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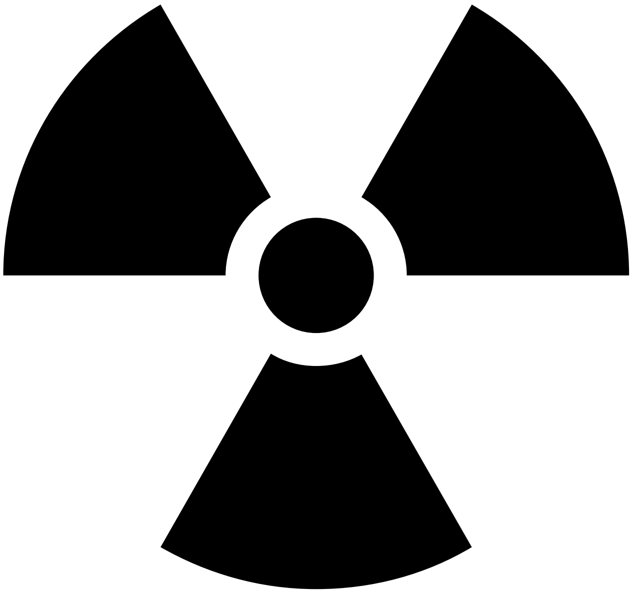
INTERNATIONAL

SAFE HANDLING OF RADIOACTIVE MATERIALS IN PORTS AND HARBOURS



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Warning

This document provides an introduction to safe handling of Radioactive Materials in Ports and Terminals. For detailed advice it is necessary to read this in conjunction with the relevant national and international legislation.

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SAFE HANDLING OF RADIOACTIVE MATERIALS IN PORTS AND HARBOURS

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INTRODUCTION

This document is written as general guidance for operators involved in handling of radioactive materials in ports and harbour areas. Handling, transporting, storing and using radioactive materials is regulated activity and anyone involved should refer to and comply with applicable international, national and local regulations, guidance and industry good practice. Relevant international as well as national regulations and guidance take precedence over the content of this publication. Occupational Exposure Limits and other standards may change over time and the reader is advised to check for the current applicable figures.

1. | BACKGROUND

Radioactive materials are used in medicine, industry, research and production of electricity around the world each day. These products must be properly and safely transported from the point of manufacture (supplier's licensed facility) to the point of use (customer's licensed facility). Radioactive material is used in many ways to improve the quality of life. It is incumbent on qualified individuals and responsible organisations to ensure that the radioactive material is prepared, used, handled, transported and disposed of in a safe manner, in accordance with the applicable regulations.

Radioisotopes having very short half-lives are used in nuclear medicine (a type of medical procedure which often involves administration of a radioactive material of small quantity into a patient's body for very accurate diagnosis and also for therapeutic purposes, e.g. cancer of thyroid) and need to be rushed to the waiting patients. Due to the very short product life these materials are transported by air or road.

Cobalt 60 is an important Radioactive Material used for cancer therapy, sterilization of medical, food products and has to be transported from the supplier to the user.

Several radioactive materials are used for non-destructive testing of welds and castings and in industrial process control, such as measurement of thickness, density and moisture content and level gauging.

The radioactive materials used in nuclear power industry have to be transported from one facility to another for efficient production of reliable and clean nuclear energy.

All the concerned organizations, viz., the manufacturer, the carrier, the handler and the customer play key roles in facilitating the transport of radioactive material for the various applications.

Radioactive material has been transported for more than 40 years the world over, without any serious accident causing damage to humans or the environment. The regulatory requirements for the manufacture, transportation and handling ensure safety and security (see Appendix G for more detailed description of the uses of radioactive material).

This research paper is written as a guide for Radiation Protection Supervisor(s) (“RPS”) working in ports and harbours. In many cases the RPS will be the Safety Officer.

Throughout this research paper the term “package” is used to describe an individual package within a Cargo Transport Unit (“CTU”).

The parameters described in this paper are expected to closely match those in busy ports worldwide. This paper is based on UK operations in a range of ports, both large and small. It includes details of workforces, methods of allocating work, anticipated radioactive material cargoes, frequency with which workers are expected to be allocated work on such cargoes and ranges of dose equivalents arising from different cargo types.

A Model for Dose Assessment is shown in Appendix D, together with a recommendation for dose review, with a suggested maximum dose for workers in ports and harbour areas. The maximum dose value suggested is not a Dose Limit. Dose Limits are internationally agreed values set out in Appendix A. Instead, a value has been chosen which

- corresponds to operational practices where no monitoring of workers is required
- is expected to have already been achieved by the majority of port authorities

The suggested value is in line with that specified by the International Atomic Energy Agency (“IAEA”) for members of the public. This is 1/5 of the value normally used for protection purposes for transport workers involved in occasional handling of radioactive materials.

Note that exposure limits are *limits* and not *targets*. The aim should always be to reduce exposure to as low as reasonably practicable below the limit.

The unit of radiation dose

The IAEA dose limits in Appendix A are in milliSieverts (mSv) but radiation doses are normally measured in microSieverts (μSv) or as dose rates in microSieverts per hour (μSv/h).

Transport Index

Every package containing Class 7 (radioactive) material has a Transport Index (TI) value assigned and marked on container placards, indicating the maximum level of external radiation exposure, 1 metre distant from the package surface. This figure is used to exercise control over stowage during a voyage and during access when cargoes are handled in port and harbour areas.

The TI can be checked as follows:
multiply the maximum radiation dose rate at 1 metre measured in milliSieverts per hour by 100 [mSv/h X 100], or if the dose rate is measured in microSieverts, divide it by 10 [μSv ÷ 10].

Using either of these methods gives the TI value for the package.

A suggested maximum dose of 1 milliSievert per annum (Appendix A) for dockworkers is intended to reflect the maximum effective dose likely to be received by them at work in a one year period. The suggested dose per worker is based on work with potential for radioactive materials exposure being distributed evenly amongst the workforce.

RPSs are recommended to use the Guidance Notes for Dose Assessments in Appendix D to determine whether the suggested model is appropriate for their port or harbour area. Appendix D is a model only, additional assessment will be necessary for the specific port or terminal context; especially if conditions are very different from the model values.

Closely linked to dose control is the Transport Index [TI]. This is a figure indicating the highest external dose rate at 1 metre from the surface of a package or a CTU. The sum of TIs for all CTUs in a consignment is used for determining on-board segregation distances, based on tables in the IMDG code. In ports and harbours, the same concept can be applied to worker protection, although handling time may be more important than separation distance.

2. | GENERAL

This paper deals with the two most important aspects of handling radioactive materials in ports and harbours

- safety factors built-into consignments
- additional practical measures to further reduce exposure of persons to radiation.

This paper is intended for the guidance of RPSs, workers and management in ports and harbours involved with the shipping of radioactive materials. References are made to external bodies where assistance and additional advice may be obtained in the event of an accident or incident involving release of radioactive materials from packages or Container Transport Units.

All exposure to radiation carries some risk of harmful effects, therefore doses should be kept as low as reasonably practical (ALARP).

Evidence gathered suggests that dockworkers are unlikely to exceed the annual dose limit applicable to a member of the public [Appendix A].

Surveys of different transport operations have been conducted in several countries in order to confirm that transport operations were satisfactory. Several European states have also researched their records in order to confirm that radiation exposure arising from accidents was limited. Whilst most information related to road and rail operations, a few events in ports were also described, but none gave rise to significant exposure.

There are several reports available on transport operations, but none are specific to operations in ports and harbour areas. The author has undertaken a number of studies of marine transport of radioactive materials and has made measurements of radiation doses to dockworkers undertaking normal operations with a range of cargoes of radioactive materials. The findings and recommendations in this paper are based on that experience.

The question of whether it is necessary to issue dockworkers with dose meters to record the doses received during loading and discharge of radioactive material cargoes has been raised. The annual doses recorded were too low to register on normal dose meters, even when working for prolonged periods. The use of personal dosemeters is, therefore, not recommended for ports and harbours, other than for those ports and harbours that consistently handle high activity radioactive materials.

