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EXECUTIVE SUMMARY

During a radiation emergency, a significant number of emergency responders and the public may become externally exposed to radiation, contaminated with radioactive materials, or both. Timely screening and treatment of the affected population are important components of emergency response and consequence management. This Canadian guide on medical management of radiation emergencies provides a common framework from which hospitals, public health authorities and emergency management organizations can base their response plans.

This guide addresses many radiation emergency scenarios that can lead to mass exposures of people, such as nuclear power reactor accidents or intentional use of radiological dispersal devices. However, catastrophic events, such as the detonation of an improvised nuclear device, are beyond the scope of this guide. In such events, there may be significant loss of infrastructure needed to support a response, and the medical presentation of casualties will be far more complex, resulting from a combination of radiation, thermal and blast injuries.

This guide covers basic information on the following: hazards associated with radiation emergencies, radiation health effects, radiation detection and measurement, protection of workers, and management of radiation emergencies in Canada. It focusses on the early medical management of radiation emergencies during the pre-hospital and Emergency Department responses. In the pre-hospital section, a public health concept for population screening and decontamination in community reception centres developed by the United States Centers for Disease Control and Prevention (US CDC) is presented. In the Emergency Department section, guidance is presented on the preparation of the Emergency Department, protection of hospital workers, triage of radiation casualties, patient decontamination, and medical management of radiation casualties. The Emergency Department section is followed by a brief discussion on the medical follow-up of radiation casualties that takes place outside of the Emergency Department. Details on specialized in-patient care are beyond the scope of this guide. At the end of this guide, special issues for vulnerable populations are discussed.

Annexes provide specific technical information such as procedures for contamination control and decontamination, population screening, casualty decontamination, emergency room set-up, and casualty assessment, and forms for ordering specialized tests. The information contained in these annexes can be adapted by users to create aide-memoires for use during radiation emergencies.
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CHAPTER 1 – INTRODUCTION

During a radiological or nuclear (RN) emergency, referred to as a “radiation emergency” in this guide (note that the term “radiation emergency” is used here rather than “nuclear emergency” as this guide concerns the exposure of individuals to radiation in both radiological and nuclear emergencies), a significant number of people, including first responders, may become externally exposed to radiation, contaminated with radioactive materials, or both. Timely screening and treatment of the affected population are important components of emergency response and consequence management. While certain jurisdictions in Canada have developed or are developing generic plans for managing health consequences during emergencies, there has been no Canadian guide for managing health consequences of radiation emergencies [1]. This Canadian guide on the medical management of radiation emergencies is intended to provide a common framework from which hospitals, public health authorities and emergency management organization can base their response plans.

1.1 Purpose and Audience
The main purpose of this guide is to provide information on screening, assessment and emergency room treatment of populations exposed to radiation or contaminated by radioactive materials. This guide is intended for medical responders and hospital emergency department personnel. However, the information contained in this guide may also be useful to emergency management and public health officials for planning purposes.

1.2 Scope, Contents and Structure
The radiation emergencies considered in this guide are limited to those listed in Chapter 2 and that have the potential to result in mass exposures of people. However, they do not include detonation of an improvised nuclear device (IND) or nuclear warfare. Such events will require different emergency management approaches due to significant loss of infrastructure. From a medical perspective, injuries resulting from a combination of radiation, heat and blast will be much more complex and difficult to manage.

The recommendations contained in this guide are focussed on early medical management of radiation emergencies. Nevertheless, the full spectrum of response, from the initial response soon after the incident to the longer-term care required after the emergency is over, is presented. It is useful for medical personnel to understand the sequence of events that may have preceded the casualty's presentation at a community reception centre or at an emergency department. Also, it is useful to understand the future impact on the casualty of the actions taken in the community reception centre and emergency room.

This guide makes only general recommendations related to instrumentation, materials, and procedures. It is recognized that the availability of equipment and materials may vary across the country. For example, not all hospitals have a radiation emergency plan – the threat of a radiation emergency may have been deemed to be too low to justify the expense of purchasing equipment and training and exercising personnel. Therefore, the guide also attempts to address the needs of those with limited resources.
The text has been organized in a way that allows readers to consider in advance how they would respond to radiation emergencies. Chapter 2 starts by providing basic information on the hazards associated with radiation emergencies. It covers topics such as radiation health effects, protection of workers, radiation detection and measurement, and discusses specific radiation emergency scenarios. There are many sources for this kind of information elsewhere – this chapter was included for completeness. Chapter 3 describes the management of radiation emergencies in Canada and provides an overview of the roles of emergency management organizations within Canada and abroad.

Chapters 4 and 5 are organized into pre-hospital and Emergency Department responses during the early phase following a radiation emergency. Chapter 4 addresses the pre-hospital response provided by emergency medical services and presents a public health model for monitoring and decontaminating affected populations in community reception centres. It is beyond the scope of this document to discuss other public health interventions such as sheltering, evacuation and restrictions on food and water. Chapter 5 describes the Emergency Department response to a radiation emergency. This chapter covers preparation of the Emergency Department for receiving casualties contaminated with radioactive materials, protection of hospital workers, triage of radiation casualties, patient decontamination, and medical management of radiation casualties. The emphasis is on early treatment that could take place in an emergency department. Detailed discussions on specialized in-patient care are beyond the scope of this guide.

Chapters 6 and 7 are extensions of chapters 4 and 5. Chapter 6 focuses on activities that are more likely to take place outside of the Emergency Department and extend into the late phase following a radiation emergency. This chapter discusses social and psychological support requirements as well as long-term medical monitoring of exposed individuals. Chapter 7 highlights special issues for populations who are more vulnerable in radiation emergencies. Annexes at the end of the guide provide specific technical information such as procedures for contamination control and decontamination, population screening, casualty decontamination, emergency room set-up, and casualty assessment, and forms for ordering specialized tests. The information contained in these annexes can be adapted by users to create aide-memoires for use during radiation emergencies.

The topic of radiation safety and protection of workers during radiation emergencies is addressed throughout the text, as required. Sections of chapters 3, 4, and 5 cover radiation protection principles, exposure guidelines, and recommended practices during population screening and medical management.

1.3 How to Use This Guide
It is important to review this guide prior to a radiation emergency in order to become familiar with its contents and structure. It may be used during the emergency planning process, or as a reference when responding to a radiation emergency. Specific technical information in the form of guidelines and procedures is provided in the annexes.

References
CHAPTER 2 – RADIATION AND RADIATION EMERGENCIES

2.1 Radiation Basics

2.1.1 WHAT IS RADIATION?

Radiation can be defined as the transmission of energy through space (refer to Figure 2.1). For example, the Sun radiates energy to us in the form of light (visible, infra-red, and ultraviolet). These familiar forms of radiation, along with microwaves and radio waves, are termed non-ionizing radiation. Too much ultra-violet radiation causes sunburns and looking directly at the sun can damage our eyesight. Microwaves can cook food, but they can also destroy the tissues of living organisms.

This guide concerns ionizing radiation. Ionizing radiation has the ability to directly or indirectly strip electrons from atoms and to break the bonds between the atoms of a molecule. When this occurs in living material, it can cause biological damage. This type of radiation is produced by certain materials, both natural and artificial, that are termed radioactive. It is also produced by certain devices such as X-ray machines, nuclear reactors, and particle accelerators. It can also reach us from outer space in the form of high-energy cosmic radiation.

Figure 2.1 The electromagnetic spectrum of radiation [1]

Ionizing radiation is naturally present in the environment. However, it is not detectable by any of the five senses. It is indeed possible to receive a high dose of radiation without even being aware that one has been exposed. The health effects of ionizing radiation are well known by the scientific community, but they are poorly understood by the general public. The potential risks from radiation exposure need to be clearly understood if one is called upon to deal with radioactive materials in a workplace accident or emergency situation.
Fortunately, ionizing radiation is readily detectable by portable measuring devices. There are well-established safety procedures for protecting first responders, medical personnel and the public from the hazards of radiation exposure. In addition, there are numerous medical interventions to aid those exposed to radiation or contaminated by radioactive materials at levels that could be potentially harmful. These are presented in more detail in Chapters 3, 4, and 5.

2.1.2 THE COMPONENTS OF THE ATOM

All matter is composed of atoms. Each atom consists of a positively-charged nucleus surrounded by negatively-charged electrons. The nucleus contains two types of particles: protons (which are positively-charged) and neutrons (which carry no electric charge).

Each element is characterized by the number of protons in its nucleus. This quantity is referred to as the atomic number. Elements having the same number of protons but differing numbers of neutrons in the nucleus are said to be isotopes of the same element. The total number of protons and neutrons in the nucleus is referred to as the mass number of the particular isotope. For example, hydrogen always has one proton in its nucleus, but may have zero, one, or two neutrons. Hydrogen then has three isotopes: common hydrogen, deuterium, and tritium, with symbols $^1$H, $^2$H, and $^3$H, respectively, where the leading superscript gives the mass number.

2.1.3 TYPES OF IONIZING RADIATION

The nuclei of some isotopes are inherently unstable and undergo radioactive decay in order to reach a stable state. Such unstable isotopes are referred to as radioisotopes or radionuclides. During the decay process, ionizing radiation is emitted. In the above example, the nuclei of hydrogen and deuterium are stable but those of tritium are unstable, and are therefore radioactive. Depending on the structure, unstable nuclei will progress to become stable through different decay pathways, emitting different types of ionizing radiation. This guide will discuss four different types of ionizing radiation: alpha ($\alpha$), beta ($\beta$), gamma ($\gamma$), and neutron ($n$), which are the most common types of radiation from radioactive decay or nuclear reaction. They are described briefly here. The properties of the different types of ionizing radiation can be found in Annex 2.1 Properties of Different Types of Ionizing Radiation.

Alpha ($\alpha$) radiation consists of charged particles (alpha particles), each a combination of two protons and two neutrons that are emitted from unstable nuclei. They are generally emitted from heavy nuclei with an atomic number greater than 82. They have a relatively short range, travelling only a few centimetres in air, because their electric charge is greater than that of other common particles such as $\beta$ particles. They can be stopped by a sheet of paper and will not penetrate the outer layers of intact human skin (refer to Figure 2.2). For this reason, $\alpha$ radiation is not an external hazard. Radioactive material that emits $\alpha$ radiation may be a hazard if it is taken into the body.

Examples of isotopes that emit alpha radiation (alpha emitters):

- Americium-241 ($^{241}$Am) used in smoke detectors
- All isotopes of uranium, whether natural, depleted, or enriched
- Polonium-210 ($^{210}$Po) used in anti-static devices
Beta (\(\beta\)) radiation consists of electrons (either positively- or negatively-charged) that are emitted from unstable nuclei. Because \(\beta\) particles have less charge than \(\alpha\) particles, they undergo less frequent interactions with the medium they penetrate and therefore have a longer range. Beta particles can travel several metres in air. They can be stopped by aluminium, plastic, or clothing, but they can penetrate unprotected skin. At high doses, \(\beta\) radiation of sufficient energy can give rise to skin burns and damage the lens of the eye, although it is primarily an internal hazard.

Examples of isotopes that emit beta radiation (beta emitters):
- Tritium (\(^3\)H) used as unpowered light sources in exit signs, compasses, gun sights
- Strontium-90 (\(^{90}\)Sr) used in eye therapy devices and thermo-generators
- Iodine-131 (\(^{131}\)I) used in nuclear medicine for diagnostic and therapeutic procedures

Gamma (\(\gamma\)) radiation (gamma rays) consists of electromagnetic waves of very high frequency. They are emitted from radioactive nuclei, usually in conjunction with \(\alpha\) or \(\beta\) radiation. Gamma radiation has no electric charge, but it indirectly ionizes matter as it passes through it. Gamma radiation travels many meters in air. Gamma radiation is highly penetrating and can pass through most materials, including the human body. Effective shielding against \(\gamma\) radiation requires up to 10 cm of lead or a meter of concrete, depending on the energy of the \(\gamma\) rays. For this reason, \(\gamma\) radiation is an external hazard as well as an internal hazard.

Examples of isotopes that emit gamma radiation (gamma emitters):
- Cobalt-60 (\(^{60}\)Co) used in cancer therapy, industrial radiography, food irradiators
- Iridium-192 (\(^{192}\)Ir) used in industrial radiography
- Cesium-137 (\(^{137}\)Cs) used in blood irradiators

X-rays are similar to \(\gamma\) rays. They can be produced by re-arrangement of the electrons outside of the nucleus, or during the interaction of beta radiation with matter. In clinical settings, X-rays are produced by X-ray machines only when turned on. Generally, X-rays are of lower frequency or energy than \(\gamma\) rays, but linear accelerators, used in cancer therapy, can produce X-rays of very high energy.

Neutrons, a fourth type of ionizing radiation, are emitted in the processes of nuclear fission and reaction (such as an americium-beryllium neutron source). Free neutrons are generally encountered inside a nuclear reactor or in the explosion of a nuclear fission device. Some radioactive materials, such as californium-252 (\(^{252}\)Cf), emit neutrons when they undergo spontaneous decay. Neutrons can travel many metres in air. Neutrons can be effectively shielded using water.
2.1.4 RADIATION QUANTITIES AND DEFINITIONS

Activity
The strength of a radioactive source is characterized by its activity, defined as the number of atoms per second undergoing radioactive decay in the source. The système internationale (SI) unit for activity is the becquerel (Bq), which is equal to one atomic disintegration per second. The older unit of activity is the curie (Ci), which is equal to $3.7 \times 10^{10}$ Bq (e.g., a cobalt-60 source for radiation therapy can have an activity of $10^{13}$ Bq). Multiples and sub-multiples of these units can be found in Annex 2.2 Summary of Système Internationale (SI) Units of Radiation and Conversion Factors and Annex 2.3 Prefixes for Multiples and Sub-multiples of SI Units. The hazard of a given radioactive source depends not only on its activity, but also on the type and energy of radiation emitted.

Radiological Half-life
The rate at which a radioactive material decays is characterized by its half-life, defined as the time required for one half of its atoms to undergo radioactive decay (e.g., cobalt-60 has a half-life of about 5.3 years). After two half-lives, only one quarter of the radioactive atoms will remain; after three half-lives, one-eighth, etc. The related terms biological half-life and effective half-life will be introduced in Chapter 5.

Absorbed Dose
In addition to other factors, the degree of radiation damage to an organ or tissue is directly related to the amount of radiation energy deposited in that tissue. The basic quantity in radiation dosimetry is the absorbed dose, measured in units of gray. A dose of one gray (Gy) corresponds to one joule of energy deposited per kilogram of material (or tissue). The gray is a rather large unit of dose and the units of milligray (mGy, $10^{-3}$ Gy) or microgray (µGy, $10^{-6}$ Gy) are often used (refer to Annex 2.2 Summary of Système Internationale (SI) Units of Radiation and Conversion Factors and Annex 2.3 Prefixes for Multiples and Sub-multiples of SI Units). The gray is the unit of dose generally used when referring to radiation effects on tissues.
Equivalent Dose
Some types of radiation are more effective at producing biological effects than others, even for the same absorbed dose in gray. This gives rise to another important concept: the equivalent dose, which is equal to the absorbed dose in gray multiplied by a radiation weighting factor ($W_R$). The weighting factor, determined primarily by the potential of the radiation to cause long-term effects such as cancer, is 1 for beta and gamma radiation, 20 for alpha radiation, and 2.5 to 20 for neutrons, depending on their energy. This means that the absorbed dose and equivalent dose are numerically equivalent for beta and gamma radiation. The SI unit of equivalent dose is the sievert (Sv), which again can be divided into millisievert (mSv, $10^{-3}$ Sv) or microsievert (µSv, $10^{-6}$ Sv). (refer to Annex 2.2 Summary of Système Internationale (SI) Units of Radiation and Conversion Factors and Annex 2.3 Prefixes for Multiples and Sub-multiples of SI Units)

Effective Dose
Different tissues and organs may vary in how they respond biologically to radiation exposure. For example, a given equivalent dose has a higher risk of inducing fatal cancer in the lung than in the thyroid gland. This is taken into account by multiplying the equivalent dose to an organ or tissue by its respective tissue weighting factor ($W_T$). The tissue weighting factor represents the fraction of the total radiation detriment to the whole body attributed to that tissue when the whole body is irradiated uniformly. Effective dose is the sum of the products of equivalent dose and the tissue weighting factor of each tissue or organ. It has the same unit as equivalent dose, the sievert (Sv). The sievert is the unit dose generally used when referring to cancer effects. Dose limits are often expressed in terms of effective dose.

The SI units of radiation and their conversion to historical units are summarized in Annex 2.2 Summary of Système Internationale (SI) Units of Radiation and Conversion Factors.

2.2 Radiation Health Effects and Radiation Protection
Ionizing radiation has the ability to break up biologically significant molecules such as DNA, which forms a part of every living cell and which carries the genetic code of the organism. If the DNA is damaged, there are three possible outcomes:

- Mechanisms within the cell may completely repair the damage so that there is no further harm.
- The cell may fail to repair the damage so that the cell dies or is unable to reproduce.
- The cell may repair the damage, but in a faulty manner, so that the genetic code is not reproduced correctly. In this case, the cell may still be able to survive and reproduce, but it has now undergone a mutation that may eventually lead to cancer in the organism or possibly hereditary effects in subsequent generations.

The effects of radiation may be short-term (occurring within minutes, hours or days following exposure) or long-term (occurring years later or possibly in subsequent generations). Short-term effects occur only at very high levels of exposure and include acute radiation syndrome, with its symptoms of nausea, vomiting, diarrhea, hair loss, infections, and possible death. Another important short-term effect is a beta radiation burn to the skin. The only well established long-term effect of radiation exposure is cancer induction in an exposed individual.
An increased risk of cardiovascular disease has also been observed in humans at high levels of exposure. To date, genetic effects have been observed only in animal experiments – they have not been observed in humans, including extensively studied populations such as the descendants of the survivors of the atomic bombings in Hiroshima and Nagasaki.

It is useful to distinguish between deterministic effects (also called tissue reactions) and stochastic effects (also called cancer and hereditary effects) of radiation. In the case of deterministic effects, damage to a given tissue will occur if the radiation dose exceeds a certain threshold value in a short period of time. Above that value, the severity of the effect will increase with the amount of radiation received. Deterministic effects generally occur within minutes, hours or days following exposure. They include damage to blood forming cells and the lining of the intestinal tract, hair loss, and temporary sterility. For stochastic effects, such as cancer, the probability of the effect increases with the amount of radiation received. Stochastic effects are expressed years after the exposure or possibly in subsequent generations.

2.2.1 SHORT-TERM EFFECTS

Acute Radiation Syndrome
Acute radiation syndrome is an acute illness caused by irradiation of the entire body (or most of the body) by a high dose of penetrating radiation (exceeding about 1 Gy). The syndrome usually begins within the first few hours or days following exposure, depending on the dose received. It is possible for symptoms to begin within minutes following exposure when acute doses are above 10 Gy, but these types of accidents are beyond the scope of this document. Symptoms include decrease in blood-cell counts, gastro-intestinal symptoms, fever and infections, bleeding, hair loss, central nervous system disorder, and death. An acute dose of 3.5 to 4.5 Gy (LD_{50/30}) is considered to be 50% lethal in humans without treatment, i.e., one half of a population receiving this dose would not survive beyond 30 days without medical treatment. Advanced medical treatment can increase the LD_{50/30} to 6 Gy. Doses beyond 10 Gy are not considered survivable as victims will develop fatal multi-organ failure.

Cutaneous Radiation Syndrome
Significant contamination with beta-emitting radioactive materials as well as exposure of the skin to X-ray or gamma radiation can lead to severe burns. The threshold dose for erythema is about 3-4 Gy. The severity of the burn will depend on the amount of radiation received, the volume of tissue affected, and the quality of radiation. These burns can take months to heal.

2.2.2 LONG-TERM EFFECTS

Long-term, or delayed, effects may not occur until years following the exposure. Certain effects (“deterministic”) are only observed above a threshold dose, with the severity of the effect increasing with dose. For other effects, there is no clear threshold and the likelihood of the effect increases with increasing dose (“stochastic”).

Cancer
For a delayed effect such as cancer, there is no clear threshold below which the effect does not occur; rather, the likelihood of the effect increases with increasing dose. There is strong evidence for an association between radiation and cancer induction in many organs such as lung, bone, breast, thyroid, colon, stomach, esophagus, bladder, ovary, brain and central nervous system, skin (non-melanoma), blood (some types of leukemia), and salivary gland; there is good evidence
only following high doses for organs such as small intestine, rectum, uterus and kidney; and, there is little evidence for other cancers such as chronic lymphocytic leukemia, pancreas, prostate, cervix, testes, uterus, non-Hodgkin’s lymphoma, Hodgkin’s disease, and multiple myeloma [2]. An excess in the incidence of leukemia may be observed about 3-5 years following exposure, while an excess in solid tumours may begin to rise at about 7-30 years following exposure.

There are many examples of cancer in populations exposed to high levels of radiation. In the atomic bomb survivors in Hiroshima and Nagasaki, leukemia and most of the cancers described above were observed. Lung cancer has been observed in underground uranium miners who have inhaled radioactive radon gas; bone cancer was seen in the radium dial painters in the earlier part of the 20th century; breast cancer was increased in women subject to repeated fluoroscopy examinations while being treated for tuberculosis; and, increased thyroid cancer has been observed in children drinking milk contaminated by radioactive iodine fallout from the Chernobyl accident [2].

Statistical increases in cancer risks have been observed at doses as low as 100 mSv in human populations. Below this level, any possible increase in radiation-induced cancers is masked by naturally-occurring cancers. Figure 2.3 gives two possibilities for extrapolating the risk at doses lower than 100 mSv. A straight line can be fitted to observed cancer risks at higher doses and extrapolated downward to zero. This gives rise to the Linear-No-Threshold (LNT) hypothesis, which assumes that there is some level of risk at all doses, however small. The S-shaped curve indicates the effect of a possible threshold just below 100 mSv. The true situation may lie anywhere between these two possibilities [3]. The LNT model is used in radiation protection for planning and setting dose limits.

Figure 2.3 Extrapolation of radiation-induced cancer risks to low doses. The open circles represent observed cancer cases. The straight dashed line is based on the Linear-No-Threshold hypothesis. The S-shaped curve illustrates the effect of a threshold.
The International Commission on Radiological Protection (ICRP) has derived a nominal cancer risk coefficient of 5.5% per sievert of exposure, which includes all fatal cancers plus a weighting factor for non-fatal cancers [4]. By comparison, the lifetime probability of cancer from all causes is about 40% with a mortality of about 25% [5].

**Effects on fetal development**

The human embryo and fetus are particularly sensitive to ionizing radiation and the consequences of exposure can include malformations, impaired brain function and cancer. For this reason, additional restrictions are placed on radiation workers and patients who are pregnant. The developing fetus is most sensitive to radiation during the early fetal period when the major organs are beginning to differentiate, somewhat less in the second trimester of pregnancy, and least in the third trimester. The incidence of gross congenital malformations and mental retardation are dose-related and appear to have thresholds, i.e., doses below which the incidence is not elevated above normal. Concerning deterministic effects, the threshold fetal dose for malformations, mainly involving the central nervous system, is 100-200 mGy, or higher. Some reduction of IQ (intelligence quotient) has been seen at doses above 100 mGy. A dose of 1000 mGy is considered to be the threshold for severe mental retardation and small head size. Concerning stochastic effects, research has shown that the risk of childhood leukemia is increased following a dose of 10 mGy received when mothers had pelvic X-ray examinations during pregnancy [6].

**Hereditary effects**

Unlike fetal effects, this type of effect refers to irradiation of germ cells before conception or fertilization takes place. If the DNA structures of the germ cells are damaged, then birth defects may occur in the first or subsequent generations of the irradiated parent(s). Hereditary effects of radiation exposure have been studied extensively in experimental animals such as fruit flies and rodents. To date, no such effects have been observed in the offspring of humans exposed to radiation, including the atomic bomb survivors.

**Cataracts**

Acute and chronic exposure of the lens of the eye to radiation can eventually lead to cataract formation. The threshold for cataract development following acute exposure is below 2 Gy and recently it has been suggested to be as low as 0.5 Gy [7].

**Cardiovascular disease**

Increased risks of cardiovascular disease have been reported in atomic bomb survivors and persons receiving high therapeutic doses of radiation. This is a deterministic tissue effect rather than a stochastic effect. The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) has not been able to draw any conclusions about a direct causal relationship between irradiation at doses below about 1 to 2 Gy and excess incidence of cardiovascular diseases [8].
2.2.3 RADIATION PROTECTION STANDARDS

The ICRP develops and maintains the international system of radiological protection used world-wide as the common basis for radiological protection standards, guidelines and practices for workers and the public. Their recommendations provide the basis for legally-binding regulations of most national authorities such as the Canadian Nuclear Safety Commission (CNSC).

Within the radiation protection system, the ICRP and most national authorities conservatively assume the validity of the Linear-No-Threshold hypothesis, i.e., that all exposures to ionizing radiation, regardless of how small, carry some degree of risk. On this basis, the ICRP has set forth three cardinal principles of radiation protection [4]:

- **Justification**: Any decision that alters the radiation exposure situation should do more good than harm.
- **Optimization of Protection**: The likelihood of incurring exposure, the number of people exposed, and the magnitude of their individual doses should all be kept as low as reasonably achievable, taking into account economic and social factors.
- **Application of Dose Limits**: The total dose to any individual from regulated sources in planned exposure situations other than medical exposure of patients should not exceed the appropriate limits specified by the ICRP.

From the above, it might seem that the optimal dose limit should be zero. However, this would exclude the many benefits a society has from radiation technologies.

The following dose limits are based on those recommended by the ICRP and are present in regulations set by the CNSC (refer to Table 2.1):

**Radiation workers (including Nuclear Energy Workers)** – an effective dose of not more than 50 mSv in any one year, and not more than 100 mSv in a 5-year period. A further restriction is placed upon pregnant Nuclear Energy Workers. In Canada, the dose to pregnant Nuclear Energy Workers is limited to 4 mSv for the balance of the pregnancy (i.e., remainder of the term) once the pregnancy is declared.

**General Public** – not more than 1 mSv/year from all licensed applications of radiation. Exposures from natural radiation and medical procedures are excluded.
Table 2.1: CNCS regulations on dose limits to nuclear energy workers and the public

<table>
<thead>
<tr>
<th>EFFECTIVE DOSE LIMITS (mSv)</th>
<th>Nuclear energy workers</th>
<th>Pregnant nuclear energy workers</th>
<th>Member of the public</th>
</tr>
</thead>
<tbody>
<tr>
<td>One-year dosimetry period</td>
<td>50</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Five-year dosimetry period</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equivalence DOSE LIMITS (mSv)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lens of an eye</td>
<td>Nuclear energy worker</td>
<td>150*</td>
<td></td>
</tr>
<tr>
<td>Any other person</td>
<td>One-year dosimetry period</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>One calendar year</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skin</td>
<td>Nuclear energy worker</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>Any other person</td>
<td>One-year dosimetry period</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td></td>
<td>One calendar year</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hands and Feet</td>
<td>Nuclear energy worker</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>Any other person</td>
<td>One-year dosimetry period</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td></td>
<td>One calendar year</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* ICRP has recently recommended reducing the limit for the lens of the eye to 20 mSv in a year, averaged over defined periods of 5 years, with no single year exceeding 50 mSv [9].

Dose limits for emergency workers may be permitted to exceed the limits in Table 2.1 during the control of an emergency. In emergencies, the effective dose limit is 500 mSv and the equivalent dose limit for the skin is 5,000 mSv. These emergency dose limits may be exceeded, however, when a person acts voluntarily to save or protect human life.

2.2.4 PROTECTION FROM EXTERNAL RADIATION EXPOSURE

It is important to distinguish between external exposure to a radiation source and contamination by radioactive material. Contamination refers to the presence of radioactive material on the surface of a person (external contamination), or taken into the body (internal contamination), or both. For external exposure, the source is not in contact with the body and the exposure ceases when the source is removed. Such sources include:

- a sealed or intact radioactive source
- radiation produced from a radiation-emitting device (e.g., X-ray device)
- an airborne cloud of radioactive material (cloudshine)
- radioactive material deposited on the ground (groundshine)

Persons who have been externally exposed to radiation, but not contaminated, pose no radiation hazard to others (i.e., they are not radioactive). In these cases, no further radiation safety precautions are necessary for responders who are handling these casualties.

There are three broad principles of protection from an external radiation source: time, distance and shielding.
**Time**
Radiation effects are directly proportional to the amount of time spent near a radiation source. If you have to approach a radiation source, you should minimize the time spent near it. If you cut the time by half, you reduce your dose by half.

**Distance**
The dose rate (dose per unit time) from a point source of radiation decreases with the inverse square of the distance away from the source. Doubling the distance from the source reduces the dose by a factor of four.

**Shielding**
The greater the shielding around a radiation source, the smaller the exposure. For example, gamma radiation can travel for tens to hundreds of metres in air. However, placing a shield of very dense material between the source and recipient can greatly reduce the exposure. A metre of water or 10 cm of lead provides an effective shield against most gamma sources.

In addition to these basic principles, radiation monitoring is used to provide an indication of the level of exposure. A hand-held survey meter can detect the presence of radiation and give an immediate assessment of the exposure hazard (see next section). For example, if a meter reads 0.5 mSv/hour at a certain location, then a person remaining at that location would receive the allowable annual dose for a member of the public in two hours. However, a person working in a contaminated area is likely to be moving from location to location, so an electronic personal dosimeter (EPD) can be used for a continuous reading of the dose accumulated by the person.

### 2.2.5 PROTECTION FROM EXTERNAL RADIOACTIVE CONTAMINATION
External contamination can occur when radioactive material from an unsealed, broken or dispersed source is deposited on skin or clothing. As long as radioactive material remains on the skin or clothing, it will continue to expose the person to radiation. People who are externally contaminated may require decontamination to effectively remove and control the contamination. Decontamination reduces the radiation exposure of the contaminated person and others; it also prevents the spread of contamination.

If one is present in or must enter a radioactively contaminated area, some protection from external contamination can be achieved through various means such as temporary sheltering or by wearing protective clothing and gloves made of disposable material. If skin or clothing is inadvertently contaminated, instruments such as hand-and-foot monitors or portal monitors can be used to detect the contamination (the most common portal monitors are sensitive only to gamma or beta radiation). If contamination is detected, usually it can be removed by changing clothes and showering.
2.2.6 PROTECTION FROM INTERNAL RADIOACTIVE CONTAMINATION

Internal contamination occurs when radioactive material gets into the body. Once taken in, potential health effects are dependent on, amongst other factors, the routes of intake:

- inhalation from a cloud or re-suspension from contaminated surfaces
- ingestion of contaminated food or drinking water
- through open wounds on contaminated skin
- by direct absorption through the skin (e.g., tritiated water)

The radiation dose from internal radioactive contamination depends on the amount of intake, the physical and chemical characteristics of the radioactive material, the organ or tissue where the radioactivity is concentrated (target organ), and the length of time that the radioactivity remains in the body. Some radioactive materials decay rapidly, in a matter of minutes or hours, while others decay over hundreds of years. Similarly, some radioactive materials are eliminated from the body in a few days while others may be incorporated into tissues and remain there for many years.

The best protection against internal contamination is to avoid the contamination in the first place. Washing one's hands or taking a shower will remove contamination from the skin before it has a chance to enter the body. The best protection from an airborne radiation hazard is prompt evacuation. If a person does become internally contaminated, there are procedures that can accelerate the elimination of a radioactive material from the body (details are given in Chapter 5).

Widespread radioactive contamination of food or drinking water can be a problem if it exceeds acceptable levels. If contamination is suspected, samples of food and water should be tested for radioactivity, and if radioactivity concentrations exceed guideline values, food and water restrictions should be considered. As food and drinking water interventions following a radiation emergency are outside of the scope of this guide, interested readers may consult the Canadian Guidelines for Intervention During a Nuclear Emergency [10] and provincial/territorial guidelines.

2.3 Radiation Detection and Measurement

2.3.1 BASIC PRINCIPLES OF DETECTION

Ionizing radiation is not perceptible to any of the five senses, and therefore requires specialized equipment for detection. There is a wide variety of methods and instrumentation available, all relying in some way on how radiation interacts with matter. As its name implies, ionizing radiation has the ability to ionize atoms, i.e., strip electrons from atoms and generate a cloud of free electrons and positive ions. The most basic method of detection involves collecting and measuring the electric charge created in a gas-filled chamber or solid state device.
In some cases, the electron is not completely removed from the atom, but is excited to a higher energy state. When the electron drops back to its original state, it emits a flash of light which can be detected with a photo-sensitive device. This flash may be detected immediately, as in a scintillation detector, or it may be delayed and measured at a later time, as in thermo-luminescent dosimeters worn by radiation workers.

Ionizing radiation may also cause a chemical change in certain substances, such as the darkening of photographic film. When the film is developed, it provides a permanent record of the amount of radiation received. This was how Becquerel discovered radioactivity by chance in 1896. Ionizing radiation may cause physical changes in a substance, which may be temporary (as in a bubble chamber or cloud chamber) or permanent (as in a track-etch detector). All of these changes can be observed and measured.

A discussion of common radiation detection and dosimetry instrumentation is provided in the following sections.

### 2.3.2 SURVEY METERS

Survey meters are hand-held instruments used to detect either the presence of a radiation field or radioactive contamination on a surface (refer to Figure 2.4). The most common type is the Geiger-Müller detector, often referred to as a Geiger counter. The detecting probe consists of a gas-filled chamber with a central wire. When an ionizing particle enters the chamber, it produces a cascade of electron-ion pairs. The negatively-charged electrons are attracted toward the positively-charged anode wire and the resulting pulse of electric current is amplified and detected by an external circuit. A Geiger counter usually gives a reading in count rate (counts per minute, [CPM], or counts per second, [CPS]) or dose rate (µSv/h).

For greater sensitivity of the measurement of gamma radiation, a scintillation detector can be used. Instead of a gas-filled chamber, the detecting element is a crystalline substance; sodium iodide (NaI) is commonly used. It emits flashes of light when radiation passes through it. These flashes of light are amplified by a device known as a photomultiplier and registered by an external circuit. A scintillation detector is heavier and more bulky than a Geiger counter, but it is more sensitive to gamma radiation and allows some limited isotope identification.

For a more complete identification of isotopes, one needs a solid state detector, which has a much higher energy resolution than a scintillation detector. These are large instruments, usually employed only in a radio-isotope laboratory, although some field portable models have been developed.
2.3.3 PERSONAL DOSIMETERS

Personal dosimeters (refer to Figure 2.5) are used to measure radiation dose of externally exposed individuals. They are useful for detecting changes in radiation levels in the workplace and to provide information in case of accidental exposures. Individuals who work in radioactive areas should wear personal dosimeters to have their doses monitored on a regular basis. CNSC regulations require licensees to use a licensed dosimetry service to measure and monitor radiation doses to nuclear energy workers who have a reasonable probability of receiving an effective dose greater than 5 mSv in a one-year dosimetry period.

The most widely used personal dosimeters are Thermo-Luminescent Dosimeters (TLDs) and Optically Stimulated Luminescence (OSL) dosimeters. TLDs and OSL dosimeters consist of a detector (commonly referred to as a chip) which, when heated or optically stimulated after an exposure to radiation, gives off light in proportion to the dose received. In occupational settings, these dosimeters are worn by personnel exposed to radiation (gamma, x-ray, beta). Some TLDs are sensitive to neutrons.

