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

The widespread use of radiation sources in medicine, agriculture, industry, and research has an admirable safety record. Throughout the world, the number of known accidents in which persons have been exposed to harmful amounts of ionising radiation is relatively small, and only a few deaths have occurred. Meticulous precautions are being taken to maintain this good record in all work with radiation sources and to keep the exposure of persons and the environment as low as practicable.

Document History

Final Version	Reason for Amendment	Effective Date
0	Old guideline document	May 2000
1	Previous guideline revision	May 2019
2	- Content structured on the new SAHPRA Guideline Template - A unique document number SAHPGL-RDN-RN-01 allocated to this Guideline	January 2024

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Glossary

Abbreviation/ Term	Meaning
Co-60	cobalt-60
NECSA	The South African Nuclear Energy Corporation
SAHPRA	South African Health Products Regulatory Authority
TLD	thermoluminescence dosimeter/dosimetry

1. INTRODUCTION

A radioactive source can emit ionising radiation in several different forms. The most penetrating type of ionising radiation is gamma radiation, which can pass through the human body and even through concrete walls. Beta radiation is less penetrating and can be stopped by, for instance, a few millimetres of Perspex. Alpha radiation is the least penetrating form of ionising radiation and 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.

1.1 Purpose

The purpose of this manual is to give practical guidance to those public authorities and others who are responsible for preparing emergency plans for the handling of radiation accidents with the aim of minimising the resulting exposure of workers and of members of the public, and of reducing, as far as practicable, any damage to property. This guidance must necessarily be of a general nature as it is not possible to predict with any precision what form an accident will take or what consequences may result.

1.2 Scope

The scope of this guideline is restricted to those topics that are directly related to the preparation of the emergency plans. Where possible, any background information that is necessary is provided by reference to other publications. Where this is not possible, explanatory material is provided to enable readers to relate the presentation to their particular circumstances.

2. LEGAL PROVISION

The Regulations relating to Group IV Hazardous Substances, made in terms of section 29 of the Hazardous Substances Act 15 of 1973 and published under Government Notice R247 in Government Gazette 14596, dated 26 February 1993 (R247) require an Authority Holder to report any accident involving radioactivity to Radiation Control. The holder shall forthwith respond to all enquiries from Radiation Control , in respect of the notification of the accident and shall provide every assistance with regard to an investigation into the incident in question.

3. UNITS

The strength or **activity** of a radioactive source is expressed in becquerel (Bq). Sources in common use range from a few kBq (10^3 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 (1 R equals 1 000 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).

4. SEALED SOURCES

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

ii) The lead or uranium shielding, which absorbs most of the 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.

iii) 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, e.g. stainless steel.

If the capsule does become damaged in some way, the radioactive material could leak out and could be dispersed, either mechanically or because of vaporisation. This then means that not only will there be a risk of external radiation, but there is also the chance of **contamination**, i.e. the radioactive material could get stuck to a person's skin, 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.

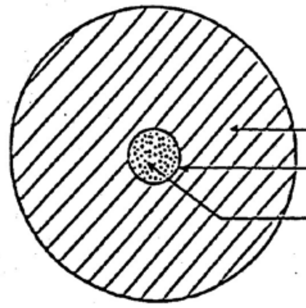

Figure 1: Construction of a typical sealed source

The types of sealed sources that generally pose an external radiation hazard are those that emit penetrating **gamma** radiation. cobalt-60, caesium-137, iridium-192 and radium-226 are the most common sources that emit such radiation.

Sealed sources that 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 that surround them are usually less resilient than those that surround gamma sources.

5. 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 refrigerator. They are generally not associated with high external radiation levels but do pose a potential contamination hazard.

6. PRE-EMERGENCY PLANNING

Persons responsible for radioactive sources, or those who may be involved in dealing with emergency situations involving radiation (e.g. disaster management centres), 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.

7. 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:

7.1 Identify the origin of the radiation

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

Figure 2: The 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 poses ***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 you are unable to establish the origin of the radiation, to be on the safe side you should assume that you are dealing with a radioactive source and take all necessary precautions.

7.2 Where Possible, Obtain Information about the Source

Wherever possible, try to establish the type and activity of the radioactive source, as well as the possible hazard it presents. Contact the radiation protection officer as soon as possible to get this information. Under no circumstances must clearing-up operations be performed without first consulting the radiation protection officer or an equally knowledgeable person.