3. | RADIATION PROTECTION SUPERVISOR

For a port with 200 shipments of radioactive materials per year, the supervisory duties of RPS should, generally, be less than one hour a week. Once a routine procedure has been established, this requirement may reduce, if workers and management observe good practice.

The scope of the RPS's duties should be dealt with in an appropriate radiological safety training course, followed by short (one day) refresher courses at intervals of about 5 years.

The RPS should have the responsibility for monitoring cargoes of radioactive material, establishing boundaries around exclusion areas or storage space and, where contamination is suspected, under-taking preliminary searches

4. | INTERNATIONAL REGULATIONS

Transport of radioactive materials has been the subject of internationally agreed regulations since 1964. These regulations are reviewed every 2 years. Most countries, transporting radioactive materials on a regular basis, have adopted the International Atomic Energy Agency regulations in order to maintain an agreed safety standard.

The IAEA Transport Regulations are now incorporated into the UN Model Regulations for the Transport of Dangerous Goods and the International Maritime Dangerous Goods Code.

the transport regulations emphasise the safety requirements for packages and CTUs, as protection against exposure to radiation by

- limiting external dose rates
- ensuring the integrity of packages and CTUs during normal transport
- limiting the release of contents of packages and CTUs in the event of any accident or incident, involving them so that radiation doses to people are kept to acceptable levels.

All countries are required to appoint a competent authority, in accordance with international transport regulations. The competent authority is responsible for the adequacy of both quality assurance and compliance assurance programmes related to the international regulations governing the transport of radioactive materials.

Inspectors may check that the essential safety requirements are being met. In addition, advice is normally provided on particular shipments and any special needs relating to that shipment. Inspectors should be informed immediately of any accident or incident involving radioactive materials on-board a ship or in a port, in accordance with national legislation.

5. | NUMBER OF RADIOACTIVE MATERIAL CARGOES THROUGH PORTS AND HARBOURS

Experience suggests that a port not specialising in handling high activity radioactive material may expect to handle between 10 and 20 single consignments of radioactive material per year.

When a country generates part of its electricity from nuclear power, raw materials of uranium ore, chemical derivatives or newly manufactured fuel may be imported from abroad. This may result in some 30 to 200 CTUs of radioactive materials per year arriving at a port. These materials are of low activity giving rise to low dose rates. LO-LO vessels would mostly carry these but RO-RO vessels are also used for short sea journeys.

If a country is also a major manufacturer and supplier of radionuclide packages, intended largely for use in hospitals, there could also be several weekly export shipments to nearby countries.

Most ports can expect to receive a few radioactive material cargoes in any year. Where a country's electricity is generated by nuclear power, radioactive material cargoes may increase many-fold. If a country manufactures or produces raw materials or chemicals for use in a nuclear power programme, additional increases in radioactive material cargoes can occur.

Up to 80% of modern vessels, reported as carrying radioactive material cargoes, are loaded and discharged by remotely operated cranes, with no manual handling involved. Radiation exposure in these cases is extremely low.

A typically busy port, handling 200 radioactive material cargoes per year is only likely to handle 20% of the cargoes manually. In such ports it is unlikely that individual dockworkers will handle more than one radioactive material cargo per year.

6. | Annual exposure times of dockworkers

A port handling 100 or 200 radioactive material cargoes per year, using manual container securing devices is likely to expose individual workers to those cargoes for no more than 6 hours per year. This is the time needed to load or discharge between 5 and 30 CTUs of radioactive materials and any other intervening cargoes.

If the same group of dockworkers carried out all of this work on radioactive material cargoes and the annual exposure time exceeded 50 hours per year, investigation and dose measurements would be required.

7. | Natural background radiation

Naturally occurring radiation, and radioactive material, surrounds us everywhere we live and work. Typically, we receive a radiation dose of about 2,200 Sv every year from this natural radiation. Half of this dose comes from radon gas seeping up out of the ground and the rest, in about equal parts, from radioactive material in the ground and building materials, from cosmic radiation from the sky and from natural radionuclides in our food.

At sea, the radon gas and ground and building material contributions are largely eliminated, so reducing the annual dose from natural background radiation to a quarter of the value experienced on land.

There are similar dose reductions on-board vessels in ports. For every 500 hours per year spent on-board a ship in port, there is a reduction of 100 Sv from natural background radiation.

8. | Radiation control

All CTUs carrying radioactive materials may give rise to radiation exposure to dockworkers, mostly from manual handling, off-loading or stowage of these cargoes.

Control of radiation exposure may be controlled by three methods –

- SHIELDING package contents;
- keeping a suitable DISTANCE away from packages or CTUs
- restricting exposure TIME to a minimum.

Very occasionally, a package or CTU is damaged during transport, and leakage of the contents occurs, giving rise to CONTAMINATION of the surroundings (see 9 below).

8.1. Shielding

Materials used for producing nuclear fuel - the ores, chemicals and new fuel itself - need not be provided with shielding, because external dose rates are already quite low, creating only limited exposure in dock areas.

When material has been irradiated within a nuclear reactor the external dose rate requires significant shielding within the package - 2 to 5 tonnes of spent nuclear fuel requires 50 to 90 tonnes of shielding.

Radionuclide packages for medical or industrial use may contain shielding but this will vary widely depending upon the package contents.

8.2. Distance

With the increasing modernisation of port operations and ship stowage systems, the original need for dockworkers to be closely involved in handling packages is decreasing. Ships fitted with open-hatch cell-guide systems have no manual twist-locks. However, on older ships and ships where on deck freight containers are not within cell guides, workers may need to be one metre or closer to secure or release the twistlocks on containers carrying radioactive materials.

Immediately after operating the twistlocks, dockworkers should, if possible, move away from the freight containers by at least the width of one container.

Other dockworkers - tug-drivers, crane operators and supervisors - are normally separated by at least 1 to 2 metres from freight containers and will be less exposed to radiation.

8.3. Time

Five freight containers of radioactive materials is an average cargo size and 20 to 30 freight containers is likely to be the maximum cargo size. Very occasionally there can be a larger numbers of containers in a cargo, but these are usually subject to special supervision by the consignor during handling.

Typical rates at which CTUs are handled when loading or discharging ships have been suggested

- LO-LO ships stow freight containers at a rate of ~15 to 30 containers an hour per crane
- RO-RO ships stow vehicles at a rate of ~5 to 10 vehicles an hour per worker
- RO-RO passenger ferries stow vehicles at a rate of ~200 vehicles an hour

These rates would indicate that the exposure time of an individual dockworker handling a typical cargo of radioactive material is likely to be less than one hour for continuous work. Times spent freeing either twist-locks or lashings during which workers are required to operate at one metre or closer to the CTU are also likely to be less than one hour.

Handling times and measured and estimated doses for dockworkers are set out in Appendix C. These are thought to be representative of all such operations and, therefore, considered to apply worldwide.

As a guide to RPSs, a system of dose assessment is in appendix D.

9. | Monitoring packages and CTUs

Every port authority should ensure that the RPS has instruments capable of monitoring the range of radioactive materials regularly shipped through the port.

Radiation monitors should be checked and calibrated once a year.

Batteries should be changed every 6 months or more frequently, if the maker requires this, or if the shelf life of the batteries is less than 6 months.

Instruments in regular use may need more frequent battery changes.

Before any monitoring operation, the instrument should be switched on well away (100 metres) from the cargo to be checked. The instrument should be pointed at the sky. If a positive reading is shown, the instrument may be defective. Some monitors have thin, lightproof windows that are easily punctured. The monitor may then give a false positive reading, indicating a 'radiation' area where none exists.

Measurements around a package or CTU should be made at a distance of one metre and the maximum reading compared with the transport index (“TI”) value on the label. These should be similar (± 25%). Even two instruments of the same type may respond slightly differently.