Extremity TLDs provide extremity radiation monitoring for workers required to manipulate or work close to radioactive materials or radiation equipment such that their extremities (i.e., fingers) receive more exposure than the rest of the body (i.e., torso). These dosimeters measure radiation doses due to gamma and beta radiation.
Personal Alarming Dosimeters (PADs) are direct-reading dosimeters that display both the dose rate and the accumulated dose at any time. They are usually worn by personnel who need real-time personal monitoring for dose management/control purposes. These dosimeters usually measure radiation doses due to gamma and beta radiation, although some PADs can measure neutron doses. PADs have built-in alarms that provide an audible and visual alert to pre-established levels of radiation. In an emergency situation, responders should wear PADs for dose control purposes. The availability and use of PADs should be considered in emergency planning.

Figure 2.5 Different types of personal dosimeters

2.4 Radiation Emergency Scenarios
Although there are many scenarios that can lead to radiation emergencies, either accidental or deliberate, the following sections discuss the most common scenarios within the scope of this guide, where a large number of responders or the public can be exposed or contaminated. Scenarios where a small number of individuals are involved, such as a spill of radioactive material in a laboratory, are not included. Catastrophic events, such as the detonation of an improvised nuclear device, are also beyond the scope of this guide.

2.4.1 LOSS OF A RADIOACTIVE SOURCE
High-intensity radioactive sources are used in hospital radiotherapy treatment centres and in industrial radiography. Normally, such sources are subject to rigid regulatory controls, but there have been incidents in several countries involving unauthorized or uninformed persons gaining access to abandoned radiation sources and receiving high doses of radiation. The main risk in these situations would be external exposure, but if the source containment is broken, there would be an additional risk of external and internal contamination. Most of the effect would occur before the source is located and identified by emergency responders.
2.4.2 RADIOLOGICAL EXPOSURE DEVICES (RED)
A radiological exposure device (RED) is a high-intensity radiation source deliberately placed in a public area to expose people in close proximity, e.g., an industrial gamma radiography source placed under the seat of a bus becomes a radiological exposure device (RED). Although radioactive contamination is not spread nor do people become radioactive, people could receive significant radiation doses. Prolonged exposure could lead to cases of acute radiation syndrome (ARS) and cutaneous radiation syndrome (CRS). The challenge is that the hazard might not be recognized until groups of people begin to present themselves at a local hospital with symptoms of ARS and/or CRS.

2.4.3 RADIOLOGICAL DISPERSAL DEVICES (RDD)
An RDD is an improvised device (or process) that intentionally disperses radioactive material, thereby contaminating people and the environment. An RDD might be noticeable such as an explosive device with radioactive material, commonly known as a “dirty bomb”. Responders and local officials would know that an RDD has been used if radiation is detected by proper instrumentation or through notification by an intelligence or law enforcement agency. Even though the radiation health risks might be low or the scope of the physical damage limited, a significant number of people would need to be screened for radioactive contamination.

2.4.4 INTENTIONAL CONTAMINATION OF FOOD AND WATER SUPPLIES
Intentional contamination of food and water supplies could occur by adding radioactive material(s) to a public drinking water supply or food source. It is unlikely that anyone would receive a high dose of radiation through this means; the chief consequence would be public fear and panic, potentially affecting thousands of people. Food and water monitoring and controls should be implemented as soon as the contamination is discovered and identified.

2.4.5 EVENTS AT NUCLEAR FACILITIES
A major emergency at a nuclear power plant could result in off-site releases of radioactive material, exposure of populations through a variety of exposure pathways, including inhalation, exposure from airborne or deposited radionuclides or ingestion of contaminated food and water, and widespread contamination of the environment. Protective measures could include evacuation, sheltering, stable iodine ingestion, access control, food and water controls and contamination control activities.

Some accidents at nuclear power plants with significant off-site radiological consequences have occurred. The most serious nuclear accident to date occurred on 26 April 1986, when an improperly conducted test at Unit #4 of the Chernobyl nuclear generating station in the Ukraine caused a violent steam explosion followed by a fire in the graphite moderator. The damaged core continued to release major amounts of radioactivity over a two-week period. Radioactive fallout from this event was detected around the world. The immediate confirmed death toll was 30, including two workers killed by the explosion and 28 fire-fighters who subsequently died from acute radiation syndrome (the total number diagnosed with ARS was 134). In the years following the accident, an increase in the incidence of thyroid cancer was detected in children living in Ukraine, Russia and Belarus [11].
More recently, on 11 March 2011, a Richter-9 earthquake struck the east coast of Japan, where the TEPCO Fukushima Dai-ichi nuclear power station was located. Although all four reactors were shut down successfully, a subsequent tsunami disabled the back-up diesel generators that were designed to provide power for the emergency core cooling system. Heat generated by radioactive decays caused core melt-downs and led to explosions from the build-up of hydrogen gas. In the attempts to control the situation, some plant workers received up to 200 mSv of radiation, and six workers received doses ranging from about 300 to 670 mSv [12]. The World Health Organisation has estimated that the majority of doses received by persons in Fukushima prefecture were within 1–10 mSv.

References


ANNEX 2.1 PROPERTIES OF THE DIFFERENT TYPES OF IONIZING RADIATION

<table>
<thead>
<tr>
<th>TYPE OF RADIATION</th>
<th>CHARGE*</th>
<th>MASS†</th>
<th>PENETRATING POWER</th>
<th>EXTERNAL HAZARD</th>
<th>INTERNAL HAZARD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpha</td>
<td>+2</td>
<td>4</td>
<td>low</td>
<td>nil</td>
<td>high</td>
</tr>
<tr>
<td>Beta</td>
<td>+/-1</td>
<td>0.00055</td>
<td>moderate</td>
<td>moderate</td>
<td>moderate</td>
</tr>
<tr>
<td>Gamma</td>
<td>0</td>
<td>0</td>
<td>high</td>
<td>high</td>
<td>moderate</td>
</tr>
<tr>
<td>Neutrons</td>
<td>0</td>
<td>1</td>
<td>high</td>
<td>high</td>
<td>high</td>
</tr>
</tbody>
</table>

* measured in units of electric charge = $1.602 \times 10^{-19}$ coulomb (C)
† measured in atomic mass unit = $1.661 \times 10^{-27}$ kg

ANNEX 2.2 SUMMARY OF SYSTÈME INTERNATIONAL (SI) UNITS OF RADIATION AND CONVERSION FACTORS

<table>
<thead>
<tr>
<th>QUANTITY</th>
<th>SI UNIT</th>
<th>HISTORICAL UNIT</th>
<th>CONVERSION FACTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absorbed dose</td>
<td>gray (Gy)</td>
<td>rad</td>
<td>1 gray = 100 rad</td>
</tr>
<tr>
<td>Equivalent and effective dose</td>
<td>sievert (Sv)</td>
<td>rem</td>
<td>1 sievert = 100 rem</td>
</tr>
<tr>
<td>Activity</td>
<td>becquerel (Bq)</td>
<td>curie (Ci)</td>
<td>1 curie = $3.7 \times 10^{10}$ Bq</td>
</tr>
</tbody>
</table>

ANNEX 2.3 PREFIXES FOR MULTIPLES AND SUB-MULTIPLES OF SI UNITS

<table>
<thead>
<tr>
<th>PREFIX</th>
<th>POWER OF TEN</th>
<th>NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tera</td>
<td>$10^{12}$</td>
<td>one trillion</td>
</tr>
<tr>
<td>Giga</td>
<td>$10^9$</td>
<td>one billion</td>
</tr>
<tr>
<td>Mega</td>
<td>$10^6$</td>
<td>one million</td>
</tr>
<tr>
<td>kilo</td>
<td>$10^3$</td>
<td>one thousand</td>
</tr>
<tr>
<td>–</td>
<td>$10^0$</td>
<td>one</td>
</tr>
<tr>
<td>milli</td>
<td>$10^{-3}$</td>
<td>one thousandth</td>
</tr>
<tr>
<td>micro</td>
<td>$10^{-6}$</td>
<td>one millionth</td>
</tr>
<tr>
<td>nano</td>
<td>$10^{-9}$</td>
<td>one billionth</td>
</tr>
<tr>
<td>pico</td>
<td>$10^{-12}$</td>
<td>one trillionth</td>
</tr>
</tbody>
</table>
CHAPTER 3 – RESPONDING TO RADIATION EMERGENCIES

3.1 Key Considerations in Responding to a Radiation Emergency

For large-scale radiation emergencies where a significant number of first responders, emergency management authorities and the general public are involved, plans for effective emergency medical management should be developed, maintained and exercised. These plans, which should be integrated with overarching all-hazards and event-specific plans, guide and coordinate the collaboration among first responders, public health, hospital, security, law enforcement, psychosocial assistance, and human services. It is important to develop, equip, train, and exercise the response teams on a regular basis.

Both the public and responders may have a substantial fear of radiation, an invisible and poorly understood threat. Providing education and training prior to and during an emergency will facilitate an appropriate understanding and perception of this hazard; effective risk communication and timely psychological counselling are crucial aspects in reducing psychological impacts [1].

Hundreds or thousands of affected people may require screening and medical assessment or care following a large-scale radiation emergency. Close to the incident location, there could be a significant imbalance between the demand for population screening and medical resources and their availability [2]. A scarcity of medical and public health personnel and medical countermeasures may compromise the overall response. Procedures are needed for the selection and prioritization of the population for screening so that screening facilities are not overwhelmed and the people who are most likely to be the most heavily contaminated are dealt with first. Careful planning and allocation of medical resources to triage casualties, evacuate patients, and implement crisis standards of care have the potential to save many lives.

Some patients may go to hospitals by self-referral and arrive soon after the emergency occurs. Hospitals must be prepared to receive patients with little or no warning and enact measures to protect personnel, hospital patients, visitors, and volunteers. Unnecessary self-referral needs to be avoided in order to prevent overwhelming medical resources – announcements in the media could provide instruction to the public in this regard. Treatment of life-threatening illness and injury takes precedence over radiological assessment and decontamination.

Well-planned decontamination procedures are very important. Because the majority of external contamination can be removed by removing clothing, individuals may be advised by public health authorities to self-decontaminate at home if resources do not permit decontamination of large numbers of people either at the site or in a community reception centre (CRC) [3].

Canada is a large country with unevenly distributed expertise and resources for screening and medical management of casualties in a radiation emergency. Pre-arranged collaboration memoranda among provinces/territories or municipalities would improve the response to a large-scale radiation emergency.
3.2 First Responders and Medical Receivers

3.2.1 GENERAL GUIDANCE FOR FIRST RESPONDERS

First responders deal with a wide variety of daily emergencies, including medical, fire, motor
vehicle collisions, natural disasters, and general calls for assistance. The general procedure
at the start of any response is reconnaissance, rescue, decontamination and zoning [4]. First
responders assess the situation using information obtained while en route to the site of the
emergency and collected at the site.

Radiation emergencies may be difficult to assess if training and equipment are not readily
available to first responders. The following provides some general guidance when faced with
radiation emergencies:

• Visual indicators and interviews with witnesses may identify radiation hazards when radiation
detection equipment is not available.

• Measuring radiation fields and identifying radioactive contamination is important for defining
safety and security perimeters and determining whether decontamination is necessary.

• Stress reactions among casualties should be anticipated, but providing clear and consistent
instructions will help control their fears.

• Removing casualties from the hazard zone and directing them to a designated safe area will
reduce their risks.

The Canadian Nuclear Safety Commission (CNSC) has published a series of Action Cards for
radiation emergency first responders covering topics from incident control to mass casualty
decontamination [4, 5].

3.2.2 GENERAL GUIDANCE FOR MEDICAL RECEIVERS

Medical receivers, also referred to as “first receivers”, typically include emergency department
personnel such as clinicians and other hospital staff who have a role in receiving and treating
contaminated victims, or whose roles support these functions. This group is considered a subset
of “first responders” whose activities take place away from the site of the incident. Familiarity
with emergency room disaster plans, emergency exercises and training in medical response to
radiation emergencies will enhance the preparedness of medical receivers. Health Canada, in
collaboration with partners, offers a training package, Medical Emergency Treatment for Exposure
to Radiation (METER) [6], which has been delivered to medical receivers in several Canadian cities.

The emergency room disaster plan forms the basis of a radiation-specific response by the
Emergency Department. A typical disaster plan will include information on the following
elements: plan activation, call-back lists, patient flow and management, additional patient care
areas, staff roles, personal protective equipment (PPE) (gowns, masks etc.), cart supplies,
communication pathways, access control, and arrangements with external agencies.

Radiation-specific response plans should include information on specialized roles, radiation-
specific equipment, radiation protection of personnel, patient management, location and set-up
of decontamination sites and patient treatment areas, specialized medical countermeasures, and
radiation-specific resources for advice, specialized tests, etc.
The organizational structures that tend to work the best under emergency situations are those that exist during routine operations. Thus, the impetus should be on developing organizational structures that are scalable for use during mass-casualty incidents and radiation emergencies.

3.3 Roles and Responsibilities of Federal, Provincial, and Local Public Health Agencies

The planning, preparedness, and response to radiation emergencies in Canada are multi-jurisdictional responsibilities shared by all levels of government. All emergencies are local in nature and are managed at the community or provincial/territorial level. The operators of nuclear generating stations, research reactors, or other nuclear facilities are responsible for on-site emergency plans. Municipal and provincial governments have the primary responsibility of protecting public health and safety, property, and the environment within their borders. The federal government coordinates the federal response to a nuclear emergency occurring in Canada or occurring in a foreign country with impact on Canadians. It also provides support to the provincial government upon request. This might occur if the scope of the emergency exceeded the province’s capability to respond.

3.3.1 MUNICIPAL ROLES

In most cases, the first response to a radiation emergency (for nuclear power plant accidents, this refers to off-site response) will come through the police, fire, or ambulance services of municipalities. For example, the Ontario Provincial Nuclear Emergency Response Plan [7] sets forth the roles of municipalities in responding to provincial emergencies.

3.3.2 PROVINCIAL ROLES

Provinces and territories have the primary responsibility for protecting public health and safety, property, and the environment within their borders. Every province/territory has its own unique emergency management structure and requirements for federal support in the event of a nuclear emergency. To facilitate timely support, the Federal Nuclear Emergency Plan (FNEP) [8] provincial annexes were developed at the request of some provinces. These annexes describe the specific arrangements between the FNEP and Provincial nuclear plans, including linkages between the federal and provincial/territorial emergency structures.

3.3.3 FEDERAL ROLES

The federal government's emergency planning, preparedness, response and recovery are based on an “all-hazards” approach. Under the Emergency Management Act, the Minister of Public Safety is responsible for coordinating the Government of Canada's response to an emergency. The Federal Emergency Response Plan (FERP) [9] is the Government of Canada's “all-hazards” response plan. The Chemical, Biological, Radiological, Nuclear, and Explosives Resilience Action Plan for Canada [10] covers the malicious use of radioactive sources, while the FNEP addresses the Government of Canada's preparedness and response framework for coordinating scientific and technical resources to support the federal off-site response to significant nuclear emergencies, either in delivery of its responsibilities or in support of provincial/territorial actions. The FNEP applies to any of the following situations:
• an emergency at a nuclear power plant in Canada
• an emergency at a nuclear power plant in the United States or Mexico
• an emergency involving nuclear-powered vessels in Canada
• other serious radiological emergencies in North America
• a nuclear emergency occurring outside of North America

Annex 3.1 List of Federal Agencies That Have Designated Responsibilities Under the Federal Nuclear Emergency Plan lists the main federal partners involved in this plan.

3.4 International Assistance

3.4.1 INTERNATIONAL ATOMIC ENERGY AGENCY (IAEA)
The IAEA is an organization within the United Nations that works with Member States to promote safe, secure, and peaceful nuclear technologies. The IAEA develops standards and guidelines on emergency preparedness and response to radiological emergencies using the lessons learned from responses to past events and from exercises. The IAEA uses the Convention on Assistance in Case of a Nuclear Accident or Radiological Emergency (Assistance Convention) [11] and the Convention on Early Notification of a Nuclear Accident (Notification Convention) [12] to establish an international framework to facilitate exchange of information and provision of assistance in the event of a nuclear accident or radiological emergency. As a signatory to the Assistance Convention, Canada can request assistance from other signatories through the IAEA. Health Canada is a “National Competent Authority” for these Conventions.

The IAEA maintains the Response and Assistance Network (RANET), which is intended to facilitate and coordinate provision of assistance within the Assistance Convention framework. RANET consists of teams that can provide technical advice, medical advice and consultation, and medical assistance on public health, dosimetry and specialized tests such as biodosimetry and bioassay. Health Canada has registered its biodosimetry capabilities under RANET.

3.4.2 WORLD HEALTH ORGANIZATION (WHO)
The WHO is the public health arm of the United Nations. The WHO’s Radiation and Environmental Health Programme aims to protect human health from ionizing radiation hazards by raising public awareness of the potential health risks associated with ionizing radiation and the importance of its safe and rational management.

The WHO is a full party to the Conventions on notification and assistance. The WHO will provide recommendations and advice to national authorities on emergency medical and public health responses to radiation emergencies. Emergency medical support for radiation-exposed individuals is provided through the WHO’s Radiation Emergency Medical Preparedness and Assistance Network (REMPAN) [13]. The REMPAN is activated by the IAEA, or directly by the WHO, following notification of a radiation emergency by a Member State or a request for help from the affected country.
3.4.3 RADIATION EMERGENCY ASSISTANCE CENTER/TRAINING SITE (REAC/TS)

The Radiation Emergency Assistance Center/Training Site (REAC/TS) [14] is a United States Department of Energy asset that works through the Oak Ridge Institute for Science and Education. REAC/TS is an international leader in emergency medical response to radiation incidents. REAC/TS is available 24 hours a day, seven days a week to provide advice to emergency personnel responsible for the medical management of radiation emergencies anywhere in the world. Their emergency number is 866-576-1005 (ask for REAC/TS). REAC/TS provides training to medical personnel, health physicists, first responders, and occupational health professionals about radiation emergency medical response. REAC/TS supports the international community as a WHO Collaborating Center of the REMPAN, offering medical assistance.

References


(9) International Atomic Energy Agency (IAEA). Convention on Assistance in the Case of a Nuclear Accident or a Radiological Emergency. September 26, 1986, Vienna, Austria

(10) Public Safety Canada, Chemical, Biological, Radiological, Nuclear, and Explosives Resilience Action Plan for Canada, January 2011


(12) International Atomic Energy Agency (IAEA), Convention on Early Notification of a Nuclear Accident. September 26, 1986, Vienna, Austria


ANNEX 3.1 LIST OF FEDERAL AGENCIES THAT HAVE DESIGNATED RESPONSIBILITIES UNDER THE FEDERAL NUCLEAR EMERGENCY PLAN (FNEP)

Health Canada and the Public Health Agency of Canada
Aboriginal Affairs and Northern Development Canada
Agriculture and Agri-Food Canada
Atomic Energy of Canada Ltd
Canada Border Services Agency
Canadian Food Inspection Agency
Canadian Nuclear Safety Commission
Department of National Defence/Canadian Forces
Environment Canada
Fisheries and Oceans Canada
Foreign Affairs, Trade and Development Canada
Employment and Social Development Canada
Natural Resources Canada
Privy Council Office
Public Safety Canada / Government Operations Centre
Royal Canadian Mounted Police
Transport Canada
CHAPTER 4 – PRE-HOSPITAL MEDICAL AND PUBLIC HEALTH RESPONSE

4.1 On-scene Medical Response

The goals of on-scene medical response are to identify, stabilize, triage, treat, and transport casualties [1]. As part of this response it is important to recognize that:

- Different types of radiation have different characteristics and hazards.
- Radiation can be detected and measured using appropriate instrumentation.
- The risk to first responders from exposure to radiation is greater from the radiation source or contamination at the scene than from radioactive contamination found on casualties.
- Time, distance, and shielding are the hallmarks of mitigating exposure from a radiation source; therefore, responders should minimize time in the warm or hot zones and wear personal protective equipment (PPE) while providing rescue and emergency stabilization.

Typical PPE for a radiological response includes:

- Tyvek coveralls
- double layer latex or nitrile gloves
- over boots and/or boot covers
- protective eyewear
- respiratory protection if necessary, or if airborne hazard unknown (i.e., air purifying respirator or N-95 mask)
- personal alarming dosimeter worn over CBRN PPE (can be covered in a plastic bag)
- TLD/OSL dosimeter under the PPE

Additional information for personnel protection may be found in Annex 4.1 General Guidelines for Personnel Protection.

Personnel should understand what measured dose rates mean and know their “turn back” dose and dose rates. The Canadian Nuclear Safety Commission recommended turn back doses and dose rates are presented in Table 4.1. The International Basic Safety Standards published by the IAEA provides similar turn back dose guidance in Table 4.2. In general, exposure of personnel should be kept “as low as reasonably achievable”.
### Table 4.1 Emergency worker dose limits and turn-back dose guidance from CNSC [2]

<table>
<thead>
<tr>
<th>SITUATION</th>
<th>DOSE LIMIT</th>
<th>RECOMMENDED TURN-BACK DOSE</th>
<th>RECOMMENDED TURN-BACK DOSE RATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-emergency situations</td>
<td>1 mSv</td>
<td>0.5 mSv</td>
<td>1 mSv/h</td>
</tr>
<tr>
<td>Emergency situations</td>
<td>500 mSv†</td>
<td>250 mSv</td>
<td>1 Sv/h</td>
</tr>
<tr>
<td>Life-saving‡</td>
<td>No limit</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
</tbody>
</table>

Note 1: Section 15(1) Emergency Situations, Radiation Protection Regulations (SOR 2000-203).
Note 2: Life-saving must be accomplished by a volunteer who is fully aware of the health risk.

### Table 4.2 Emergency worker turn-back dose guidance from the IAEA [3]

<table>
<thead>
<tr>
<th>TASKS</th>
<th>RECOMMENDED TURN-BACK DOSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life-saving actions, such as:</td>
<td></td>
</tr>
<tr>
<td>• rescue from immediate threats to life</td>
<td></td>
</tr>
<tr>
<td>• provision of first aid for life threatening injuries</td>
<td></td>
</tr>
<tr>
<td>• prevention/mitigation of conditions that could be life threatening</td>
<td></td>
</tr>
<tr>
<td></td>
<td>250 mSv*</td>
</tr>
<tr>
<td>Actions to prevent severe health effects or injuries, such as:</td>
<td></td>
</tr>
<tr>
<td>• evacuation/protection of the public</td>
<td></td>
</tr>
<tr>
<td>• environmental monitoring of populated areas to identify where</td>
<td></td>
</tr>
<tr>
<td>evacuation, sheltering or food restrictions are warranted</td>
<td></td>
</tr>
<tr>
<td>• rescue from potential threats of serious injury</td>
<td></td>
</tr>
<tr>
<td>• immediate treatment of serious injuries</td>
<td></td>
</tr>
<tr>
<td>• urgent decontamination of people</td>
<td></td>
</tr>
<tr>
<td></td>
<td>250 mSv*</td>
</tr>
<tr>
<td>Actions to prevent the development of catastrophic conditions, such as:</td>
<td></td>
</tr>
<tr>
<td>• prevention or mitigation of fires, etc.</td>
<td></td>
</tr>
<tr>
<td>• apprehension of terrorist suspects</td>
<td></td>
</tr>
<tr>
<td></td>
<td>50 mSv*</td>
</tr>
<tr>
<td>Actions to avert a large collective dose, such as:</td>
<td></td>
</tr>
<tr>
<td>• environmental sample collection and analysis for environmental</td>
<td></td>
</tr>
<tr>
<td>monitoring of populated areas</td>
<td></td>
</tr>
<tr>
<td>• localized decontamination if required to protect the public</td>
<td></td>
</tr>
<tr>
<td></td>
<td>50 mSv*</td>
</tr>
</tbody>
</table>

* For emergency worker dose limits, it is assumed that all necessary precautions are taken to prevent internal exposure. The limits and guidance are for the entire duration of the emergency.

Note 1: Pregnant or breastfeeding women should not be permitted to perform these tasks.

Note 2: Persons who undertake emergency actions in which the doses received might exceed 50 mSv should do so voluntarily, should be clearly and comprehensively informed in advance of the associated health risks as well as of available protective measures, and should be, to the extent possible, trained in the actions that they may be planning to take.

Note 3: All reasonable steps should be taken to assess and record the doses received by workers in an emergency. Information on doses received and the associated health risks should be communicated to the workers.
4.1.1 INITIAL ACTIONS OF MEDICAL AND RADIATION SAFETY PERSONNEL

More than one organization will be involved in the response to a radiation emergency. The actions of emergency medical services (EMS) should therefore be coordinated with the joint response effort according to existing planning arrangements.

The first persons on the scene should approach the site with caution and look for evidence of hazardous materials. If a radiation hazard is suspected, personnel, vehicles, and command post should be positioned at a safe distance upwind of the site, authorities and hospitals should be notified, and personnel should wear appropriate PPE.

The general procedure at the start of any radiological response is reconnaissance, rescue, decontamination and zoning [4].

Recce

The reconnaissance phase of the response involves establishing the “cold zone” using a survey meter, and a contamination meter, if available. Procedures for conducting a survey are found in Annex 4.2 Radiation Survey at Incident Site. The cold zone is established where both meters measure typical natural background levels of radiation. Surveyors advance towards the incident until twice background is measured on either meter to identify the “initial contact point” which is inside the “warm zone”. The highest dose rate readings and their location also should be noted. When resources are available, following the rescue, a “decontamination control point” is set up at least 5 meters behind the initial contact point (refer to Figure 4.1).

Figure 4.1 Initial Response and Scene Control [4]
Rescue

The rescue phase of the response involves extraction of casualties from the hazard area and forward treatment triage. Until EMS arrives on the scene, police, fire services, or other first responders who have been adequately trained in techniques of basic first aid can provide emergency first aid for injured persons. EMS personnel may be expected, depending on local training and protocols, to treat casualties in the “warm zone”. They should utilize appropriate PPE for a radiological response unless it has been determined that there is no radioactive contamination present. Sometimes, proximity to the hazard can make it difficult to confirm the presence of contamination if ambient dose rates are high.

The IAEA provides step-by-step procedures for emergency medical responders on-scene (adapted from IAEA EPR-First Responders (2006) [5]):

1. If you are first at the scene, assume the role of the on-scene controller until relieved. If not, get briefing by the incident commander.
2. Wear personal dosimeters and protective clothing, as required.
3. Perform search-and-rescue for injured persons as soon as possible, following established procedures. Perform medical triage and emergency care as soon as possible after rescue. Remove injured persons from hazard area as soon as possible. If necessary, request additional medical help.
4. Perform radiological triage (i.e., sorting of casualties based on measured radiation levels) and isolate contaminated person(s). Remove all contaminated clothing unless medically contraindicated. Isolate (bag and secure) clothing, shoes, and personal belongings. Cover wounds with sterile dressings and prepare injured persons for transport to hospitals.
5. Transport injured persons in a suitable manner to prevent further contamination of the casualty, the ambulance, and attending personnel, taking care not to spread contamination. This is discussed in Section 4.1.2.
6. Inform the receiving hospital of the radioactive materials, if known.
7. Perform personal and equipment contamination check or request assistance from the radiological assessor.

During a response to a radiation emergency, the priority for casualty care should always be focused on saving lives. It is the overriding principle of medical triage that priority of care should depend on the need for care and the chance to benefit from such care. Even if a casualty is contaminated by radioactive materials, life-threatening injuries should always be treated as a priority. Although the presence of contamination may affect the handling of the casualty, it should not have any influence on life-saving treatment. Therefore, conventional methods of medical triage may be employed. Certain mass casualty algorithms, such as the SALT (Sort, Assess, Lifesaving Interventions, Treatment/Transport) Mass-Casualty Triage Algorithm [6], have been proposed for use in large-scale radiation emergencies for trauma triage and critical assessment (refer to Figure 4.2).
Figure 4.2 SALT Mass-casualty triage algorithm (Sort, Assess, Lifesaving Interventions, Treatment/Transport) – Adapted for a very large radiation emergency (adapted from Radiation Emergency Medical Management [6])

Step 1 - Sort: Global Sorting

Step 2 - Assess: Individual Assessment

Lifesaving Interventions:
- Control major hemorrhage
- Open airway (if child consider 2 rescue breaths)
- Chest decompression

Breathing?
- Yes
  - Obey commands or makes purposeful movements?
    - Yes
      - All
        - Minor Injuries only?
          - Yes
            - Minimal
          - No
            - Delayed
    - No
      - Any
        - Expectant

- No
  - Dead
  - Reassess: Consider patient conditions, resources, scene safety

Step 3 - Treatment and/or Transport

Walk
- Assess 3rd

Wave/Purposeful Movement
- Assess 2nd

Still/Obvious Life Threat
- Assess 1st
EMS personnel are unlikely to receive clinically-relevant radiation doses from handling casualties contaminated with radioactive materials [7, 8], unless there are radioactive hot particles embedded in casualties or in their clothing. Removal of a casualty’s clothing removes the majority of the contamination. Clothing should be removed in the following manner:

- Ensure that the responder is wearing appropriate PPE.
- Cut from head to toe and down the sleeves.
- Fold clothing back under itself as it is cut, so as to expose the inside part of the clothing (inside out).
- Roll up and place removed clothing into a container designated for contaminated waste.

**Decontamination**

The standard approach is to set up a decontamination area such that the exit of the decontamination area is where the cold zone begins, the clean/dirty line. The decontamination area will be used for first responders, evacuees and casualties (ambulatory and non-ambulatory), and forensic exhibits. Details on performing on-scene decontamination can be found in Annex 4.3 Radiation Control and Decontamination.

**Zoning**

Establishing the “hot zone” is the last priority in the initial response when casualties are involved. Different situations will warrant different values for establishing the hot zone. Instructions for establishing zones are provided in Annex 4.3 Radiation Control and Decontamination.

### 4.1.2 TRANSPORT OF CASUALTIES

Transport of casualties with life-threatening injuries to emergency rooms should not be delayed. If contaminated casualties are transported, EMS personnel should use PPE and the ambulance must be monitored and, if required, decontaminated after removing the casualties. However, if the casualties’ clothes were removed, and the casualties were decontaminated in the field, the level of cross-contamination would be negligible.

The procedure for transferring contaminated casualties across the control zones from the “warm zone” (contaminated side) to the “cool zone” (clean side) (e.g. Figure 4.1) and transporting the casualties is as follows [9]:

- On the clean side, place an unfolded clean sheet or blanket over the stretcher.
- Move the stretcher next to the clean side of the contamination control line.
- Transfer casualty over the contamination control line onto the covered stretcher.*
- Fold the sheet/blanket over the casualty to “package” it to ensure control of contamination; if the casualty is on a backboard, the sheet/blanket should cover both the casualty and the backboard.
- Do not wrap casualties in plastic as this may lead to hyperthermia.
- If casualties are properly wrapped in the sheet or blanket, it is not necessary to cover the inside of the ambulance, although covering the ambulance floor (with non-plastic material) is recommended.
• EMS personnel who carried the stretcher should remove gloves and place them in marked plastic bags prior to entering the vehicle; EMS personnel caring for casualties should use clean gloves.

* Casualties who are not ambulatory should be placed on a covered stretcher. Casualties with suspected or known spinal injuries should be securely immobilized and only the backboard or scoop device is transferred from one team to the next. Ideally, the backboard should have a sheet over the top surface, provided that the sheet does not create a prolonged or more difficult extraction. Casualties that don’t require immobilization can be transferred via disposable sheet-style devices or on individually used “Number 9” or pole stretchers.

EMS personnel should notify the receiving hospitals of the following while en route:
• casualty’s medical condition
• presence of external and/or internal contamination, if known
• radioisotopes, if known
• level of contamination on patient, if known
• chemical form of contamination, if known
• presence of other hazardous materials
• any other relevant information

Figure 4.3 provides a summary of the on-scene response [9].

4.2 Community Reception Centres (CRC): A US CDC Concept
Some emergency response plans in Canada have included the community reception centre concept, but have not necessarily addressed specific issues related to radiation emergencies. The US Centers for Disease Control and Prevention (CDC) proposed a community reception centre (CRC) concept for radiological population screening following a large-scale radiation emergency [10]. It is introduced here as a model for public health response to a large-scale radiation emergency. In the Canadian context, it is likely that such an operation would require collaboration among emergency preparedness and response organizations for its management.

Following a radiation emergency that results in mass casualties, one or more population screening and decontamination sites, called CRCs, should be set up immediately to screen the population for potential exposure/contamination, to decontaminate individuals who were contaminated by radioactive materials, and to register people for follow-up assessment, medical monitoring and treatment.

A CRC, depending on its availability and proximity to the incident site, can be a high school, a convention centre, a sport facility, or even a park or large parking lot. Ideally, it should be able to support not only the screening and decontamination of the population, but also the provision of information and instructions to a large number of people.
4.2.1 PRACTICAL CONSIDERATIONS

The primary purpose of the CRC is to manage, in a coordinated manner, individuals who may have left or need to leave an identified area, or have been otherwise impacted locally, as a result of the emergency situation, and to identify people who may need immediate assistance – medical attention, decontamination, psychosocial needs, and other special assistance. These services must be provided expeditiously for large numbers of people in a short period of time.

Many people who come to the CRC may not need any of these services, but are nevertheless concerned. Although it is better for them to go to a CRC, rather than to a nearby hospital, which could already be overwhelmed, the CRC also has the potential of becoming overwhelmed. Local communication media should be used to educate the public on how to control the spread of contamination and self-decontaminate at home, if possible, before they go to a CRC. Removal of clothing can eliminate most external contamination on a person and showering can remove most of the rest.
Effective communications are critical for implementing a successful screening and recording process. Having an adequate number of “greeters” is important for controlling a large number of people as it helps them understand what is happening and that their needs will be addressed quickly. In addition, “greeters” need to make sure that the line of people is moving, even very slowly, rather than remaining stagnant.

Families should not be separated, except in life-threatening situations in which no alternatives exist.

4.2.2 MANAGING A CRC

The CRC should have sufficient technical and non-technical personnel to manage the flow of individuals, as well as a plan to manage the volunteers who may show up to assist following an emergency. A well-planned CRC operations manual should be developed in advance. To make the CRC operational, the following are needed:

- CRC Manager: a competent CRC manager is essential to maintain order and efficiency of services.
- CRC Safety Officer: a trained safety officer is able to determine the use of PPE by personnel at each area of the CRC.
- Greeters: an adequate number of greeters are needed for crowd control, quickly answering questions, directing people to screening areas, and identifying those needing special attention.
- Registration service: a well-organized registration area that uses a computer database is important for efficiency. Those who arrive should be registered and issued identification tags. Registration personnel should collect basic contact information for follow-up and exposure and health information related to the incident, and distribute information sheet(s).
- Communication and Inquiry service: effective communication of radiation health risks to people arriving at the CRC is crucial for crowd control. A means of external communication (phone, internet) also needs to be available.
- Psychosocial support: people are afraid of radiation. Psychological services will be needed following a radiation emergency; mental health professionals should be present to provide group or individual counselling, diffuse potentially volatile situations, and monitor staff for emotional strain.
- Medical service: clinicians are needed to provide first aid services, to assess and refer individuals who need medical follow-up, and to administer pharmaceutical countermeasures, if necessary.
- Security service: law enforcement is essential support for a CRC to help control the crowd and keep order.
- Technical personnel for contamination screening: competent technical personnel are needed to conduct hand-held surveys or portal monitoring at various stages of the CRC process, before and after decontamination.
- Technical personnel for decontamination: trained technical personnel are needed to instruct and assist people to conduct self-decontamination using wet wipes or by showering.
• Caring of vulnerable populations: special attention and care need to be provided to children, elderly, pregnant women, immune-compromised individuals, and disabled persons, as well as those who need the assistance of a translator. The needs of vulnerable populations are discussed further in Chapter 7.
• Pet services: people arriving with pets need to have services provided to their pets.
• Transportation service: the CRC needs to provide transportation for people who need to leave the CRC but have no means of transportation – this is important to effectively reduce the total number of people in the CRC.

