Department of Health

PROTECTIVE MEASURES TO TAKE IN THE EVENT OF AN ACCIDENT INVOLVING RADIOACTIVITY

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Directorate Radiation Control

FIRE
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Introduction

A radioactive source can emit ionising radiation in a number of different forms. The most penetrating type of ionising radiation is **gamma** radiation which is capable of passing through the human body and even through concrete walls. **Beta** radiation is less penetrating, and can be stopped, for instance, by a few millimeters of perspex. **Alpha** radiation is the least penetrating form of ionising radiation, and, for example, is not able to pass through a sheet of paper or through human skin.

Although our senses cannot detect it, ionising radiation can cause physical damage to the human body. Low doses of radiation produce no observable effects, but the probability of the occurrence of long term effects like cancer will increase as the radiation dose increases. A large dose of radiation received over a short period of time can also result in severe short term effects such as radiation burns, nausea, internal bleeding and even death.

Units

The strength or **activity** of a radioactive source is expressed in units called Bequerel (Bq). Sources commonly in use range from a few kBq (1000 Bq) up to PBq (10^{15} Bq). Most industrial sources are measured in MBq (10^{6} Bq), GBq (10^{9}) or TBq (10^{12} Bq).

The old unit of activity was the Curie (Ci) with its corresponding sub-units of μCi (10^{-6} Ci), mCi (10^{-3} Ci) and kCi (10^{3} Ci). One Curie is equivalent to 37 GBq.

The unit of **exposure rate** is Roentgen per hour (R/h) or mR/h (1R equals 1000 mR). Exposure to 100 R of gamma radiation will result in a radiation **dose** of 1 Sievert (Sv). (The old unit for radiation dose was the Rem, which is equivalent to 0.01 Sv).

Sealed Sources

There are two things that can happen to equipment containing sealed radioactive sources in the event of a fire, explosion or other accidental occurrence:

i) The lead or uranium shielding, which absorbs most of the rays of gamma radiation given off by the source, can melt or become damaged (See figure 1). This would result in an increase in the amount of gamma radiation in the vicinity of the source. This would present an EXTERNAL radiation risk to anyone approaching the equipment.

ii) The metal capsule surrounding the source material could melt or become damaged. This is a very unusual occurrence, firstly because the capsule is protected by the lead or uranium shielding, and secondly because the capsule is usually made of an extremely strong metal that cannot melt easily eg stainless steel.

If the capsule does become damaged in some way, the actual radioactive material could leak out, and could be dispersed either mechanically, or as a result of vaporisation. This then means that not only will there be a risk of external radiation, but there is also the chance of CONTAMINATION ie the radioactive material could get stuck to a person's clothing or shoes, or there might be a chance that a person could inhale it, or even accidentally swallow it. Some material might also enter the body via a cut or wound. Contaminated clothing can be removed, contaminated hands can be washed, but once the radioactive material is inside a person's body, it is not so easy to get rid of it - and for this reason it can have harmful consequences.

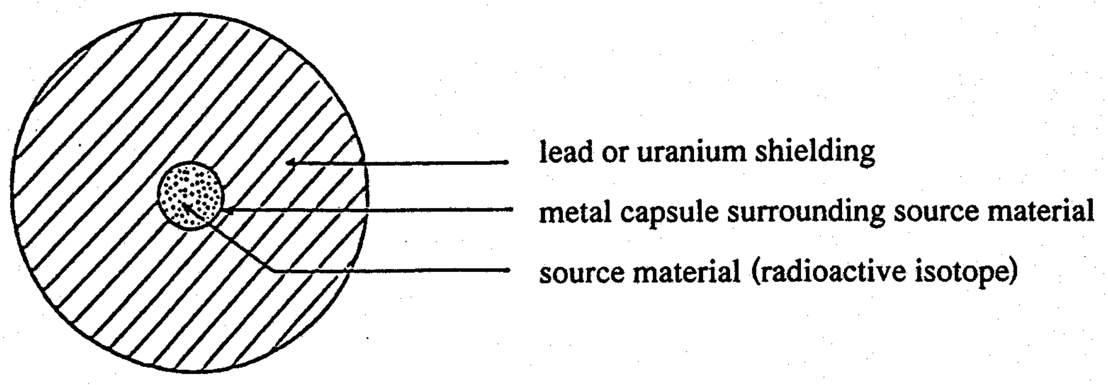

FIGURE 1: CONSTRUCTION OF A TYPICAL SEALED SOURCE

The type of sealed sources which generally pose an external radiation hazard are those which emit penetrating gamma radiation. Cobalt-60, Caesium-137, Iridium-192 and Radium-226 are the most common sources which emit such radiation.