The TI value is a figure indicating the maximum value of external dose rate at a distance of 1 metre from the CTU surface. The maximum dose rate would normally be found opposite the longest side. Confirmation of the TI value provides assurance that this CTU is normal.

10. | Contamination

Release or escape of material may cause radioactive contamination from packages or CTUs, as a powder, a liquid or a gas. Because the material is no longer properly contained it can be picked up on hands, inhaled or ingested and may lead to internal radiation exposure.

All packages and CTUs should be checked for contamination before shipping.

11. | Monitoring for contamination

Some radiation monitoring instruments have only limited ability to monitor contamination. Professional advice should be sought about an appropriate type of instrument for radiation and contamination measurements.

Where no contamination monitor is available, arrangements for assistance, when required, should be made with a nearby organisation with monitoring equipment. This organisation's up- to-date phone number should be kept and made available to the emergency services.

Care needs to be exercised when taking contamination measurements, since an instrument will give a positive reading of external radiation from radioactive materials in a package.

The recommended procedure for monitoring a suspected contamination area is to wipe a small, hand-sized, area of that surface with a dampened absorbent paper tissue. Move at least three container-lengths away, to minimise the radiation effect from the package. Take a reading from the tissue by passing a detection probe across and then away from the tissue so allowing the presence of contamination to be quickly confirmed.

If a positive contamination reading is obtained pre-planned and exercised procedures must be immediately initiated. These may include but are not limited to:

- the package should immediately be isolated with a suitable and sufficient exclusion zone, identified through competent risk assessment. Historically distances such as 'at least 5 freight container lengths' were given in guidance. This may be appropriate in certain circumstances but should be assessed based on prevailing conditions.

- all persons involved should be checked for contamination including exposed skin and personal protective equipment (PPE). If contamination is found on persons, decontamination procedures including but not limited to safe washing, changing and disposal of clothes/PPE should be implemented in a controlled manner.

- the work area should be monitored and any part affected isolated in order to prevent the spread of the contamination and to prevent further people from becoming contaminated

- emergency help should be sought from the consignor / consignee who may provide additional assistance

- statutory authorities, emergency services and relevant inspectors should be informed, as required by national legislation

12. | Handling radioactive material cargoes

Packages and CTUs carrying radioactive materials should be clearly identified by labelling and placarding in accordance with the IMDG Code.

If possible, the work should be organised so that handling of these packages and CTUs proceeds as a single continuous operation. This will help to minimise total exposure.

If interruptions occur, workers should be moved to a safe area, away from the cargo of radioactive material, until work resumes. Separation will depend on suitable and sufficient risk assessment but is likely to be at least the length of one CTU (6 m).

Where a mixed cargo is being loaded or off-loaded, the work should be structured so as to avoid workers having to remain close to packages or CTUs holding the radioactive materials, whilst other cargo is being handled.

When a mixed cargo includes radioactive material in transit, as well as radioactive material for loading or off-loading, the work should be structured so as to avoid workers being close to the containers in transit, maintaining a suitable and sufficient risk assessed distance (likely to be not less than one container length separation and may be greater).

By following these recommendations, annual doses should remain low and not be expected to exceed the values specified for members of the public.

The RPS should make assessments of frequency of use of individual dockworkers, exposure times and dose rates. Further advice may be obtained from the Radiological Protection Adviser [see 14].

13. | Accidents and incidents involving radioactive materials

Any damage occurring to a package or CTU involving radioactive materials should be reported to the RPS as soon as possible. This report should include full details of the ship, harbour area or location and the unit involved.

Injured persons should be rescued providing it is safe so to do.

A minimum safe distance in the event of an incident should be pre-established in the emergency plan and be implemented until context specific controls can be put into place. This distance should be identified by risk assessment. It will depend on local circumstances but is unlikely to be less than 30 metres away from the site of the incident. It should be maintained unless or until the RPS or competent emergency controller issues other instructions

If injured persons require an ambulance, the medical authorities should be informed of any possible contamination and the need for additional precautions.

If a release of radioactive materials occurs, priorities include but are not limited to:

- avoiding creating further contamination
- ensuring persons leave the immediate vicinity of the potentially contaminated area
- preventing others entering the contaminated area
- checking for potentially contaminated persons

Where practicable, a contamination zone should be established around the damaged package or CTU. All non-essential persons should be excluded. Begin with a larger zone, which can be reduced rather than with a smaller zone that may need extending.

The person in charge of the incident should establish a clearly identified contamination-free zone, away from the contaminated area. Ambulances and visitors can report to and work from this area without contaminating themselves or their equipment.

Between the two zones a change area should be established where clean protective clothing may be held ready for use. A disposal bag for dirty contaminated clothing should also be provided. Barriers should be provided between the clean, dirty and contaminated areas.

For most radioactive materials being transported an escape of radioactive material will be obvious, where the damage is extensive. Immediate evacuation of all workers is essential in the event of a spillage.

All workers should avoid getting any radioactive material onto bare skin or clothing. If this occurs, safe washing of persons and removal and disposal of contaminated clothing should be implemented. Contaminated persons must be monitored to ensure removal of contamination is complete. Washing with simple soap and water can be effective in reducing contamination.

Transferring radioactive material away from the area should be avoided, as this increases the risk of other people becoming contaminated. Contaminated articles and clothing should be secured in suitable containment such as wrapping in polythene sheeting or polythene bags in the change area (12).

Where radioactive material is released from a package or CTU, control measures should include seeking to prevent the spread of released material. This may include the use of impervious sheeting such as a lorry tarpaulin, or a large polythene sheet. Speed of containment is important but any action must take into account the safety of persons involved. Suitable and sufficient protection must be provided and used during contamination containment. This must include protection from inhalation, ingestion and skin contamination. Minimum PPE includes but is not limited to protective coveralls, gloves, rubber boots and respiratory and dust protection. The work should be supervised by an RPS or suitably competent person. Risk of exposure should be limited to the minimum practicable number of persons and time. Those involved should be safely decontaminated before the protective clothing and equipment is removed in the change area.

14. | Emergency plans

All port and harbours should have an emergency plan in place, irrespective of the cargoes handled (see ICHCA International Guidance on the preparation of emergency plans).

Management and workers should be involved in the drawing up of emergency plans. They should have the relevant local knowledge to overcome many of the immediate problems arising from both normal transport and accidents and incidents.

The emergency plans should include normal and emergency operational instructions to workers, supervisors and to emergency-response teams.

Where radioactive material cargoes are handled the emergency plan must include the preparedness for this type of emergency.

Where an emergency situation is declared, the emergency plan must be implemented. Such plans normally include arrangements for obtaining assistance from local services, but additional assistance from more distant organisations may be required if the local services do not have the full range of monitoring equipment, or expertise, needed.

The scope and availability of local services should be investigated, after consultation with consignors of radioactive materials likely to be handled in the port or harbour areas.

An up-to-date list of other specialist providers of emergency services should be kept, with the information of the local emergency services.

The local emergency services should draw up their own plans for co-ordination of local and distant services. Consideration should be given to the carrying out of joint exercises within the port area, at suitable intervals.

A full investigation should be carried out if

- the contents of CTUs have moved or package restraints are found to be inadequate or to have broken
- handling equipment (e.g. lift-truck tines) have damaged CTUs or packaging
- containers or CTUs have been damaged by external penetration
- CTUs have been dropped, with anticipated damage of the contents
- loose materials – powders or liquids – are released from CTUs or packages

The examples above are likely to cover the majority of accidents, incidents and resulting emergencies, which could be encountered in any port or harbour area. However, the port or terminal operator should also consider other risk factors appropriate to their circumstances.

Packages or CTUs containing radioactive materials that are suspected of having been damaged, should not be shipped, moved or opened without a competent, safe, examination being undertaken and corrective action applied as appropriate. This may have the consequence of delaying sailing or transport or the cargo not being shipped at all.