4.2.3 OVERVIEW OF THE CRC PROCESSES
A CRC has seven stations [11]:
• Initial Sorting Station
• First Aid Station
• Contamination Screening Station
• Wash Station for Decontamination
• Registration Station
• Radiation Dose Assessment Station
• Discharge Station

The CRC is divided into a contamination control zone and a clean zone. Personnel working in the contamination control zone need to wear personal protective equipment (PPE) to limit cross-contamination, while personnel working in the clean zone do not have to wear PPE. The safety officer will work with radiation protection professionals to determine what protective gear workers should wear at each station.

Initial Sorting Station: At the Initial Sorting Station, personnel welcome and direct people to where they should go. All arrivals must visit the Initial Sorting Station, which might be outside of the CRC or at the entrance of the CRC. A competent greeter at the beginning of the line should be able to answer questions correctly and give instructions that are clear and easy to understand and follow.

Initial Sorting personnel will determine whether a person:
• has an urgent medical need
• is externally contaminated with radioactive material
• requires special assistance
• has already showered or been decontaminated before coming to the CRC

Initial Sorting personnel may also assign identification numbers (e.g., wrist bands) to people as they enter the reception centre. These identification numbers can be used for record-keeping purposes and to track people and their belongings through the centre. They also help the management of registration later in the CRC process.
As the sorting line forms, a greeter and a radiation screening specialist should walk the line looking for the individuals who might have special needs or who might slow down the process and need to be moved to the front of the line. Such individuals could include those who:

- are highly contaminated (external contamination)
- might have a medical problem or mobility limitations
- might be pregnant or have small children
- have language or culture barriers
- are confused, disoriented, or panic-stricken

In all cases, it is important not to separate family members. Those needing immediate medical assistance should be taken to the First Aid Station directly.

To identify highly contaminated people, personnel at the Initial Sorting Station should use hand-held contamination detectors (e.g., Geiger-Müller counters, or G-M counters). If a quick survey reveals a person is contaminated beyond established criteria (refer to Section 4.3), the contaminated person should be provided with respiratory protection and moved directly to the Wash Station. Using headphones connected to the detectors will prevent audible alarms and help reduce anxiety among people being screened. Their use also can improve the operator’s ability to recognize elevated radiation levels.

People who have showered or been decontaminated before arriving at the CRC may be eligible to proceed through an express lane to expedite their visit. People who have special needs should be accompanied through the CRC by a staff member, a caregiver, or a volunteer.

Personnel at the Initial Sorting Station should wear PPE, as determined by the radiation safety officer. Adequate protection includes gown, gloves, respiratory protection (minimum N95 respirator), and protective eyewear. This is similar to the recommendations made by the Public Health Agency of Canada on infection control practices in health care [12]. Personnel should try to minimize physical contact with people. Gloves should be changed or checked for contamination frequently.

**First Aid Station:** First aid personnel and contamination screening personnel should work together to assess the casualty’s medical needs and screen the casualty for contamination. If the casualty needs advanced medical care, first aid personnel will request transport of the casualty to a nearby hospital. If the casualty is externally contaminated with radioactive material, first aid personnel can perform a gross decontamination by carefully removing the casualty’s outer layer of clothing before transport. Clothing should be bagged, labelled and stored in designated containers. Life-saving care should take precedence over concerns of cross-contamination and therefore should not be delayed.

First aid personnel should follow routine precautions. When used properly, these precautions are adequate to effectively control cross-contamination. To ensure that first aid personnel are adequately protected, the safety officer needs to determine if additional personal protective equipment is necessary.

The First Aid Station should be close to the Initial Sorting Station, and should be easily accessible to medical transport and other stations.
Contamination Screening Station: At the Contamination Screening Station people get screened more thoroughly for radioactive contamination. Depending on the resources available, a combination of partial-body and full-body contamination screening can be used to identify contaminated people. An express lane can be established for people who have showered or been decontaminated before coming to the reception centre.

Partial-body contamination screening focuses on the hands, feet, face, shoulders, and head. Personnel use hand-held radiation detection instruments to identify contaminated people and then direct them to the Wash Station for decontamination. The partial-body screening is an optional step in the contamination control process – it helps protect staff and other people waiting in line.

Full-body contamination screening is required by each person before entering the clean zone. The full-body screening should be conducted by trained personnel using either a hand-held radiation detector or a portal monitor. If contamination is detected during this screening, the contaminated person will be sent to the Wash Station. Uncontaminated people will proceed directly to Registration. Individuals who have been decontaminated at the Wash Station need to be re-screened to ensure that external contamination has been sufficiently removed. Technical details for contamination screening, including screening procedures and release criteria, are provided in Section 4.3. A sample form (Form 1) to record the results of contamination screening is provided in Annex 4.4 Community Reception Centre Processing Forms.

Personnel working at the Contamination Screening Station should wear personal protective equipment to control cross-contamination. The site safety officer should work with technical personnel to conduct a hazard assessment and issue the appropriate personal protective equipment to staff members in this area.

Wash Station: Contaminated people will go to the Wash Station for decontamination. Depending on the resources available, CRC managers may decide to use existing indoor shower facilities or an outdoor decontamination unit, weather permitting. Wash Station personnel will review contamination screening results to determine the best method of decontamination for each person (see Annex 4.5 Instructions for Decontamination at a Decontamination Centre).

Contaminated clothing should be bagged and labelled with the person’s name and the identification number assigned to them upon entering the reception centre. Contaminated clothing may be required later for further investigations. Bagged clothes should be stored in a secure, remote location at the reception centre. Other personal belongings, such as wallets, keys, jewellery, and glasses, should be decontaminated, bagged together, labelled with the owner’s name and identification number, and returned to the owner when he or she exits the Wash Station.

Wash station personnel work directly with contaminated people and need personal protective equipment to control cross-contamination. This equipment should provide splash protection when working near showers or decontamination units. The site safety officer should work with technical personnel to conduct a hazard assessment and issue the appropriate personal protective equipment to personnel in this area.

Some people may need only minimal decontamination, such as removing an article of clothing or washing their hands. Partial-body cleaning stations help to keep showers or decontamination units open for those who need full-body decontamination.
After a person finishes washing, Contamination Screening personnel perform a full-body screening to ensure the person is clean and can proceed to Registration. People who are still contaminated after a second shower may have internal contamination. These people should proceed to Registration and then be evaluated for internal contamination at the Radiation Dose Assessment Station.

Technical details for decontamination are provided in Section 4.4.

Registration Station: Registration personnel collect demographic and event-specific information from people who have been screened for radioactive contamination and cleared to enter the clean zone. Registration personnel use this information to determine whether someone needs immediate follow-up at the Radiation Dose Assessment Station or possible long-term follow-up. As people reporting to this area are free of external contamination, personnel at this station require no personal protection against radiological contamination.

Information collected at the reception centre needs to be accurate and accessible for follow-up interviews and epidemiological or law enforcement investigations. Forms for managing data need to be clear and easy for personnel to understand. Planners should consider modifying existing tools (if any) to capture information unique to radiological or nuclear incidents. Annex 4.4 Community Reception Centre Processing Forms provides a sample form (Form II) for this purpose.

Radiation Dose Assessment Station: The Radiation Dose Assessment Station requires specialized personnel and equipment to:

- assess people for radiation exposure
- screen people for internal contamination
- assess individual need for medical treatment
- collect blood or urine specimens for laboratory analysis

Plans to provide these services should be scalable and flexible, incorporating additional services as they become available. If possible, the CRC manager should assign a physician and a health physicist to oversee the Radiation Dose Assessment Station. Clinicians and health physicists will need to work together to estimate the casualty’s radiation dose and need for additional medical intervention or follow-up.

Screening people for internal contamination may not be possible in all situations; however, the information gathered from this process can help clinicians prioritize casualties for additional medical care. Health physicists or medical radiation specialists should oversee internal contamination screening and provide guidance to appropriate clinical personnel. Collecting blood or urine specimens for bioassay is another way to assess a casualty’s radiation dose or degree of internal contamination. Trained laboratory personnel should oversee sample collection and ship specimens to radionuclide bioassay laboratories for processing.

Annex 4.4 Community Reception Centre Processing Forms provides a sample form (Form III) that can be used to register the information on the radiation dose assessment. Procedures for the medical management of radiation casualties are presented in Chapter 5.
**Discharge Station:** The Discharge Station provides people with additional information as they exit the CRC. People leaving the CRC may be referred to additional care or discharged to their home, to the home of a friend or family member, or to a public shelter.

### 4.3 Population Screening Principles and Procedures

Population screening is an essential element of response to a radiation emergency. It starts soon after a radiation emergency is reported in order to screen and evaluate populations for potential exposure to radiation or contamination (external or internal) with radioactive materials [10].

#### 4.3.1 OBJECTIVES OF POPULATION SCREENING

The key objectives of population screening are to:

- Identify individuals whose health is in immediate danger and who need immediate medical care (not necessarily radiation-related), or decontamination
- Identify individuals who may need medical treatment for radiation exposure or contamination, further evaluation, or short-term health monitoring
- Recommend and, to the extent possible, facilitate treatments that may reduce the risk of future health consequences of radiation exposure or contamination (e.g., cancer)
- Register potentially affected populations for long-term health monitoring

#### 4.3.2 GUIDING PRINCIPLES AND CONSIDERATIONS

Several key principles specific to a radiation emergency are important in planning radiation emergency population screening [10, 11]:

- The first priority is to save lives by responding to, and treating, the injured first. Treatment of life- or limb-threatening medical conditions should take precedence over decontamination. The PPE described above, including gown, gloves, footwear, respiratory protection, and protective eyewear, is generally adequate to provide protection for first responders, emergency medical personnel, and clinicians.
- First responders and local officials may not be aware initially that a radiation incident has occurred. The initial response may be an “all-hazard” response. However, once the existence of a radioactive source or material is confirmed, they should begin addressing the radiation issues.
- Initial population screening activities should focus on preventing acute radiation health effects. Cross-contamination issues are a secondary concern, especially when the contaminated area or the affected population is large.
- Scalability and flexibility are important parameters of the population screening plan. The initial screening criteria and radiation survey methods used may need to be adjusted to accommodate the scale of the incident and availability of resources.
- Contamination with radioactive material is not immediately life-threatening. Decontamination procedures are straightforward. Removing clothing and washing the body thoroughly with soap and water will eliminate most external contamination.
- Radiological decontamination should be done as soon as possible, but it usually doesn’t require the same immediacy as chemical decontamination. Radiological decontamination
can be done at a CRC or at home (refer to Annex 4.5 Instructions for Decontamination at a Decontamination Centre and Annex 4.6 Instructions for Decontamination at Home). More efficient decontamination may be achieved by sending people home to shower.

- Every effort should be made to keep those who do not need immediate medical attention from overwhelming local hospitals.

### 4.3.3 Screening of Populations for Contamination

The IAEA has published population screening criteria for use in preparedness for and response to a radiation emergency [13]. However, the size of the population to be screened, and the resources available (personnel, equipment, techniques, etc.), may vary significantly from one radiation emergency to another, making it difficult to apply these criteria in all cases. The US CDC, in its guidance document on screening populations following a radiation emergency, suggests that generic screening criteria can be referenced in establishing practical screening criteria for a specific emergency [10].

**Screening Criteria for External Contamination**

Screening for external radioactive contamination is performed to assess the amount of radioactive material on the skin and/or clothing. Radioactive materials can irradiate the body when beta- and gamma-emitting radionuclides are present. They can also be spread, resulting in cross-contamination, or they can be inhaled or ingested by the casualty or others, resulting in internal contamination. Internal contamination is particularly significant in the case of alpha-emitting radionuclides.

The International Atomic Energy Agency (IAEA) published the *Manual for First Responders to a Radiological Emergency* [5]. It provides specific criteria for population screening taking into account all important radioisotopes, all members of the public (including children and pregnant women), inadvertent intake of contamination from skin, external dose from skin contamination, and skin contamination as an indicator of inhalation dose.

Many factors should be considered in deciding on practical screening criteria. The screening criteria must focus on preventing acute health effects and must take into account the scale of the incident and availability of resources. It is suggested that the benchmark criteria provided by IAEA should be discussed with radiation protection specialists, such as health physicists, in public health and emergency management agencies when radiation emergency plans are being developed.

**Screening Criteria for Internal Contamination**

Internal contamination occurs when radioactive materials enter the body through inhalation, ingestion, an open wound, or skin absorption. Some radioactive materials may be excreted in a short period of time, while others can remain in the body for a long time or be deposited in body organs.

Having internal contamination does not necessarily mean the person will experience health effects. If the amount of internal contamination is medically significant, the person may have increased risk of stochastic effects, such as cancer. Severe deterministic effects, such as acute radiation syndrome or death, are extremely rare following internal contamination and would occur only at very high levels of internal contamination as in the case of intentional poisoning.
with polonium-210 in London, UK in 2006 [14].

The International Commission on Radiological Protection (ICRP) recommends that treatment of the general public be undertaken only when intake is high [15]. Except for radioisotopes of iodine, if the intake is less than one annual limit of intake (ALI), corresponding to 20 mSv committed effective dose, treatment is not recommended; if the intake is more than ten ALI, corresponding to 200 mSv committed effective dose, treatment is usually indicated. It should be noted that the concept of ALI was intended for protection of workers, not the public, and assumed a continuous low level exposure. However, it can be used for emergency screening.

**Screening Procedures and Discharge**

An individual arriving at the CRC will be screened at the Initial Sorting Station using a hand-held detector, such as a G-M detector. Individuals who are identified as highly-contaminated at the Initial Sorting Station are sent directly to the Wash Station to perform decontamination. After decontamination at the Wash Station, the individual will be screened for full-body contamination using a portal detector and released to the Clean Zone if no longer contaminated. (Note that portal detectors cannot be used for alpha radiation detection.) If the individual is determined to already be decontaminated at the Initial Sorting Station, the individual can be directed immediately through the express lane for full-body contamination screening at the Contamination Screening Station using a portal detector. All others screened at the Initial Sorting Station will be sent to the Contamination Screening Station for partial-body screening and directed to the Wash Station for decontamination, if required. If decontamination is not required, a full-body screening is performed before the individual is released to the Clean Zone.

Details on how to perform the screening using various techniques are provided in the following Annexes:

- Annex 4.7  Screening a person using a hand-held detector
- Annex 4.8  Screening a person using a portal monitor
- Annex 4.9  Screening of high level radioactive contamination

In a mass-casualty radiation emergency, a large number of people will need to be screened in a short period of time. Therefore, fast screening throughput is desired. The following may be considered as options:

- “group screening” (screening a group of individuals at the same time) at the Initial Sorting Station to identify the highly-contaminated individuals
- using geographical information (where the person was when the incident occurred) to estimate the possible level of contamination (external and internal)
• using nasal swabs or facial swipe samples to estimate internal contamination (only suitable within one hour following exposure)
• revising the original screening criteria, if necessary

Individuals who have gone through screening and decontamination (for external contamination) can proceed to the Clean Zone, for registration and release. When internal contamination is suspected, the decontaminated individual needs to be assessed. Follow-up bioassay sample collection may be planned, or whole-body counting may be performed [16].

4.4 Decontamination Guidance
Radioactive materials may have contaminated the hair, skin, and clothing of individuals in the form of dust, sand, or ash. Although the affected individuals are not in immediate danger from these radioactive materials, people should be asked to go home, or to another designated area, such as the CRC, to decontaminate without unnecessary delay. Removal of outer clothing can reduce the external contamination by up to 90%. Washing exposed skin and hair will remove most of the rest [1, 5, 6, 17]. Cutting the hair is rarely necessary.

In a mass-casualty radiation emergency, uninjured people can be encouraged to go home to self-decontaminate and then return for monitoring at designated locations, such as CRCs, according to a priority schedule. Guidance should be given to this population, either through the media or through handouts at the scene or the CRC, on what to do and how to perform their own decontamination. Annex 4.6 Instructions for Decontamination at Home provides instructions for decontamination at home.

For people who are unable to go home for any reason, field decontamination or decontamination at a CRC should be provided to those identified as contaminated. Decontamination with soap and water or showering is the best method of external decontamination; however, the available washing or showering facilities may not be adequate to accommodate a large number of people.

In the event that water is not immediately available, individuals can take several practical steps by themselves without any washing to greatly reduce the levels of external contamination and the likelihood of internal contamination. Moist towels or disposable wipes can be provided to clean faces and hands. These methods may be preferred initially to outdoor showering, especially when temperatures are low or the number of people is large.

In a mass-casualty radiation emergency, it may not be possible to process a large number of people quickly enough using portable decontamination facilities. Sports arenas and high school gymnasiums may provide suitable showering facilities. If such facilities are far from the incident area, transporting people to another area, or using a nearby hotel, may be considered, especially if outdoor weather conditions are not favourable. Hotels can provide additional showering facilities as well as telephones and televisions to help keep people calm and informed.

At a decontamination centre, such as those mentioned above, or a CRC, the instructions for decontamination may be slightly different than instructions given for decontamination at home. Details are given in Annex 4.5 Instructions for Decontamination at a Decontamination Centre. After decontamination has been completed, people will be sent to the Registration Station.
References


(4) Canadian Nuclear Safety Commission, Incident Control and Decontamination, INFO-0754-4, 2006


(9) Chemical, Biological, Radiological/Nuclear and Explosives Research and Technology Initiative. Medical Emergency Treatment for Exposures to Radiation (METER) course (Module 5), 2008


(16) Kramer, G. H., Capello, K. and Hauck, B. The HML's new field deployable, high-resolution whole body counter. Health Physics 89(5 Supplement): S60-68, 2005

ANNEX 4.1 GENERAL GUIDELINES FOR PERSONNEL PROTECTION IN RADIATION EMERGENCIES

Caution: Female workers who become aware that they may be pregnant should notify the appropriate authority and should be excluded from radiation emergency duties.

- Follow standard safety procedures for your professional area.
- Be visually identifiable and ensure you are in the accountability system when within the inner cordon area.
- Do not touch/hold suspected radioactive items including bomb fragments (shrapnel).
- Limit the activities to life-saving actions if you are located within:
  - 1 metre from suspected dangerous radioactive materials/source and/or
  - 100 metres from a fire or an explosion, unless you are equipped with respiratory protection.
- Minimize time spent within 10 metres of a suspected dangerous radioactive source or radioactive contamination.
- When the presence of radioactive contamination is suspected or confirmed:
  - Use available respiratory protection equipment, or cover mouth and nose with a mask.
  - Keep hands away from mouth and do not smoke, eat or drink. Wash hands regularly.
  - When treating or transporting contaminated persons use normal barrier methods (standard precautions) such as surgical gloves and masks.
  - Get monitored for radioactive contamination after leaving the inner cordon area; change clothing and shower as soon as possible.
  - If survey meters or dosimeters are available, establish and follow the turn-back dose and dose rates.
- Ensure that your name and the activities you performed are recorded for possible follow-up and dose reconstruction.
- Once emergency operations have ended, other activities (source recovery, cleanup, waste disposal, etc.) should follow occupational radiation protection guidance directed by radiological assessor.
ANNEX 4.2 RADIATION SURVEY AT INCIDENT SITE

First responders appropriately trained in the use of radiation detection equipment can perform a radiation survey of the incident site if radiation detection equipment is available. The following instructions will assist the first responder in conducting radiation survey:

- Gather all information from incident command.
- If not already done, establish turn-back radiation doses for first responders (the Canadian Nuclear Safety Commission recommends a 250 mSv dose limit for emergency response, but a much lower turn-back dose limit may be applicable depending on the situation).
- Establish appropriate personal protective equipment (PPE) based on preliminary information from the emergency scene.
- Determine where the radiation levels are twice background, back up at least 5 m and set up decontamination areas for responders and casualties. Ensure that survey meters are reading at, or near, natural background levels. The exit of the decontamination area is the beginning of the “cold zone”.
- Perform reconnaissance of incident site focusing on locating highest radiation hazards. (Dose rates in the µSv/h range present negligible risk, those in the mSv/h range may warrant work plans and dose management, and those in the Sv/h range can present immediate risk to responders and casualties).
- Establish or rule out the presence of contamination by collecting a swipe sample of a surface at the incident site and measuring the sample with a contamination meter (such as a pancake detector) in a low background area (greater than 2 times background is considered to be contaminated).
- Establish “hot zone” boundaries using the following recommendations:
  - 5-10 times background (on a pancake detector measuring the ground for contamination) or 5-10 µSv/h (with a gamma dose-rate meter) for a non-emergency or small-scale incident
  - up to 100 µSv/h for an emergency or large-scale incident.
- Process responders through decontamination, as required.
ANNEX 4.3 RADIATION CONTROL AND DECONTAMINATION

The following instructions will help first responders establish radiation control zones and perform on-site decontamination, if required.

- The entire incident site should be managed using three zones and an outer perimeter. The establishment of these zones should also consider other non-radiological risks (fire, risk of explosion, risk of building collapse).
  - A “hot zone” where radiation exposure is the highest, (gamma dose rate higher than 5-10 µSv/h and possible high levels of contamination).
  - A “warm zone” which is used to transition between the hot and cold zones. There is risk of receiving a radiation dose from the source and, if the source has been compromised, contamination is possible. Outside that zone, the radiological hazard is small and it is unlikely that contamination will be present. Decontamination and safe havens can be established here.
  - A “cold zone” (or security perimeter) which allows the first responders to deploy their teams without concern for radiological risk. It should surround the “warm zone” completely unless there is an atmospheric release; Incident command and the staging and rehabilitation areas may be located here. The exit of the decontamination area is located at the cold zone.
  - Finally, a controlled area (or staging area), where access by the public, media or others is restricted, and whose perimeter should encompass the “cold zone”. Outside this perimeter, access is not controlled. This area is for personnel and equipment not yet deployed in the response. This is where the pool of resources ready for immediate or nearly immediate employment is kept.

- The choice of personal protective equipment (PPE) should be commensurate with the risk involved. The minimum level of PPE for a radiological response involving airborne contamination would be a Tyvek coverall with dual layer of latex/nitrile gloves (first pair of gloves taped to Tyvek), over-boots, and respiratory protection (minimum N-95 mask and protective eyewear). A personal alarming dosimeter should also be worn.

- The decontamination area should allow for three corridors:
  - responder decontamination
  - casualty decontamination (which can be separated further into ambulatory and non-ambulatory)
  - forensic exhibit decontamination
The visual and physical boundary between the clean and dirty areas can be accomplished with a simple bench and is the most important aspect of the decontamination area.

- Factors to consider when surveying responders for contamination and performing decontamination:
  - Contamination meter within 1 cm of a surface reading twice background is considered dirty.
  - Once contamination is detected, stop and remove the responder for decontamination.
  - Do not assume PPE is contaminated without checking; radioactive waste disposal is expensive.
  - Avoid use of water for decontamination (manageable incidents).
  - Periodically remove contaminated garbage away from decontamination area.
  - Periodically survey the ‘surveyor’.
  - Do not cross over clean/dirty line unless free of contamination.

- Factors to consider when surveying casualties for contamination and performing decontamination:
  - **GOAL:** Life saving. Life saving takes precedence over decontamination; wrap and send casualty to hospital if required.
  - Twice background is considered dirty.
  - If contaminated, clean face, provide respiratory protection (e.g., surgical mask), then remove clothing.
  - Place clothing/personal effects in clean/dirty bags and identify.
  - Clean open wounds with sterile water. Contain run-off if possible.
  - Clean contaminated skin with wet wipes.
  - Apparent persistent contamination on the body over chest or gut may be an indication of internal contamination; medical attention should be sought.
  - Decontamination of ambulatory casualties is conducted in the same manner as first responder decontamination, with special considerations given to privacy.
  - Bring stretchers to non-ambulatory line. Decontaminate stretcher before re-use or cover it with a sheet.
  - Check front and back of the casualty for contamination (360° verification).
  - If contamination on skin persists, consider wrapping to contain it, and identify the hazard (e.g., by indicating the meter reading in cpm).
  - Decontaminate if injuries are not serious and minimize cross-contamination before transport to a medical facility.
• For a large scale incident with many casualties, the above instructions may need to be modified to accommodate a larger number of casualties. Consider the following alternative recommendations for decontamination:
  • 10 times background may be considered dirty; allow a 10 to 15 second check per person.
  • If contaminated, remove clothing.
  • Consider showers; do not plan to contain run-off water.
  • For very large numbers when decontamination may be unmanageable, guidance should include:
    • Do not report to hospital if uninjured.
    • Avoid eating or drinking, return home, remove and bag clothing before entering dwelling.
    • Shower immediately with warm water and soap, shampoo hair but do not use conditioner.

• Radiological waste generated at the decontamination area needs to be managed:
  • Trained first responders for CBRN (chemical, biological, radiological and nuclear) are responsible for removal, containment, and segregation (distance) of radiological waste.
  • Temporary storage of radioactive material must be secure.
  • Final disposal may be required at a licensed facility (for example, Canadian Nuclear Laboratories) and should be in solid form.
ANNEX 4.4 COMMUNITY RECEPTION CENTRES PROCESSING FORMS

Form I: Contamination Assessment Form

Name ___________________________________       ID ____________________________________
Age ________   M or F _________  If female, pregnant? ______________________________
Recent nuclear medicine procedure? ___________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________

Instrument Used _________________________________________________________
Background “count per minute” (CPM) ________________________________
Detector efficiency _______________________________________________________
Survey Before Decontamination:
Date ________________    Time ________________   By ________________
Survey After Decontamination:
Date ________________    Time ________________   By ________________

Circle location of contamination, then number consecutively. List details below. Be sure to survey nose, mouth, hands and feet. Readings should be in “counts per minute” (CPM)

<table>
<thead>
<tr>
<th>Site</th>
<th>Description</th>
<th>CPM (before)</th>
<th>CPM (after)</th>
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Indication of Internal Contamination?
No _________     Yes __________  If “yes”, send to Radiation Dose Assessment Station.
FORM II: DEMOGRAPHIC AND EVENT-SPECIFIC EXPOSURE INFORMATION

Name _________________________________________   ID _____________________________

Height ____________ cm
Weight ____________ kg

Home Address ___________________
City _____________________________
Province/Territory _________________
Postal Code ______________________
Phone ___________________________
Email ____________________________

Names of Family Members here with you  ____________________________________________
                                                                                         
                                                                                         
                                                                                         
1) Where were you at the time of the incident? How long stayed there?

2) Since the incident, have you experienced any of the following?
☐ Vomiting
☐ Diarrhea
☐ Severe headache
☐ Fever
☐ Confusion
☐ Loss of Consciousness

3) If “yes” in any of the symptoms indicated in 2), send to Radiation Dose Assessment Station.
FORM III: PRELIMINARY RADIATION DOSE ASSESSMENT

Name ___________________________   ID ___________________________

External Exposure [based on information in Form II]

Internal Contamination [based on Information in Form I and the following]
Type of Detector: ________________________________
Detector efficiency: ________________________________
Background (CPM): ________________________________

Surveyed Locations and Results (CPM)
- Whole Body
- Lung
- Thyroid
- Wound
- Other

Intake Estimate and Description of Method ______________ (Bq)

Dose Estimate and Description of Method ____________ (mSv)

Patient Referred to ________________________ (name of medical facility) for countermeasures

Physician Signature ___________________________     Date ___________________________
ANNEX 4.5 INSTRUCTIONS FOR DECONTAMINATION AT A DECONTAMINATION CENTRE

- Go to the designated area.
- Do not touch your face or put anything into your mouth.
- Enter the screening area and stand fully clothed while you are being screened.
- You will be directed to leave if little or no contamination is present. Otherwise, you will be directed to a wash area.
- You may be grouped with other people. Prepare to remove your clothes behind a privacy curtain.
- Be careful of any clothing that has to be pulled over your head. Either ask for help to cut it off or prevent the outer layer from touching your nose and mouth. You may hold your breath while carefully pulling the article over your head, or you may be provided with a mask.
- Put all of your clothing (you can wear your undergarments as they are less likely to be contaminated) in one plastic bag and your valuables in another plastic bag. Seal them.
- You will be allowed to keep your valuables. If there is any chance your valuables may be contaminated, remove them from the bag carefully and wash them when you get home. Wash your hands thoroughly after that.
- At the wash station, if a shower is provided, shower thoroughly using liquid soap and water; if a shower is not provided, wash your hair first, then your skin (“sponge bath”), with liquid soap and water. Dry your face, hair and body.
- Cover yourself with clean clothes or a towel for a full body contamination screening, if available.
- You may be sent to the Registration Station, if clean. Otherwise, you may be asked to go for further decontamination.

References for Annex 4.5


ANNEX 4.6 INSTRUCTIONS FOR DECONTAMINATION AT HOME

- Leave the immediate area quickly.
- Avoid unnecessary hand-to-face contact to minimize potential spread of contamination.
- Go home or to a place you feel safe, using your own or public transportation.
- Act as if you were arriving home in clothes covered with dust or mud and did not want to track it into your home.
- Remove your clothes in an outside area, such as a garage or a doorway, if possible. When removing clothing, be careful when pulling clothing over the head. Try to either cut off the clothing or prevent the outer layer from touching your nose and mouth. Or, you may hold your breath while carefully pulling the article over your head.
- If possible, place the clothing in a plastic bag, and leave it in an out-of-the-way area, such as a garage, outside location, the corner of a room, or a closet. Keep people away from it. You may be asked to bring this bag for a follow-up check at a later time.
- Shower and wash your body and hair using a lot of warm water and soap. Do not use abrasive cleaners or scrub too hard. Do not use conditioner on your hair.
- Gently blow your nose and wash out your eyes, ears, and mouth.
- Put on clean clothes.
- Wash valuables and identification cards that may have been contaminated and wash your hands again.
- If you cannot shower or remove all of your clothes, remove your outer clothing and wash exposed parts of your body, such as your head, neck, hair, hands, and arms.

References for Annex 4.6


ANNEX 4.7 SCREENING A PERSON USING A HAND-HELD DETECTOR

- Equipment check:
  - Inspect the equipment for obvious damage.
  - Verify the equipment for functionality.
  - Inspect the cable connecting the detector and the survey meter.

- Battery check:
  - Turn the equipment on.
  - Check batteries, using the “range” switch or “bat” button, depending on the type of instrument. The meter needle should move to “bat” indicating the batteries are good. Some equipment performs automatic battery check on power on.

- Source check:
  - Place the detector close to a check source.
  - Select appropriate range.
  - Verify meter response.

- Background reading:
  - A background reading should be typically 30 to 200 counts per minute.

- Survey:
  - Hold the detector probe about 1 cm from the surface and move the detector probe slowly (about 2.5 cm per second).
  - Avoid touching the probe to the surface.
  - Pay particular attention to head, face, hands, shoulders, and feet.
  - Locate the spots that give the highest rates (most clicks), and record the reading. In general, areas with more than twice of background reading are considered contaminated.

Reference for Annex 4.7
Annex 4.8 Screening a Person Using a Portal Monitor

• Setting up the portal monitor:
  • Check cable connections and power source.
  • Turn on monitor and allow it to perform its start-up check.
  • Conduct an operational check using a check source.

• Operating the portal monitor:
  • When ready, signal line control to send a person toward the portal monitor.
  • Instruct the person to walk directly to the centre of the portal and pause there for 1-2 seconds (ensure the occupancy sensor has detected the person); if time permits, ask the person to turn 90 degrees and get checked a second time.
  • If an alarm sounds or a red light comes on, ask the person to turn around and have a member of the personnel escort the person to the Wash Station.
  • If the green light comes on, the person is not contaminated and can proceed to the Registration Station.
  • When path is clear, signal line control to send the next person.

Note: A portal monitor is highly sensitive to gamma radiation. It should be positioned at a sufficiently shielded area (corners, doors, pillars, etc.) in the CRC where it will not pick up gamma radiation from surroundings.

Reference for Annex 4.8
ANNEX 4.9 SCREENING OF HIGH LEVEL RADIOACTIVE CONTAMINATION

Screening for highly contaminated people is an important contamination control measure in the CRC. Personnel at the Initial Sorting Station should walk the line with a hand-held meter (the count-rate mode is preferred as the response in dose-rate mode is slower) to perform high contamination screening. This screening should be rapid and non-intrusive, and it should not delay entry into the CRC. Highly contaminated people should step out of the line and be escorted directly to the Wash Station, avoiding physical contact with other people.

- Set the dose meter to the established screening criteria (count rate or dose rate below this level will not set off the alarm).
- If the meter has an audible alarm, use headphones or an earpiece to eliminate the audible alarm, which will help avoid anxiety among people in line.
- Walk slowly along the line, engaging new arrivals as they approach or enter the CRC.
- If the meter alarms, ask the person being screened to walk out of the line.
- Ask a member of the personnel to walk the contaminated person directly to the Wash Station.

Reference for Annex 4.9
CHAPTER 5 – EMERGENCY DEPARTMENT MEDICAL RESPONSE

5.1 General Issues
Medical management of radiation casualties involves a wide spectrum of activities beginning with planning and training early on, providing the necessary medical response in an emergency and ending with psychological support and epidemiologic follow-up long after a radiation emergency is over. This chapter focuses on Emergency Department (ED) response during a radiation emergency. The main differences between a conventional mass-casualty emergency and a radiation emergency are the possibility of encountering acute radiation exposure and radioactive contamination. Receiving medical personnel will need to know how to recognize these conditions and manage patients in a potentially contaminated environment while protecting themselves and preventing the spread of contamination. The potential reluctance of receiving medical personnel to manage contaminated patients may need to be addressed. Efforts are generally made to decontaminate patients prior to arrival at, or entry into, medical treatment facilities. However, urgent medical care should take priority over decontamination. Therefore, “designated” areas for handling contaminated casualties in the ED may be needed. If there is no radioactive contamination involved, routine procedures for patient flow and handling may be followed.

The possibility of exposure to an “invisible” hazard that can cause irreversible health effects can elicit fear in an affected population. Therefore, it should be expected that a radiation emergency has the potential to quickly overwhelm the ED with concerned citizens who do not need medical care but may require psychological support and information about the emergency. Misinformation about the effects of radiation exposure is one of the greatest challenges in managing a radiation emergency.

5.1.1 EMERGENCY DEPARTMENT PLAN FOR RADIATION EMERGENCIES
The Emergency Department Disaster Plan should contain information that is applicable to a wide range of disasters. Disaster plans are frequently organized with sections that provide information specific to the type of incident, such as a radiation emergency. The radiation emergency plan ideally should inform medical personnel of actions that will be necessary for assessing the hazard, setting up decontamination sites and radiation emergency treatment areas, protecting personnel (e.g., the location and correct use of personal protective equipment, if appropriate), identifying radiation-specific resources, and locating radiation detection equipment and supply carts. It should also discuss the surge capability that will be required given the demand on system resources and the inability to discharge existing patients. The details contained in an ED radiation emergency plan will vary from ED to ED depending on the planning basis – what is considered a realistic threat in one location may be unrealistic in another, and the cost of maintaining a radiation emergency response capability may not be justified.