Sealed sources which emit mainly beta or alpha radiation (such as Strontium-90, Americium-241, Thallium-204 and Plutonium-238) would not pose a significant external radiation hazard, unless they were of a fairly high activity (greater than 10 GBq). These sources would, however, be more likely to cause contamination, because the source capsules which surround them are usually less resilient than those which surround gamma sources.

Unsealed Sources

Unsealed radioactive nuclides are used mainly for medical purposes and for research work. Unsealed sources are usually in a liquid form, and are most often stored in bottles or vials in a refridgerator. They are generally not associated with high external radiation levels, but do pose a potential contamination hazard.

Pre-Emergency Planning

Persons responsible for radioactive sources, or those who may be involved in dealing with emergency situations involving radiation (eg fire brigades), should ensure wherever possible that specific pre-emergency planning is carried out. The particular hazards associated with the sources under their control should be identified, and guidelines should be drawn up detailing recommended emergency procedures for the sources in question.

Procedures to Follow in an Emergency

Where specific pre-emergency planning has been carried out, the planned emergency procedures should be followed. If, however, no such guidelines have been drawn up, then the following procedure should be followed:

1. Where Possible Identify the Origin of the Radiation

When dealing with an incident involving radiation one should first establish whether one is dealing with a radioactive source (ie a radioactive nuclide) or with an item of X-Ray equipment.

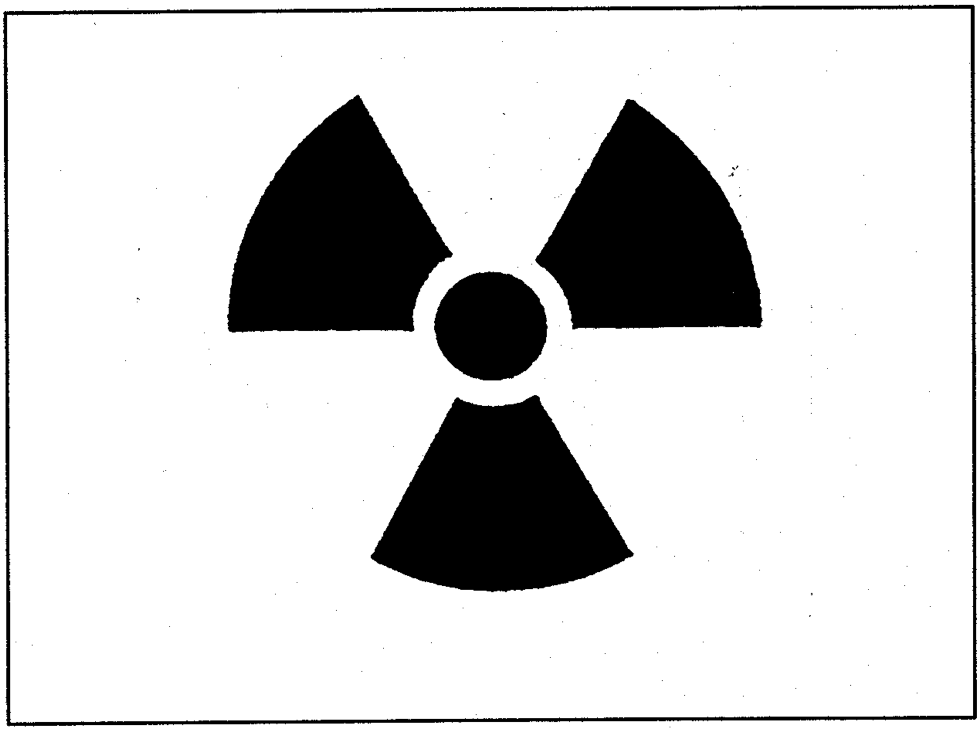

FIGURE 2: INTERNATIONAL SYMBOL FOR RADIATION

The above radiation warning sign is used in both instances, but in the case of X-Ray equipment, the radiation is produced electrically and is therefore only present when the unit is switched on. In other words, when X-Ray equipment is not connected to a power supply, it possess NO radiation hazard whatsoever, even if it has been damaged in some way. X-Ray units used by doctors and dentists, and for non-destructive testing in industry, are the most common examples of such equipment.

A radioactive source, on the other hand, is composed of inherently unstable material which emits radiation continuously. Although it may be possible to shield the radiation, it cannot be "switched off" like an X-Ray machine.

If one is unable to establish the origin of the radiation, to be on the safe side one should assume that one is dealing with a radioactive source and take all necessary precautions.