Incidents requiring this degree of attention are rare - only one such incident was reported in the period, worldwide, between 1988 and 1998. Such an incident would normally be recognised by the amount of damage sustained by the package, or CTU, either before the ship docks, or departs, or while it is within the port or harbour area.

If damage occurs whilst a ship is at sea, special arrangements should be made for extra monitoring as soon as the ship docks, thus minimising risks to dockworkers. If events occur within port areas, initial monitoring must be carried out by the RPS, or other competent person.

Emphasis has been given here to preparation for and response to accidents and incidents which are rare. It should be noted that normal transport also has potential for exposure to radiation.

The potential consequences and risk of an incident will be reduced by:

- complying with applicable international, national and local regulations
- conducting competent risk assessment
- applying the hierarchy of controls eliminating risks where reasonably practicable, reducing and controlling where risks can not be eliminated
- training and informing persons involved
  and
- applying the precautions in this paper

15. | Sources of external help

A wide range of expertise may be required when dealing with accidents and incidents involving the release of dangerous goods into the environment of port or harbour areas.

Ports may require radioactive material cargoes to go directly to or from a ship. If it is necessary to temporarily keep such cargoes in transit at a port, they should be kept in a specifically segregated area, subject to risk assessment and controls designed to reduce risk to as low as reasonably practicable (ALARP).

Any CTU containing radioactive material cargoes that is found to be damaged should be temporarily kept in a separately segregated area. This area should have appropriate agreed access for emergency personnel.

Protective equipment should be stored centrally and regularly maintained.

15.1. Radiation Protection Advisor ("RPA")

Because the normal radiological protection duties of the RPS may be occasional and restricted to local matters, it is often appropriate to appoint an adviser, who is employed full-time in radiological safety - the Radiological Protection Adviser. The RPA serves as a point of reference for any queries that may arise in an emergency. Such queries may be legal matters, interpretation of regulations, technical matters, improvements in instruments, suitability of segregation distances. The RPA may also carry out reviews of doses received in ports and harbour areas, as well as making recommendations on restricting exposure to radiation. Advice may be provided where unusual materials are encountered together with recommendations for any additional precautions that may be needed. The RPA does not need to be an employee of the dutyholder.

When spills occur and extra monitoring is required, the RPA may have access to additional information not normally available to the RPS.

15.2. The consignee / consignor

The person or organisation to or from whom the radioactive material is being delivered should have detailed knowledge of the contents of the packages and CTUs forming the cargo of radioactive material. The packers are responsible for ensuring the correct packaging and stowage recommendations have been followed. Consignors and consignees should be expected to provide useful information in the event of any incident or suspected release of radioactive material within the transport chain, as well as additional support, where necessary.

15.3. Central medical facilities

Central medical facilities are likely to be receivers of radionuclide packages, used in patient diagnosis. They may be a useful resource should a person become contaminated and require medical assistance.

The RPS and RPA should arrange to meet the relevant medical staff and to draw up plans for such eventualities.

16. | Special situations

Potential radioactive risk may occur in different cargos and/or circumstances. For example, metal scrap incorporating radioactive materials. Bulk ores could have trace levels of naturally occurring radionuclides, derived from uranium and thorium parent ores, present in these ores. Dust clouds, generated when loading or off-loading, can give rise to radiation exposure by inhalation or ingestion of the dust.

16.1. Contaminated scrap metal

Gas and oil field installations extract materials that have been deep underground, in association with rock strata that may incorporate uranium and thorium ores in very small quantities. Some of this radioactive material may be picked-up by the gas and oil and carried along through the pipework, depositing a scale inside the pipes similar to limescale. At intervals, pipework from such installations becomes scrap or surplus to requirements. This is frequently despatched and sold to scrap metal dealers for recycling. Because such material is transported as bulk cargo, the scale inside this pipework may become detached and can be 'powdered' by typical handling methods, giving rise to dust with potential contamination to handlers.

Monitoring of such pipework can show whether any radioactive contamination is present. These cargoes of scrap metals should be provided with certificates from consignors, certifying them to be free from contamination.

16.2. Radiation sources in scrap metal

Instances have occurred where scrap metals sent for recycling to furnaces have been found to contain industrial radionuclide gauges. Such gauges are extremely difficult to detect, when still held in their original containers and even more difficult to detect when surrounded by several tonnes of other non-radioactive scrap. Whilst they usually present a negligible risk of additional radiation exposure to dockworkers, they may be over-looked when smelting of scrap metals takes place, and may then give rise to extensive contamination of furnaces.

Bulk scrap metal cargoes are normally transported by road or rail to their eventual destination after discharge from the ship. If single lorry or rail wagonloads were be monitored, one at a time, along the exterior surfaces, such radioactive sources would then be more readily detectable. Unfortunately, the chance of finding such source material is low and would require a disproportionate effort for each radioactive material cargo found. As with scale contaminated cargoes, certification of freedom from significant radiation or radioactive materials by the consignor should be required. If certification is not possible then the cargo should be shipped as contaminated waste.

16.3. Low activity radioactive ores

Most materials extracted by mining contain trace levels of uranium and thorium ores, both of which are radioactive elements that occur naturally and are frequently encountered along-side ore bodies with other elements. Extraction processes sometimes fail to remove such contaminants from bulk shipments.

Bulk handling techniques, large grabs or suction piping, delivering to truck or rail wagons, can give rise to dust containing radioactive contaminants. The dust may be inhaled or ingested by dockworkers, resulting in internal radiation exposure. Many such ores and materials have been studied and efforts have been made to reduce or eliminate these hazards.

If there is any doubt about a consignment, or a risk that contamination might arise, action should be taken to establish if there is a problem. If there is a problem, the RPA should be consulted.

16.4. Radionuclides

Radionuclides packages may be shipped unaccompanied in freight containers or other CTUs but may also be shipped in accompanied road vehicles, particularly in RO-ROs on short sea crossings from countries that are major manufacturers and suppliers of such packages. Typical radionuclide packages may be radionuclides for medical use, industrial level gauges and industrial radiography sources.

As shown in appendix B, the Transport Index of some road vehicles carrying radionuclides may be as high as 200. While the transient dose to a person the vehicle passes may be low, the dose rate at 1 metre may be as much as 33 uSv/minute. Therefore, it is essential that persons are not permitted to remain in the vicinity of such a vehicle. If it is necessary to secure such a vehicle on board a ship, lashers could receive a significant radiation dose, as exemplified by ship E in the table in appendix C. The RPS should consider what precautions need to be taken in connection with traffic with a high Transport Index.

As is the case with other Class 7 (IMDG Code) cargoes, many ports require radionuclide packages to go directly to or from the ship. These operations will often be under the direct control of the driver of the vehicle carrying the radionuclide packages. However, if a port accepts and temporarily keeps such cargoes in transit, it should set up an appropriate accounting procedure to ensure that the whereabouts of all radionuclides is known and that any loss, including theft, is quickly identified. The records should include the identity of the radionuclide, its activity, the date of receipt, the state of the package on receipt, its location and date of departure. In such circumstances it may be necessary to set aside a suitable secure store or storage area, such as a clearly marked locked cage. Radionuclides should be kept in suitable receptacles at all times. In all cases security should be a prime consideration.

17. | Conclusions

Evidence gathered at the time [Appendix A] suggested that dockworkers were unlikely to exceed the annual dose limit applicable to a member of the public.

Use of personal dose meters is unlikely to provide risk control value where annual doses recorded during loading and discharge of radioactive material cargoes are too low to register on normal dose meters, even when working for prolonged periods. However they should be considered ports and harbours that consistently handle high activity radioactive materials.

18. | Appendix A - Objective and Scope of Basic Safety Standards for ionising radiation

The objective of the IAEA standards is to provide guidance for the protection of persons from undue risks of the harmful effects of ionising radiation, whilst still allowing operations involving exposure to radiation.