It is recognized that not all EDs will have specific radiation emergency plans, or the equipment and personnel trained to check for contamination. Nevertheless, there are radiation-specific resources and knowledgeable personnel in other hospital departments (e.g., Nuclear Medicine) or in external organizations (e.g., municipal HAZMAT) that may provide assistance. Health Canada offers a training package, Medical Emergency Treatment for Exposures to Radiation (METER), which has been delivered to medical receivers in several Canadian cities.
5.1.2 PSYCHOLOGICAL SUPPORT FOR PERSONNEL
Psychological trauma is not limited to the members of the public. The psychological stress encountered by first responders, medical receivers and their families during an emergency can be greater than the stress felt by the community. Psychological support for emergency responders should be based on continuing education. Much of the anxiety experienced by medical responders is related to their lack of knowledge about radiation and its health effects; therefore, education is needed before, during, and after an accident to reduce negative psychological effects.

5.2 Emergency Department Preparation for Patients Contaminated with Radioactive Material
The first step taken by the hospital upon learning about a radiation emergency with more than a few isolated casualties should be to control the entry into the ED and hospital in order to avoid the possible spread of contamination. Many potentially contaminated individuals are likely to bypass the Emergency Medical Services’ (EMS) response and present themselves by foot, taxi or private car. All self-referrals at the usual entrances should be quickly screened (and possibly surveyed for contamination). If there is no radiation contamination monitoring capability (e.g., a Geiger-Müller counter) immediately available, and there is a possibility that there are casualties of a radiation emergency, they should be considered contaminated and directed to the entrance designated for reception and triage of contaminated casualties. (refer to Annex 5.1 Setting Up the Emergency Room for Receiving Casualties Potentially Contaminated with Radionuclides)

The next step should be to set up the ED to provide three functional areas unique to radiation emergencies that are required for managing contaminated casualties (refer to Figure 5.1):

- Reception and Triage
- Contaminated Treatment Area (for patients who are contaminated)
- Decontamination Area

These functional areas are described in the next section.

During ED preparation, it may be useful to remind medical personnel of the hazards and the measures that will be used to help limit their exposure to radiation, including detection equipment, personal protective equipment, and radiation dosimeters. If patients have been exposed to radiation, but are not contaminated, they do not pose any risk to health-care workers. For example, if a patient was exposed to radiation from a sealed source of cesium-137 that had been in his pocket, there would be no radioactive contamination on his skin or in his body, so this patient would not be “radioactive”, nor would he contaminate personnel treating him.
If there is potential for radioactive contamination, hospital personnel will need to wear appropriate personal protective equipment (PPE). When handling or treating contaminated patients, personnel may also become contaminated because contamination spreads easily via physical contact and can become airborne with movement. The goal of wearing PPE is to prevent external and internal contamination while managing the patient. When personnel have removed their contaminated PPE and have been surveyed to ensure no contamination remains, they have avoided risk of contamination to themselves and of cross-contamination of other personnel (if there is no survey capability, contaminated PPE will be carefully removed and bagged to limit the spread of contamination).
The following supplies will provide adequate PPE in the hospital setting:

- scrub suit and gown (cloth or paper)
- water-proof shoe covers
- cap, protective eyewear (or face shield), and mask (a surgical mask is sufficient unless there is contaminated dust - then an N-95 mask provides better protection)
- inner pair of surgical gloves (sleeves of the gown should be taped to the outside of the gloves)
- outer pair of surgical gloves (should not be taped, so that they can be changed often; consider using a different colour from inner gloves)
- water resistant outer gown, such as Tyvek® suit, if using liquids for decontamination

Personnel should also be supplied with personal dosimeters, if available. Dosimeters for direct reading should be placed on the outside of the outer gown; if not for direct reading, dosimeters should be placed on the inside of the outer gown. Since it can get very hot while wearing a water-resistant gown, it is advisable to wear light garments underneath it. The possibility of heat stress should be considered when assigning personnel and determining personnel work-rest cycles.

Unlike chemical and biological contamination, which requires specialized equipment or lengthy detection time, radioactive contamination is easy to detect using a radiation contamination meter. The only exception to this rule would be the event of contamination with one of the rare radioactive materials that emit only $\alpha$ particles. Alpha radiation can be difficult to detect and specifically designed detection instruments may be necessary. Although radioactive materials that emit only alpha radiation are typically only hazardous in the context of internal contamination, users should be aware of the limitations of their meters. A well publicized example was the case of Alexander Litvinenko who was poisoned in London, UK in 2006 with polonium-210, a radioactive material that emits only alpha radiation. The polonium-210 was not initially detected when he was surveyed with a Geiger-Müller counter [1]. Nevertheless, doses to personnel who cared for him over the three-week period before he died were very low (i.e., under 6 mSv [2], approximately the amount of radiation received from an abdominal CT scan).

5.2.1 RECEPTION AND TRIAGE AREA

The general principles for triage in radiation emergencies are: (i) medically-unstable patients who are contaminated should receive required emergency treatment in a specifically designated area (the Contaminated Treatment Area), then be decontaminated; and (ii) medically-stable patients who are contaminated should be decontaminated first, then receive treatment. The patient flow in the triage area is shown in Figure 5.2.

Therefore, the three key triage issues are the following:

- Is patient stable or unstable?
- Is there any measurable surface contamination?
- Is there any early evidence of significant external radiation exposure?
The Reception Team will be staffed with non-clinical personnel to meet arriving ambulatory casualties and keep them in one place until they can be surveyed for contamination and medically triaged (if there is no survey capability, assume they are contaminated). Triage is the priority, but the speed with which this happens will depend on the number of casualties and the number of resources. If casualties must wait to be triaged, they can be surveyed for contamination at this time, if there are sufficient resources. The use of portal monitors to identify contaminated casualties should be considered, but is not without its challenges [3]. The Reception Team could also be tasked with identifying casualties who appear unstable and presenting them to the Triage Team. When faced with multiple potentially contaminated patients at one time, the Triage Team can use “bullhorn triage” (i.e., global sorting of patients using voice commands) to separate those who are unstable from those who are stable. Subsequent treatment and decontamination should start with those who are unstable, followed by stable injured, uninjured (i.e., no surgical or medical issues), and psychological casualties.

The Triage Team should consist of at least a triage nurse and/or doctor, a registration clerk (to keep track of triaged casualties), and a surveyor to operate the radiation contamination meter. This guide assumes that the surveyor is the site Radiation Safety Officer. Although hospitals without Nuclear Medicine or Radiation Oncology departments may not have Radiation Safety Officers, surveying can be done by anyone trained in using a radiation contamination meter. The roles and responsibilities of all personnel should be described in the Emergency Department disaster plan.

Is the patient stable or unstable?
The triage team will first determine if the patient is medically stable. This is done using conventional methods to rule out an unstable airway, problems with breathing or circulation, significant hypotension, possible cardiac chest pain, etc. Unstable patients can be moved through triage within several minutes. Patients who are unstable may be moved into a Contaminated Treatment Area by default when they cannot be surveyed in a timely fashion at the Triage Area; it should be assumed that they are contaminated until shown otherwise.

Is there any measurable surface contamination?
It is important in radiological triage to determine whether contamination is present, as this will determine the patient flow, whether the patient needs to be decontaminated, and whether special procedures are required to manage the patient. This assessment should be made by taking a quick history and surveying the patient for contamination using a radiation contamination meter (if this capability exists). Individuals who do not require urgent medical treatment but are contaminated can be held for subsequent decontamination when more resources become available. In the meantime, these individuals could be given cleansing tissues to wash their face and surgical masks to prevent inhalation of further contamination. (For details on transferring patients into the Contaminated Area refer to Annex 5.2 Procedures for Minimizing the Spread of Contamination in the Emergency Room.)
Figure 5.2 Patient flow in the ER during a radiation emergency

RECEPTION AND TRIAGE AREA
- Is the patient unstable?
  No  Yes
- Is there any measurable surface contamination? If no survey meter, assume contaminated
  No  Yes
- Is there any early evidence of significant radiation exposure?
  Yes  No

CONTAMINATED TREATMENT AREA
- Stabilize
- Remove clothing
- Survey
- Collect samples (swabs)
- Decontaminate
- Re-survey
- Transfer when cleared

DECONTAMINATION AREA
- Remove clothing
- Collect samples (swabs)
- Decontaminate wounds, orifices, skin
- Re-Survey
- Transfer when cleared

CLEAN TREATMENT AREA
- Final registration and triage
- Assessment of internal contamination, if necessary
- Assessment of acute radiation syndrome, if necessary
- Psychological treatment area
**Is there any early evidence of significant radiation exposure?**

The triage team should take a short history to determine if the patient has any symptoms that could be prodromal manifestations of the acute radiation syndrome, such as nausea and vomiting. However, this will not be possible if casualties are arriving rapidly in a mass casualty emergency, or there is a concern about contaminating a casualty who is not contaminated. Symptoms of acute radiation syndrome can signal the need for further follow-up to assess the patient’s level of exposure to radiation. Tools are available to help record these symptoms during triage (refer to Annex 5.3 Radiation Casualty Assessment Tool). It should be noted that in a patient with significant radiation exposure, the history, physical examination and simple laboratory tests, such as lymphocyte counts, can be critical determinants of treatment and disposition.

After the key triage questions have been answered, the team can assign a Canadian Emergency Department Triage and Acuity Scale (CTAS) score and go on to the next patient. The CTAS scale is a 5-level triage scale for classifying the acuity of a patient’s condition, primarily on the basis of the patient’s presenting complaint. The level will determine the urgency with which this patient requires care relative to other patients and the frequency of reassessment required while waiting to be seen. CTAS 1 patients are the most urgent and require continuous monitoring or resuscitation. All CTAS 1 and most CTAS 2 patients will be taken directly to the Contamination Treatment Area, while others are sent to the Decontamination Area, Clean Treatment Area, or a psychological treatment area, as appropriate. Any patients proceeding to a clean area should be cleared (i.e., their hands and feet) by a surveyor with a radiation contamination meter before crossing the **clean/dirty line** (control line) into the rest of the ED, since they may have become contaminated while crossing through Triage. (If a survey capability does not exist, all potentially contaminated patients should be decontaminated prior to entry into a clean area.)

**5.2.2 CONTAMINATED TREATMENT AREA**

The second functional area in the ED response to a radiation emergency is the ‘Contaminated Treatment Area’. This is the area where patients who are contaminated, but too unstable to be decontaminated prior to treatment, are brought for lifesaving treatment. This area functions like any other high-acuity (as measured by CTAS score) treatment area. The main differences are:

- Everyone is in appropriate PPE (refer to Annex 5.1 Setting Up the Emergency Room for Receiving Casualties Potentially Contaminated with Radionuclides).
- Movement in and out of the area is strictly controlled to prevent the rest of the ED from becoming contaminated.
- In addition to the medical team, there is someone qualified to use a radiation contamination meter surveying the patient for contamination (may not be available in all EDs).
- In addition to receiving urgent medical treatment, the patient will be decontaminated in situ.
It should be reiterated that the Contaminated Treatment Area is an area in the hospital or ED that is cordoned off from the clean areas. All equipment that is used in this area should be considered contaminated until it can be "cleared" using a radiation contamination meter. For details on how to set up the Contaminated Treatment Area, refer to Annex 5.1 Setting Up the Emergency Room for Receiving Casualties Potentially Contaminated with Radionuclides.

The ‘Contaminated Treatment Team’ consists of one or more nurses, a physician, and a person trained to operate a radiation contamination meter (may not be available in all EDs). All should be wearing appropriate PPE. If specialized PPE and survey equipment is not available, following good radiation protection practice and taking additional precautions, including use of gloves, gown, respiratory protection and protective eyewear, will minimize risk to personnel. The highest dose received by medical personnel while treating hundreds of highly contaminated workers during the Chernobyl accident was about 10 mSv [4], approximately the amount of radiation received from an abdominal CT scan with contrast. This is about four times above the annual dose received from background radiation in Canada, and one fifth of the annual dose limit for nuclear energy workers.

The priorities in the ‘Contaminated Treatment Area’, in descending order, are:

- Assess and resuscitate the patient as per existing protocols.
- Treat life- and limb-threatening injuries and medical conditions requiring urgent treatment.
- Remove contaminated clothing and contaminated bed sheet as promptly as possible (a brief radiological survey has already been performed to determine if patient is contaminated; survey patient’s back when patient is log-rolled to remove sheet).
- Remove contaminated material from immediate area.
- Complete physical examination and identify other injuries.
- Complete radiological survey (if survey capability available), then take swabs of mouth, nose, and wounds.
- Record activity measurements (if available).
- Decontaminate wounds and orifices first, then decontaminate intact skin.
- Re-survey the patient and repeat the decontamination process if necessary (if survey capability available).
- Transfer the patient out of the Contaminated Treatment Area.
- Personnel may remove PPE and exit after being surveyed.
- Clean the Contaminated Treatment Area.

Up to 90% of surface contamination can be found on the patient’s clothing [5]. Therefore, removing clothing as soon as practicable will reduce the exposure of the patient and those nearby, and minimize the spread of contamination (refer to Annex 5.2 Procedures for Minimizing the Spread of Contamination in the Emergency Room).
Where a survey capability is available, the patient should be surveyed for contamination. The results of the survey will guide decontamination efforts and will reassure personnel if contamination is absent. There is also the chance that the surveyor may discover the presence of highly radioactive fragments on the patient’s body or in a wound; these fragments should be removed with long-handled forceps and put into a lead container, if available, or stored in another location well away from people.

The surveyor should use a systematic approach when surveying the patient’s body and record the activity measurements on a chart. Prior to decontamination, the surveyor should also measure activity of swabs taken from the mouth, nose, and wounds (or wound dressings). This information is useful to assess whether the patient has been internally contaminated.

### 5.2.3 DECONTAMINATION AREA

The Decontamination Area is intended for stable patients who will require medical treatment but can be decontaminated first. They may be ambulatory or on stretchers. These patients have been identified as contaminated while they were in the Reception and Triage Area. The ED Decontamination Area is not intended for people who have no medical complaints or injuries; ideally, these people should be decontaminated elsewhere. However, it is expected that the ED will receive people in this category until other decontamination facilities have been set up.

The goals of decontamination are to reduce the patient’s overall exposure to radiation, as well as the risk of beta burns to the skin (shallow burns resulting from beta particles) and internal contamination. Decontamination also protects personnel, and others, by reducing the spread of contamination throughout the ED and other areas in the hospital. The order of priority when decontaminating patients is wounds, orifices, then intact skin and hair (refer to Annex 5.4 Patient Decontamination).

The setup of the decontamination site should include rational patient flow, a supply of warm water, and shower curtains for privacy. Personnel for ambulatory decontamination will be needed to manage the pre-shower and post-shower areas, and survey each patient who has finished showering to determine whether decontamination efforts have been successful. Supplies needed for the decontamination area include: bags with labels for contaminated clothing, waterproof dressings, soap, shampoo (no conditioner), towels, clean clothes (i.e., scrubs, gowns, water resistant suits, slippers, etc.), spare batteries compatible with the radiation contamination meter being used, and garbage bags.

The site for the decontamination facility will depend, in part, on the expected number of patients. For a few patients (i.e., 1-2), a shower room in or near the ambulance bay may be sufficient; for a moderate number of patients (i.e., 3-15), a specialized decontamination shower would make the process more efficient; finally, for a large scale event (i.e., >15-20), such as the terrorist use of a radioactivity dispersal device, a specialized decontamination tent designed for one-way patient flow may be required. One-way patient flow is most efficient but must be able to accommodate stretchers as well as ambulatory patients. Ambulatory patients should ideally have two “lanes”, one for males and one for females.
The general procedure for decontamination of ambulatory patients begins with having them remove their clothing and valuables and placing them in a labeled bag. Consideration could be given towards allowing patients to keep their undergarments as it is unlikely that they would be contaminated. If there are any open wounds, these should be covered with a bio-occlusive dressing that will protect the wound from contaminated run-off in the shower. Soap and shampoo (without conditioner) are used in the shower. After showering, patients should dry off with a towel, then present themselves to be re-surveyed. If contamination levels remain greater than two times background, the shower should be repeated; if it is less than two times background, the patient may dress in clean clothes and leave the decontamination area (background readings should be taken first). Open wounds can be decontaminated separately. Decontamination is usually considered complete when the activity measures less than twice the background level, or no further reduction in activity is achievable. However, in mass-casualty situations, this goal may not be practicable.

5.2.4 ENTRY INTO THE CLEAN TREATMENT AREA OF THE EMERGENCY ROOM
Once decontaminated, ambulatory patients are led into the ED where they can be fully triaged and registered. Non-ambulatory patients that have been decontaminated are brought on their gurney or stretcher to the edge of the clean/dirty line. In both cases, ambulatory and non-ambulatory, the transfer from the site of decontamination to the clean ED must be done under the direct supervision of a surveyor with a radiation contamination meter. After this has been completed, personnel may remove PPE at the clean/dirty line (control line) before exiting the dirty area. For details on transferring patients out of the Contamination Area and removing PPE, refer to Annex 5.2 Procedures for Minimizing the Spread of Contamination in the Emergency Room.

5.3 Medical Management of Radiation Emergencies
5.3.1 LIFE-THREATENING MEDICAL CONDITIONS AND INJURIES
Medical emergencies take priority over the contamination, as shown in Figure 5.2. Contaminated casualties who are unstable should be stabilized immediately by personnel who are dressed in appropriate PPE with a surveyor present. This activity should take place inside the clean/dirty lines (control lines) of the Contaminated Treatment Area. After the medical emergency has been dealt with, the patient can be decontaminated following the procedures found in Annex 5.4 Patient Decontamination, then treated for internal contamination, if necessary, and assessed further for level of radiation exposure.

5.3.2 RADIATION EXPOSURE WITHOUT CONTAMINATION
Patients who have been externally exposed to radiation but are not contaminated do not need to be handled any differently from other patients. These patients do not pose a radiation hazard to attending personnel. The management of these patients is discussed in Section 5.5.

5.3.3 EXTERNAL CONTAMINATION
If external contamination is the only presenting problem, decontamination is the only treatment required. In such cases, decontamination should take place in a location away from the ED.
Radioactive contamination on the body may be harmful depending on the specific contaminant, the quantity, and the duration of time it remains on the skin. The presence of radioactive contamination on the skin may lead to internal contamination if the contaminant is inhaled, ingested, or absorbed through a wound or intact skin. It may also spread and contaminate others, a process known as cross-contamination. Therefore, it is important to remove contamination as soon as practicable. However, external contamination is not a medical emergency, and should not delay surgery or other necessary treatments. If urgent treatment is needed, areas of contamination may be covered with temporary dressing to prevent the spread of contamination.

After life-threatening injuries have been addressed, an assessment of external contamination should be made. The presence of contamination on a patient's hands or around the patient's nose and mouth indicates the possibility of internal contamination. In this case, the patient's nose and mouth, as well as any wounds, should be swabbed prior to decontamination. Activity measurements of swabs and wound dressings should be recorded, as this information is used to assess whether a patient has been internally contaminated.

5.3.4 INTERNAL CONTAMINATION

Radioactive contamination inside the body will irradiate the patient for a variable period of time, dependent upon the half-life of the radionuclide and the elimination rate from the body. Early recognition of internal contamination, therefore, provides the greatest opportunity to remove the contaminant before it can be taken up by the target tissues and organs and reduce the risk of long-term health effects. Internal contamination alone has only rarely resulted in serious acute injury. Two notable exceptions are the cases of intentional poisoning with highly radiotoxic polonium-210 in London, UK [6], and accidental ingestion of a massive amount of cesium-137 from a dismantled radiotherapy source in Goiânia, Brazil [7]. However, internal contamination may increase the risk of cancer, as observed in occupationally exposed radium dial painters, patients who received the contrast media, Thorotrast® (containing thorium-232), and children exposed to iodine-131 following the Chernobyl accident [8]. Since internal contamination does not usually present with radiation-related symptoms soon after exposure (although early symptoms may arise because of other chemical contaminants), the presence of contamination must be confirmed using instruments and tests.

The goal of treatment is to reduce the radiation dose to the patient by decreasing absorption and deposition into critical organs, and increasing excretion of radionuclides. Early treatment can reduce the dose a few fold, but that may be enough to make a significant impact on the health consequences. Sometimes, the goal of treatment is to reduce the chemical toxicity caused by a contaminant, rather than the radiotoxicity, as is the case with natural uranium (massive contamination with uranium may cause heavy metal renal damage).

Internal contamination with radionuclides that emit gamma radiation can also be a source of exposure to health care personnel. However, the use of universal precautions and good radiation protection practices as described in Chapter 2 will minimize exposure of personnel to the radiation [9]. Health care personnel routinely deal with patients who are internally contaminated with medical isotopes. Hospitals with nuclear medicine departments have protocols on how to manage these patients in an in-patient setting.
5.3.5 NO CONTAMINATION OR RADIATION EXPOSURE
Some individuals who present to the ED may not have been exposed to radiation or contaminated with radioactive materials. These people should be reassured and may be sent home with follow-up instructions. However, some people may require psychological support. More information on psychological casualties and psychological follow-up is presented in Section 5.10 and Chapter 6.

5.4 Treatment of Internal Contamination

5.4.1 INTERNAL CONTAMINATION PATHWAYS
There are five different pathways through which casualties may become internally contaminated:

• inhalation of radioactive particles, usually in the form of radioactive dust
• ingestion of radioactive material
• absorption of radioactive material through an open wound
• absorption of radioactive material through intact skin
• injection of radioactive material into the bloodstream

The most likely pathways during a radiation emergency will be inhalation, ingestion, and absorption through an open wound. Identification of these pathways is important because they may influence the choice of treatment.

Inhalation
Inhalation of radioactive materials may occur during radiation emergencies involving accidental emissions from nuclear power reactors and from spread of radioactive material by a radiological dispersion device (RDD). Intake via the respiratory tract may also occur from cross-contamination of the nose and mouth by contaminated hands. The biokinetics of inhaled radionuclides depends on their physiochemical characteristics, especially particle size and solubility. Particles with an aerodynamic diameter greater than 10 microns (0.01 mm) tend to remain in the upper respiratory tract and are further cleared to the gastro-intestinal (GI) tract by the mucociliary route. Smaller particles are deposited in the deeper respiratory tract, where they may irradiate lung tissue or be absorbed into the body and later deposited in other organs. Soluble particles (e.g., tritiated water and cesium chloride) are absorbed directly into the circulatory system, while insoluble particles (e.g., plutonium dioxide) enter the lymphatic system or are carried by mucociliary clearance to the gastrointestinal tract.

Ingestion
For large-scale radiation emergencies involving emissions from nuclear power reactors, the possibility of ingesting food and water contaminated with radioactive materials such as iodine-131, cesium-137 and strontium-90 are of concern. In Canada, distribution or sale of contaminated food and milk would be restricted following a radiation emergency if the level of contamination is above established guidelines, in order to reduce the radiation exposure of the public [10]. All swallowed radioactive material – whether from ingestion of contaminated food and water, cross-contamination of the mouth from contaminated hands, or from clearance of the respiratory tract – will enter the digestive tract and behave like non-radioactive material. Absorption from the GI
tract depends on the chemical properties of the contaminant and its solubility. A very small fraction of heavy metal radionuclides, such as uranium, is absorbed through the GI tract, while the remainder is excreted unchanged. In contrast, radionuclides such as iodine-131, tritium, and cesium-137 are rapidly absorbed.

**Absorption through wounds**
In radiological emergencies, all wounds should be considered contaminated until proven otherwise, and must therefore be meticulously examined for the presence of radioactive contaminants when they are present in a radiation emergency. Mechanical damage of the skin by repeated abrasive scrubbing during skin decontamination may also allow for absorption. Skin wounds, including acid burns, create a portal for any particulate contamination to come into direct contact with the subcutaneous tissue, bypassing the epithelial barrier. Solubility, acidity, tissue reactivity, and particle size are factors that determine the speed of absorption from a wound. The higher the solubility of a particle, the faster the absorption rate; however, insoluble particles of smaller size may be cleared by phagocytosis and enter the lymphatic system. If the contaminant is highly acidic, local tissue coagulation may occur, decreasing the dispersion rate.

**Absorption through intact skin**
Absorption through intact skin occurs primarily through passive diffusion. The physical barrier of the epithelium is resistant to particulate matter. Therefore, very few radionuclides can penetrate the skin to any significant degree. Tritium (hydrogen-3) is the primary exception to this since, in the form of tritiated water, it can pass readily through the skin like other water molecules. All substances have a skin permeability rate dependent on their relative solubility in both lipids and water. Skin that has been exposed to certain chemicals, for example, dimethyl sulphoxide, will also be more permeable.

**5.4.2 BIOKINETICS OF ABSORBED RADIONUCLIDES**
Once a radionuclide is absorbed, it crosses capillary membranes through passive diffusion and active transport mechanisms, and is then distributed through the body or metabolised following the same pharmacokinetics as its stable (non-radioactive) form. For example, sodium-24 or cesium-137 is evenly distributed throughout the body, while iodine-131 is concentrated mainly in the thyroid gland as the critical organ. The primary sites for uranium deposition are the liver and bones. The rate of distribution to each organ is related to the metabolism of the organ and the affinity of the radionuclide for naturally occurring chemicals within the organ. The liver, kidney, adipose tissue and bone have higher capacities for binding chemicals due to their high protein and lipid content.

An absorbed radionuclide will be metabolized according to its chemical properties and will be excreted either in its original state, or as a metabolite. Most elimination will occur through the urinary and GI tracts. Minor routes of elimination include the skin (i.e., sweating), salivary glands and mammary glands (i.e., breast milk). Excretion is determined by the relative solubility of the compound and its transport to and distribution in the target organ. In general, water-soluble compounds are excreted in the urine, and lipid soluble compounds are excreted into the feces via the hepatobiliary circulation.
The biological half-life of a radionuclide (the time it takes for half the original amount of radionuclide to be eliminated from the body through biological means) is just as important as its radiological half-life in determining the significance of the exposure. There is considerable individual variability in the biological half-life of a radionuclide, depending on factors such as bowel motility, metabolism and diet. For example, the clearance time (the time that particles remain in an area of the body before they are eliminated by the body’s normal clearance mechanisms) for the GI tract is approximately 24 hours for individuals who maintain a high fibre diet, while it is slower, up to 5 days, for individuals on a low fibre diet. The slower the transit time, the greater the radiation exposure of the GI tract.

The effective half-life, $H_{\text{eff}}$, is a combination of the radiological half-life, $H_{\text{R}}$, and the biological half-life, $H_{\text{B}}$: $H_{\text{eff}} = (H_{\text{R}} \times H_{\text{B}})/(H_{\text{R}} + H_{\text{B}})$. Both radiological half-life and biological half-life work simultaneously to eliminate the radioactive isotopes from the body. For example, for strontium-90 $H_{\text{R}} = 29.1$ years, $H_{\text{B}} = 50$ years, and $H_{\text{eff}} = 18.4$ years. Similarly, for tritium, ($^3$H) $H_{\text{R}} = 12$ years, $H_{\text{B}} = 12$ days, and $H_{\text{eff}} = 12$ days. Tritium will be eliminated primarily through biological processes.

5.4.3 METHODS OF DETECTING, IDENTIFYING, AND QUANTIFYING INTERNAL CONTAMINATION

Detection
A radiation contamination meter, generally used to detect the presence of external contamination, can be used to get an indication of internal contamination. For example, the presence of contamination on the face and hands may be a good indication that the casualty has inhaled or ingested contamination and is also internally contaminated. Checking a patient for contamination should be done prior to decontaminating the patient so that the presence of contamination on the face and hands can be confirmed. A radiation contamination meter or survey meter can sometimes be used to detect radioactivity inside the body of a decontaminated person, such as when a person ingests iodine-131.

Sampling and Identification
Radiation contamination meters do not have the capability to identify radionuclides. If this information is not already known from other sources, sampling of the contaminated areas on the patient or the collection of excreta, can be performed for subsequent identification of the radionuclides. It should be noted that in a mass-casualty scenario, such as a radiological dispersion device explosion, once the radionuclide(s) has been identified, it should likely be the same for all casualties.

If contamination is detected around the nose and mouth, separate swabs of both nostrils and the mouth should be taken and counted using a radiation contamination meter. If both nostrils have roughly the same count rates, it is likely that the patient inhaled homogenously distributed radioactive particles. If one nostril demonstrates markedly higher counts than the other, this suggests mechanical contamination of the nostril (i.e., from a contaminated finger) and potentially lower risk of significant internal contamination via inhalation. Inhaled contaminants remain only a short period of time in the upper respiratory tract before being removed by the normal clearance mechanisms. Therefore, nasal swabs should be performed within the first hour after exposure, if possible. If more than one hour has passed, a sputum sample may be useful. A sputum sample may be obtained after administering a saline fog via nebulizer for about 20-30 minutes. However, collecting a sputum sample may not be possible in a mass-casualty situation.
If there are wounds present, they should also be swabbed at this time. If there are radioactive particles or shrapnel in the wounds, they should be removed with long-handled forceps and stored within a shielding container (available in nuclear medicine departments).

All swab samples should be placed in double Ziploc® bags to reduce cross contamination of the sample, and labeled with time and count rate (sample containers are used for sputum). Swabs and particle samples should be sent to a pre-identified laboratory where the contaminants can be identified and quantified.

The radiation emissions from radionuclides may be identified using a radiation contamination meter, but to identify the radionuclides, other methods are used. Gamma-emitting radionuclides can be identified using a gamma spectrometer. Some emergency response organizations have portable gamma spectrometers for in-field radionuclide identification. Fixed spectrometers are used in laboratories for more accurate quantification. For alpha- and beta-emitting radionuclides, alpha spectrometer and beta spectrometer must be used. Because radioisotope identification is not routinely performed in the hospital laboratory, laboratories with this capability should be identified in advance during the emergency planning process.

**Quantification**

Quantifying the intake of contamination is a necessary step in determining whether treatment of internal radionuclide contamination is indicated. Since this may not be possible in a timely manner, some assumptions may have to be made so that treatment decisions are not delayed. Quantifying intake is a complex process that requires detailed information on chemical and physical properties of the radioactive contamination, clinical sampling for bioassay, and health physicist assistance. The information presented in this section is intended to provide the reader with some background information on how radionuclides can be quantified; ED personnel are not expected to perform this role.

**Indirect (in vitro) bioassay monitoring**

For exposure through inhalation, a gross estimate of intake can be made by evaluating the nasal swabs. The summed counts from both nostrils are converted to activity which represents roughly 10% of the deep-lung deposition of small, insoluble particles. If the swab samples were taken more than one hour following exposure, the estimation will be affected because most of the particles will have been cleared from the nasal passages. A gross estimate of intake can be used to identify individuals who may not require treatment, as well as those who need it the most [11].

The most common method for assessing intake is bioassay of a 24 hr urine sample or stool sample. The presence of radioactivity in the urine indicates that radionuclides were absorbed and are now being eliminated from the body. The presence of radioactivity in the feces indicates that some fraction of ingested radionuclides (or inhaled radionuclides that have been cleared via mucociliary action and swallowed) was not absorbed, or that some fraction had been absorbed but is now being eliminated via the biliary system. Data from multiple bioassay samples and models of the radionuclide metabolic pathways are used to estimate the original intake, and from this, a radiation dose can be calculated. Software programs are available that allow rapid calculation of internal contamination from limited bioassay results.
Bioassay requires a specialized laboratory capability. In Canada, there are about 20 laboratories that have some bioassay capability. Therefore, laboratories with the capability to perform bioassay should be identified during the emergency planning process. Assistance in identifying these laboratories and their capabilities may be sought from the Radiation Protection Bureau of Health Canada.

Health Canada has the National Calibration Reference Centre for Bioassay and in vivo Monitoring (NCRC) which provides proficiency test programs to laboratories that perform these functions. On occasion, the NCRC will be involved in bioassay measurements and internal dose assessments of suspected radionuclide intakes. It provides this service to the Canadian Nuclear Safety Commission under a Memorandum of Understanding, and supports the Federal Nuclear Emergency Plan. Some of the radionuclides it can measure include: tritium, carbon-14, phosphorus-32, cobalt-60, iodine-131, uranium, plutonium-239, radium-226, americium-241, strontium-90, and polonium-210. The form for requesting bioassay measurement from Health Canada provided in Annex 5.7 Procedures to Follow When Requesting Bioassay Measurements gives an indication of the kind of information that will be required by laboratories performing bioassay.

**Direct (in vivo) bioassay monitoring**

Whole body counters can be used to quantify internal intake of radionuclides that emit penetrating radiation. However, these devices are not readily available for clinical use. Portable whole body counters and portal monitors are available in some locations but they require highly trained personnel for their operation and are used primarily for screening purposes.

Nuclear medicine equipment and portable meters can be used to provide gross estimates for many gamma emitters [12]. Detailed information on the use of such equipment can be found on the CDC website [13].

**5.4.4 TREATMENT MODALITIES**

The goal of treatment is to reduce the amount of incorporated radioactive material (decorporation) in order to reduce the acute and long-term health effects of radiation by either reducing absorption and internal deposition or enhancing excretion. Once radionuclides become incorporated into tissues with slow turn-over, the effectiveness of decorporating agents is significantly reduced. It is therefore generally accepted that decorporating agents are most effective when used as soon as practicable after exposure.

Decorporating agents and chelating agents both work upon the same principle. They are compounds that bind with a specific element, or group of elements, preventing them from being incorporated into the body. Chelating agents enhance elimination of metals from critical organs. Because they only bind with certain elements, it is important to identify the radionuclide before treatment can begin.
Blocking agents reduce the body's uptake of a radionuclide by saturating organs with an identical non-radioactive element. The most commonly used blocking agent is potassium iodide (KI). KI will saturate the thyroid with non-radioactive iodine so that all radioactive iodine, inhaled or ingested, will be excreted instead of being taken up by the thyroid. The effectiveness of KI is dependent on the time the agent is taken before internal contamination occurs. If the blocking agent is taken after internal contamination occurs, it is not as useful because the body has already incorporated the radioactive material. For example, potassium iodide taken 4 hrs after exposure will only avert about 50% of the dose [14].

Laxatives and emetics can help increase elimination from the gastrointestinal tract. Emetics can be used in conscious patients soon after ingestion. Activated charcoal has been used, with varying success, to reduce absorption. Adsorbents, such as aluminium/magnesium oral antacid, make radionuclides, such as insoluble or colloidal strontium-90, less absorbable [15].

Tritium contamination can be treated by forced fluid intake (isotopic dilution). Enhanced fluid intake (e.g., water, tea, beer, milk) will increase excretion (accelerated metabolism) and can reduce the time tritium stays in the body by a factor of two.

Stomach lavage, if done within the first hour after ingestion, may be effective. The solution and gastric contents, as with other clinical samples, should be retained and sent for analysis.

Little can be done to reduce lung absorption and deposition. Expectorants and mucolytics have not proven effective in increasing the transit rate of insoluble particles to the posterior pharynx. Lung lavage has been used in a few patients following inhalation of insoluble radioactive material. Lung lavage is used infrequently and the risk/benefit should be considered carefully; it is not suitable for a mass-casualty event, however [16].

For wounds, irrigation with chelating agents may be indicated. Debridement and excision for removal of fixed contamination may also be necessary [17].