In case of an emergency that is beyond the ability of the facility to handle, call the local Disaster Management Centre and, if applicable, the SAPS Explosives Unit to cordon off the area and keep the public out until the first responders arrive. The NECSA 24-hour National Emergency Centre on 012-305 3333 can also advise and/or assist depending on need and location. If you have high-risk sources that could require that kind of reaction, ensure that you have the relevant phone numbers available *before* they are required. SAHPRA Radiation Control must be informed of any radiation occurrences (accidents, incidents and near misses) as soon as practicable on 021-015 5505 or 5511.

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-case radiation levels for a completely unshielded source from Table 1:

Table 1: Radiation Levels

RADIATION LEVELS AT 1M FROM A COMPLETELY UNSHIELDED SOURCE	
Type of source (nuclide)	**Exposure rate (mR/hr) per Ci**
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. So 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 Ci Co-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.

7.3 If radiation monitoring equipment is available, use it

There are two main groups of radiation monitoring equipment, namely, exposure rate meters and contamination monitors.

i) Exposure rate meters are used to measure external radiation levels and are usually calibrated in units of mR/h or mSv/h.

ii) Contamination monitors are much more sensitive than exposure rate meters and usually measure contamination in units of counts/second or Bq/cm2.

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

   a) Members of the public should not be allowed into areas where the exposure rate exceeds 2.5 µSv/h. Use barrier ropes or tape to keep them out if necessary.

b) The international "safe" limit laid down for radiation workers 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 reasonably achievable (ALARA).

c) Only actions involving lifesaving justify an acute exposure in excess of 0.1 Sv (10 rem).

d) If someone receives a whole-body exposure of 5 Sv (500 rem), their chances of surviving the acute effects of the radiation would be about 50 %.

e) 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 done to distinguish between external radiation and contamination. This entails wiping the surface which is suspected of being contaminated with a piece of absorbent material (e.g. cotton wool) and moving 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 (e.g. TLD badges or direct-reading dosimeters) are available, rescue workers should wear them in order to facilitate later estimations of doses received.

7.4 Remove 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 minimise 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 (e.g. 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 radiation protection officer. 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.

7.5 If no information or equipment is available, follow this procedure

In many cases a monitor will not be available, and the type of source and its activity will be unknown. 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 Co-60 source, such as 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 ˚C, which has passed rigorous mechanical endurance tests, e.g. 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 (e.g. 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.

7.6 Safety precautions to adopt

The following precautions should always be adopted when dealing with radioactive sources to minimise external radiation dose and contamination.

Ways to minimise external radiation dose: Time, distance, shielding

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

ii) Keep as large a distance as possible between yourself and the radioactive source. If a patient can safely be moved, they should be evacuated from the immediate vicinity of the source.

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 millimetres of lead shielding would not be very effective anyway.)

iv) Other materials such as iron, heavy metals or concrete are effective in varying degrees at blocking radiation. Wherever possible, use existing structures such as concrete walls.

v) 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) Take care not to touch anything in the vicinity of the source, unless with a gloved hand.

ii) Do not eat, drink or smoke at the scene of the emergency.

iii) Where possible, separate the scene of the emergency into two areas - a "clean" area and a "contaminated" area. The contaminated area should include any area where contamination is confirmed or where it is likely to occur. Access to the contaminated area should be limited. 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 occurred.

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 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, in particular 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.

7.7 Additional procedures to follow in the event of a fire

Persons involved in firefighting should take note of the following:

i) If a gauge (or other equipment) 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 vaporised due to intense heat from a fire. In instances where such an occurrence is likely, firefighters 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 firefighting 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.

8. REFERENCES

The following related documents are referenced:

South Africa. 1973. Hazardous Substances Act, No.15 of 1973. Pretoria: Government Printer.

South Africa. 1993. Regulations relating to Group IV Hazardous Substances. Published under Government Notice R247 in *Government Gazette* 14596 of 26 February 1993

9. VALIDITY

This guideline is valid for a period of 5 years from the effective date of revision and replaces the old *Fire Protective measures to take in the event of an accident involving radioactivity, revised, implemented in May 2019.* It will be reviewed on this timeframe or as and when required.

10. CONCLUSION

It must be stressed that all incidents involving radioactivity must be reported to Radiation Control unit of SAHPRA as soon as possible, followed by a more detailed report. An incident report form is provided for this purpose.