Two conditions of exposure are recognised

- those which are foreseeable and which can be limited by control, by application of a system of dose limitation, including development of satisfactory operating procedures
- conditions in which the source of exposure is not subject to control, so that any subsequent exposure can be limited only by remedial actions

The system for restricting doses requires justification of the operation, optimisation of protection and specified annual dose limits. Justification requires the operation to produce a net positive benefit. Optimisation requires procedures and practices to ensure that doses are "as low as reasonably practicable" taking economic and social factors into account.

18.1. International Atomic Energy Agency dose limits:

The occupational exposure of any worker shall be so controlled that the following limits be not exceeded:

	Recommended annual effective dose limit, averaged over 5 consecutive years	Maximum effective dose limit, in any single year
Radiation Worker	20 mSv	50 mSv
Member of the Public	1 mSv	5 mSv

ICHCA Suggested:

Dock/Port Worker	1 mSv	5 mSv

The suggested values for dock/port workers are not dose limits. Instead they are suggested values, appropriate if suitable and sufficient controls are put into place in ports and harbour areas. The aim should be to ensure that dock/port workers are not exposed to radiation levels greater than those set for members of the public.

If the Radiation Protection Supervisor has any doubts on the annual exposure limits discussed in this paper, and thus of meeting the suggested dose values, a local study of exposure frequency, rate of exposure and range of dose rates associated with CTUs handled should confirm that the radiation dose received by workers is sufficiently low. Where doubts persist, the Radiological Protection Adviser should be consulted and an investigation carried out on the relevant circumstances. This investigation may require workers to wear individual dose meters.

In the event that higher doses than the suggested values are found, despite efforts to achieve reductions, persons should not continue working unless or until the exposure is properly controlled. The Radiological Protection Supervisor should maintain specific records of any such higher doses received, investigate and report to the appropriate dutyholder and authorities, including providing details of what steps have been, or should be taken to achieve lower exposure levels.

18.2. Appendix A Notes: example research project

At the original time of writing, there was a particular case of a UK terminal dedicated to the loading and off-loading of flasks containing spent nuclear fuel. Findings were that a single group of eight dockworkers was employed for that purpose. Because external package dose rates exceeded those normally encountered in other ports by a factor of about 10, this single, small group of workers were individually monitored via dose meters throughout their normal duty. This was considered exceptional circumstances.

The worker group handled some ten to twenty consignments annually, consisting, in total, of about 100 packages, each package weighing between 40 and 90 tonnes. Records show that annual doses received by this single group of workers met the lesser of the current suggested dose values, despite all work being carried out by the single worker group. The bulk of their work involved close manual handling of CTUs, freeing lashings, and fixing lifting equipment.

The workload was considered to be equivalent to ten times the normal rate of handling radioactive material cargoes for similar workers in non-dedicated ports and harbour areas. As the only known group of monitored dockworkers at the time, their intensive levels of radiation exposure provided support for the assumptions made for all other groups of UK dockworkers who carried out work on radioactive material cargoes on fewer occasions with lesser dose rates.

19. | Appendix B - Handling Radioactive Material in UK Ports

19.1. Measurements of dose rates on radioactive material cargoes

Non-irradiated nuclear fuel materials

The following suggested modelling was based on data from the UK at the time this document was originally published. It assumed that a 'busy' port may handle up to 200 cargoes of radioactive materials in a year. Of which it was estimated that approximately 20% (40 ships) might require dock/port workers to carry out close-proximity manual work, removing or fastening lashings and or twist-locks, securing standard ISO freight containers. The other 80% of the cargoes were assumed to be loaded or discharged from ships with cell-guides below deck and automatic, or semi-automatic, twistlocks on deck.

Typical bulk cargoes were assumed to consist of materials intended for the production of new fuel for nuclear power stations. These are shown below:

MATERIAL	AVERAGE CARGO	MAXIMUM CARGO	DOSE RATE AT 1M DISTANCE
URANIUM ORE CONCENTRATE [UOC]	5 containers	50 containers	20 μSv/h
URANIUM HEXAFLUORIDE [HEX]	5 containers	25 containers	10 μSv/h
ENRICHED HEX	2 containers	5 containers	<2 μSv/h
URANIUM DIOXIDE [UO_2]	2 containers	4 containers	10 μSv/h
LARGE MEDICAL THERAPY SOURCE[1]	1 container	1 container	10 to 30 μSv/h

19.2. Uranium ore concentrate [UOC]

This material consists of the extracted and chemically purified ore, produced at a mine, loaded into 210 litre drums, carried in freight containers holding from 36 up to 54 drums, either as a single or double layer, with an internal restraining system to prevent movements of drums during transport. It can be a yellow, green, olive/brown or black powder, as fine as sand or in coarse 10 to 20 mm long pellets.

Figure 1 - Drums of Uranium Ore Concentrate

[1] This source was assumed to rarely exceed 1 cubic metre in size, but would be carried in a standard 6 m freight container. The dose rates (in column 4) at 1 metre are assumed to be much reduced on the outside of that container.

19.3. Uranium hexafluoride [HEX]

This material is produced from uranium ore concentrate, at a stage prior to production of uranium dioxide. In the raw uranium hexafluoride form, the component producing power (uranium-235) is relatively low at 0.7% and requires to be increased to between 2% and 4% for modern power station use. This is done by extracting the uranium 235 from the raw uranium hexafluoride and concentrating (enriching) part of the hexafluoride, which is then designated as "fissile" (see below). The remaining hexafluoride is then known as "depleted" uranium hexafluoride.

Figure 2 - Uranium hexafluoride [HEX] cylinder ready for transport

Uranium hexafluoride, in all its different forms, is a white crystalline solid at room temperature and is usually transported in large steel tanks (1.2 m diameter by 4 m long) or in smaller tanks (0.2 m diameter by 3 m long). Large tanks are carried on flatracks and smaller tanks are carried five to a standard freight container. Tanks should be securely bolted onto frames, with tie-downs, and then mounted on the flatracks or inside containers. Emptied tanks often still contain other remnant fluorides unless they have been subjected to special cleaning procedures.

Figure 3 - Enriched Uranium hexafluoride [HEX] cylinders ready for transport

19.4. Uranium dioxide [UO2]

Uranium dioxide is the processed material derived from the enriched uranium hexafluoride. Initially it consists of a black powder which can be sintered into small cylindrical pellets. Several hundred of these pellets are loaded into stainless steel tubes assembled into arrays forming new fuel elements for use in nuclear power stations.

Figure 4 - Nuclear Fuel Assembly

19.5. Fissile material

Contained in the UOC is a small quantity (0.7%) of uranium-235 - the "fissile" component. It is this that provides the energy for nuclear power stations, but it needs to be in a higher concentration - 2% up to 4%. Because this concentrated material is classed as "fissile", and carried in even smaller tanks (0.8m diameter by 2 metres long), these smaller tanks also need separation distances to be provided, but present no greater hazard than any other radioactive material cargo.

All the above materials are routinely carried in small to medium sized chests, drums or tanks, with securing devices to prevent movement within freight containers.

19.6. Common radiological characteristics

1.7.1 All these materials have relatively low external dose rates around their containers, as shown in the table. They constitute the majority of consignments encountered in frequently used ports and harbour areas, where radioactive materials shipments amount to more than 200 consignments a year. The exception to this is radionuclide package movements.

Radionuclide packages

Whether or not a country is a major producer of radionuclides is likely to determine the frequency of cargoes of these packages being handled in ports or harbour areas.

A non-producing country is likely to handle less than ten or twenty consignments a year. Such packages would normally consist of single large heavy, 1 tonne units, in freight containers, destined for local hospital use, for oil- and gas-rig operations or for industrial applications. Alternatively, several smaller 5 to 50 kg packages, similarly intended for industrial applications, might be encountered in a year. Most such packages are unlikely to have TI values exceeding 3 (30 μSv/h), similar to the other packages above.

A radionuclide-producing country, with local exports to adjoining countries, is likely to handle several consignments per week (each of a few tens to a few hundreds of packages), normally carried by road vehicle on RO-RO vessels, undertaking short duration voyages. These packages are destined for hospital use, industrial application use etc. and contain many different materials, many of which are short lived and need prompt delivery.