The preferred treatment modality will depend on the properties of the radionuclide and the route of entry. Information on specific treatments can be found in Annex 5.5 Treatment of Patients for Internal Contamination with Radionuclides. It should be noted that not all drugs for treatment of internal contamination are commercially available in Canada (for example, the manufacturer may not have applied for market authorization in Canada). Physicians may have to request authorization from Health Canada’s Special Access Programme to allow the manufacturer to sell the drug to the physician. (An example of the information that must be provided by the physician can be found in Annex 5.6 Special Access Programme - Patient Specific Request Form.) Instructions for completing the form can be found at the Special Access Program website. As manufacturers may be located outside of Canada, the process can delay treatment if the drug is not locally stockpiled.
5.4.5 TRIGGER TO TREAT – WHEN IS TREATMENT JUSTIFIED?

As mentioned in the previous section, treatment for internal contamination will most likely be used to reduce the long-term risk of cancer, but it may be needed in some cases to reduce the dose to an organ to avoid non-cancer effects. In general, treatment is justified when the benefit of treatment outweighs the risk. If the level of radionuclide intake is low, treatment may not be justified because there are treatment-associated risks, albeit low. Patient discomfort and the potentially lengthy duration of treatment and monitoring are other considerations. As the level of intake and potential dose increases, so will the risk. Therefore the magnitude of intake and dose will be an important determinant of the decision to treat. Time since exposure and the target tissues are other considerations. Decorporation may no longer be effective after the radionuclide becomes incorporated into tissues with slow turn-over. The decision to initiate treatment should be done in consultation with health physicists, unless an empiric approach is adopted. A software tool to facilitate timely treatment decisions has been developed [18]. It should be remembered that early treatment of internal radionuclide contamination can only reduce the risk by a factor of a few fold, but that may be enough to make a significant impact on future health consequences.

The International Commission on Radiological Protection (ICRP) has developed guidance on the treatment of internal contamination following occupational exposure using the Annual Limit on Intake (ALI) as a reference value. The ALI is the intake in a year of a specific radioactive material (expressed as an activity measurement, in Bq) that would irradiate a person to 20 mSv over a period of 50 years for adults (equivalent to the annual average limit for workplace exposure). The ALI was designed to protect workers based on occupational exposure limits, and assumes a continuous low level exposure. When internal contamination occurs following a radiological emergency, the ICRP recommends that treatment of the general public be undertaken only when the intake is high [19]. Except for isotopes of iodine, if the intake is less than one annual limit on intake (ALI), treatment usually is not indicated; conversely, if the intake is more than ten ALI (equivalent to 200 mSv), treatment usually is indicated. Between one and ten ALI, the decision to treat will depend on clinical judgement of risk versus benefit and the available resources.

The US National Council on Radiation Protection and Measurements (NCRP) Report No. 161 has introduced a new operational quantity, the Clinical Decision Guide (CDG), to guide treatment of internal contamination of the general public [15]. CDG values represent thresholds for initiating treatment with specific radionuclides. Like the ALI, they take into account long-term health effects, but also provide guidance on the rarer occasions when acute effects, such as bone marrow suppression or lung damage, may result from internal contamination.

In practice, during mass-casualty radiation emergencies, it will be necessary to reserve medical countermeasures for significantly contaminated individuals who need treatment the most, in order to do the greatest good with limited resources.
5.4.6 A CASE FOR EMPIRIC TREATMENT

In a mass casualty radiation emergency it may not be possible to identify and characterize the radioactive material, or quantify intake, in a timely manner. Initial treatment decisions may have to be based on the accident characteristics, rather than estimates of intake or dose. Follow-on treatment, however, should be based on estimates of the dose derived from a reconstruction of the incident, information from air and surface sampling, and early reports of bioassay. Early empiric treatment should be considered when the potential intake is large, as there is an opportunity for significant dose-saving.

5.4.7 SPECIALIZED TESTS FOR ESTIMATING INTERNAL CONTAMINATION: BIOASSAY

In the hospital environment, the most practical test to be employed for assessing internal contamination is the bioassay (described in Section 5.4.3). Because it is unlikely that the hospital laboratory will have the capability to perform this test, it is important to identify specialized laboratories during the emergency planning process.

Because of its convenience, urine is the preferred sample for bioassay measurements. Urine bioassay can be used to measure a wide range of radionuclides. Protocols for collection of urine should, ideally, be obtained from the laboratory in advance. In general, 24-hour samples are preferred because biokinetic models used to interpret data are based on daily excretion rates. The first sample collection should be initiated as soon as possible after exposure. Repeat samples will initially be necessary to assess the intake, but will be used later to monitor the effectiveness of treatment. In a mass-casualty emergency, spot samples are more practical than 24-hr samples. Measurements of spot samples can be normalized using the specific gravity or creatinine method [20, 21].

5.5 Treatment of Acute Radiation Syndrome (ARS)

Most of the information in this section deals with the management of the patient after the patient has been transferred out of the ED. This section does not provide details of specialist care; rather, it links the activities that take place in the ED with eventual in-hospital patient management.

In the ED, after the patient has been stabilized and appropriate measures have been taken to deal with external contamination, the patient can be assessed for signs of acute radiation injury and treatment can be initiated. It will be unlikely for the ED to receive many patients presenting with acute radiation symptoms in the early phase following a radiation emergency because symptoms can be delayed. However, if an incident goes unrecognized, patients will begin presenting to the ED with manifest radiation illness.

5.5.1 CHARACTERISTICS OF ARS

ARS is caused by a high dose of penetrating radiation received over a short period of time by most or all of the body. However, exposure is usually heterogeneous, i.e., parts of the body may be shielded and therefore unexposed, or exposed to a lesser degree. This has important implications for treatment which are described later in the text. When referring to tissue reactions, the gray is used as the unit of absorbed dose.
ARS follows a predictable course over a period of time ranging from hours to several weeks. It is characterized by the development of groups of signs and symptoms that are manifestations of the reactions of various organs and organ systems (organ-specific sub-syndromes). Typically affected are organ systems with stem cells having a high turnover rate, such as the bone marrow, gastrointestinal lining and basal layer of the skin. The following sub-syndromes are clinically significant: hematopoietic, gastrointestinal, and neurovascular. Cutaneous radiation syndrome is discussed separately in Section 5.8.

The hematopoietic syndrome seen following a whole-body absorbed dose of 1-8 Gy is caused by depletion of hematopoietic stem cells, resulting in hemorrhage (platelet reduction), infection (white blood cell reduction), and anemia (red blood cell reduction). When stem cells are killed, the effect may not be apparent until the mature cells are depleted and there are no maturing cells to take their place. When the radiation dose is high enough to cause irreversible damage of the hematopoietic system, death from infection or hemorrhage may result 30-60 days later (LD_{50/60} is about 3.5-4.5 Gy). The gastrointestinal syndrome seen following a whole-body absorbed dose above 8 Gy is caused by depletion of epithelial cells lining the GI tract. Death may occur about 10 days later (massive fluid loss and high risk of septicemia). The neurovascular syndrome, also known as the cardiovascular/central nervous system syndrome, seen following a whole-body absorbed dose above 30 Gy is caused by vascular injury or effects on parenchymal components of the brain. An increase in the fluid content of the brain from leakage of small blood vessels usually causes death within about 24-72 hours without treatment or other complications.

Figure 5.3 illustrates the time of onset and the duration of the clinical manifestations of ARS as a function of dose. While it is possible to experience signs and symptoms from any of the organ-specific syndromes, the syndrome which dominates the clinical picture following whole-body exposure roughly corresponds to whole-body dose (i.e., hematological syndrome predominates at 1-8 Gy, gastrointestinal syndrome at >8 Gy). In non-uniform exposures of significant parts of the body, the clinical picture will be determined by the dose to the bone marrow, the lining of the gastrointestinal tract or the neurovascular system. The organ-specific syndromes of ARS form the basis of the European Medical Treatment Protocols for Radiation Accident Victims (METREPOL) concept of diagnosis and triage of radiation injury [22], and the Canadian adaptation of this tool, the Radiation Casualty Assessment Tool [23, 24].

The clinical course of ARS is divided into 4 stages: prodromal, latent, manifest illness and recovery (or death). The time lag before onset of symptoms and the duration of the latent period is inversely proportional to dose; the earlier the appearance of symptoms, the worse the prognosis. The length of the period of manifest illness and the severity of the symptoms is directly proportional to dose. In other words, a high dose will produce symptoms earlier, there will be a shorter latent period, and time to death will occur earlier.
The prodromal phase is characterized by non-specific symptoms, such as vomiting, which are not the result of cell depletion, but of cell membrane effects. Whole-body exposure, or exposure of the lower torso to radiation, causes release of 5-hydroxytryptamine3 (5-HT3) from cells of the gastrointestinal mucosa due to the effect of radiation on the cell membranes. The increase of 5-HT3 activates 5-HT3 receptors and results in vomiting. 5-HT3 receptor antagonists, such as ondansetron, can be used to alleviate the nausea and vomiting; they are effective up to about 8 Gy to the lower torso. At higher doses to the upper torso/head, central effects predominate; this may be from edema due to increased capillary permeability causing pressure on critical structures.

Although a small temporary decrease in cell counts (especially peripheral lymphocytes) can be observed at a whole-body dose of 0.5 Gy, doses below 1 Gy are usually considered subclinical. Following a 1 Gy dose, there may be minimal prodromal symptoms; only about 5% of those who receive 1 Gy will vomit. Full recovery without treatment is expected if there are no other medical problems. At higher doses, the prodrome will be more severe and be observed earlier.
5.5.2 SYSTEMIC EFFECTS OF THE HEMATOPOIETIC SYNDROME

The hematopoietic syndrome is the predominant clinical syndrome starting at doses above 1 Gy. The systemic effects of the hematopoietic syndrome are those that one would expect to see following depletion of stem cells in the bone marrow; bleeding, infection, and anemia (Table 5.1; Figure 5.4). As the dose increases, the latent period shortens, with symptoms appearing earlier, and the period of profound neutropenia lengthens. The period of neutropenia is the most critical time for the ARS patient with the LD$_{50/30}$ being in the 3.5-4.5 Gy range without specialized treatment. Although there is a drop in red blood cells, this is rarely survival-limiting.

Table 5.1 Degrees of severity of the hematopoietic syndrome (adapted from METREPOL [22])

<table>
<thead>
<tr>
<th>ACUTE SIGN/SYMPTOM</th>
<th>GRADE 1 (MILD)</th>
<th>GRADE 2 (MODERATE)</th>
<th>GRADE 3 (SEVERE)</th>
<th>GRADE 4 (VERY SEVERE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolute lymphocyte count</td>
<td>≥1.5 x 10$^9$/L</td>
<td>1.0-1.5 x 10$^9$/L</td>
<td>0.5-1.0 x 10$^9$/L</td>
<td>&lt;0.5 x 10$^9$/L</td>
</tr>
<tr>
<td>Absolute granulocyte count</td>
<td>≥2 x 10$^9$/L</td>
<td>1.0-2.0 x 10$^9$/L</td>
<td>0.5-1.0 x 10$^9$/L</td>
<td>&lt;0.5 x 10$^9$/L, or initial granulocytosis</td>
</tr>
<tr>
<td>Absolute platelet count</td>
<td>≥100 x 10$^9$/L</td>
<td>50-100 x 10$^9$/L</td>
<td>20-50 x 10$^9$/L</td>
<td>&lt;20 x 10$^9$/L</td>
</tr>
<tr>
<td>Infection</td>
<td>Local; no antibiotics</td>
<td>Local; topical or oral antibiotics</td>
<td>Systemic; oral antibiotics</td>
<td>Sepsis, IV antibiotics necessary</td>
</tr>
<tr>
<td>Bleeding</td>
<td>Petechiae, easy bruising, normal hemoglobin (Hgb)</td>
<td>Mild blood loss, &lt; 10% reduction in Hgb</td>
<td>Severe blood loss; 10-20% reduction in Hgb</td>
<td>Spontaneous bleeding or blood loss with &gt;20% reduction in Hgb</td>
</tr>
</tbody>
</table>
5.5.3 SYSTEMIC EFFECTS OF THE GASTROINTESTINAL (GI) SYNDROME

The GI syndrome is the predominant clinical syndrome at whole-body doses above 8 Gy (Table 5.2). The systemic effects of the GI syndrome are those that arise from death of stem cells in the crypts of villi; diarrhea and abdominal cramps are the primary symptoms, but vomiting can also occur. The latent period is much shorter than that seen in the hematopoietic syndrome. Eventually, cells of the epithelial cell lining in the lumen of the GI tract become depleted. Death usually occurs due to loss of GI lining integrity, massive fluid loss, hemorrhage, and infection.

Table 5.2 Degrees of severity of the gastrointestinal syndrome (adapted from METREPOL [22])

<table>
<thead>
<tr>
<th>ACUTE SIGN/ SYMPTOM</th>
<th>GRADE 1 (MILD)</th>
<th>GRADE 2 (MODERATE)</th>
<th>GRADE 3 (SEVERE)</th>
<th>GRADE 4 (VERY SEVERE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 h Stool frequency</td>
<td>2-3 per day</td>
<td>4-6 per day</td>
<td>7-9 per day</td>
<td>≥10 per day, refractory diarrhea</td>
</tr>
<tr>
<td>Stool consistency</td>
<td>Bulky</td>
<td>Loose</td>
<td>Sloppy</td>
<td>Watery</td>
</tr>
<tr>
<td>Mucosal loss with diarrhea</td>
<td>Rare</td>
<td>Intermittent with moderate patches</td>
<td>Persistent, with large patches</td>
<td>Persistent, with large amount</td>
</tr>
<tr>
<td>Bleeding with diarrhea</td>
<td>Occult</td>
<td>Blood occasionally visible</td>
<td>Persistent frank blood</td>
<td>Gross hemorrhage</td>
</tr>
<tr>
<td>Abdominal pain/cramps</td>
<td>Minimal</td>
<td>Tolerable</td>
<td>Intense</td>
<td>Excruciating</td>
</tr>
</tbody>
</table>
5.5.4 SYSTEMIC EFFECTS OF THE CARDIOVASCULAR/NEUROVASCULAR SYNDROME
The neurovascular syndrome is the predominant clinical syndrome at very high doses, above 30 Gy (Table 5.3). It is characterized by vomiting and diarrhea within minutes and prompt onset of confusion followed by unconsciousness. This syndrome is inevitably fatal, with death occurring within a day or two. Vomiting at these very high doses is thought to be from a direct central nervous system effect rather than from release of 5-HT3.

Table 5.3 Degrees of severity of the neurovascular syndrome (adapted from METREPOL [22])

<table>
<thead>
<tr>
<th>ACUTE SIGN/SYMPTOM</th>
<th>GRADE 1 (MILD)</th>
<th>GRADE 2 (MODERATE)</th>
<th>GRADE 3 (SEVERE)</th>
<th>GRADE 4 (VERY SEVERE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nausea</td>
<td>Mild</td>
<td>Moderate</td>
<td>Severe</td>
<td>Excruciating</td>
</tr>
<tr>
<td>Vomiting</td>
<td>1 per day</td>
<td>2-5 per day</td>
<td>6-10 per day</td>
<td>&gt;10 per day</td>
</tr>
<tr>
<td>Anorexia</td>
<td>Mildly decreased appetite</td>
<td>Moderately decreased appetite</td>
<td>Severely decreased appetite</td>
<td>Parenteral nutrition</td>
</tr>
<tr>
<td>Fatigue syndrome</td>
<td>No functional impairment</td>
<td>Moderate functional impairment</td>
<td>Severe functional impairment</td>
<td>Prevents daily activity</td>
</tr>
<tr>
<td>Fever</td>
<td>37.5-38.0 °C</td>
<td>38.1-40.0 °C</td>
<td>&gt;40 °C for &lt;24 hrs</td>
<td>&gt;40 °C for &gt;24 hrs, or accompanied by hypotension</td>
</tr>
<tr>
<td>Headache</td>
<td>Mild</td>
<td>Moderate</td>
<td>Severe</td>
<td>Excruciating</td>
</tr>
<tr>
<td>Hypotension</td>
<td>HR&gt;100, BP&gt;100/70</td>
<td>BP&lt;100/70</td>
<td>BP&lt;90/60 (transient)</td>
<td>BP&lt;80/? (persistent)</td>
</tr>
<tr>
<td>Neurological deficits</td>
<td>Mild deficit; No functional impairment</td>
<td>Moderate deficit and functional impairment</td>
<td>Marked deficit and functional impairment</td>
<td>Life threatening neurological signs, loss of consciousness</td>
</tr>
<tr>
<td>Cognitive</td>
<td>Mild cognitive impairment</td>
<td>Moderate cognitive impairment</td>
<td>Severe cognitive impairment</td>
<td>Complete memory loss; incapable of rational thought</td>
</tr>
</tbody>
</table>

5.5.5 GENERAL PRINCIPLES OF MANAGING ARS
The general principles of managing acute radiation syndrome are to provide medical and psychological support to the patient and to treat symptoms. Prophylactic drugs (e.g., antibiotics, cytokines) based on the predicted clinical course are provided when supported by current evidence.

• Stabilize.
• Assess the dose or severity of injury for planning purposes.
• Treat prodromal symptoms.
• Provide supportive care.
• Consider urgent surgery.
• Treat manifest illness (hematology unit).
• Treat cutaneous syndrome, if present.
• Provide counselling.

For the most part, management of ARS is like management of the neutropenic patient, although there may be other complicating factors at very high radiation doses.

**Assessment of dose and severity of injury**

The patient’s diagnosis and prognosis is based on the assessment of dose and the evolution of clinical symptoms. Estimating radiation dose is important for selecting the appropriate treatment option. This is not different than when treating a drug overdose. Specific interventions may be necessary at high doses and, as shown in Table 5.4, there is a dose range at which treatment is both necessary and effective. However, even without knowing the actual dose, the patient should be treated in accordance with the clinical and laboratory indicators of severity of injury. For example, blood counts may indicate a need for antibiotics, platelets, cytokines, etc.

**Table 5.4 Association of dose to clinical observations and laboratory results (adapted from METER [24])**

<table>
<thead>
<tr>
<th>DOSE (GY)</th>
<th>CLINICAL/LABORATORY OBSERVATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.15</td>
<td>No symptoms; chromosome aberrations</td>
</tr>
<tr>
<td>0.5</td>
<td>No symptoms; blood cell count begins to drop</td>
</tr>
<tr>
<td>1</td>
<td>Nausea and vomiting within 48 hrs in 5-10% of affected population</td>
</tr>
<tr>
<td>2</td>
<td>Nausea and vomiting within 24 hrs in 50% of affected population; serious drop in white blood cells; generally survivable without treatment</td>
</tr>
<tr>
<td>4</td>
<td>Nausea and vomiting within 8 hrs in 90% of affected population; mortality from bone marrow failure; LD(_{50/30}) 3.5 – 4.5 Gy without treatment</td>
</tr>
<tr>
<td>6</td>
<td>LD(_{100}) without treatment</td>
</tr>
<tr>
<td>~10</td>
<td>LD(_{100}) even with treatment</td>
</tr>
</tbody>
</table>

Note: Although the LD\(_{50}\) is useful for making comparisons it may not be applicable to an individual’s response to radiation injury because there is wide spectrum of response in the population. It does not apply when radiation exposure is combined with other injuries or when it occurs in the presence of underlying disease. The effect of age is also not clear.
The radiation dose may be determined from physical dosimetry, if available (i.e., a reading on an electronic dosimeter, dose reconstruction calculation, etc.). However, a physician does not treat only according to a dosimeter reading. An assessment of an individual's response to radiation injury using biological indicators may be more appropriate. The patient's history, onset and duration of prodromal symptoms, and laboratory investigations, such as absolute lymphocyte count (ALC), can all be used as part of a multi-parameter approach [26, 27].

One clinical indicator of severity of injury is time to onset of vomiting. Vomiting within the first hour post exposure can indicate a severe injury (Table 5.5). However, the presence of vomiting should be taken in context. Patients whose history does not suggest any radiation exposure may vomit due to anxiety or another co-morbid illness or condition. Although there is wide variation within the population, time to onset of vomiting is a sign that may be effective when used in conjunction with other parameters [28]. It can also be useful for mass-casualty triage. The disadvantage of this sign is that it is not applicable to exposure from internal sources of radiation or partial body exposure.

Table 5.5 Relationship between time to onset and duration of vomiting and radiation dose (adapted from METER [24])

<table>
<thead>
<tr>
<th>DOSE (GY)</th>
<th>ONSET OF VOMITING (HOURS)</th>
<th>DURATION OF VOMITING (HOURS)</th>
<th>LATENT PERIOD BEFORE ONSET OF MANIFEST ILLNESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5-2</td>
<td>Absent to 6</td>
<td>&lt;24</td>
<td>Absent to 3 weeks</td>
</tr>
<tr>
<td>2-3.5</td>
<td>2-6</td>
<td>12-24</td>
<td>2-3 weeks</td>
</tr>
<tr>
<td>3.5-5.5</td>
<td>1-2</td>
<td>24</td>
<td>1-2.5 weeks</td>
</tr>
<tr>
<td>&gt;5.5</td>
<td>Minutes to 1</td>
<td>48</td>
<td>2-4 days</td>
</tr>
</tbody>
</table>

As a minimum, a complete blood count (CBC) should be performed and repeated every 6 hours for the first 24-48 hours. The Andrews nomogram shown in Figure 5.5 illustrates the predictive value of the absolute lymphocyte count (ALC) on the first day following exposure. After this period of time, serial CBCs are used to monitor blood cell depletion kinetics. Serum amylase concentration is a biomarker of exposure to the upper body. Newer biomarkers have been developed to assess the status of different organ systems at different times following exposure (e.g., C-reactive protein), but there is no consensus on their use at this time [26]. Blood can be drawn for chromosome aberration studies, such as the dicentric chromosome assay (refer to Section 5.5.6), to assess the level of radiation-induced chromosome damage from which the level of exposure can be derived. However, results from this form of “biological dosimetry” may not be available for several days.
Figure 5.5 Andrews nomogram showing early changes in peripheral blood lymphocyte counts and degree of radiation injury (taken from REMM [5])

There are several software programs and printed tools available for assessing the severity of a radiation injury. The Radiation Casualty Assessment Tool found in Annex 5.3 is one example. It provides a template for regular, systematic assessment of signs and symptoms to aid in assessment of injury.

**Management during the prodromal and latent periods**

Symptomatic support may be provided during the prodromal period for pain, nausea and vomiting (e.g., odansetron), diarrhea (e.g., atropine/diphenoxylate, loperamide), and seizures (e.g., diazepam). For nausea and vomiting, use of 5-HT3 receptor antagonists is effective below whole-body doses of 8 Gy.

Any necessary surgical procedures should be scheduled as soon as possible, before white blood cells are depleted, or alternatively, left until after recovery.

Laboratory tests are initiated during the prodromal period not only to assess the degree of injury (e.g., serial CBCs, dicentric chromosome assay), but also to predict the patient’s expected clinical course (i.e., ABO and HLA typing when transfusions and stem cell transplants may be necessary, respectively). Because some of these tests, such as the dicentric chromosome assay and HLA typing, depend on the presence of a significant number of white blood cells, blood samples should be taken before the white blood cell count falls significantly. Ideally, the following tests should be performed:

- CBC with differential and complete blood chemistry, including serum amylase, repeated every 6 hours for the first 24–48 hours
- ABO typing
- HLA typing if a whole-body dose of 7–10 Gy is suspected and there are no other injuries
- IgG levels for herpes simplex virus (HSV) I and II, cytomegalovirus (CMV), varicella-zoster virus (VZV) to determine prior exposures in patients with severe ARS (Consider extending the testing beyond 30 days if the patient has persistent immunosuppression.)
- Absolute CD4+ T-cell count at 30 days. If < 200 cells/ml, reassess every three months until above this level.
A recent global assessment of evidence-based management of the hematopoietic syndrome [29] indicated that there is strong evidence that administering cytokines (e.g., granulocyte colony stimulating factor (G-CSF), granulocyte-macrophage colony stimulating factor (GM-CSF)) when the absolute neutrophil count (ANC) is less than 500 (i.e., there is a risk of subsequent aplasia) will reduce the duration and degree of neutropenia, provided there is sufficient non-irradiated bone marrow to respond to cytokine administration. Cytokine growth factors can be potent stimulators of hematopoiesis. The effectiveness of cytokine treatment, however, relies on the presence of viable bone marrow. This treatment should be started as early as possible, although there appears to be benefit even when started several days post exposure. Treatment should be continued until the ANC reaches 1000. The recommended dose for GM-CSF is 2.5-5 μg/kg/day, and for G-CSF it is 5-10 μg/kg/day.

Table 5.6 Principal management for ARS relative to whole-body dose (Adapted from IAEA [30])

<table>
<thead>
<tr>
<th>1-2 GY</th>
<th>2-4 GY</th>
<th>4-6 GY</th>
<th>6-8 GY</th>
<th>&gt;8 GY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outpatient</td>
<td>Hospitalization and treatment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assess 1 month</td>
<td>Isolation as early as possible</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Antiemetics and analgesics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cytokines as early as possible</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Broad spectrum antibiotics from end of latent period</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Antifungals and antivirals when necessary</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blood component transfusion when necessary</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Complete parenteral nutrition (first week)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fluid and electrolyte replacement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hematopoietic stem cells</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Palliative</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

When severe aplasia persists on day 21 with no sign of residual hematopoiesis, despite cytokine treatment, a hematopoietic stem cell transplant may be necessary (this is not managed in the ED). Multi-organ failure is a contraindication for stem cell transplantation. Stem cell transplantation is generally not a first-line treatment, except at doses above 8 Gy, where no viable bone marrow may remain. Stem cells from peripheral or cord blood, or bone marrow are used for stem cell transplantation. Results of stem cell transplantation have been disappointing, but at high doses, the presence of the gastrointestinal syndrome and other concurrent conditions interfere with the response. Graft versus host disease (GVHD) is a major problem. Partially differentiated myeloid progenitor cells are being investigated as an alternative, since they do not affect lymphoid cells and should eliminate GVHD.
Management during the period of manifest illness

ARS management is similar to management of neutropenia from other causes (Table 5.6). The primary determinants of survival are control of infection and control of bleeding during periods of neutropenia and thrombocytopenia. The main goal of treatment is to prevent mortality due to infection during the period of severe neutropenia (ANC <100 cells/mm³). During this period, the patient should receive supportive care and specific treatment.

Supportive care includes prevention of infection, treatment of established infection, and provision of fluids and irradiated blood products, if required. In the absence of any other treatment, supportive care can raise the LD₅₀/₃₀ from about 3.5-4.5 to over 6 Gy. Unfortunately, it may not be possible to deliver intense supportive care during a mass-casualty situation. Treatment success will be limited by the degree of GI syndrome and future onset of pulmonary fibrosis. In practice, there is a therapeutic window where treatment is necessary for survival, but at the same time, where treatment retains its effectiveness.

As mentioned in the previous section, early treatment with cytokines, G-CSF and GM-CSF, will reduce the depth and duration of neutropenia. Other cytokines are being investigated for treating thrombocytopenia. While the patient is neutropenic, prophylaxis continues to be important. Guidance for prophylaxis in ARS patients when ANC<100 cells/mm³ has been adopted from guidance for neutropenic cancer patients developed by the Infectious Diseases Society of America [31]. The following should be considered:

- early cytokine therapy
- barrier/isolation
- wound closure, early surgical interventions
- no invasive procedures
- antibiotic prophylaxis (fluoroquinolones)
- antiviral agents (acyclovir)
- antifungal agents (fluconazole)
- pneumocystis prophylaxis (trimethoprim/sulfamethoxazole)

Prophylaxis is directed towards Gram negative bacteria, Herpes simplex virus (HSV), Pneumocystis, and fungal infections. Abdominal radiation treatment has been shown to reduce the content of normal gastrointestinal bacteria, resulting in greatly increased numbers of enterobacteriaceae, a cause of lethal sepsis. HSV and Pneumocystis are potential concerns since previous infection may be reactivated during periods of immune suppression [32]. Recently, a global consensus on evidence-based management of radiation associated injury provided only a weak recommendation for the use of prophylactic fluoroquinolones and bowel decontamination [29].

Cultures for all possible foci of infection should be performed. With or without a focus of infection, empiric treatment of febrile neutropenia should be guided by current infectious diseases recommendations [31].
Treatment for the gastrointestinal and neurovascular syndromes remains supportive (i.e., preventing, controlling and mitigating complications and ensuring patient comfort). A recent literature review and global consensus meeting concluded that there was weak evidence for current recommendations for treatment of the gastrointestinal syndrome [33]. A pre-clinical proof-of-concept for the use of mesenchymal stem cells (MSC) for treatment of gastrointestinal syndrome has been demonstrated and is being investigated further [34, 35].

5.5.6 SPECIALIZED TESTS: DICENTRIC CHROMOSOME ASSAY (DCA)
Chromosome aberration studies can be used to assess radiation dose in an individual who was exposed to whole body or partial body radiation but not wearing a physical dosimeter, or to confirm the results of physical dosimetry. These are specialized tests that are not always readily available and may not provide results quickly enough for initial patient management of those with high dose exposure. However, these tests may subsequently help to confirm or modify the treatment. In those with low-dose exposure, these tests may be useful for the prediction of long-term health risks. If the dose was below the threshold for the test, this information may be used to reassure individuals that a significant dose was not received and alleviate psychosocial concerns.

Chromosomal aberrations have been used as indicators of radiation induced cell damage for over 50 years [36]. When ionizing radiation produces double-strand breaks in the DNA, it may lead to non-lethal and lethal changes in the chromosomes. Non-lethal aberrations are generally harder to visualize under brightfield microscopy and for that reason lethal aberrations are used as indicators of radiation damage. Typical lethal aberrations result from the misrepair of deletions (when a part of a chromosome becomes lost) occurring in one or more chromosomes. Due to this misrepair, dicentric (chromosome containing two centromeres) or ring chromosomes and acentric fragments (segment of chromosome containing no centromere) (AF) are formed (Figure 5.6). Unstable chromosomes are radiation- or radiomimetic-agent-specific and presently considered to be the most sensitive biological indicators of radiation exposure.

Figure 5.6 Dicentric and ring chromosomes (photos provided by R. Wilkins, Health Canada)
Radiation induced DNA damage can be detected using a number of biodosimetry techniques. The dicentric chromosome assay (DCA) is the accepted “gold standard” for biological dosimetry by the International Organization for Standardization, the WHO and IAEA. It evaluates chromosomal damage in cells that have been arrested in metaphase, one of the stages of cell division. Approximately 50 hours of sample processing are required prior to enumeration of the DNA damage. At this time, the frequency of lethal aberrations per cell can be determined and translated into a dose received through the use of a pre-existing dose response curve (Figure 5.7). Whole-body doses between 0.2 and 5.0 Gy can be determined accurately for whole-body exposures. Since this type of damage is unstable and does not persist in the body for long after exposure, measurement should be made within three months. Whole-body doses above 8 Gy make it difficult to perform chromosome analysis by the classic method. As the dose increases, the number of lymphocytes is deleted very quickly, making them unavailable for this method.

Although this method is most useful for acute whole-body exposure to penetrating radiation, it can provide useful information on chronic exposure and local radiation injury (non-uniform exposure). Based on the distribution of damage per affected cells, the DCA can provide predictive values on whether the exposure was a whole-body or a non-uniform exposure. This is important to know because if there is a non-uniform exposure, there is chance that a fraction of the bone marrow may have been spared. In this case, cytokine treatment will be preferable to stem cell transplantation. Since the exposure usually is non-uniform, it is important to wait for 24 hours post exposure to draw the blood. This will allow the damaged cells to redistribute throughout the body so that the blood sample contains representative damage from the exposure.

Figure 5.7 Yield of Dicentric Chromosomes as a Function of Dose (provided by R.Wilkins, Health Canada)
Health Canada coordinates and contributes to a National Biological Dosimetry Response Plan (NBDRP) network consisting of three reference laboratories (two federal laboratories and a university laboratory) and several satellite clinical cytogenetics laboratories. The reference laboratories have the expertise and capability of performing the DCA and develop their own dose response curves for different types of radiation. The clinical laboratories must be capable of enumerating the unstable chromosome damage once the blood samples have been processed at a reference laboratory. Using a more rapid triage mode for assessing samples, Canada has the capacity to evaluate about 40 samples/hour in an 8-hour day. If the Canadian capacity for biodosimetry becomes overwhelmed, an international biodosimetry network, managed by the WHO, BioDoseNet, would be available to assist in the analyses. International biodosimetry capabilities can also be accessed through the IAEA’s Response and Assistance Network, for which Health Canada provides the Canadian focal point.

More information on activating the NBDRP network or contacting Health Canada directly for biodosimetry assessment is provided in Annex 5.8 Procedures to Follow When Requesting Biodosimetry Assessment (Dicentric Chromosome Assay).

5.6 Radiation Pneumonia
Also called radiation pneumonitis, radiation pneumonia is a manifestation of radiation injury to lung tissue following high doses of radiation (>8 Gy whole-body dose). There is a relatively long latent period before the onset of interstitial pneumonitis, about 50 days. This is followed by pulmonary fibrosis several months later. Even if a patient manages to survive the gastrointestinal syndrome, the patient may succumb from pulmonary fibrosis months or years later. This is a survival-limiting condition with no effective treatment. Lung damage is not usually described in the ARS subsyndromes because symptoms are delayed and do not have to be dealt with during the initial management of the patient – it is usually reported as part of multi-organ failure.

5.7 Multi-Organ Failure
A newer concept of radiation pathophysiology, which is not limited to the subsyndromes mentioned above, has been introduced by European researchers. Inflammation is thought to be the primary characteristic of radiation injury, but the role of anti-inflammatory treatment is not known. At high doses, organs such as the kidney, liver and lungs are involved. Clinically, radiation injury is seen as a continuum of multi-organ injury, multi-organ dysfunction, and irreversible multi-organ failure [37, 38].

5.8 Treatment of Cutaneous Radiation Syndrome (CRS) - Local Radiation Injury
The terms cutaneous radiation syndrome, cutaneous radiation injury, local radiation injury, and radiation “burns” are often used interchangeably. Some authors distinguish these terms. In the context of this document, the term cutaneous radiation syndrome will be used when referring to injury resulting from a localized radiation exposure. Although CRS may also occur following high-dose whole-body irradiation with gamma and neutrons, this type of exposure would not be expected in the scenarios described in Chapter 2.
CRS is the clinical manifestation of pathophysiological reactions of skin and underlying structures to high doses of radiation. These reactions may last days, months, and often years. CRS may occur following two different radiation exposure scenarios: in one, there is a high dose (>25 Gy) of local and penetrating radiation, typically gamma or x-rays; in the other, there is partial-body superficial radiation exposure, usually following surface contamination with beta emitters (as seen in Chernobyl and Goiania) [39, 40].

In the early phase following a radiation emergency, few skin symptoms are likely to be seen; however, when a radiation incident initially goes unnoticed, patients may present to the ED when burns become manifest.

5.8.1 RESPONSE OF SKIN TO RADIATION
Skin is considered a radiation sensitive tissue. As described in Chapter 2, high doses of radiation can result in cell death. When radiation-induced cell death of the epidermis exceeds the regenerative capacity of epidermal stem cells, denudation of the epidermis will result. However, the response of skin to radiation exposure is far more complex. Following radiation exposure of the skin microvasculature, vascular endothelial cells swell or detach from the basement membrane. Edema occurs as leaks in the denuded areas allow extravasation of plasma constituents from the capillaries. Platelets fill in areas of denuded basement membrane and microthrombi form, causing capillary occlusion and impaired oxygenation. Tissue hypoxia may lead to progressive ischemic necrosis.

