RISK ASSESSMENT FOR EMERGENCY SERVICE RESPONSE TO INCIDENTS INVOLVING RADIOACTIVE MATERIAL TRANSPORTED IN TYPE B PACKAGES

DATE: April 1999

1. ACTIVITY
Emergency service response following an accident involving radioactive materials transported in Type B packages.

2. GENERIC HAZARD : Radiation

3. PERSONS AT RISK : Emergency service personnel

4. DESCRIPTION OF RISK AND LIKELY CONSEQUENCES
The hazard considered here could lead to risks to emergency service personnel in the form of health effects resulting from a radiation dose. All doses quoted in this document are in the form of effective dose. This is the principal measure of risk associated with radiation exposure.

The highest radiation dose likely to be received by emergency service personnel undertaking representative duties as part of their response to such an accident has been assessed to be approximately **0.00001 mSv** effective dose. In most cases, however, it is expected that the doses would be lower.

This is much less than a day's worth of the average annual radiation dose of

2.6 mSv that is received every year by people in the UK, most of which arises from sources of natural origin.

The primary hazard from radiation exposure at this level is additional risk of the development of cancer. The additional risk of an individual developing cancer as a result of the radiation exposure assessed here is approximately $5\ 10^{-10}$ or

1 in 2,000,000,000.

There is a **low** likelihood of harm, as specified in HS(G)65, resulting from undertaking duties as part of the off-site response to the accident considered here.

The radiation doses that might be received by individual personnel could vary markedly according a number of factors including the details of the accident and the duties of the individual.

This assessment was made on the basis of accident information authorised by RADSAFE.

5. PROTECTIVE MEASURES
Following initial response, Chemical Protection Suits (CPS) are assumed to be worn by responders within a 45 m cordon.

6. ASSESSOR : National Radiological Protection Board

APPENDIX C GENERIC RISK ASSESSMENT FOR AN ACCIDENT INVOLVING AN INDUSTRIAL PACKAGE

SUMMARY

GENERIC RISK ASSESSMENT FOR EMERGENCY SERVICE RESPONSE TO INCIDENTS INVOLVING RADIOACTIVE MATERIAL TRANSPORTED IN INDUSTRIAL PACKAGES

DATE: April 1999

1. ACTIVITY
Emergency service response following an accident involving radioactive materials transported in industrial packages.

2. GENERIC HAZARD : Radiation

3. PERSONS AT RISK : Emergency service personnel

4. DESCRIPTION OF RISK AND LIKELY CONSEQUENCES
The hazard considered here could lead to risks to emergency service personnel in the form of health effects resulting from a radiation dose. All doses quoted in this document are in the form of effective dose. This is the principal measure of risk associated with radiation exposure.

The highest radiation dose likely to be received by emergency service personnel undertaking representative duties as part of their response to such an accident has been assessed to be approximately **0.0002 mSv** effective dose. In most cases, however, it is expected that the doses would be lower.

This is much less than a day's worth of the average annual radiation dose of 2.6 mSv that is received every year by people in the UK, most of which arises from sources of natural origin.

The primary hazard from radiation exposure at this level is additional risk of the development of cancer. The additional risk of an individual developing cancer as a result of the radiation exposure assessed here is approximately 1×10^{-8} or

1 in 100,000,000.

There is a **low** likelihood of harm, as specified in HS(G)65, resulting from undertaking duties as part of the off-site response to the accident considered here.

The radiation doses that might be received by individual personnel could vary markedly according a number of factors including the details of the accident and the duties of the individual.

This assessment was made on the basis of accident information authorised by NIREP.

5. PROTECTIVE MEASURES
Following initial response, Chemical Protection Suits (CPS) are assumed to be worn by responders within a 45 m cordon.

6. ASSESSOR : National Radiological Protection Board

APPENDIX D EARLY GENERIC ADVICE TO THE EMERGENCY SERVICES