These consignments, with tens and sometimes hundreds of individual packages making up the load, can have external dose rates amongst the highest to be encountered, with vehicle TIs ranging from 10 up to 200. Loading and off-loading times are quick, often without involvement of dockworkers, although transient exposure as vehicles pass can amount to ten or twenty microSieverts per year.

Irradiated nuclear fuel materials

These items normally consist of large, 100 tonne, flasks containing spent nuclear fuel, transported either on rail wagons or on specially designed road vehicles, using either RO-RO or LO-LO vessels. Occasionally, research reactor fuel is carried in much smaller, 10 to 20 tonne, flasks bolted into specially strengthened freight containers.

Because of the specialist nature of these shipments they are normally handled at dedicated port terminals where dockworkers are closely supervised throughout the operation.

Normal access times around such consignments in non-dedicated ports and harbour areas have been documented as minutes of access time for a single flask, with negligible dose arising from this work.

19.7. Interpreting Measurements and Taking Appropriate Actions

The measurements shown in the table in 1.1 of Section A of this appendix are typical of the radioactive material cargoes most frequently handled in ports and harbour areas.

Measurements made 1 metre from the CTU, using a standard hand held monitor, will show the maximum value equivalent to the TI value marked on the placard. This maximum measured dose rate is usually found partway along the two long sides of a freight container but rarely found everywhere around the CTU. Dose rates found at the ends and corners will typically be reduced to about half the maximum value. The corners are the positions where twist-locks are normally located.

Mobile situations

The dose rates shown in the table suggest that, for a typical off-loading period of 4 to 8 hours, quite high daily doses of 40 to 160 μSv could be received by a dockworker. In practice, persons are highly unlikely to stand in the same spot for the four to eight hour discharge period. For up to 30 CTUs, the actual time spent close to each unit is estimated to be less than 5 to 6 minutes. With the workload shared between two groups of six people, working together in pairs on each CTU in turn, this would result in each pair typically dealing with five CTUs each for 1/10 hour. Using such criteria, exposure per cargo would, therefore, be no more than one hour, resulting in a dose of up to 20 μSv (see Table in Appendix C).

Large consignments are usually stowed as a group of CTUs, two high, four to eight wide, two or more rows deep. This arrangement makes it difficult for a worker to move to another set of CTUs and away from those holding the radioactive materials. It is important that the work arrangements ensure that persons move away from the areas of radioactive materials, wherever possible.

Without supervision, it could be easy to exceed the suggested dose values. In Appendix C. A modelled example is shown of a crane breakdown where members of the two groups of dock/port workers remain sitting on top of the radioactive materials CTUs for an hour, resulting in an extra dose of 10 to 20 μSv.

Measurements should be made to confirm that cargo TI values are as expected and detailed on the placards. Time spent close to such cargoes is a more significant factor for dose control than the actual dose rate, hence the need for supervisory vigilance.

Static situations

Where consignments of several CTUs have to remain on port or harbour premises for periods of more than a few hours, extra precautions will be required in the vicinity of the stacks. It is understood that it is customary to stow such cargoes in the centre of stacks of CTUs and to exclude all persons except those delivering the units. This practice should normally prevent persons from remaining close to such stacks. Delivery speeds are such that a lift-truck, tug and trailer or straddle carrier would pass by such a stack in a period of less than a minute. This could be repeated several times during a day before a different route is required. Exposure periods in such circumstances would be short, resulting in estimated daily doses of less than 1 or 2 μSv

It is estimated that if pedestrian workers need to be in the stack area, a separation of 5 to 10 metres between worker and stack would be required if the total work periods could amount to 24 hours during the storage period. It is estimated that this would limit doses received during the 24 hours to between 5 and 10 μSv.

Other persons who are not part of the operation should be excluded from the stack region and separated from it by a barrier at a minimum distance of 10 to 20 metres from the stack.

Persons who need to enter the stack area should be properly authorised, supervised, accompanied and their time there limited such that they are unlikely to exceed a dose of 10 μSv in any working week. If persons are already subject to personal radiation monitoring programmes the constraint may not apply. In these cases the RPS should be consulted.

20. Appendix C - Measured and assessed doses during radioactive material cargo handling

Calculation assumptions

In one year, three ships carrying uranium ore concentrate in freight containers docked in the same berth on three successive months. All of the unloading operations required manual handling to release lashings and twist-locks on containers. The consignments consisted of 25, 27 and 29 containers, with dose rates ranging from 10 to 20 μSv/h at 1 metre separation. Individual electronic dosemeters were issued to selected tug drivers, straddle carrier drivers and groups on-board the ships for the duration of each cargo discharge.

Three other RO-RO ships, carrying vehicles loaded with different types of radioactive materials, have also been studied and dose assessments made on dockworkers or crew members involved in securing vehicles.

Modelling doses received by workers on-board vessels during loading and discharge

VESSEL	Cargo	Time spent	On-board dockworkers	Quay side workers
A [MODERN RO-RO]	29 containers	4 h	10 and 12 μSv	5 μSv Tug driver
B [MODERN LO-LO]	27 containers	8 h (#1)	~20 μSv	
C [OLDER LO-LO] HALF OF CARGO REMOVED, PRIOR TO BREAKDOWN OF CRANE. DOCKWORKERS REMAINED ON-BOARD AND RECEIVED AN EXTRA ~10 μSV	13 containers (~50%) Crane break-down#2 21 containers 25 containers	2 h 4 h 6 h	11 and 12 μSv 20 and 22 μSv 28 and 38 μSv	2 μSv, Quayside
D [MODERN FREIGHT FERRY RO-RO]	6 tanks on lorries	1 h	~1 μSv	
E [PASSENGER FERRY RO-RO]	1 vehicle, radionuclides	< 5 min	~10 μSv	
F [RAIL FERRY RO-RO]	2 flasks, (spent nuclear fuel.)	< 5 min	< 5 μSv	

(#1) damaged container, frame distorted, required slings to remove container from vessel.

(#2) crane failed during discharge, workers remained on-board, receiving extra 8 to 16 μSv during delay period.

Doses recorded in column 4 for vessel C, show progressive increase in dose with containers handled due to the delay.

Ships A, B and C were the only ships with radioactive materials handled in this port in one year. The three groups of workers were different on each occasion. The three consignments represented 25% of all uranium ore concentrate imported in the year, with the remainder entering the country through other ports. For other LO-LO vessels, handling was done remotely with no dose to on-board dockworkers.

Calculation

A dockworker discharging a large cargo of radioactive material (20 - 30 CTUs), requiring manual handling of twist-locks or lashings, would receive between 10 and 30 μSv over a 4 to 6 hour period. During much of this time non-radioactive materials cargo would be handled.

Average consignments consist of 5 CTUs, with doses to individual workers not expected to exceed 5 μSv.

21. Appendix D - Guidance on dose assessments in ports and harbour areas

A review of UK ports and harbour areas visited for the survey suggests that there are two broad extremes:

- large ports, with from 300 to 2000 dockworkers, with more than 2,000 ships, annually
- smaller ports with less than 20 or 30 dockworkers, with between 200 and 300 ships a year

There is also a range of ports between these extremes.

21.1. Basic Model for dose assessment

Dockworker numbers in ports and harbours

PORT	APPROX WORKERS	NOTES
BUSY PORT	= ~1200+	Random selection of workers.
SMALLER PORT	= ~ 300	
SMALLEST PORTS	= ~ 10 to 30	

These are persons manually handling cargoes as their principal duty in a port, with other workers excluded from this assessment.

Many freight containers can be loaded or discharged from container ships without dockworkers having to handle twistlocks manually but some on-deck containers and those on non-cellular ships require manual handling of lashings and twistlocks during loading or discharge of cargo.

Manual handling predominates on smaller ships, remote handling in container terminals.