The CRS may be associated to a pathological wound repair process. Normal wound repair involves inflammation, granulation and tissue remodelling. This is a complex process integrating highly ordered molecular and cellular processes. After a cutaneous injury, a blood clot forms and inflammatory cells infiltrate the wound, secreting cytokines and growth factors during the inflammation phase. During the granulation phase, fibroblasts differentiate into myofibroblasts which deposit extracellular matrix proteins. Angiogenesis takes place to sustain the newly formed granulation tissue. Keratinocytes proliferate and migrate to close the wound. In the tissue remodelling phase, apoptosis eliminates myofibroblasts and extraneous blood vessels, and the extracellular matrix is remodelled to resemble the original tissue. Many of these processes are adversely affected by radiation exposure, resulting in impaired wound repair [41].

Factors affecting the effectiveness of wound repair include: severity of injury to epidermal stem cells, adequacy of microvasculature, structural support of the damaged dermis, damage to underlying structures, and avoidance of infection and trauma. Permanent sequelae, such as dermal atrophy, recurrent ulcers, invasive fibrosis, and pigmentary change may occur.

5.8.2 CLINICAL COURSE OF CUTANEOUS RADIATION SYNDROME
The signs, symptoms, and clinical course of CRS are dependent upon the radiation dose, the volume of tissue receiving more than 25 Gy, and the radiation quality. The clinical course has a roughly similar pattern to the ARS: prodromal, latent, manifest illness, and recovery phases. However, CRS differs in that the course has a more unpredictable evolution, and recovery can take much longer. As with ARS, recovery does not always occur – amputation may be necessary and death may result from complications such as sepsis.
As the dose increases, the latent period shortens while manifest illness occurs sooner, lasts longer, and is more severe. Dose thresholds for varying degrees of skin injury are classically described for acute gamma radiation. Table 5.7 provides a range of such threshold values, although there is considerable variation reported in the literature. When the dose is not acute, but spread out over a period of time, as in radiotherapy, the thresholds for skin injury are higher.

Table 5.7 Dose thresholds for skin effects following acute gamma radiation exposure (data from Gusev [42])

<table>
<thead>
<tr>
<th>ABSORBED DOSE TO SKIN (GY)</th>
<th>SKIN EFFECT</th>
</tr>
</thead>
<tbody>
<tr>
<td>3–4</td>
<td>Epilation (hair loss) in 2–3 weeks</td>
</tr>
<tr>
<td>10–15</td>
<td>Erythema in 18–20 days at lower doses</td>
</tr>
<tr>
<td>20</td>
<td>Moist desquamation, possible ulceration</td>
</tr>
<tr>
<td>25</td>
<td>Ulceration with slow healing</td>
</tr>
<tr>
<td>30–50</td>
<td>Blistering, necrosis at 3 weeks</td>
</tr>
</tbody>
</table>

The prodromal phase, which can last up to 48 hours, may go unnoticed if the dose is not high, with redness only appearing a few weeks later. At higher doses, tingling or redness of skin (or conjunctivitis if the eye is involved) may be observed early for a short period of time (Table 5.8). It has been proposed that prodromal signs of skin injury could be used to screen individuals in mass-casualty situations involving whole-body exposure. For example, a 3 Gy whole-body exposure will show some transient erythema after about 1.5 h [43].

The prodromal phase is followed by a latent period lasting from hours to about 21 days with no signs or symptoms. A very short latent period suggests that a very high dose of radiation was received.

The period of manifest illness is a dynamic process in which the skin lesion evolves to an extent that is proportional to dose. For example, a dose >25 Gy will result in erythema initially and evolve to blistering, desquamation, and necrosis. However, this evolution can be unpredictable and may involve successive waves of inflammation. The observed clinical effects, poor wound healing, pain and infection, are a result of both vascular and cutaneous damage.

Recovery can take as long as months or years, but tissue or limb loss, or death, may occur. Recovery time will be dependent upon many factors, including severity of injury and complicating factors arising from damage to underlying tissues. At doses to muscle and bone in the 40 Gy range, rhabdomyolysis and radio-osteonecrosis may appear several months after exposure. Recurrent and chronic tissue inflammation induce further necrosis making it difficult to stabilize such patients. Even at doses below the threshold for necrosis, secondary necrosis may arise as a result of the progression of late-onset fibrosis.
5.8.3 ASSESSMENT OF CUTANEOUS RADIATION SYNDROME

Making an early diagnosis of CRS may be difficult without knowledge that a radiation incident had occurred. The transient prodromal period may go unnoticed and the long latent period may make it difficult to obtain a history. Furthermore, the initial presentation may be misleading. Radiation should be suspected as the cause of a skin burn in the absence of a thermal or chemical exposure.

The assessment of the severity of a radiation injury is an important part of clinical management. The severity of injury to skin and underlying structures is dependent upon the radiation dose, the volume of tissue receiving more than 25 Gy, and the radiation quality. Because skin lesions will evolve over time, the initial signs and symptoms may not be representative of the true extent of damage. It is therefore clinically difficult to distinguish injured tissue from normal tissue. Dose assessments are generally revised retrospectively by observing clinical signs as they evolve. The Radiation Casualty Assessment Tool in Annex 5.3 provides a template for regular, systematic assessment of signs and symptoms to aid in assessment of injury.

Routine laboratory tests will be part of the overall assessment (e.g., CBCs). More sophisticated tools and resources are sometimes available to assess the extent of injury, but these may be available only at specialized centres. These include electron spin resonance, thermography, and ultrasound. Repeat assessment will be necessary as the skin lesions evolve. When there is eye involvement, slit lamp ophthalmoscopy may be conducted as a baseline assessment since posterior pole cataracts are a potential long-term effect of radiation exposure to the eye.

Dose reconstruction performed by health physicists is useful but may be imprecise. When the dose is “reconstructed” from the details of the incident, it is possible to estimate the dose to different sections of the affected skin and identify areas of relatively normal tissue. This information is important when determining how much debridement is necessary before closing a wound, or when planning an amputation. If dosimetry is used to guide surgery, very detailed dose information must be mapped using CT scans of the affected areas and mathematic modelling.

Because management of the cutaneous syndrome is complex, early consultation with the following specialists is recommended: plastic surgery, vascular surgery, dermatology, and radiation oncology.
Table 5.8 Degrees of severity of the cutaneous radiation syndrome (adapted from METREPOL [22])

<table>
<thead>
<tr>
<th>ACUTE SIGN/ SYMPTOM</th>
<th>GRADE 1 (MILD)</th>
<th>GRADE 2 (MODERATE)</th>
<th>GRADE 3 (SEVERE)</th>
<th>GRADE 4 (VERY SEVERE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erythema</td>
<td>Minimal; transient</td>
<td>Moderate; isolated patches &lt; 10 cm²; less than 10% body surface area (BSA)</td>
<td>Marked; isolated patches or confluent; 10–40% BSA</td>
<td>Severe; isolated patches or confluent; &gt;40% BSA</td>
</tr>
<tr>
<td>Sensation/itching</td>
<td>Occasional pruritis</td>
<td>Slight; intermittent pain</td>
<td>Moderate; persistent pain</td>
<td>Severe; persistent pain</td>
</tr>
<tr>
<td>Swelling/edema</td>
<td>Mild; asymptomatic</td>
<td>Moderate; symptomatic</td>
<td>Severe; symptomatic</td>
<td>Total dysfunction</td>
</tr>
<tr>
<td>Blistering</td>
<td>Vesicles, with sterile fluid</td>
<td>Vesicles, with hemorrhage</td>
<td>Bullae, with sterile fluid</td>
<td>Bullae, with hemorrhage</td>
</tr>
<tr>
<td>Desquamation</td>
<td>Mild</td>
<td>Patchy, dry</td>
<td>Patchy, moist</td>
<td>Confluent, moist</td>
</tr>
<tr>
<td>Ulcer/necrosis</td>
<td>Epidermal only</td>
<td>Dermal</td>
<td>Subcutaneous</td>
<td>Muscle/bone involvement</td>
</tr>
<tr>
<td>Hair loss</td>
<td>Thinning, not striking</td>
<td>Patchy, visible</td>
<td>Extensive</td>
<td>Complete; most likely irreversible</td>
</tr>
<tr>
<td>Onycholysis</td>
<td>Minimal</td>
<td>Moderate</td>
<td>Severe</td>
<td>Complete</td>
</tr>
</tbody>
</table>

5.8.4 GENERAL PRINCIPLES OF MANAGING CRS

While it is recognized that the management of CRS will require specialist care outside of the Emergency Department, a brief overview of some of the current approaches to management of CRS has been provided for completeness.

The medical management of CRS is complex and historically based on management of thermal and electrical burns. This includes debridement of necrotic tissue and full thickness skin grafting. However, clinical experience with CRS has shown that management of CRS involves not only skin necrosis but also complications in the underlying muscle and bone compartments which contribute to the recurrence of CRS, need for repeat surgery, and long-term hospitalization. Severe CRS is managed in some centres using combination surgery and stem cell therapy [41, 44-46]. Early treatment of the cutaneous syndrome is believed to positively influence the outcome of multi-organ involvement.
Controlling infection and pain are significant challenges, made all the more difficult due to the slow and unpredictable evolution of wounds, impaired wound healing, and the ease with which healed epidermis is traumatized. Pain is typically resistant to classic opiate administration. The prognosis of CRS is influenced by factors such as co-existing bone marrow depression, infection, and trauma.

A recent global consensus group [33] reported that there was strong evidence for supportive care using topical Class II-III steroids, antibiotics, and antihistamines for radiation burns, blisters, and ulcers. Other measures such as use of fluids, electrolytes, and sedatives for burns, hypovolemia, and shock were also reported as useful.

**Early management**
Early excision and debridement of potentially septic tissue as well as early closure of wounds, preferably by skin grafting, may be necessary. Although bioengineered skin and dermal constructs have been used, full-thickness skin grafts and microsurgical techniques have been more successful. If there is any co-existing hematopoietic damage, required surgery should be carried out within 36-48 hours post exposure or postponed until late in the convalescent period.

**Protecting the healing epidermis**
Topical antibiotics and non-adherent wound dressings should be used to protect the healing epidermis. A variety of drugs have been used to help reduce infection and trauma to the epidermis. These include antihistamines, antipruritic preparations, topical antibiotics, topical corticosteroids, and mild sedatives. Drugs that may help control itching, such as antihistamines and topical antipruritic preparations, may also help attenuate or delay the manifestation stage.

**Improving microcirculation**
Use of pentoxyfylline at about 3–4 weeks post-exposure has been recommended to stimulate vascularization after tissue regeneration has begun [43, 47]. Nicotine should be avoided because it further impairs oxygenation of tissue.

**Reduction of fibrosis**
Fibrosis is one of the late effects of injury to the skin. Interferon gamma and superoxide dismutase (antioxidant) have been used in combination with drugs to stimulate vascularization. Recently, freshly harvested mesenchymal stem cells from adipose tissue have been successfully used to treat severe fibrosis in radiation therapy patients [48].

**Stimulating regeneration**
Early regeneration may be stimulated by using proteolytic inhibitors, such as aprotinin, during the latent phase [40]. Topical growth factors, such as keratinocyte growth factor, have been reported to cause proliferation, differentiation, and migration of epithelial cells. More recently, there has been success using repeated mesenchymal stem cell injections in conjunction with plastic surgery or skin grafting for early lesions [41].
Anti-inflammatory agents
Topical steroids are used to reduce the edema which impairs oxygenation needed for healing. Systemic steroids should not be used for this indication as they increase susceptibility to infection.

Preventing/treating infections
During the manifestation stage, prevention of infection is important. Topical antibiotics are helpful. All nutritional requirements should be met.

Controlling pain
Controlling pain may be the most difficult part of patient management and will require consultation with specialists in pain management.

5.9 Combined Injury
When radiation-induced injury is combined with non-radiation (traumatic, chemical or thermal) injuries, the prognosis is much poorer. Combined injuries generally have a more than additive effect. Mortality associated with thermal burns increases in the presence of radiation injury - 50% mortality increases to 90% with radiation doses as low as 1.5 Gy.

The effect of radiation on traumatic injury is delayed wound healing, susceptibility to infection, and late effects due to microvascular damage. If the patient has other trauma, wounds should be closed, burns covered, fractures reduced, surgical stabilization performed, and definitive treatment given within the first 48 hours after injury. After 48 hours, surgical interventions should be delayed until hematopoietic recovery has occurred.

5.10 Psychological Effects
For most people affected by a radiation emergency, the invisible and poorly understood threat of radiation generates considerable anxiety. This leads to a far larger number of psychological casualties compared to medical casualties. Therefore, it is essential that psychiatrists, psychologists and social workers be involved in the response to radiation emergencies. It makes sense to consider setting up a treatment area for psychological casualties that is located away from the ED (i.e., another area in the same building); this will reduce the burden on the ED, making it easier for medical patients to access, and for personnel to provide medical care. Once patients are cleared medically and have been cleared by a surveyor with a radiation contamination meter, they can be referred directly to the Psychological Treatment Area.

More details on psychological effects and treatment are found in Chapter 6.

5.11 Handling Decedents Contaminated with Radioactive Materials
Although this topic is outside of the scope of this document it is mentioned here as a reminder of this issue. Guidance on this topic has been published elsewhere [49].
5.12 Recovery of the Hospital Facility
As with medical responders at the scene, the primary objective for hospital facilities will be to return their assets back to normal operation as soon as possible. For the Emergency Department, this means being able to function adequately to meet the ongoing influx of patients with medical issues unrelated to the radiological disaster. The magnitude of the hospital recovery depends on the amount of decontamination required.

Surveying potentially contaminated areas is important in the early identification of contamination and minimization of its spread. Closing contaminated rooms from the public and personnel prevents contamination from inadvertently being moved from a dirty room into a clean area of the hospital. PPE is important during a recovery process to protect those conducting cleanup operations.

Prioritizing decontamination requires the application of simple common sense during a recovery operation. Operating and emergency rooms along with other hospital essential service areas should always be given priority over non-essential areas.

References


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ANNEX 5.1 SETTING UP THE EMERGENCY ROOM FOR RECEIVING CASUALTIES POTENTIALLY CONTAMINATED WITH RADIONUCLIDES

1. SETTING UP THE CONTAMINATED TREATMENT AREA:

- Tape Kraft paper or other non-slip material to the floor.
- Designate the entrance (contaminated) and exit (transition to clean area).
- Remove equipment, supplies and personnel that are not essential.
- Cover all shelving and remaining supplies not likely to be needed with plastic covering material – this will facilitate site recovery.
- Prepare supplies necessary for decontamination and contaminated waste (several bottles of saline, drapes, bags for contaminated waste, Ziplock® bags, several pairs of gloves).
- Arrange how the run-off from decontamination will be collected - it can be flushed down the waste disposal system.

2. LIST OF USEFUL SUPPLIES

- bags with labels for contaminated clothing
- waterproof dressings
- soap
- shampoo (no conditioner)
- towels
- clean clothes (i.e., scrubs, water resistant suits, gowns, slippers, etc.)
- garbage bags
- extra batteries, suitable for contamination meters being used

3. PERSONAL PROTECTIVE EQUIPMENT IN THE HOSPITAL SETTING

- scrub suit and gown (cloth or paper)
- water-proof shoe covers
- cap, goggles (or face shield) and mask (a surgical mask is sufficient unless there is contaminated dust - then an N-95 mask provides better protection)
- inner pair of surgical gloves (Sleeves of the gown should be taped to the outside of the gloves.)
- outer pair of surgical gloves (Do not tape so that they can be changed often; consider using a different colour from inner gloves.)
- water resistant outer gown, if using liquids for decontamination
- masking tape label on front and back of outer garment showing name of worker
- personal dosimeters, if available (Dosimeters used for direct reading should be worn on the outside of the gown, while other dosimeters should be worn on the inside of the gown.)
ANNEX 5.2 PROCEDURES FOR MINIMIZING THE SPREAD OF CONTAMINATION IN THE EMERGENCY ROOM

1. TRANSFERRING A PATIENT FROM THE RECEPTION AND TRIAGE AREA TO THE CONTAMINATED TREATMENT AREA

Unstable patients who are being transported from the Reception and Triage Area to the Contaminated Treatment Area should be handled in the following manner to minimize the spread of contamination:

- Cover clean gurney with two sheets.
- Lift patient onto clean gurney.
- Wrap sheets over the patient.
- Roll clean gurney into the Contaminated Treatment Area.

2. REMOVING CLOTHING FROM A PATIENT ON A GURNEY

The following steps should be followed when removing clothing from a patient on a gurney:

- Two clean sheets are put on the gurney before the patient is transferred from the ambulance stretcher.
- Cut off patient's clothing down long axis of trunk and each limb.
- Roll the clothing away from cut edge (to trap loose contamination).
- Log-roll patient (to complete assessment) so that the clothing lies rolled up on the stretcher, trapping contaminated particulates.
- Roll up contaminated sheet and clothing; replace with clean sheet.
- Remove and replace outer gloves after handling patient’s clothing and contaminated sheet.

3. TRANSFERRING A PATIENT OUT OF THE CONTAMINATED TREATMENT AREA

The procedure for transferring a patient out of the Contamination Treatment Area is described below:

- Start with clean patient on a clean sheet.
- Surveyor surveys gurney - checking wheels, railings, control handles/buttons of gurney.
- If the gurney is clean, roll across clean/dirty line (control line).
- If the gurney is contaminated, transfer patient to clean gurney then re-survey.
4. REMOVING PPE

- Stand at clean/dirty line with surveyor nearby.
- Remove outer gloves.
- Return electronic dosimeter, if it was being used.
- Undo tape at wrists and ankles, then remove outer garments without shaking them.
- Remove cap, goggles and mask.
- Remove shoe covers, preferably while sitting on a chair covered with plastic.
- Keep feet off the floor in the ‘clean’ area until surveyed clean.
- You must essentially ‘straddle’ the clean/dirty line (control line) as you doff your PPE, so that as you step out of your contaminated shoe covers you are stepping over the clean/dirty line (control line).
- Finally, remove inner gloves.
- All discarded clothing goes in garbage bags identified as ‘contaminated’.
ANNEX 5.3 RADIATION CASUALTY ASSESSMENT TOOL

The Radiation Casualty Assessment Tool provides a template for regular, systematic assessment of signs and symptoms following penetrating radiation to aid in the determination of severity of injury. This tool utilizes history, symptom onset and duration, and observed signs to aid in assessment of injury.

Reference for Annex 5.3

Instructions on use of RADIATION CASUALTY ASSESSMENT TOOL

This information packet (‘tool’) is designed to help with the assessment and management of casualties of an incident involving radiation. Use one packet per casualty, labelling each page. It should become part of the permanent record for that casualty. You do not have to use those parts of the tool that do not apply to that casualty.

1. TRIAGE GUIDE

- filled out by triage MD or RN
- used to establish initial priority (i.e. immediate treatment vs. immediate decontamination vs delayed treatment and/or decontamination)
- designed to look and function like the SARS screening tool

2. HISTORY AND PHYSICAL FORM

- filled out by treating MD
- used to record findings on history and physical
- prompts physician to obtain specifics relevant to treatment and disposition decisions unique to radiation exposure and/or contamination

3. BODY MAPPING FORM FOR SKIN CONTAMINATION AND INJURY

- filled out by treating MD or RN
- used to facilitate recording location of skin contamination
- contaminated areas are recorded (with initial count and description) as they are discovered by person performing survey. All contaminated areas must be decontaminated, with final counts recorded as well
- also used to record location of injuries

4. STANDING ORDERS

- filled out by treating MD
- prompts physician to order specific labs, specimens, and medications relevant to treatment of radiation exposure and/or contamination

5. SEVERITY SCORING FORM

- reference material for treating MD
- allows physician to estimate severity of injury due to radiation exposure when the exposure dose has not been determined. This may help with disposition decision
- Also lists Decorporating agents for internal contamination with various agents
RADIATION CASUALTY ASSESSMENT TOOL

Name _______________________________ Age___________ M/F

Date ________________________________ Time of Arrival ___________ h

Triaged by: ___________________________ Time seen _____________ h

Mode of arrival: self □ EMS □ ambulatory □ stretcher □

**STABILITY**

**Question 1:** Is patient medically stable?

- ☐ “NO” then
  1. Cover with sheet, assume contaminated
  2. Move immediately to Contaminated Treatment Area

- ☐ “YES” then go to Question 2

**CONTAMINATION**

**Question 2:** Does patient have measurable skin contamination during 2 minute survey with Geiger Counter in triage?

- ☐ “YES” then
  1. Identify as contaminated
  2. Record sites/activity of contamination (p 5)
  3. Prioritise for decon, move patient to decon site, then integrate into cohorted stream of uncontaminated ED patients
  4. Further assess for Exposure ASAP

- ☐ “NO” then
  1. Identify patient as uncontaminated (using local standard colour coding)
  2. go to Question 3

**EXPOSURE**

**Question 3:** Does patient have history, signs and symptoms of possible exposure to radiation?

- ☐ “YES”
  - New onset of nausea, vomiting, diarrhea or skin changes?
  - New onset of weakness, confusion, unexplained low BP?

- ☐ “NO”
  1. Prioritise for treatment
  2. integrate into cohorted stream of uncontaminated ED patients
RADIATION CASUALTY ASSESSMENT TOOL

Name ___________________________ Age ________ M/F
Date ____________________________ Time of Arrival ________ h
Physician: _________________________ Time seen ________ h

**HISTORY AND PHYSICAL Form**

Vitals: HR _______ BP _____/____ Temp ___°C
RR ___ sats ___% on ________RA/Lpm

Chief complaint: ______________________

HPI:
____________________________________
____________________________________
____________________________________
____________________________________
____________________________________
____________________________________
____________________________________

Review of Systems (selected)

**Neuro:** Confusion ☐ Fatigue ☐
Changes in: speech ☐ vision ☐
   dizzy ☐ headache ☐

Vomiting: yes ☐ or no ☐ # of times:
   (began at _____ h, =______ h after exposure)

Motor/sensory deficits? ____________
Cognitive deficits? ____________

**Blood:** Active bleeding? ☐
Bruising ☐ Petechiae ☐

**Derm:** Redness or Rash ☐ (Time of onset: _____ h)
   Swelling ☐ Blisters ☐ Ulcers ☐
   Desquamation ☐ Hair loss ☐ Onycholysis ☐
   Dysesthesia/pruritis ☐

**GI:** Nausea ☐ (severity: _____/10)
   Anorexia ☐ Abdominal pain ☐
   Blood ☐/mucus ☐ in stool
   Diarrhea ☐ (began at _____ h; # of times: _____)
   if female: LMP ________, Pregnant: yes/no/

Details of radiation contamination/exposure:
__________________________________________
__________________________________________
__________________________________________

**Isotope** known:__________ unknown ☐
Type of particle: α ☐ β ☐ γ ☐ X-rays ☐ neutrons ☐
State: solid/powder ☐ liquid ☐ gas/steam ☐

**Contamination** see diagram ☐

**External** contamination:
yes ☐ no ☐ unknown ☐
Extensive contamination (see diagram):
localised (skin/hair) ☐ Wound ☐
   Generalised ☐

**Internal** contamination:
yes ☐ no ☐ unknown ☐

**Decontamination**
Location: in field ☐ at ED ☐, done by________

**Exposure**
yes ☐ no ☐ unknown ☐
Time of exposure:______ h
Duration:______ h______min
Whole body ☐ Parts of Body ☐

**Past Medical History**
   Immunosuppression ☐
   Cancer ☐ (radiation ☐ chemo ☐, when? _____)
   Previous fluoroscopy/Nuc Med testing/
occupational exposure? ____________________
   Other: ____________________

**Medications** (include dose & freq if known):
Allergies to meds: NKDA/__________________

Social history: __________________________
RADIATION CASUALTY ASSESSMENT TOOL

Name _____________________________ Age___________ M/F
Date ________________________________ Time of Arrival ___________ h
Physician: ____________________________ Time seen _______________ h

| Physical exam:                      |
|                                  |
|                                  |
|                                  |
|                                  |
|                                  |
|                                  |
|                                  |
|                                  |

Biodosimetry  
using different methods  
of estimating severity of exposure; use tables  
p 114-115 or REMM Tool to calculate estimated  
dose (in Grays)

1. Time of onset of vomiting (see table on page 116)
- Interval between exposure & onset vomiting: __ h
- Estimated dose: _______ gray

2. Absolute Lymphocyte depletion rate (use REMM)
- single ALC ____x10^3, ____ hrs post-exposure
- serial ALC’s; 2nd ____x10^3, ____ hrs post-exposure
- Estimated dose: _______ gray

3. Response Category: Select highest value from
4 individual categories below
- Neurological: 1  2  3  4
- Hematologic:  1  2  3  4
- Cutaneous:  1  2  3  4
- Gastrointestinal:  1  2  3  4

OVERALL RESPONSE CATEGORY:
1  2  3  4

ESTIMATED DOSE (Gy): (1-2) (3-4) (5-7) (8-10)

Consistent biodosimetry estimate using all 3 methods is suggestive of radiation exposure at the indicated dose
(source: REMM ☐, other: ________________)

Resources (all are available 24/7 throughout Canada):
☐ Health Canada: (613) 954-6651
☐ Radiation Trauma Unit (UHN in Toronto): (416) 603-5800 ext 5098
☐ REAC/TS: (865) 576-3131,
☐ www.remm.nlm.gov

Labs & Investigations:

Blood samples
☐ CBC: WBC ____x10^3.
Abs Lymphoocytes ___ Abs Neutrophils ___.
Hgb ____mg/dL, Plt ____x10^3
☐ Chem 7: Na ___ Cl ___ K ___ CO2 ___.
BUN ____Creat ____ Glc ____.
☐ Pregnancy test (all females): neg/pos
☐ Thyroid: TSH, T3, free T4
☐ Tubes for chromosomal analysis (cytogenetics) collected, room temperature (if exposure potentially > 0.5 gray)

Specimens (scan with Geiger Counter, then label & save)
☐ Nasal swabs (labeled L&R): activity: yes/no
☐ Mouth Swab: activity yes/no
☐ Urine sample: activity yes/no
☐ Stool sample: activity yes/no
☐ Emesis sample: activity yes/no
ECG: ______________________________________
imaging studies: ______________________________

Course in ED: _____________________________
__________________________________________
__________________________________________
__________________________________________

Reassessed: Time _______ h: ________________

Diagnosis: 1) _____________________________
2) _____________________________ 3)

Decorporating agent considered: Yes ☐ No ☐

Disposition: home ☐, transfer ☐ (to: ________), admit ☐
Follow-up: RTED if: _________________________
FP/ED in _____ days (pt aware ☐)
outpt labs ☐ _______________________________
Prescriptions: ______________________________

see RADIATION STANDING ORDERS ☐

Signature: _____________________________ time _____h
see continuation sheet ☐
RADIATION CASUALTY ASSESSMENT TOOL

Name ________________________________  Age_________  M/F
Date ________________________________  Time of Arrival ________ h
Physician: ____________________________  Time seen _____________ h

**BODY MAPPING Form**

### INJURIES, BURNS, OR SKIN CHANGES

Circle location of injuries, number consecutively. List details.

<table>
<thead>
<tr>
<th>Site #</th>
<th>Details of Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### CONTAMINATION

Initial survey done by ______________ at _____ h  
Final survey done by ______________ at _____ h

Instrument: ______________  
Background counts per minute: ___________

Circle location of contamination, then number consecutively.  
List details below. Be sure to survey nose, mouth, hands & feet.  
Readings should be in ‘counts per minute’ (CPM).

<table>
<thead>
<tr>
<th>Site #</th>
<th>Description</th>
<th>Counts/min (initial)</th>
<th>Counts/min (final)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
RADIATION CASUALTY ASSESSMENT TOOL

Name ___________________________ Age___________ M/F
Date ___________________________ Time of Arrival ___________ h
Physician: _________________________ Time seen _______________ h

PHYSICIANS ORDERS

ALLERGY ALERT
☐ No known drug allergy
☐ Known allergies:

<table>
<thead>
<tr>
<th>DATE</th>
<th>TIME</th>
<th>PHYSICIAN’S SIGNED ORDERS</th>
<th>INITIAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>☐ i.v.: ☐ NS vs ☐ other _____, initial bolus _____cc, then ____cc/hr</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>☐ O₂ @ ____L/min by ☐ NP ☐ non-rebreather</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Monitor: ☐ cardiac ☐ O₂ sats</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Labs: ☐ CBC &amp; manual diff q6hx4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>☐ Lytes, BUN, creatinine, glucose</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>☐ Qualitative HCG (ICON)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>☐ TSH, T3, free T4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>☐ Tube for chromosomal analysis (use green top tube)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>☐ other:</td>
<td></td>
</tr>
</tbody>
</table>

Specimens (note: label specimen, test with Geiger Counter, then save)

☐ Nasal swab (L&R)
☐ Skin wipe
☐ Urine sample
☐ Stool sample
☐ Vomit sample
☐ other:

Medications

☐ Pain:
☐ Nausea/vomiting:
☐ Anti-diarrheal agent:
☐ Home Meds (itemize home meds including dose/route/schedule on separate page)
☐ Decorporating agent¹: __________________________
other:

☐ see additional order sheet Signed:________________________ MD

---
¹ SEE ‘SEVERITY SCORING FORM’, PAGES 116
RADIATION CASUALTY ASSESSMENT TOOL

Name ____________________________ Age ___________ M/F

Date ____________________________ Time of Arrival ___________ h

Physician: ____________________________ Time seen _______________ h

SEVERITY SCORING Form

Time of Exposure ________________
Time of Symptom Onset ____________
Time of Assessment ________________


1. NEUROLOGICAL (Circle most appropriate description for each symptom)

<table>
<thead>
<tr>
<th>ACUTE SYMPTOM</th>
<th>1 (MILD)</th>
<th>2 (MODERATE)</th>
<th>3 (SEVERE)</th>
<th>4 (MOST SEVERE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nausea</td>
<td>Mild</td>
<td>Moderate</td>
<td>Severe</td>
<td>Unbearable</td>
</tr>
<tr>
<td>Vomiting</td>
<td>~ 1 per day</td>
<td>~ 2-5 per day</td>
<td>~ 6-10 per day</td>
<td>&gt; 10 per day</td>
</tr>
<tr>
<td>Anorexia</td>
<td>Mildly decreased appetite</td>
<td>Moderately decreased appetite</td>
<td>Severely decreased appetite</td>
<td>Unable to eat</td>
</tr>
<tr>
<td>Fatigue Syndrome</td>
<td>No functional impairment</td>
<td>Moderate functional impairment</td>
<td>Severe functional impairment</td>
<td>Unable to function</td>
</tr>
<tr>
<td>Fever</td>
<td>37.5-38 °C</td>
<td>38.1 - 40 °C</td>
<td>&gt;40 °C for &lt;24h</td>
<td>&gt;40 °C for &gt;24 h</td>
</tr>
<tr>
<td>Headache</td>
<td>Mild</td>
<td>Moderate</td>
<td>Severe</td>
<td>Unbearable</td>
</tr>
<tr>
<td>Hypotension</td>
<td>HR&gt;100, BP&gt;100/70</td>
<td>BP&lt;100/70</td>
<td>BP &lt;90/60 (transient)</td>
<td>BP &lt;80/60 (persistent)</td>
</tr>
<tr>
<td>Neurological deficits</td>
<td>Minor deficit; no functional impairment</td>
<td>Moderate deficit; moderate functional impairment</td>
<td>Marked deficit; marked functional impairment</td>
<td>Severe deficit; loss of consciousness</td>
</tr>
<tr>
<td>Cognitive deficits</td>
<td>Mild cognitive impairment</td>
<td>Moderate cognitive impairment</td>
<td>Severe cognitive impairment</td>
<td>Profound cognitive impairment</td>
</tr>
</tbody>
</table>

2. HEMATOLOGIC (Circle most appropriate description for each symptom)

<table>
<thead>
<tr>
<th>ACUTE SYMPTOM</th>
<th>1 (MILD)</th>
<th>2 (MODERATE)</th>
<th>3 (SEVERE)</th>
<th>4 (MOST SEVERE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abs Lymphocyte</td>
<td>&gt;1.5 x 10^9/l</td>
<td>1.0-1.5 x 10^9/l</td>
<td>0.5-1.0 x 10^9/l</td>
<td>&lt;0.5 x 10^9/l</td>
</tr>
<tr>
<td>Abs Granulocyte</td>
<td>&gt;2.0 x 10^9/l</td>
<td>1.0-2.0 x 10^9/l</td>
<td>0.5 – 1.0 x 10^9/l</td>
<td>&lt;0.5 x 10^9/l</td>
</tr>
<tr>
<td>Abs Platelet count</td>
<td>&gt;100 x 10^3/l</td>
<td>50-100 X 10^3/l</td>
<td>20-50 x 10^3/l</td>
<td>&lt;20 x 10^3/l</td>
</tr>
<tr>
<td>Infection ^3</td>
<td>Local; no antibiotics required</td>
<td>Local; topical or oral antibiotics</td>
<td>Systemic; oral antibiotics</td>
<td>Sepsis; i.v. antibiotics</td>
</tr>
<tr>
<td>Bleeding ^3</td>
<td>Petechiae; easy bruising; normal Hgb</td>
<td>Mild blood loss; &lt;10% decrease in Hgb</td>
<td>Gross blood loss; 10-20% decrease in Hgb</td>
<td>Spontaneous bleeding; &gt;20% decrease in Hgb</td>
</tr>
</tbody>
</table>

^2 ACUTE SYMPTOMS ARE THOSE THAT BEGAN AFTER THE RADIATION EXPOSURE, AND NOT THOUGHT TO BE ATTRIBUTABLE TO ANOTHER ACUTE CAUSE

^3 ONLY PRESENT SUBACUTELY
RADIATION CASUALTY ASSESSMENT TOOL

Name ___________________________ Age___________ M/F
Date ____________________________ Time of Arrival ___________ h
Physician: ___________________________ Time seen ___________ h

3. CUTANEOUS  (Circle most appropriate description for each symptom)

<table>
<thead>
<tr>
<th>ACUTE SYMPTOM</th>
<th>1 (MILD)</th>
<th>2 (MODERATE)</th>
<th>3 (SEVERE)</th>
<th>4 (MOST SEVERE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erythema</td>
<td>Minimal, transient</td>
<td>Moderate; isolated patches &lt;10cm²; &lt;10% of body surface area (BSA)</td>
<td>Marked; isolated patches or confluent; 10 -40% BSA</td>
<td>Severe; isolated patches or confluent; erythroderma; &gt;40% BSA</td>
</tr>
<tr>
<td>Sensation/ itching</td>
<td>Occasional pruritis</td>
<td>Slight; intermittent pain</td>
<td>Moderate; persistent pain</td>
<td>Severe; persistent pain</td>
</tr>
<tr>
<td>Swelling / Edema</td>
<td>Mild; asymptomatic</td>
<td>Moderate; symptomatic</td>
<td>Severe; symptomatic</td>
<td>Compartment syndrome</td>
</tr>
<tr>
<td>Blistering</td>
<td>Vesicles, with sterile fluid</td>
<td>Vesicles, with haemorrhage</td>
<td>Bullae, with sterile fluid</td>
<td>Bullae, with haemorrhage</td>
</tr>
<tr>
<td>Desquamation</td>
<td>Mild</td>
<td>Patchy, dry</td>
<td>Patchy, moist</td>
<td>Confluent, moist</td>
</tr>
<tr>
<td>Ulcer/ necrosis</td>
<td>Epidermal only</td>
<td>Dermal</td>
<td>Subcutaneous</td>
<td>Muscle / bone involvement</td>
</tr>
<tr>
<td>Hair loss</td>
<td>Thinning, not striking</td>
<td>Patchy, visible</td>
<td>Extensive</td>
<td>Complete and most likely irreversible</td>
</tr>
<tr>
<td>Onycholysis</td>
<td>Minimal</td>
<td>Moderate</td>
<td>Severe</td>
<td>Complete</td>
</tr>
</tbody>
</table>

4. GASTROINTESTINAL  (Circle most appropriate description for each symptom)

<table>
<thead>
<tr>
<th>ACUTE SYMPTOM</th>
<th>1 (MILD)</th>
<th>2 (MODERATE)</th>
<th>3 (SEVERE)</th>
<th>4 (MOST SEVERE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stool frequency</td>
<td>2 - 3 stools per day</td>
<td>4 - 6 stools per day</td>
<td>7 - 9 stools per day</td>
<td>&gt;10 stools per day; intractable diarrhea</td>
</tr>
<tr>
<td>Mucosal loss with diarrhea</td>
<td>Rare</td>
<td>Intermittent, with moderate patches</td>
<td>Persistent, with larger patches</td>
<td>Continuous, with large patches</td>
</tr>
<tr>
<td>Bleeding with diarrhea</td>
<td>Occult</td>
<td>Intermittent</td>
<td>Persistent</td>
<td>Gross hemorrhage</td>
</tr>
<tr>
<td>Abdominal cramping &amp; pain</td>
<td>Minimal</td>
<td>Tolerable</td>
<td>Intense</td>
<td>Excruciating</td>
</tr>
</tbody>
</table>

2 ACUTE SYMPTOMS ARE THOSE THAT BEGAN AFTER THE RADIATION EXPOSURE, AND NOT THOUGHT TO BE ATTRIBUTABLE TO ANOTHER ACUTE CAUSE
3 ONLY PRESENT SUBACUTELY
<table>
<thead>
<tr>
<th>Onset of Vomiting After Exposure</th>
<th>Time (hours)</th>
<th>Duration</th>
<th>Dose (Grays)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cesium</td>
<td>&gt;6, or absent</td>
<td>&lt;24 hours</td>
<td>0.5-2.0</td>
</tr>
<tr>
<td>Iodine</td>
<td>2-6</td>
<td>12-24</td>
<td>2.0-3.5</td>
</tr>
<tr>
<td></td>
<td>1-2</td>
<td>24</td>
<td>3.5-5.5</td>
</tr>
<tr>
<td></td>
<td>Minutes</td>
<td>48</td>
<td>&gt;5.5</td>
</tr>
</tbody>
</table>

Time interval prior to onset of vomiting for initial biodosimetry

<table>
<thead>
<tr>
<th>Decorporating Agents (For Use with Internal Contamination)</th>
<th>Contaminant</th>
<th>Treatment</th>
<th>Dose and Administration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cesium</td>
<td>Prussian Blue</td>
<td>1g tid po</td>
</tr>
<tr>
<td></td>
<td>Iodine</td>
<td>Potassium Iodide (KI)</td>
<td>age dependent dose; 130mg po for adults</td>
</tr>
<tr>
<td></td>
<td>Plutonium, Americium</td>
<td>DTPA</td>
<td>1g iv Ca-DTPA on day 1, followed on day 2 by 1 g iv Zn-DTPA daily - slow iv push or iv infusion over 30 min diluted in 100-250 ml 5% dextrose in water. Nebulized inhalation is an alternate route.</td>
</tr>
<tr>
<td></td>
<td>Uranium</td>
<td>Sodium bicarbonate</td>
<td>250mL (1-2 mEq/kg) NaHCO₃ slow iv infusion</td>
</tr>
<tr>
<td></td>
<td>Tritium</td>
<td>Water</td>
<td>&gt;6 L/day po</td>
</tr>
<tr>
<td></td>
<td>Radium, Strontium</td>
<td>Barium sulphate, Sodium alginate, or Ca-gluconate</td>
<td>-300g po single dose -5g po bid, then 1 g qid with water (Gaviscon) -2.5g iv infusion over 4 h diluted in 500ml of 5% dextrose in water; daily up to six days</td>
</tr>
</tbody>
</table>

4 FOR PRESCRIBING INFORMATION AND OTHER DECORPORATING AGENTS, REFER TO REMM; FOR LOCAL AVAILABILITY REFER TO DISASTER PLAN.
ANNEX 5.4 PATIENT DECONTAMINATION

The surveyor should survey the patient for contamination to determine whether decontamination is necessary. The results of the survey will guide decontamination efforts and will reassure personnel when contamination is absent. Prior to decontamination, the surveyor will measure activity of swabs taken from the mouth, nose and wounds (or wound dressings). This information is used to assess whether a patient has been internally contaminated. After decontamination, the surveyor will verify whether decontamination efforts have been successful by re-surveying the body. Decontamination is considered complete when the activity measures less than twice the background level, or no further reduction in activity is achieved. Radioactive waste generated during decontamination should be properly collected.