2. Where Possible Obtain Information about the Source

Wherever possible one should try to establish the type and activity of the radioactive source, as well as the possible hazard it presents. The responsible person should be contacted as soon as possible in order to ascertain this information. Under no circumstances must clearing up operations be performed without first consulting the responsible person.

The Department of Health - Directorate: Radiation Control can advise on further action to be taken and can provide radiation monitoring equipment, if required. During office hours, phone 021-948 6162; Fax: 021-946 1589. After hours, call the Necsa 24-hour National Emergency Centre on 012-305 3333.

If a radiation monitor is not available, but the type of source and its activity is known (this information should appear on the source container), then it is possible to estimate "worst possible" radiation levels for a completely unshielded source from the following table:

RADIATION LEVELS AT 1M FROM A COMPLETELY UNSHIELDED SOURCE

Type of Source (Nuclide)	Exposure rate (mR/hr) per Curie
Cobalt-60	1320
Radium-226	825
Iridium-192	480
Caesium-137	330

Exposure rate is inversely proportional to the square of the distance from the source ie if the distance from the source is doubled, the exposure rate will decrease to a quarter of its original value. Thus, at 2m from a 1 Curie Cobalt-60 source, the exposure rate will be 1320/4 = 307 mR/h. Remember, however, that the above values only apply when the source is NOT shielded within its transport or storage container.

If the nuclide is not one of those mentioned on the above list, then it is unlikely that it would pose a significant external radiation hazard.

3. If Radiation Monitoring Equipment is Available, Use it.

There are two main groups of radiation monitoring equipment, namely, exposure rate meters and contamination monitors. The former are used to measure external radiation levels and are usually calibrated in units of mR/h or mSv/h. Contamination monitors are much more sensitive than exposure rate meters and usually measure contamination in units of counts/second or Bq/cm^2.

If an exposure rate meter is available it should be used to measure external radiation levels directly. When estimating or measuring radiation levels, the following should be borne in mind:

i) Wherever possible members of the public should not be allowed into areas where the exposure rate exceeds 0.25 mR/h (2.5μSv/h). Barrier ropes should be set up to ensure this.

ii) The international "safe" limit laid down for persons who work with radiation is 20 mSv per year, averaged over 5 years and not more than 50 mSv in any one year. Doses should always be kept as low as is reasonably achievable.

iii) Only actions involving life saving, justify an acute exposure in excess of 0.1 Sv (10 rem).

iv) If a dose of 5 Sv (500 rem) is received, one's chances of surviving the acute effects of the radiation would be about 50%.

As far as contamination monitoring is concerned, any reading above background radiation levels should be considered as a positive indication that contamination is present. A normal background level is ± 5 counts per second. Background levels can, however, vary from place to place, and can be increased as a result of external radiation from sources in the vicinity.

Where background radiation levels are high, a wipe test can be performed in order to distinguish between external radiation and contamination. This entails wiping the surface which is suspected of being contaminated with a piece of absorbent material (eg tissue paper) and retiring to an area where background radiation levels are low. The wipe sample is then monitored in the usual way with a contamination monitor.

If personal dosimeters (eg TLD badges or direct-reading dosimeters) are available, rescue workers should wear them in order to facilitate later estimations of doses received.

4. Removing Radioactive Sources from the Scene of the Emergency

Where the emergency (for example in the case of a fire) is so limited that radioactive sources are not directly involved, but the risk of involvement exists, the best way to minimize the radiation risk is to remove the radioactive material from the immediate area.

If the source forms part of a measuring device or gauge, the shutter of the device must be moved to the "off" or fully shielded position before it is moved. Where possible, a monitor should be used to confirm that the shutter is correctly closed. As an additional safety measure, the persons carrying the gauge should ensure that the primary beam aperture (radiation opening) is directed away from them.

When moving unsealed sources (eg bottles of radioactive liquid), or gauges containing sealed alpha or beta sources (for example thickness gauges containing Strontium sources), extra care should be taken to protect oneself against possible contamination. (Refer to point 6 below)

A radioactive source must never be removed from its shielding container unless such removal is performed under the supervision of a qualified person, such as a health physicist. If the container cannot be moved then the source should be left where it is. Cancer therapy units in hospitals containing radioisotopes are examples of equipment which generally cannot be easily moved.

Sources which have been moved should not be left unattended. A guard should be posted nearby to ensure that no one approaches the sources.

5. If No Information or Equipment is Available, Follow this Procedure.

In many cases a monitor will not be available, the type of source and its activity will be unknown and it is quite possible that time, or the nature of the emergency, might not allow for expert advice to be sought. In such circumstances the emergency workers have to decide on an immediate course of action with the limited information at their disposal.