On-board ships, 1 or 2 groups of dockworkers (depending on ship size) are employed in handling lashings or twistlocks.

Radioactive material cargoes

$$\text{Radioactive traffic factor} = \frac{\text{Number of radioactive material cargoes}}{\text{Number of all cargoes entering port}} = 1 \text{ in } 10 \text{ to } 1 \text{ in } 20$$

PORT		RA CARGOES PER YEAR
BUSY PORT	=	200 in 4000 cargoes per year
SMALLER PORT	=	50 in 1000 cargoes per year
SMALLEST PORT	=	12 in 250 cargoes per year

Random selection and cargo handling

For an average size container ship (~150 metres long) there would be two groups of dockworkers assigned to release or fit lashings or twistlocks.

There would be 12 workers out of about 1200 total, or 1 in 100.

For 200 cargoes per year, this suggests that randomly selected assignments would lead to an exposure risk of two cargoes per year for one group of dockworkers.

Basic assumption for dose assessment

Assume one group of dockworkers would handle one cargo of radioactive material, once a month, or 12 times a year and further assume that these are average-sized cargoes of 5 CTUs, with no more than one large consignment =>25 CTUs in a year.

Dose arising from handling a single cargo of radioactive material [based on Appendix C]

For a typical 5 container cargo	10 μSv
time spent	< 1 h
For a typical 25 container cargo	30 μSv
time spent	~ 4 h

Both dose and time represent typical observed values

Example of assessment – annual dose from handling cargo

11 small consignments x 10 μSv plus 1 large consignment x 30 μSv = 140 μSv per year

The above evaluation is provided as an example on which other evaluations might be based for different circumstances. Provided that manual handling duties are shared equally among groups of dockworkers - whether by random selection from larger workforces or by rostered duty allocation for smaller groups - it is unlikely that any worker in a port will greatly exceed the value suggested above. It is also unlikely that they would exceed the 1mSv/annum suggested dose.

21.2. Comments for RPSs implementing assessment procedures

The model described above provides a framework. It is estimated that for the majority of ports, it is unlikely to differ by more than a factor of two from the assessment example.

Further, based on the model, it is unlikely that any dockworker, employed in a general (as opposed to a dedicated) port, will exceed the suggested dose of 1mSv or one fifth of the current dose limit for a member of the public [5mSv].

Dedicated ports are normally next to nuclear sites. Nuclear sites provide radiological supervision of cargoes, workers and environment in the port. Doses at the only dedicated UK port were just beginning to exceed the suggested dose of 1 mSv/annum in 1997. The dockworkers there were subject to full supervision and monitoring as all their cargo handling work was on radioactive material cargoes.

However, work force, ship numbers, allocation of work and dose arising from different cargoes are variable. The examples quoted are based on UK experience of work in small and large ports with cargoes of radioactive materials entering and leaving - some with 80% remote handling, some with 100% manual handling. The doses given in Appendix C have been measured where possible, or estimated when time has prevented monitoring.

No two ports have been found to be identical in their operations, but all ports were similar in practice. The RPS, with advice from the Radiological Protection Advisor, should be able to confirm whether the practices and operations in that port vary greatly from that described above and factor this into their own detailed evaluation.

The starting point for any evaluation is a review of the consignment numbers from a previous year showing the numbers of radioactive material cargoes handled. Care should be taken to distinguish between import/ export and in-transit, remain-on-board, consignments. The latter are frequently stowed below deck and may have limited effect on port workers.

For a busy port with large numbers of dockworkers involved in manual handling of these cargoes, it might prove difficult to determine the actual number of times any one group of workers is allocated to this work and records should be kept to enable this to be managed.

Smaller ports, with fewer dockworkers, may be located so that higher workload factors may arise. An example of a port where higher factors can arise would be one providing services to offshore gas and oil installations where industrial well-logging radiation sources are shipped on small offshore service ships loaded by the same few dockworkers.

Radiation emissions from different consignments are limited by the international regulations governing the external dose rates around packages and CTUs.

Exposure times on-board ships have been observed. Consignments with small numbers of CTUs tend to be stowed together, either in one hold or on a single hatch, such that stowage or removal is typically a single continuous operation of relatively short duration. Where a larger consignment is located in several groups, other cargo has to be off-loaded or stowed in the intervening positions between the groups. If dockworkers remain close to that part of the consignment of radioactive materials already on-board, whilst the non-radioactive cargo is stowed, then exposure times may increase if they do not move away from the exposure area.

22. APPENDIX E SEGREGATION

22.1. On-board ships

Radioactive material cargoes on-board ships are normally segregated from accommodation and working areas by distances ranging from 1 or 2 metres up to 20 or 30 metres.

These separating distances reduce dose rates in the relevant areas by more than a hundred-fold, because crews, on ships carrying radioactive materials, spend several hundred hours on-board during each voyage and cannot move away from the cargo when their duty shift ends. Their annual exposure times could amount to some several hundred up to a few thousand hours annually, hence the requirement for the additional segregation.

Dockworkers undertaking manual operations alongside CTUs of radioactive materials have to work much closer, but for shorter times during a year. Typical exposure times may amount to less than 10 or 20 hours per annum. A few specialist groups may be employed for 30 to 50 hours per annum.

22.2. In port

If unloaded containers cannot be moved away from dock and harbour areas rapidly, then similar stowage separation as applied on-board the ships, becomes necessary.

22.3. Temporary keeping of radioactive materials in ports and harbours areas

As for all dangerous goods, port authorities either set aside a separate dangerous goods area within the harbour area for the temporary keeping of radioactive materials, which is usually some distance from occupied areas or, as currently in some UK ports, stacking dangerous goods centrally in the larger stacks of non-dangerous goods in order to provide a buffer zone around that consignment.

Unlike other dangerous goods, the segregation of radioactive materials is governed by the radiation doses that persons in the surrounding areas might receive. Central stack locations would provide radiation shielding and considerable reductions in dose rates in surrounding occupied areas. This would be a significant benefit to the Port Authorities that keep radioactive materials for more than 24 hours.

22.4. Exposure of vehicle drivers

Dangerous goods areas in ports and harbours, whether well segregated or centrally stacked, are likely to be regularly passed by vehicles and straddle carriers, carrying CTUs into and out of the storage areas. Vehicles travelling at speeds of up to 40 km/h (11 m/second) and thus would pass a 50 m long dangerous goods area in less than 5 seconds. For much lower speeds, such as 10 km/h (3 m/second), a 50 m stack would still be passed in less than 20 seconds.

Passing such areas several times during a working day would lead to a driver exposure time of a fraction of an hour if the same route is used every pass. For vehicles driving a few metres from the segregation area, exposure is limited to fractions of a micro Sievert for each passage and annual exposure is similarly likely to be limited to less than that for dockworkers on-board ships. Most radioactive materials are rarely held in keeping for more than a day, since most of these cargoes are collected direct from the ship immediately after discharge.

22.5. Exposure of persons on foot

Because various categories of dangerous goods may require closer supervision and inspection than other cargoes, such areas can sometimes be located close to offices. Separation, typically not less than 20 m, should be implemented in order to reduce exposure to radiation from any larger radioactive material cargoes requiring to be kept until despatched or collected from the ports or harbours.

22.6. Alternatives to temporary keeping

Delays in collection or despatch of CTUs should be the exception rather than the rule. Arrangements should be made for

- consignors or carriers to deliver just-in-time for loading - for example no more than 1 or 2 hours prior to loading
- consignees or carriers to be ready to accept direct delivery and removal of radioactive materials from ports and harbour areas when discharge commences.

Such arrangements with carriers, consignors and consignees will assist port authorities to keep radiation exposure to a minimum for dockworkers and others.

23. APPENDIX F SUBSIDIARY RISKS

23.1. Non-irradiated nuclear fuel materials

For the non-irradiated nuclear fuel materials - such as uranium ore concentrate, uranium hexafluoride and uranium oxide - other '*subsidiary*' risks have to be considered if releases occur in accidents or incidents.