1. GENERAL PRINCIPLES

- Keep radiation exposures ALARA: “as low as reasonably achievable”.
- Follow good radiation protection practices.
- Minimize time of exposure.
- Work quickly and efficiently.
- Rotate teams.
- Maintain distance.
- Stand back from the patient unless direct patient care is required.
- Use long-handled forceps.
- Use shielding.
- PPE shields staff from all α- and some β-particles.
- Radioactive fragments should be put in lead “pig”, preferably lined with plastic of 1 cm thickness.
- Reduce quantity of radioactive material present.
- Remove contaminated debris from the treatment area.

2. DECONTAMINATION SOLUTIONS

Contaminants may be held to the surface of the skin by electrostatic forces, surface tension, or binding with skin proteins. A variety of decontamination solutions have been recommended including soap and water, betadine and water, phisoderm and water, hydrogen peroxide, 0.25% sodium hypochlorite and waterless cleaners. For mass casualty emergencies, soap and water is acceptable. Washing the patient with soap and water is 95 percent effective. Soap emulsifies and dissolves contamination. Gentle brushing or buffing, or the use of a mild scrub, dislodges some contamination physically held by skin protein or removes portion of the horny layer of the skin. Addition of a chelating agent may help by binding specific contaminants to free them from the skin. Covering small contaminated areas of skin with an absorbent pad and plastic wrap for a few hours may help by “sweating off” the contaminant. Keep in mind that the stratum corneum of the epithelium is replaced every 12-15 days. Thus, contamination that is not removed and is not dissolved will not be removed by this method. A variety of decontamination solutions have been recommended including soap and water, betadine and water, phisoderm and water, hydrogen peroxide, 0.25% sodium hypochlorite and waterless cleaners. For mass casualty emergencies, soap and water is acceptable. Washing the patient with soap and water is 95 percent effective. Soap emulsifies and dissolves contamination. Gentle brushing or buffing, or the use of a mild scrub, dislodges some contamination physically held by skin protein or removes portion of the horny layer of the skin. Addition of a chelating agent may help by binding specific contaminants to free them from the skin. Covering small contaminated areas of skin with an absorbent pad and plastic wrap for a few hours may help by “sweating off” the contaminant. Keep in mind that the stratum corneum of the epithelium is replaced every 12-15 days. Thus, contamination that is not removed and is not dissolved will not be removed by this method.
absorbed by the body will be sloughed off within several days.

To decontaminate hair, any commercial shampoo without conditioner will suffice. Conditioners bind material to hair protein, making contamination removal more difficult.

For wound decontamination, copious irrigation with normal saline is generally used, although chelating solutions are sometimes indicated. Debridement and excision for removal of fixed contamination may be necessary.

3. DECONTAMINATION OF STABLE PATIENTS

Stable patients will be decontaminated in the Decontamination Area. The following steps should be followed:

- Remove all clothing (save in labeled bag).
- Cover open wounds with waterproof dressing.
- Shower using soap and water and wash hair.
- Dry with towel.
- Repeat radiation survey.
  - If activity is greater than two times background and there has been a significant drop in counts since the last survey, repeat shower (stop when additional intervention does not reduce activity more than 10%).
  - If activity is less than two times background, patient may dress (will need clean clothes) and leave decontamination area.
  - In mass casualty emergencies, a higher level of residual activity may be acceptable.

Do not abrade skin during decontamination; do not shave, since this can abrade skin and allow surface contamination to be internalized.

4. DECONTAMINATION OF UNSTABLE PATIENTS

Unstable patients will be assessed and treated in the Contamination Treatment Area before they are decontaminated. When decontaminating patients, the following steps should be taken in the order shown below:

- Remove clothing.
- Start by decontaminating open wounds: remove dressings, drape to control runoff, irrigate, dry, remove drape, then re-survey. Repeat as required until activity measures less than twice background, or there is no appreciable drop in activity with subsequent decontamination efforts. A reasonable goal is three times background. If significant contamination remains, cover with a bio-occlusive dressing and seek consultation. If contamination levels are high, debridement must be considered.
- Decontaminate orifices by irrigating.
- Decontaminate hair and intact skin. Hair should only be cut if difficult to decontaminate.
• Do not abrade skin by being too vigorous.

5. TIPS FOR HEALTH CARE PERSONNEL:

• Change outer gloves frequently to minimize spread of contamination.
• Save contaminated dressings in a bag; use a permanent marker to identify the site of the dressing removal, date, time and initials; measure activity right away to provide an early clue to internal contamination.
• Use 2x2 gauze or make-up pads to “pick up and roll” contaminated material away from open wounds.
• Use a 60 cc syringe with a 3-way valve to irrigate (other options include an Irrijet® or an irrigation tray containing bowl, syringe and normal saline); do not use any more force than you would for an uncontaminated wound.
• Do not remove eyebrows without significant cause since they grow back slowly, if at all.
• Put any fragments that are highly contaminated (or potentially emitting radiation) into a lead container (called ‘pigs’) that should be available from Nuclear Medicine or Radiation Oncology departments. A plastic liner will reduce radiation from beta emitters.
• Cover any open wounds with residual contamination three times background or higher with a waterproof dressing and label with marker; they can be managed later (i.e., debrided in operating room, if necessary).

References for Annex 5.4


ANNEX 5.5 TREATMENT OF PATIENTS FOR INTERNAL CONTAMINATION WITH RADIONUCLIDES

The following table provides a summary of the recommended treatment for specific radionuclides potentially used in radiological dispersal devices and encountered during nuclear power reactor emergencies. For many of these radionuclides, there is limited clinical experience in treating internal contamination. In general, treatment should be initiated as soon as possible after exposure. However, treatment may still be justified days after exposure depending on the dose and radionuclide. Currently there is no commercially available prediction tool that would provide medical personnel with guidance on the risks and benefits of treatment in a time-dependent manner.

<table>
<thead>
<tr>
<th>RADIONUCLIDE</th>
<th>TREATMENT</th>
<th>DOSE AND ADMINISTRATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cobalt Iridium/Plutonium Americium/Curium</td>
<td>Diethylenetriamine-pentaacetate (DTPA)</td>
<td>1g IV Ca-DTPA on day 1, followed on day 2 by 1 g IV Zn-DTPA - slow IV push or IV infusion over 30 min diluted in 100-250mL 5% dextrose in water. Nebulized inhalation is an alternate route.</td>
</tr>
<tr>
<td>Strontium/Radium</td>
<td>Barium sulphate or Sodium alginate or Ca-gluconate</td>
<td>300g PO single dose 5g PO b.i.d., then 1 g q.i.d. with water (Gaviscon) 2.5g IV infusion over 4 h (diluted in 500mL of 5% dextrose in water) daily up to six days</td>
</tr>
<tr>
<td>Iodine</td>
<td>Potassium Iodide</td>
<td>Age dependent dose; 130mg daily PO for adults</td>
</tr>
<tr>
<td>Cesium</td>
<td>Prussian Blue</td>
<td>1g t.i.d. PO</td>
</tr>
<tr>
<td>Polonium</td>
<td>Dimercaprol or Penicillamine</td>
<td>2.5mg/kg IM q4h for 2 d, then b.i.d. for 1 day, then daily for days 5-10 250mg PO daily between meals and at bedtime; may increase to 4-5g daily in divided doses</td>
</tr>
<tr>
<td>Uranium</td>
<td>Sodium bicarbonate</td>
<td>1-2mEq/kg slow IV infusion (diluted in 250mL 5% dextrose in water or 0.9% normal saline); administer therapy until pH is 8-9; continue 3 days</td>
</tr>
</tbody>
</table>

References for Annex 5.5


Background on the Special Access Programme

The SAP considers requests from practitioners for access to non-marketed drugs for treatment, diagnosis or prevention of serious or life-threatening conditions when conventional therapies have been considered and ruled out, have failed, are unsuitable, and/or unavailable. The regulatory authority supporting the programme is discretionary and a decision to authorize or deny a request is made on a case-by-case basis by taking into consideration the nature of the medical emergency, the availability of marketed alternatives and the information provided in support of the request regarding the use, safety and efficacy of the drug. This authority however, does not extend to covering the cost of drugs and does not take into consideration the cost of marketed alternatives. If access is granted, the physician agrees to report on the use of the drug including any adverse events encountered with such use, and must account for all quantities received to both the SAP and the manufacturer.

The SAP authorizes a manufacturer to sell a drug that cannot otherwise be sold or distributed in Canada. Drugs considered for release by the SAP include pharmaceutical, biologic, and radiopharmaceutical products.

The SAP does not authorize the use or administration of a drug. This authority falls within the practice of medicine, which is regulated at the provincial level. A SAP authorization does not constitute an opinion or statement that a drug is safe, efficacious or of high quality. The SAP does not conduct a comprehensive evaluation to ensure the validity of drug information or attestations of the manufacturer respecting safety, efficacy and quality. These are important factors for practitioners to consider when recommending the use of a drug and in making an appropriate risk/benefit decision in the best interests of the patient. The SAP strongly encourages practitioners treating individuals with drugs obtained through the SAP to seek informed consent before treatment.

Practitioners are encouraged to contact individual manufacturers to confirm the availability of a drug as well as to obtain the most up-to-date drug information such as prescribing information and other data supporting the use of the drug. In all cases, the manufacturer has the final word on whether the drug will be supplied. The manufacturer also has the right to impose certain restrictions or conditions on the release of the drug to ensure that it is used in accordance with the latest information available. For instance, they may restrict the amount of drug released, request further patient information, restrict the indications for which it is released, etc. Inquiries concerning the shipping, cost and/or payment should be directed to the manufacturer of the drug.

Please refer to the SAP guidance document for further information.
Instructions for Completing the Special Access Request Form

The request form consists of two pages containing five sections. Practitioners are required to complete all five sections of the form each time a request is made, including renewal requests. The five sections are as follows:

**SECTION A: PRACTITIONER AND SHIPPING INFORMATION**

**Practitioner’s Name:** First and last name of the requesting practitioner.

**Note:** Practitioner is defined as a person authorized by law of a province of Canada to treat patients with any drug listed or described in Schedule F of the Regulations as a drug substance intended for human use and requiring a prescription to be sold in Canada.

**Hospital or Clinic Name:** Full name of clinic or hospital where drug is to be sent- if applicable.

**Address:** Address of the practitioner’s office/clinic or hospital pharmacy where the drug is to be delivered, including the city, province and postal code.

**Contact Person:** Full name and position (e.g. Pharmacist, Nurse, Resident, etc.) of the person completing the form, if other than the requesting practitioner.

**Contact Tel. # /Fax#:** A telephone and fax number including an area code and extension (if applicable) where the practitioner or contact person can be reached if further information or follow-up is required.

**Send Drug c/o:** Check the box that applies to where the drug is to be sent: a hospital in-patient pharmacy, the practitioner’s office, a nuclear medicine department or blood bank.

**Note:** A drug cannot be sent to retail or out-patient pharmacy.

**Contact’s email address:** An email address for the contact person should they need to be reached if further information or follow-up is required. This is an optional field.

**Practitioner’s email address:** An email address for the requesting practitioner should they need to be reached if further information or follow-up is required. This is an optional field.

**SECTION B: DRUG AND MANUFACTURER INFORMATION**

**Trade Name/Other Name:** Full name of drug, including when possible, both trade and generic name or company designated code.

**Name of Manufacturer:** Full name of the manufacturer and location if applicable (i.e. Canadian office).

**Note:** For new drugs if the requesting practitioner has spoken to a representative at the company regarding their request, please provide a note indicating this including a name and number for the contact person.

**PO#:** An optional field that can be used by hospitals or other institutions to specify a purchase order number.

**Route of Administration/Dosage Form:** Check the boxes that apply, or specify “other” if applicable.
SECTION C: PATIENT INFORMATION

Initials: First, middle (if applicable) and last initials of the patient

Note: To ensure the patient's confidentiality, please do not indicate the patient's full name.

DOB: specify the date of birth in order of date, month, year order (i.e. DD/MM/YYYY).

Sex: Check off the applicable box for the specified patient- Male or Female.

Indication: Exact medical indication for which the drug is being requested.

New or Repeat Patient: Check the applicable box indicating whether this represents an initial or repeat request for the patient for the specified drug via the SAP.

Dosage and Duration: Prescribed dosage including planned duration of therapy.

Strength: Required strength or combination of strengths.

Quantity: Precise number of tabs, vials, etc. requested for each patient.

No Supply Needed -Authorization only: transfer of a supply of drug on hand from one patient to another (e.g. one patient has discontinued treatment). The requesting practitioner will be required to check off the box, indicating this is a “no supply needed” request, requiring authorization only. The amount being transferred will need to be specified in the quantity section. Consideration/authorization by the SAP and the manufacturer is required prior to starting treatment.

Total: Sum of the quantities for all patients Note: Specify the exact amount of drug requested (e.g. number of tabs, vials, units, etc.). Your request will be returned if the amount of drug required is not clearly stated; the SAP will not calculate quantity.

When will the drug be administered?: specify the date when administration/dispensing of the drug is scheduled/anticipated.

SECTION D: CLINICAL RATIONALE

QUESTION 1A) NEW PATIENTS:
Provide information about the patient(s)’s medical history, including the severity of their condition, prognosis as well as treatments considered, failed, unsuitable or unavailable to achieve an adequate response. Include a rationale indicating what about the requested drug makes it the best choice for your patient(s) (i.e. mechanism of action, dosage form, drug class)****

QUESTION 1B) REPEAT PATIENTS:
Provide information on your patient(s)’s condition since treatment was initiated, including a rationale for continued access. Note: this section should be updated each time a renewal is requested to ensure that the patient(s)’s current medical state is well described.

****In instances when a drug request is for more than 4 patients additional copies of the form should be filled out. All rationales should be patient specific. In such cases where additional pages are added, please number the pages appropriately.

QUESTION 2) REFERENCES:
Provide specific data/references with respect to the safety and efficacy of the product that support the requesting practitioner's decision to prescribe the drug for the specified indication. This can be in the form of medical literature, clinical protocols, investigator brochures etc. If copies of the reference(s) are appended to the request form, please check off the box. Otherwise provide a complete citation including journal/article titles, author(s), volume, issue, date and page information.

SECTION E: PRACTITIONER ATTESTATION

Section E consists of three attestations for the requesting practitioner to acknowledge and sign off on before requesting a drug through the SAP.

Practitioner’s Signature: Requesting practitioner’s signature

License #: Requesting practitioner’s licence # (i.e. license to practice medicine or dentistry as issued by a provincial licensing authority)

Date: Date when request was signed and submitted to the SAP.

Processing of Requests and Hours of Operation Information

Completed forms should be faxed to the SAP without an accompanying cover sheet. Telephone calls should be reserved for urgent requests requiring immediate attention.

A complete form does not guarantee that a request will be authorized and additional information may be required during the consideration process. Every effort is made to process requests within 24 hours of receipt. However, given the mandate of the Programme and the volume of requests received, the SAP adopts a triage system to ensure that requests for drugs for life-threatening conditions take precedence over less urgent requests. If a drug is new to the Programme, the total processing time may be extended, although every effort is made to contact the practitioner within 24 hours to discuss the process for handling new drugs.

After consideration of a request, authorization may be granted. The manufacturer is notified by fax. A Letter of Authorization is sent to the manufacturer and copied to the practitioner. Practitioners will be notified in the event that a request is denied.

The SAP operates 24 hours a day, 365 days a year. Regular business hours are weekdays from 8:30 am to 4:30 pm Eastern Standard Time (EST). Outside of regular business hours and during statutory holidays, an on-call officer is available. The on-call officer can be reached by calling the regular business line, (613)941-2108 and pressing 0. The officer will either answer directly or return the phone call within 20 minutes. Should an authorization be provided, practitioners will be required to submit a completed request form to the SAP, by fax, the following day.
SPECIAL ACCESS PROGRAMME
FORM A – PATIENT SPECIFIC REQUEST

SECTION A: PRACTITIONER INFORMATION

Practitioner’s Name:
Hospital or Clinic Name: (if applicable)
Address: (shipping address only)
City: Province: Postal Code:
Contact Person: (if other than practitioner)
Send Drug c/o:
In-patient Hospital Pharmacy □
Practitioner’s Office □
Nuclear Medicine □
Blood Bank □
Contact Telephone #:
Contact Fax #:
Contact’s Email Address: (optional)
Practitioner’s Email Address: (optional)

SECTION B: DRUG AND MANUFACTURER INFORMATION

Trade Name: Other Name:
Manufacturer: PO#:
Route of Administration: ORAL □ I.V. □ I.M. □ TOPICAL □ S.C. □
OTHER:
Dosage Form: TAB □ CAP □ LIQUID □ POWDER □ CREAM □ OINT. □ PATCH □
OTHER:

SECTION C: PATIENT INFORMATION

If you have supply of the drug on hand and would like to transfer it to another patient, thus requiring authorization only, please check here □ and complete the table below. Specify the amount being transferred in the quantity section.

<table>
<thead>
<tr>
<th>Patient Initials (e.g. A.B.C.)</th>
<th>DOB (DD/MM/YYYY)</th>
<th>Gender</th>
<th>Indication for Use of Drug</th>
<th>New or Repeat patient via the SAP for this drug?</th>
<th>Dosage and Duration (e.g. #mg bid x #days)</th>
<th>Strength (e.g. #mg)</th>
<th>Quantity (e.g. ## tabs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M □ F □</td>
<td>N □</td>
<td>□</td>
<td>N □</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>M □ F □</td>
<td>N □</td>
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<td>N □</td>
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<td>□</td>
<td>□</td>
</tr>
<tr>
<td>M □ F □</td>
<td>N □</td>
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</tr>
<tr>
<td>M □ F □</td>
<td>N □</td>
<td>□</td>
<td>N □</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>

Please specify the EXACT AMOUNT of drug requested (e.g. number of tabs, vials, units, etc.). The SAP will not calculate quantity.

Please specify when the drug will be administered/dispensed? (i.e. a date):
SECTION D: CLINICAL RATIONALE

1a. For *new* patients, provide specific information about your patient(s)’s medical history including conventional therapies considered, ruled out and/or failed or that are unsuitable and/or unavailable to achieve an adequate response. What specifically about this drug (e.g. mechanism of action, drug class, dosage form) makes it the best choice for your patient(s)? Please explain.

1b. For *repeat* patients, describe your patient(s)’s response to the drug relative to the initial treatment goal(s) and provide a rationale for requesting continued access.

2. Please provide **SPECIFIC** data, references and/or resources in your possession, with respect to the use, safety and efficacy that support your decision to prescribe this drug. For citations include, journal/article titles, author(s), volume, issue, date and page information. Check here if reference(s) is/are attached ☐

SECTION E: PRACTITIONER ATTESTATION

I, the practitioner, am accessing this non-marketed drug for use in the emergency treatment of a patient under my care in accordance with the *Food and Drug Regulations C.08.010*.

I, the practitioner, am aware that by accessing this drug through the SAP, the sale of the drug is exempt from all aspects of the *Food and Drugs Regulations* including those respecting the safety, efficacy and quality.

I, the practitioner, agree to provide a report on the results of the use of the drug including information on Adverse Drug Reactions and, on request, to account for quantities of the drug received.

Practitioner’s Signature:   
License #:   
Date:   

Special Access Programme  
Therapeutic Products Directorate  
c/o Health Canada  
AL 3105 A  
Tunney’s Pasture  
Ottawa, ON  
K1A 0K9  

FAX all requests to  
613-941-3194  
For urgent requests requiring immediate attention please follow up with a call to the SAP at: 613-941-2108.

**AUTHORIZATION ONLY VALID WITH SIGNATURE & SAP STAMP**  

website: www.hc-sc.gc.ca/dhp-mps/acces/drugs-drogues/index_e.html  
email: sapdrugs@hc-sc.gc.ca
ANNEX 5.7 PROCEDURES TO FOLLOW WHEN REQUESTING BIOASSAY MEASUREMENTS

The procedures below were developed by the Radiation Protection Bureau (RPB), Health Canada to facilitate the process for requesting bioassay measurements during a radiation emergency. These procedures are used by Health Canada’s bioassay laboratory but could be used other laboratories performing bioassay.

For more details about the procedures, please contact:

National Internal Radiation Assessment Section
Radiation Protection Bureau
Health Canada
613-954-6667

PERSONAL DATA REQUIRED

<table>
<thead>
<tr>
<th>Surname</th>
<th>First Name; Initials</th>
<th>Sex</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Age (y)</th>
<th>Weight (kg)</th>
<th>Height (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

EXPOSURE DATA REQUIRED

Date and Time of Potential Exposure

Year _______________ Month _______________ Day _______________ Time _______________

Description of exposure (including description of the exposure scenario and any available preliminary data (e.g., radionuclides involved, chemical forms of radionuclides, particle size distribution, activity measurements of nasal swabs or facial swipes)
FOR IN VITRO MEASUREMENT

24-Hour Urine Collection and Shipment
1. Empty bladder and record the time of the start of the 24-hour period;
2. In the following 24 hours, collect all voidings, up to and including the voiding at the end of the 24-hour period, into a 4 litre plastic collection container;
3. Wash hands thoroughly before voiding urine;
4. Collect urine directly into the collection container. Do not freeze;
5. It is essential that no radioactive contamination, other than that in the urine, is introduced into the collection container. Ensure, therefore, that dust from clothing or surroundings does not enter the container;
6. Provide the following information:
   Name:
   ID assigned by emergency staff (if available):
   Organization (if available):
   Telephone:
   Exposure Date:
   Start Sampling Date ___________________ Time _____________________
   Stop Sampling Date ___________________ Time _____________________
7. Ship the sample to the pre-arranged bioassay laboratory within 24-hours following collection.

Spot Urine Collection and Shipment
During a large-scale radiation emergency where a large number of people may be internally contaminated, it is often not practical to have 24-hour urine samples for measurement. Instead, spot samples can be collected for measurement (results from the measurement of spot samples can be normalized using the creatinine method or specific gravity method).

1. It is essential that no radioactive contamination, other than that in the urine, is introduced into the collection container. Ensure, therefore, that dust from clothing or surroundings does not enter the sample container;
2. Wash hands thoroughly before voiding urine;
3. Collect urine directly into the plastic cup provided. Do not freeze;
4. Provide the following information on container label:
   Name:
   ID assigned by emergency staff (if available):
   Organization (if available):
   Telephone:
   Exposure Date:
   Sampling Date ___________________ Time _____________________
5. Close container tightly, seal with tape and place in Ziploc Bag with absorbent sheet;
6. Ship the sample to the pre-arranged bioassay laboratory within 24-hours following collection.
Faecal Sample Collection and Shipment

1. Wash hands thoroughly before defecating;
2. Open one plastic container bag (reclosable plastic bag, 12” X 15”)
3. Defecate directly into the plastic bag, or insert the open plastic bag into a plastic container (Multipurpose specimen container, 1000 mL) before defecating into it;
4. Close plastic bag and place inside second plastic bag and close;
5. Place bagged sample into plastic container (Multipurpose specimen container, 1000 mL) and cover with lid;
6. Provide the following information:
   Name:
   ID assigned by emergency staff (if available):
   Organization (if available):
   Telephone:
   Exposure Date:
   Sampling Date ___________________   Time ______________________
7. If possible, freeze sample;
8. Use separate plastic bags and container for each collection;
9. It is essential that no radioactive contamination, other than that in the faeces, is introduced into the collection container. Ensure, therefore, that dust from clothing or surrounding does not enter the container;
10. Ship the sample to the pre-arranged bioassay laboratory within 24-hours following collection.

FOR IN VIVO MEASUREMENT

When whole-body or partial-body (lung, thyroid) measurements are required, the individual is required to visit the counting facility in person. Trained staff at the in vivo measurement facility will conduct the measurements.
ANNEX 5.8 PROCEDURES TO FOLLOW WHEN REQUESTING BIODOSIMETRY ASSESSMENT (DICENTRIC CHROMOSOME ASSAY)

Biodosimetry assessment is requested through the National Biological Dosimetry Response Plan (NBDRP) network (which may be activated by the Federal Nuclear Emergency Plan) or by directly contacting the Radiobiology Division at the Consumer and Clinical Radiation Protection Bureau, Health Canada.

Tel.: 613-941-7263
Cell.: 613-355-6028 (24/7)

At that time, details of the suspected over-exposure will be discussed and it will be decided whether biodosimetry will be warranted based on the exposure scenario. If samples need to be taken, a questionnaire and consent form will be sent to the requesting physician along with instructions on blood sampling and shipping (next page).
Instructions for Customer

PROCEDURES FOR BLOOD COLLECTION, PACKAGING AND SHIPPING, FOR CHROMOSOMAL ANALYSIS FOR SUSPECTED OVEREXPOSURE TO IONISING RADIATION

Analysis of chromosomal aberrations in human peripheral blood lymphocytes is the present day standard for the biological assessment of radiation exposure. It is used when a person’s physical dosimeter is absent or inoperative or when the reading of the physical dosimeter is missing or in dispute. To optimize the recovery of lymphocytes from the blood, it is very important that the blood be collected and shipped according to the protocol outlined below.

- Before the blood sample is taken, please notify Health Canada to allow us to be prepared for the arrival and pick up.
- Fill out the Questionnaire/consent form provided for each donor and send it by secure Fax to the Health, Radiobiology Division at Health Canada or with the blood shipment. If sent by Fax, notify the Radiobiology Division before to ensure that confidentiality will be respected.
- For each donor, all blood samples are to be collected into 1 x 4 mL lithium heparin tube, if not available, sodium heparin tubes are acceptable, + 1 x 4 mL EDTA tube. Gently rock the tubes for 1 minute to ensure proper mixing. Label the tubes unambiguously and add date and time of blood draw.
- As soon as possible following blood collection, ship the sample by courier using overnight air express so that the blood can be received the morning following sample collection. Contact the Radiobiology Division at Health Canada to confirm the shipment and provide us with the Waybill number. THIS IS IMPORTANT FOR TRACKING THE SAMPLE.
- For best results, blood must be received within 24 h of sampling.
- Package the blood samples carefully to prevent breakage of the tubes in transit. The blood temperature should be maintained ideally between 18°C and 24°C. Blood samples must not be frozen nor cold. One method for maintaining blood around room temperature is to surround the tubes with gel packs that are at room temperature for several hours or use Saftpak gel packs such as STP 315 or STP317 or STT-521-1000 (www.saftpak.com).
- For air transport, packaging and labelling should conform to the current International Air Transport Association (IATA) regulations. These require that blood samples be packed to conform to Packing Instructions 650 for biological substances, category B. Saf-T-Pak manufactures packaging meeting these requirements (STP320 boxes) (www.saftpak.com). Other packaging is acceptable but has to conform to the requirements stated below.
- If available, include a temperature recorder and a physical dosimeter in the inner package with the blood samples. (Those can be provided by Health Canada)
- Please include 3 paper or electronic copies of the Waybill, 3 copies of the Commercial Invoice and 3 copies of the Itemized List on the outside of the shipping box.
- Include the Questionnaire/consent of the blood donor and send it by secure Fax to the Head, Radiobiology Division at Health Canada or with the blood shipment. If sent by Fax, notify the Radiobiology Division before to ensure that the confidentiality will be respected.
PACKAGING:
• leak proof primary container (blood collection tube).
• the blood collection tube must be secure with parafilm or tape
• place the blood tubes in Saf-T-Pouch® Bubble Wrap slots.
• place bubble packaged tubes into STP-711 or Secura “T” Specimen bag.
• place STP-711 or Secura “T” Specimen bag into leak proof pressure vessel,
• secondary receptacle (STP-710 Tyvek bag).
• place absorbent material between the primary and the secondary receptacle
  (*One absorbent strip absorbs 100mL).
• surround the secondary container with about 10 gel packs at room temperature.
• if purchased must be marked with TC-125-1B (e.g. STP 320 packaging)
• if the shipper is making his own packaging, it must be a rigid outer packaging and a
  styrofoam box inside. The exterior must be marked with 125-1B.
• An itemized list of package contents must be placed between the secondary and outer
  packaging. (Example attached see page 4)

MARKING AND LABELLING ON OUTER PACKAGE FOR AIR TRANSPORT:
• name, address and telephone number of receiver and shipper
• name, address and telephone number of person responsible if other than shipper
• Biological substances, category B
• diamond shaped UN3373 label
• 2 orientation arrows placed on opposite sides of the package

DO NOT X-RAY, DO NOT FREEZE, RUSH labels

WAYBILL:
• in “Description”, enter only UN3373 Biological substances, category B (check the □DG box).

SHIPPING INFORMATION
Ship to:   Head, Radiobiology Division
          Health Canada
          Consumer and Clinical Radiation Protection Bureau
          775 Brookfield Road, PL 6303B
          Ottawa, ON   K1A 0K9
          CANADA

Emergency phone:   613-355-6028 (24/7)
Phone:           613-941-7263
Secure Fax:             613-952-7584
ITEMIZED LIST, BLOOD TRANSPORT

Date: __________________________

To whom it may concern:

Included are _______ x _______ mL vials of human blood to be used for research purposes.

The samples are “UN3373 Biological Substances, Category B” to be used for experiment and investigational purposes.

If there are any questions concerning these samples, please contact anyone of the following:

Person responsible name: __________________________
Phone number: __________________________

Thank you.

___________________________________________
(Signature)
QUESTIONNAIRE AND CONSENT FORM FOR THE CUSTOMER

Exposure Information for Chromosome Aberration Analysis

(TO BE FILLED OUT BY THE REQUESTOR)

I, _____________________ (Name), born _____________________ (dd/mm/yy) consent to giving a blood sample for the purpose of estimating chromosome aberrations induced by exposure to ionizing radiation.

___________________________________
Signature

Blood sample taken by: _____________________ Laboratory name: _____________________

Laboratory Address: ________________________________________________________________

Telephone #: _____________________ Fax: _____________________ Email: _____________________

Date and time blood sample taken: ________ (dd/mm/yy) Specify anticoagulant: ________

Exposure Data: Radiation Worker or Non-Radiation Worker

1. Date and time of overexposure: ____________________ (dd/mm/yy - time)

2. Place ____________________ Company: ____________________

3. Brief description of overexposure:

4. Whole body exposure   ☐ Partial body exposure   ☐ Internal contamination   ☐
Dose value: _____________ Part of body: _____________ Nuclide: _____________
Dose value: _____________ Dose value: _____________

How was this dose value obtained __________________________________________________________________________________________

5. Type of radiation:  x - ray   ☐   kV
γ   ☐   nuclide? _____________________
α   ☐   nuclide? _____________________
Neutrons   ☐   source? _____________________
Electrons   ☐   source? _____________________
PATIENT DATA:

1. Previous exposure through medical practice:
   - Radiation therapy  □  Date, Part of Body ________________________________
   - x-ray diagnoses   □  Date, Part of Body ________________________________
   - Nuclear medicine  □  Date, Part of Body ________________________________

2. Illness within the last 4 weeks before taking the blood sample: _________________________

3. Intake of medication: □
   - Name of medication: ____________  Dose: ____________  Duration: ____________

4. Smoker:  no □    yes □  number/day: ______________________________

5. Other diseases:  HIV □    Hepatitis □

Results of chromosomal analyses to be sent to:
   - Name: _______________________________________________________________________
   - Address: _____________________________________________________________________
   - Telephone #: __________________________________________________________________

To be completed by Health Canada

Sample coding: __________________________________________
CHAPTER 6 – MEDICAL FOLLOW-UP OF POTENTIALLY EXPOSED INDIVIDUALS

6.1 Medical Follow-up of Potentially Exposed Individuals.
It is expected that medical facilities will be overwhelmed during a radiation emergency. It will therefore be necessary to send away those who do not require urgent care, and to refer them for further follow-up, if appropriate. Follow-up may be necessary to provide psychological support, reassess the medical condition and treat delayed long-term health effects.