As a general rule, the emergency worker should give priority to immediate dangers (for example, render first aid, or extinguish a fire) BEFORE considering the radiation hazard.

This rule is based on the fact that high activity sources which could produce dangerously high levels of external radiation, are required by law to be stored and transported in approved containers or facilities which are designed to ensure safety under all foreseeable conditions.

For example, a high activity Cobalt source, such as is used in hospitals for the treatment of cancer, would have to be stored and transported in a container which shields all radiation to acceptable levels, which can withstand temperatures of up to 800^{o}C, which has passed rigorous mechanical endurance tests, eg impact, compression, penetration and drop tests, and which is designed to withstand all foreseeable accidental occurrences.

If the source is not being transported in such an approved container, then it is likely that it is a relatively low activity source, which could be approached for fairly long periods (eg a couple of minutes) without any ill-effects being experienced as a result of the radiation received.

However, during the course of their duties, emergency workers should always adopt the safety precautions mentioned below in order to keep their potential exposure to radiation to a minimum.

6. Safety Precautions to be Adopted

The following precautions should always be adopted when dealing with radioactive sources:

WAYS TO MINIMISE EXTERNAL RADIATION DOSE

i) Keep as large a distance as possible between oneself and the radioactive source. If a patient can safely be moved, he or she should be evacuated from the immediate vicinity of the source.

ii) Limit time spent near the source to a minimum.

iii) Wherever possible, shield yourself from the source, unless by doing so you will increase the time which you spend near the source. For example, it is pointless to wear a heavy lead apron during a rescue operation if it means that you will take twice as long to carry out your task, and thus be exposed to twice as much radiation. (For those isotopes which could pose a significant external radiation hazard, a few millimeters of lead shielding would not be very effective anyway.)

Other materials such as iron, heavy metals or concrete are effective in varying degrees at blocking radiation. Wherever possible use should be made of existing structures eg concrete walls, etc.

When dealing with unsealed sources, or a sealed source which has been badly crushed or damaged, it is best to take the following additional precautions to avoid contamination:

WAYS TO MINIMISE CONTAMINATION

i) Care should be taken not to touch anything in the vicinity of the gauge, unless with a gloved hand.

ii) No eating, drinking or smoking should be permitted at the scene of the emergency.

iii) The scene of the emergency should where possible be separated into two areas - a "clean" area and a "contaminated" area. The latter area should include any area where contamination is confirmed, or where it is likely to occur. Access to the contaminated area should be limited and emergency workers and equipment used in the two areas should be separated.

iv) Where possible emergency workers should remain upwind of radioactive sources, or areas where contamination may have occured.

v) If ventilation could spread contaminated air, it should be switched off.

vi) If available, a mask with a filter, or other breathing apparatus, should be worn in order to prevent possible inhalation of airborne radioactive particles or gases.

vii) Once the emergency has been dealt with, emergency workers who entered the contaminated area should gather in a central place. Clothing or shoes suspected of being contaminated must be removed carefully in order to avoid spreading contamination. If a mask is being worn, it should only be removed after all contaminated clothes (excluding gloves) have been removed. Gloves should be removed last. All items of clothing should then be placed in a plastic bag and sealed.

viii) Workers should gently wash areas suspected of being contaminated using a mild soap or detergent. Care should be taken not to spread contamination to other parts of the body, and should in particular be kept away from the eyes, mouth and nose. A contamination monitor should be obtained as soon as possible in order to assist in the identification of contaminated areas.

7. Additional Procedures to Follow in the Event of a Fire

Persons involved in fire-fighting should take note of the following:

i) If a gauge is directly involved in a fire it is possible that the shielding surrounding the source could melt. This could result in a high external radiation level in the vicinity of the gauge. Wherever possible, a radiation monitor should be used to assess radiation levels when approaching a gauge which has been directly involved in a fire.

ii) A jet of water directed at the source housing could help prevent the source shielding from overheating and melting.

iii) It is theoretically possible that a source could be vapourised due to intense heat from a fire. In instances where such an occurrence is likely, fire fighters should take precautions to prevent inhalation of the radioactive vapour, such as remaining up-wind when fighting the fire, or wearing self-contained breathing apparatus.

iv) Care should be taken during fire-fighting to avoid the spread of radioactive contamination. The use of water jets should be kept to a minimum (particularly in a laboratory fire) and where possible, salvage techniques other than water should be used in order to limit the mechanical dispersion of radioactive material.

Conclusion

It must be stressed that all incidents involving radioactivity should be reported to the Radiation Control Division of the Department of Health, who will be only too willing to give advice or render assistance, should it be needed.

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