Uranium compounds, like most heavy metals (such as mercury, lead, bismuth and cadmium), are chemically more toxic to persons handling such materials than the hazard arising from their radioactive properties.

Many of the precautions used for protection against radioactive contamination - preventing material from being inhaled, ingested or deposited on bare skin - are applicable for prevention of chemical attack.

With uranium hexafluoride, special precautions will be essential if a leak should develop from the cylinders and tanks used to contain and transport this material.

In normal transport, uranium hexafluoride consists of a white, dense, crystalline solid, which sublimes at temperatures exceeding about 55^0C, with a rapid expansion in the gaseous phase. In addition, when both solid and gaseous uranium hexafluoride come into contact with moisture, there is a breakdown of this material into uranium hydrates and hydrofluoric acid gas. Both the hexafluoride and hydrofluoric acid gases are extremely hazardous and exposure can result in skin burns and lung impairment.

Where cargoes of uranium hexafluoride form part of regular consignments through a port, suitable precautions for dealing with such releases must be incorporated into the Emergency Plan.

In the event of such releases, an immediate evacuation of the area is essential.

23.2. Radionuclides and irradiated nuclear fuel materials

Subsidiary risks from these materials are lower when compared with radiological risks should there be a release in an accident or incident, as previously discussed.

24. APPENDIX G - USES OF RADIOACTIVE MATERIAL

24.1. Introduction

Radioactive materials are used in medicine, industry, research and production of electricity around the world each day. These products must be properly and safely shipped from the point of manufacture (supplier's licensed facility) to the point of use (customer's licensed facility). Radioactive material is used in many ways to improve the quality of life. Whenever or wherever it is used, it is incumbent on qualified individuals and responsible organizations to ensure that the radioactive material is prepared, used, handled, transported and disposed of in a safe manner.

24.2. Health care product and consumer product irradiation

Gamma rays from cobalt 60 [60Co] are commonly used to irradiate health care and consumer products. This includes surgeon's gloves, gowns, sutures, syringes, catheters, etc. In fact, about 45% of all medical disposables are sterilized using gamma radiation from 60Co. Consumer products such as bandages, cosmetics, hygiene products and solutions are also sterilized by 60Co. The prevention of infection through this sterilization technique complements the basic healing goal of medicine. About 200 facilities located in more than 50 countries worldwide provide sterile medical devices using gamma irradiation techniques. Radioactive materials (typically 137Cs) are also used for blood irradiation (for patients with deficient immune systems so as to preclude rejection of graft).

24.3. Nuclear applications in medicine

There are many applications of nuclear technology in the medical field, ranging from diagnostics, to treatment, to disease management. The safe transport of the radionuclides from the production sites to the hospitals is vital to the success of nuclear medicine. Several tens of thousands of nuclear medicine procedures are conducted every day all over the world. Unlike other tests/procedures, etc., nuclear medicine provides information about the function of virtually every major organ system within the body.

24.4. Treatment of disease

Radiation is widely used for the treatment of diseases such as hypothyroidism and cancer. Cobalt 60 is the primary isotope used in cancer therapy. In addition to teletherapy, where the radiation source has no physical contact with the tumour, the radiation source may be placed in immediate contact with the tumour, as in brachytherapy.

24.5. Food irradiation

The use of gamma rays and electron beams in irradiating foods to control disease-causing micro-organisms and to extend shelf life of food products is growing throughout the world. Food sterilization has been approved by 40 countries and is encouraged by the World Health

Organization. The radiation source that is commonly used for this purpose is 60Co, which is produced at one facility and transported to another facility for irradiation of the product.

24.6. Nuclear applications in industry

Radioisotopes are used in a wide range of industrial applications. Examples include gamma radiography of structures, castings, or welds where the use of X-rays is not feasible, using radioisotope thickness gauges in the manufacture of products such as steel and paper. Radioisotopes are also used as level indicators in industrial process control. Moisture and density gauges use radioactive sources for analysis of soil water content and compaction. Radioisotopes are used in smoke detectors, and as lasting, fail-safe light sources for emergency signs in aircraft and public buildings. Clearly, the variety of applications is enormous and growing annually.

24.7. Nuclear reactors

One of the major uses of radioactive material is in the generation of electricity in nuclear power reactors. The nuclear power industry now generates electricity in 32 countries contributing 17% of the world's supply of electricity, while 63% comes from the burning of fossil fuels. Some countries have over 75% of their electricity generated from nuclear power plants. The nuclear fuel cycle, which supports this generation requires the transport of radioactive material in many forms, including ores, uranium hexafluoride, fresh nuclear fuel, irradiated (or spent) nuclear fuel, and wastes.

Specific types of power reactors produce cobalt 60 and research reactors are used for production of radioisotopes used in nuclear medicine. Nuclear power will continue to play a significant role in meeting the world's increasing need for safe, clean, affordable and secure electricity.

The nuclear fuel cycle begins with conventional mining of the ore which is shipped in conventional 210 litre drums and standard ISO containers. Certain types of reactors cannot be operated on natural uranium so the content of the isotope of uranium called U-235, is increased by a process known as enrichment. Upon enrichment, the material is transported in the form of uranium hexafluoride (UF6) to fuel fabrication facility. The fabricated fuel assemblies are then transported to the reactor where they are used to produce electricity. The fuel stays in the reactor about 3 to 5 years after which the spent fuel may be sent to be reprocessed or stored in a dedicated storage.

24.8. Importance of effective and efficient transport

Radioisotopes having very short half-lives are used in nuclear medicine and need to be rushed to the waiting patients. The radioactive material, Cobalt 60, being an important source used for cancer therapy and sterilization of medical products and food has to be transported from the supplier to the user. Several radioactive materials are used for non-destructive testing on welds and castings and in industrial process control. The radioactive materials used in nuclear power industry have to be carried from one facility to another for efficient production of reliable and clean energy. All the concerned organizations, viz., the manufacturer, the carrier, the handler and the customer play key roles in facilitating the transport of radioactive material for the various safe applications. Radioactive material has been transported for more than 40 years without any serious accident. The regulatory requirements for the manufacture, transportation and handling ensure safety and security.

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About The Authors

Roger Gelder

Roger Gelder was employed in radiation safety work from 1960, with the last thirty years spent with the United Kingdom National Radiological Protection Board, from which he retired in May 2001.

For twenty years he studied transport movements of radioactive materials, carried by road, by rail, by sea and by air, and in ports and harbours, making direct radiation measurements on such movements and determining doses to workers. Much of this work was undertaken for the UK Department of Transport (now Department, Radioactive Materials Transport Division). The approach adopted has enabled ranges of dose to be assessed for port and harbour workers which are directly related to the work undertaken and the results have been incorporated into these guidance notes.

Mr A. Nandakumar

This research paper was reviewed for the International Safety Panel by Mr A. Nandakumar of the International Atomic Energy Authority (IAEA) in December 2005. Whilst the contents were generally approved, some additions were suggested and have been incorporated as paragraphs 1.1 and 1.2 and Appendix G.

Mr Trevor Dixon

The research paper was further reviewed for the International Safety Panel by Mr Trevor Dixon of the World Nuclear Transport Institute (WNTI) in March 2008. Whilst the contents were generally approved, some minor alterations to the text were suggested and some photographs added.

International Cargo Handling Coordination Association

Established in 1952, ICHCA International is an independent, not-for-profit organisation dedicated to improving the safety, productivity and efficiency of cargo handling and movement worldwide. ICHCA's privileged NGO status enables it to represent its members, and the cargo handling industry at large, in front of national and international agencies and regulatory bodies, while its Technical Panel provides best practice advice and develops publications on a wide range of practical cargo handling issues. Operating through a series of national and regional chapters, including ICHCA Australia, ICHCA Japan and Correspondence and Working Groups, ICHCA provides a focal point for informing, educating, lobbying and networking to improve knowledge and best practice across the cargo handling chain.

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