6.2 Follow-up for Psychological Support
A number of common reactions and psychological consequences following radiation emergencies have been identified from studies performed after major radiological accidents. Individuals often attribute current health problems to radiation, without knowing whether they were exposed to radiation, and disbelieve reported assessments of radiation exposure. They often live under the threat of possible delayed health effects; this manifests as fear and worry. Lifestyles often change resulting in elimination of normal activities (exercise, sport participation, school classes, etc.) and increased or decreased food consumption and substance abuse.

Individuals typically rely on different coping mechanisms that may include apathy, avoidance, depression, or denial. High levels of stress can result in physical, cognitive, and emotional symptoms. Symptoms seen in the early (minutes, hours, days) phase following a radiation emergency differ somewhat from those seen in the late (days, months, years) phase. Table 6.1 provides examples of the symptoms of stress that may be witnessed in the ED soon after an emergency. Treatment of early psychological effects should be focused on providing information and counseling to reduce the stress caused by the event, in order to minimize the long-term psychological effects. Table 6.2, on the other hand, shows some examples of the late effects of stress that could be witnessed during follow-up. Table 6.2 illustrates the need to put longer-term measures in place for potentially exposed individuals that will address the fear and worry caused by the event.
To help responders be better prepared to deal with the unique psychological consequences of mass casualty radiation emergencies, the US CDC has developed a web-based training tool called, *Psychological First Aid in Radiation Disasters* [2].

### 6.3 Follow-up for Medical Reassessment

Radiation exposed individuals who do not require emergency medical treatment or early intervention to treat radiation exposure, but who may have been exposed to clinically relevant levels of radiation, should be reassessed for signs of radiation health effects at a later date. The initial assessment of radiation exposure may need to be confirmed using additional tests. Patients may need serial blood counts to monitor the status of the hematopoietic system. If a registry is established (i.e., at a community reception centre), it could be used to notify people who may require follow-up.

### 6.4 Follow-up for Long-term Radiation Health Effects

#### 6.4.1 MEDICAL MONITORING

Medical monitoring of asymptomatic individuals aims at detecting pre-clinical disease, in order to delay or prevent development of clinical (symptomatic) disease. The decision to implement a medical monitoring program should be based on several factors, including a cost-benefit analysis. Some of the factors to be considered include the disease of interest, availability of

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### Table 6.1 Early symptoms of stress following an emergency (taken from METER [1])

<table>
<thead>
<tr>
<th>PHYSICAL</th>
<th>COGNITIVE</th>
<th>EMOTIONAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nausea</td>
<td>Confusion</td>
<td>Anxiety</td>
</tr>
<tr>
<td>Muscle Tremors</td>
<td>Difficulty making decisions</td>
<td>Anger</td>
</tr>
<tr>
<td>Sweating</td>
<td>Impaired thinking</td>
<td>Fear</td>
</tr>
<tr>
<td>Dizziness</td>
<td>Difficulty solving problems</td>
<td>Irritability</td>
</tr>
<tr>
<td>Chills</td>
<td>Memory loss</td>
<td>Guilt</td>
</tr>
<tr>
<td>Increased heart rate</td>
<td>Difficulty making calculations</td>
<td>Feeling overwhelmed</td>
</tr>
<tr>
<td>Increased blood pressure</td>
<td></td>
<td>Grief</td>
</tr>
<tr>
<td>Hyperventilation</td>
<td></td>
<td>Hopelessness</td>
</tr>
</tbody>
</table>

### Table 6.2 Long-term Effects of Stress (taken from METER [1])

<table>
<thead>
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<th>PHYSICAL</th>
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<tbody>
<tr>
<td>Fatigue</td>
<td>Decreased attention span</td>
<td>Feeling abandoned</td>
</tr>
<tr>
<td>Increased use of alcohol</td>
<td>Poor concentration</td>
<td>Resentment</td>
</tr>
<tr>
<td>Exaggerated startle</td>
<td>Memory problems</td>
<td>Feeling alienated</td>
</tr>
<tr>
<td>response</td>
<td></td>
<td>Withdrawal</td>
</tr>
<tr>
<td>Difficulty sleeping</td>
<td></td>
<td>Numbness</td>
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<td></td>
<td></td>
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screening tests for these diseases, and evidence that screening provides a clinical benefit. In general, radiation exposure by itself does not justify a medical monitoring program [3]. The long-term health effects sometimes considered for monitoring programs are described below.

**Tissue reactions**
As indicated in earlier text, high doses of radiation above a certain dose threshold can cause tissue reactions (also known as “deterministic effects”). These effects most commonly appear relatively early following exposure, but some effects, such as radiation-induced cataracts and radiation dermatitis, do not become clinically evident for several years. In the case of eye exposure, slit lamp ophthalmoscopy may be conducted periodically to screen for radiation-induced cataracts.

**Cancer and hereditary effects**
Radiation can induce cancer and hereditary effects (known as “stochastic effects”). Some tissues are more susceptible than others to radiation-induced cancer induction. In contrast to tissue reactions, cancer and hereditary effects may not have a threshold. The likelihood that radiation will cause cancer is proportional to the dose. At small doses, the risk of developing cancer is small; as the dose increases, the risk increases. Based on epidemiological studies, the increased risk of developing a fatal cancer due to radiation exposure has been estimated to be about 5.5% per Sv. In Canada, the probability of developing a fatal cancer (from all causes) during a lifetime is about 25% [4]. Therefore, a dose of 0.1 Sv (100 mSv) results in an increase risk of about 0.5%, increasing the probability of developing a fatal cancer from all causes to 25.5%. Radiation is considered to be a relatively weak carcinogen.

It is not possible to prove that an individual cancer was caused by past radiation exposure. At doses below about 0.1 Sv (100 mSv), it is difficult to detect a difference between exposed and unexposed populations because of the high background incidence of cancer. There is also a long latent period for the development of cancer and appearance of symptoms. For most cancers, the latent period can typically range from 7-30 years. This, however, depends on the person and on the organ involved. Leukemia and thyroid cancers have the shortest latent periods, typically between 2-5 years. Cancers that appear a few months after exposure can be assumed to have been developing before the exposure [3].

In animals, radiation exposure of germ cells can result in health effects in the next generation. Such hereditary effects have not been observed in humans. No hereditary effects were observed in the offspring of in utero exposed individuals following the atomic bombings of Hiroshima and Nagasaki.

**In utero effects**
Both tissue reactions and cancer effects can occur following fetal exposure to radiation [5]. Radiation exposure during the early stage of pregnancy (0-2 weeks) may result in an “all or none” effect (spontaneous abortion), with a threshold dose above 100 mGy. Exposure during the 3-25 week period may result in developmental effects, such as small head size, reduced IQ, and mental retardation. The threshold for severe mental retardation and small head size is above 1000 mGy. Exposure after 25 weeks does not result in any of these effects.
Fetal exposure to radiation may increase the risk of a future childhood or adult cancer. The data on risk of childhood cancer vary. Some studies show no increase in risk, but one large study shows an increased risk in childhood leukemia following a dose of 10 mGy received when mothers had pelvic X-ray examinations during pregnancy [6].

**6.4.2 EPIDEMIOLOGICAL STUDIES**

Follow-up of a population group may be used to achieve a better understanding of the relationship between the exposure and the health outcomes. In this case, healthcare records of affected population groups could be used for epidemiological studies. Epidemiological study can also help identify groups at greater risk and other risk factors, such as smoking, that may influence the outcome. Epidemiological assessment of populations exposed to radiation is challenging. There is no unique disease caused by radiation, a large population size is required in order to be able to detect a difference in risk between exposed and unexposed populations, there is a long latent period, and there may be many confounding factors. Some of the considerations when planning an epidemiological assessment include study design, choice of population and health outcome (i.e., mortality), data sources and quality, and privacy and confidentiality.

Health planners should consider the possibility that an epidemiological assessment will be desired after the emergency has passed. Research ethics approval will be required to conduct such a study. If a registry is to be set up during a radiation emergency, it could be used to identify the potential study population.

**References**


CHAPTER 7 – VULNERABLE POPULATIONS

A vulnerable population is any group that is more susceptible to radiation exposure than the average population or that requires special consideration during a radiation emergency [1]. These groups include children, pregnant women, the elderly, people with physical or mental disabilities, ethnic groups with cultural or linguistic barriers, Aboriginal groups, and pet owners. For each group, special considerations may be needed in the planning, response, and recovery phases of the emergency.

7.1 Children

The group evoking greatest concern during a radiation emergency is children. Physiological, anatomical, developmental, and psychological differences make children more vulnerable than adults to the physical and psychological stresses of disasters.

A quantitative evaluation of internal contamination during a radiation emergency has shown that inhalation hazards to children, compared to adults, are largely offset by lower breathing rates. The sole exception is the inhalation of radioiodine, especially iodine-131(131I), which has a greater impact on the smaller thyroid glands of children [2-3]. With regard to ingestion of radioactive contamination, children were found to be at greater risk than adults. Since children drink large quantities of milk, they are particularly vulnerable to the grass → cow → milk ingestion pathway and to contamination by iodine-131 (\(^{131}\)I) and strontium-90 (\(^{90}\)Sr) [3].

Children are more susceptible to the long-term effects of radiation [4]. The cells of growing children are dividing more rapidly and are more prone to mutations that could lead to cancer later in life. For a child, there is a longer period during which a potential cancer could be expressed. In the regions affected by the Chernobyl nuclear power plant accident, 4000 excess cases of thyroid cancer had been detected in children by 2006, resulting mainly from ingestion of contaminated milk.

Children are also more vulnerable to the psychological aspects of any disaster situation. They may lack the cognitive ability to process what is happening around them and may overreact to adult expressions of anxiety or exaggerated media reports. Children can become especially anxious when separated from their parents or care-givers and at the time of the emergency they may be at daycare, in school, or in transit.

The involvement of children in emergency response exercises could greatly augment their capacity to deal with the real emergency [5]. During an exercise, children would be dealing with adults who are relaxed, calm, and likely have a sense of humour. The involvement of children in exercises would also provide excellent training for the responders themselves. As a final benefit, children are fast learners and can act as vectors of communication to their families and peers. For example, they might be able to explain the difference between radiation exposure and radioactive contamination.
One of the earliest countermeasures to be invoked in a radiation emergency may be an evacuation order and this could lead to separation of family members who are not all together at the time of the emergency. The first concern of parents will be for their children, so the highest priority must be given to re-uniting families. Parents should know in advance of any emergency where their children are likely to be taken [5]. Identification and tracking of children who are not with their guardians will be necessary.

If a large population is known or suspected to be contaminated, people will be instructed to proceed to a monitoring and decontamination centre, such as a CRC (refer to Chapter 4). Families should be kept together and any attempt to separate them (e.g., one family member is contaminated and the others are not) should be avoided. The separation anxiety of children outweighs the slight risk of cross-contamination of family members. Long queues may form at contamination monitoring sites, so families with children should be moved to the front of the queue.

Operators of portal monitors should be aware of a possible complication if members of a contaminated family approach the monitor together [6]. A contaminated member may trip the monitor from a distance while an uncontaminated member is passing through the monitor. Additional scans with hand-held monitors can help sort out any ambiguities. If decontamination by showering is required, children should be accompanied by an adult whom they know and trust. Children are more prone to hypothermia than adults, so they must be protected from the cold. Emergency reception centres will have to be stocked with protective clothing in sizes to fit children rather than just one-size-fits-all for adults [7].

If the emergency situation involves traumatic injuries, a child may be taken to a hospital before reunification with parents. If the child is known or suspected to have been exposed to radioactive iodine, thyroid blocking with potassium iodide should be started immediately. The risks are small and the benefits are large if therapy is begun within a few hours after exposure.

Since children are particularly vulnerable to Post Traumatic Stress Disorder, psychological counselling is important during the recovery phase. Although a child might appear unaffected at the time, symptoms of psychosomatic illnesses or sleep disorders could become evident at a later date.

7.2 Pregnant Women

Pregnant women are the vulnerable group of greatest concern, after children. Pregnant women themselves have no increased sensitivity to radiation, but the fetus does. The developing fetus is most sensitive to radiation during the early fetal period when the major organs are beginning to differentiate, somewhat less in the second trimester, and least in the third trimester of pregnancy. Among atomic bomb survivors who were exposed to high doses of radiation in utero, smaller-than-average head size and increased incidence of mental retardation were observed. Research has shown that the risk of childhood leukemia is increased following a dose of 10 mGy received when mothers had pelvic X-ray examinations during pregnancy.
Along with families with children, pregnant women should be moved to the front of the queue in a population monitoring operation. This will quickly provide reassurance to pregnant women who are not contaminated.

Perhaps the greatest impact on pregnant women will be the fear that their unborn babies may have been affected by radiation-induced health effects. There was a 60% increase in clinical abortions in some European countries following the Chernobyl accident, even though the risks were negligible and there were no reported increases in unfavourable pregnancy outcomes. All pregnant women affected by a nuclear emergency should receive counselling from competent medical authorities before making any decisions about pregnancy termination.

7.3 The Elderly and Persons with Physical or Mental Disabilities

These populations are treated as a single group in this chapter because they are often characterized by a lack of physical mobility and, in many cases, a lack of auditory, visual, or cognitive ability to understand or to follow instructions from authorities. Over half a million Canadians suffer from Alzheimer’s disease or other forms of dementia, amounting to 1 in 11 persons over 60 years of age. In addition to the disabled, many elders live in nursing homes or specialized care facilities. Many others live alone, often without support of family members or the community. Elderly people may ignore evacuation orders because they do not appreciate the danger, they have no place to go, they cannot afford to go, or there is no one to assist them.

Provisions for evacuation from institutions such as long-term care facilities and hospitals should be an essential component of emergency planning in any community. A recent publication dealing with the evacuation of in-patients and the disabled during the radiation emergency in Fukushima, Japan, describes the consequences of not having such plans in place [8]. These plans should consider the risks to these populations from the evacuation itself, and include the ongoing provision of essential medications and treatments. It should be noted that in most foreseeable cases, the radiation risks do not justify an evacuation. If possible, such as in a small community, records should be maintained on elderly and disabled persons living at home, especially those who may require assistance with evacuation or transportation to a community reception centre.

During the actual emergency response, care should be taken to ensure that the elderly and the disabled are not overlooked. They may need to be warned of the dangers and they may need assistance with evacuation or transportation to a community reception centre. For persons in institutionalized care, it may be preferable to conduct on-site monitoring with hand-held meters if contamination of the facility is suspected.

There are no indications that the elderly are more at risk than the general population from the long-term effects of radiation. In fact, the latency period for radiation-induced cancers may well extend beyond the lifespan of many seniors. However, it is important to note that many elderly as well as others may be suffering from illnesses that leave them immune-compromised. One of the major effects of high-level exposure to radiation is suppression of the immune system. Special precautions will be required to protect these people from opportunistic infections.
Seniors often exhibit a high degree of resiliency in dealing with the aftermath of disasters, perhaps due to a lifetime of experience in overcoming hardships and solving problems. This resiliency may make them valuable assets in serving as volunteers during the response phase or as counsellors during the recovery phase [9].

7.4 Ethnic Groups with Linguistic or Cultural Barriers
For many new Canadians and landed immigrants, their first language is neither English nor French. These individuals may have difficulty in understanding official information about the emergency situation or in following oral instructions.

Emergency planners should work together with community organizations representing distinct ethnic or religious groups. The specific needs of each local group should be assessed and written materials in the appropriate languages should be prepared in advance according to need.

It would be desirable to have interpreters present at reception centres, but this may not always be feasible. An alternative would be to provide signs with pictures and visual symbols to direct those who may have difficulty understanding English or French. With regard to personal decontamination, some people may have strict religious or cultural taboos against partially or totally disrobing in a public place. Special consideration may be required, such as providing separate decontamination lines for men and women.

7.5 Aboriginal Communities
Aboriginal communities are particularly vulnerable to the effects of a radiation emergency with widespread environmental contamination. These individuals may live closer to the land and often obtain a large portion of their food supply from the land. One historic example is the increased radiation exposure of some residents of Northern Canada from radioactive contamination of the lichen → caribou → human food chain during the nuclear weapons testing of the 1960s. Food restrictions may be a problem, often exacerbated by poverty, lower literacy skills, and a general mistrust of government authorities in Aboriginal communities.

Much progress has been achieved through the Northern Contaminants Program of Aboriginal Affairs and Northern Development Canada (AANDC). In this program, scientists have learned to work in partnership with Aboriginal communities to study the effects of environmental contaminants. Educational materials have been prepared in aboriginal languages. Emergency planners can benefit from this extensive body of knowledge.

7.6 Owners of Pets or Farm Animals
While not strictly speaking a vulnerable population, pet and animal owners may put themselves at greater risk—they have been known to defy evacuation orders and have re-entered contaminated zones in order to rescue their animals, and prevent them from perishing from starvation or neglect.
A different kind of problem arises if people show up at a decontamination facility with family pets. Dogs and cats that were outdoors at the time of the nuclear event may have radioactive contamination on their fur. Emergency planners need to consider how pets would be decontaminated. They need to be decontaminated, not so much because of a health risk to themselves, but because of the risk of spreading the contamination to their owners. As pet owners will attest, putting a dog or cat through a shower is not generally a good choice. The best solution is to bathe the animal, preferably by the owner.

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(3) Tracy, B. Would children be adequately protected by existing intervention levels during a radionuclear emergency. Radiation Protection Dosimetry. 142(1); 40-5, 2010
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GLOSSARY

(Italicized terms within a definition are defined elsewhere in the glossary)

**Absorbed dose**: The quantity of radiation energy imparted to a unit mass of matter such as tissue. The SI unit of absorbed dose is the gray, equal to one joule per kilogram.

**Activity**: The rate of decay of a radioactive material expressed as the number of atoms breaking down, or disintegrating, per unit time. The SI unit of activity is the becquerel (Bq) equal to one disintegration per second.

**Acute radiation syndrome (ARS)**: An illness which begins following an acute, high dose of penetrating radiation received over a short period of time by most or all of the body. ARS is characterized by nausea, vomiting, diarrhea, and drop in the number of circulating blood cells.

**Alpha (α) radiation**: A form of ionizing radiation, consisting of tightly bound particles containing two protons (positively charged) and two neutrons. Alpha radiation originates in the nuclei of very heavy unstable atoms. This is the least penetrating form of ionizing radiation and can be stopped by a sheet of paper or by a layer of skin.

**Annual limit of intake (ALI)**: The activity, expressed in Becquerel (Bq), of a radionuclide, taken into the body over a year, that will result in an effective dose of 20 mSv to a person 18 years of age or older, during a 50-year period following intake of the radionuclide into the body.

**Atomic number**: The number of protons in the nucleus of an atom. Each element has a unique atomic number, e.g., one for hydrogen, 8 for oxygen, 92 for uranium.

**Atom**: The smallest particle of an element that retains the properties of that element. An atom consists of a positively charged nucleus (containing protons and neutrons) surrounded by negatively charged electrons.

**Background radiation**: Ionizing radiation from natural sources, such as radionuclides in soil or air, and from cosmic radiation originating in outer space. Our total exposure to background radiation is about 2 to 3 mSv (millisieverts) per year.

**Becquerel (Bq)**: The SI unit of activity equal to one disintegration per second.

**Beta (β) radiation**: A form of ionizing radiation consisting of positively or negatively charged electrons. Beta radiation originates in the unstable nuclei of atoms having an imbalance in the numbers of protons and neutrons. It is a moderately penetrating form of ionizing radiation and can be stopped by a few millimetres of aluminum.

**Beta burns**: Erythema and dry (or wet) desquamation caused by energetic beta particles with high enough specific activity left on the skin surface for a sufficient length of time.

**Bioassay**: A laboratory process for assessing internal radioactive contamination by measuring the radioactivity in excreted urine or feces.

**Cataract**: A disease of the eye in which the lens becomes opaque and vision is impaired or lost. Cataracts can result from exposure of the eye to ionizing radiation from acute or chronic exposure.
**Chelating agent**: A compound that binds to a specific element or group of elements and enhances their elimination from critical organs or the body.

**Cloudshine**: External radiation exposure resulting from immersion in or proximity to a cloud of radioactive material.

**Cosmic radiation**: A form of natural radiation originating in outer space. A small fraction of cosmic radiation penetrates the earth’s atmosphere and contributes to background radiation at the earth’s surface.

**Curie (Ci)**: An historical unit of activity, originally defined as the activity of one gram of pure radium-226. The curie is now defined as $3.7 \times 10^{10}$ Becquerels.

**Cytokine**: Small proteins released by cells that affect cell-cell interactions and communications, and the behaviour of cells. Cytokines include Granulocyte Colony Stimulating Factor (G-CSF) used to treat acute radiation syndrome.

**Decorporating agent**: A compound which helps remove internally deposited radionuclides from the body after an intake. Decorporating agents act by reducing radionuclide translocation from site of entry, stimulating excretion, diluting the radionuclide, or chelating it.

**Desquamation**: A process of exfoliation, or peeling, of the skin.

**Deterministic effect**: A health effect of radiation that occurs above a threshold dose. Generally, the severity of the effect increases with dose. In current literature, the term has been replaced by tissue effect.

**Deuterium**: A stable isotope of hydrogen, with one proton and one neutron in the nucleus. The heavy water used as a moderator in CANDU reactors has a molecule consisting of two deuterium atoms and one oxygen atom.

**Dicentric chromosome assay**: A technique used in biological dosimetry to estimate the radiation dose that the person received. The number of abnormal chromosomes in peripheral blood lymphocytes is proportional to the dose in a person who has been exposed to radiation.

**Deoxyribose nucleic acid (DNA)**: A molecular substance inside all living cells that contains the complete genetic code of the organism.

**Dose**: See absorbed dose, equivalent dose, and effective dose.

**Dosimetry**: Assessment, by measurement or calculation, of radiation dose.

**Effective dose**: The sum of the weighted equivalent doses to all tissues and organs of the body. The unit of effective dose is the sievert (Sv), which has the same dimensions (joules/kilogram) as the gray.

**Effective half-life**: The time in which the activity of the radionuclide within an organ decreases by one-half as a result of radioactive decay and biological elimination.
Electromagnetic waves: Oscillations in electric and magnetic fields which are propagated through space or through a vacuum. Electromagnetic waves cover a complete spectrum of wavelengths, beginning with very long radio waves, progressing to shorter microwaves, then to infrared, visible and ultraviolet light, finally to the very short waves of X-rays and gamma rays.

Electronic personal dosimeter (EPD): A device worn by a person working in a radiation field that can be read at any time to give the cumulative radiation dose to the person. Most EPDs can also alarm when predefined dose or dose rate levels are reached.

Electron: An elementary particle with a negative electrical charge and a mass 1/1837 that of the proton. Electrons surround the nucleus of an atom.

Element: A chemical substance that cannot be broken down into simpler substances. There are about 92 naturally-occurring elements ranging from hydrogen (the lightest) to uranium (the heaviest).

Epidemiology: The study of incidence, distribution and control of diseases in the population.

Epilation: Loss of hair, a short term effect of high level radiation.

Equivalent dose: The absorbed dose multiplied by a radiation weighting factor, equal to one for beta and gamma radiation, 20 for alpha radiation, etc. The equivalent dose is a predictor of long-term radiation effects, such as cancer. The SI unit of equivalent dose is the sievert (Sv), which has the same dimensions as the gray (joules per kilogram).

Erythema: Reddening of the skin.

External radioactive contamination: A radioactive material on the surface of the skin or clothing.

Fibrosis: A thickening and scarring of connective tissue, usually as a result of injury or illness.

First responder: A member of an emergency service who is first on the scene of an emergency (e.g., fire, police, EMS).

Fissile (radionuclide): A radionuclide capable of capturing a neutron and undergoing nuclear fission. The most common fissile radionuclides are uranium-233, uranium-235, and plutonium-239.

Fission: The splitting of a heavy nucleus into two, accompanied by the release of a large amount of energy and generally one or more neutrons. It may occur spontaneously but it is usually due to a man-made reaction in which a neutron strikes a nucleus, releasing other neutrons which may set off a chain reaction.

Gamma (γ) radiation: A form of ionizing radiation originating in the nuclei of unstable atoms and consisting of very high frequency or very short wavelength electromagnetic waves. This is the most penetrating form of radiation normally encountered and requires up to 10 cm of lead to significantly reduce its intensity.

Geiger-Müller detector: A radiation detection device consisting of a gas-filled chamber with a central wire. When an ionizing particle enters the chamber, it produces a cascade of electron-ion pairs. The negatively charged electrons are attracted toward the positively charged anode wire and the resulting pulse of electric current is amplified and detected by an external circuit.
Genetic effects: Effects of radiation on genes.

Gray (Gy): The SI unit of absorbed dose, equal to one joule per kilogram. For convenience the gray can be divided into milligrays (mGy) or micrograys (μGy).

Groundshine: External radiation exposure resulting from radioactive material deposited on the ground.

Health physicist: A radiation specialist with expertise in the measurement and calculation of radiation doses and in proper safety procedures for working with radioactivity.

Hemorrhage: Uncontrolled loss of blood from an organ or tissue.

Hereditary effects: Effects of radiation on future generations, as a result of the irradiation of the germ (reproductive) cells of the current generation.

Improvised nuclear device (IND): A makeshift nuclear weapon using illegally obtained fissile material such as uranium-233, uranium-235, and plutonium-239.

Industrial Radiography: The industrial use of a high energy radioactive source to test for leaks or flaws in welds and metal seams.

Ionizing radiation: A form of radiation, usually of high energy or frequency, having the ability to strip electrons from atoms and thus to create ionization.

Irradiation: The process of exposing any tissue or material to ionizing radiation.

Isotope: Refers to differing forms of an element where the atoms have the same number of protons but differing numbers of neutrons. For example, uranium has isotopes uranium-235 and uranium-238.

Joule: The SI unit of energy, equal to a force of one newton (0.22 lbs) acting through a distance of one metre. A 100-watt light bulb consumes 100 joules of electrical energy per second.

Leukemia: Cancer of the body’s blood-forming tissue including the bone marrow and lymphatic system.

Linear-No-Threshold hypothesis (LNT): The doctrine that all exposures to radiation, however small, carry some element of risk and that this risk is directly proportional to the radiation dose.

Lymphoma: Cancer of the lymphatic system (includes lymph nodes, spleen, thymus gland and bone marrow).

Mass number: The total number of protons and neutrons in an atom. For example, the nucleus of oxygen-16 has 8 protons and 8 neutrons for a total of 16 elementary particles.

Medical receiver: Hospital-based emergency department personnel who receive victims from a mass casualty emergency occurring at a location other than the hospital.

Molecule: A particle consisting of two or more atoms bound together by electrical forces. A molecule is the smallest particle of a chemical compound that retains the properties of that compound.
Necrosis: The death of cells or tissues due to disease or injury (e.g., from radiation or lack of oxygen).

Neutron: An uncharged elementary particle found in the nucleus of an atom. Neutrons are released from the nucleus during nuclear fission and constitute another form of ionizing radiation.

Neutropenia: Decrease in the number of neutrophils, a type of white blood cell.

Non-ionizing radiation: A form of radiation with a lower frequency or energy than ionizing radiation, and not capable of stripping electrons from atoms. Non-ionizing radiation includes radio waves, microwaves, and infrared and visible light.

Nuclear emergency: An event which has led or could lead to the uncontrolled release of radioactive materials from a source such as a nuclear reactor or nuclear device, and which requires urgent action to reduce the threat to public health and safety, property and/or the environment.

Nuclear Energy Worker: A worker who may be exposed to radioactivity or a radiation field during the normal course of work and whose exposure to radiation must be monitored.

Nuclear facility: Any facility that is a component of the nuclear fuel cycle, including a uranium mine, a uranium purification or conversion plant, a nuclear reactor, and a facility for the storage or disposal of nuclear waste.

Nuclear medicine: The branch of medicine that utilizes radioisotopes for diagnosis and treatment.

Nuclear reactor: An apparatus or structure in which a nuclear fission chain reaction occurs under controlled conditions so that the heat yielded may be harnessed to produce electricity or the neutron beam utilised to produce radioisotopes.

Nucleus: The dense centre core of an atom, containing protons and neutrons.

Nuclide: A single nuclear species characterized by a certain number of protons and neutrons in its nucleus. An example of a nuclide is oxygen-16, with 8 protons and 8 neutrons in its nucleus.

Optically stimulated luminescence (OSL) device: A personal dosimeter containing a material which, when stimulated by green light, gives off a quantity of blue light proportional to the amount of radiation received by the device.

Personal alarming dosimeters (PADs): Direct-reading dosimeters that display instantaneous dose rate and accumulated dose at any point in time.

Particle accelerator: An engineering construction that accelerates charged particles to very high energies for research purposes or for cancer treatment in certain hospitals.

Photomultiplier: A device which amplifies a very weak light signal by producing a cascade of electrons through a series of charged plates. It is used to measure the light output from a scintillator detector or a TLD or OSL device.
Plutonium: An artificial element with atomic number 94. One of its isotopes, plutonium-239, is highly fissionable and is used in nuclear weapons.

Prodrome: An early symptom indicating the onset of a disease.

Prophylaxis: Preventive treatment against disease, for example, the administration of stable iodine to block the uptake of radioactive iodine by the thyroid gland.

Proton: A positively charged elementary particle found in the nucleus of an atom. Each element has a characteristic number of protons in its nucleus (atomic number).

Radiation: Broadly speaking, radiation is the transmission of energy through space.

Radiation Control Zones: Zoning the emergency scene into hot, warm and cold zones will help reduce radiation exposures to first responders and aid in controlling the spread of radioactive contamination. A “hot zone” refers to the area where radiation exposure is the highest; a “cold zone” refers to the area where radiation is at background level; and, the “warm zone” refers to the area in transition.

Radiation pneumonitis: Inflammation of the lungs following high doses of radiation, also known as radiation pneumonia.

Radiation weighting factor: A factor which accounts for the varying carcinogenic potential of different types of radiation, e.g., one for beta and gamma radiation, 20 for alpha radiation.

Radioactive material: Any substance containing atoms that undergo radioactive decay and emit ionizing radiation.

Radioactivity: The process by which the nuclei of certain substances emit ionizing radiation. The term is sometimes used interchangeably with activity.

Radiography: The industrial use of a high energy radioactive source to test for leaks or flaws in welds and metal seams.

Radioisotope: A radioactive isotope of an element. The term often refers loosely to any radionuclide that is used in medicine or industry.

Radiological dispersal device (RDD): An improvised device (or process) that disperses radioactive material, thereby intentionally exposing people and the environment to radiation. An RDD employing an explosive is commonly referred to as a “dirty bomb”.

Radiological emergency: An event which has led or could lead to the uncontrolled release of radioactive material, or exposure to uncontrolled sources of radiation, and which requires urgent action to reduce the threat to public health and safety, property and/or the environment.

Radiological exposure devices (RED): A high-intensity radiation source deliberately placed in a public area to expose people in close proximity, for example an industrial radiography source placed under the seat of a bus.

Radiological half-life: The time required for the activity of a radioactive material to decrease to one half of its initial value. After two half-lives, the activity will decrease to one quarter, after three half-lives, to one eighth, etc.

Radionuclide: A radioactive nuclide or nuclear species. The term is sometimes confused with radioisotope, although the latter strictly refers only to a different radionuclide of the same element.
Radiotherapy: The use of beams of radiation or radioisotopes for the treatment of disease such as cancer.

Radon: A natural radioactive gas formed by the decay of uranium in the soil. It becomes an inhalation hazard when it diffuses into closed spaces such as basements or underground mines.

Scintillation detector: A material such as zinc sulphide or sodium iodide that gives off a flash of light when traversed by ionizing radiation.

Sievert (Sv): The SI unit of equivalent dose and effective dose, which has the same dimensions as the gray (joules per kilogram). For convenience the sievert can be divided into millisievers (mSv) or microsievers (μSv).

Stochastic effect: A health effect of radiation, such as cancer – the probability of occurrence increases with radiation dose. It is also referred to as a probabilistic effect, or cancer and hereditary effects.

Survey meter: A hand held device that gives an immediate reading of the strength of a radiation field.

Syndrome: A group of symptoms or pathological signs that together are characteristic of a specific disorder or disease.

International System of Units (SI): From the French, Système internationale d’unités. The modern form of the metric system based on the metre, the kilogram, and the second, and adopted by most countries.

Tissue weighting factor: The factor by which the equivalent dose in a tissue or organ is weighted to represent the relative contribution of that tissue or organ to the total detriment (i.e., cancers and hereditary effects) resulting from uniform irradiation of the body.

Thermo-luminescent dosimeter (TLD): A personal dosimeter containing a material which, when heated, gives off a quantity of light proportional to the amount of radiation received by the device.

Tritium: A radioactive isotope of hydrogen, with one proton and two neutrons in its nucleus. Tritium has a half-life of 12.3 years and is one of the chief emissions from heavy water moderated reactors such as the Canada Deuterium Uranium (CANDU) reactor.

Uranium: The heaviest of the naturally occurring elements, with an atomic number of 92. Although all its isotopes are radioactive, two of them (U-238 and U-235) have half-lives long enough to have survived since the formation of the solar system (about 5 billion years ago).

Whole body counter (full body counter): A radiation measurement chamber containing one or more high efficiency gamma radiation detectors and usually housed within a lead-lined chamber to reduce background radiation. The counter is used to measure internal radioactive contamination in the human body.

X-ray: A form of ionizing radiation consisting of very high frequency or short wavelength electromagnetic waves and originating from re-arrangement of atomic electrons. X-rays are usually but not always of lower energy than gamma rays.
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
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<tbody>
<tr>
<td>ABO</td>
<td>A, B, O blood type alleles</td>
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<tr>
<td>AF</td>
<td>Acentric fragment</td>
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<tr>
<td>ALC</td>
<td>Absolute Lymphocyte Count</td>
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<tr>
<td>ANC</td>
<td>Absolute Neutrophil Count</td>
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<tr>
<td>ALI</td>
<td>Annual Limit of Intake</td>
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<tr>
<td>ARS</td>
<td>Acute Radiation Syndrome</td>
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<tr>
<td>Bq</td>
<td>Becquerel</td>
</tr>
<tr>
<td>CBC</td>
<td>Complete Blood Count</td>
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<tr>
<td>CBRN</td>
<td>Chemical, Biological, Radiological, Nuclear</td>
</tr>
<tr>
<td>CD4+</td>
<td>Cluster of differentiation 4 (glycoprotein on surface of immune cells)</td>
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<tr>
<td>CDC</td>
<td>Centers for Disease Control and Prevention (USA)</td>
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<tr>
<td>CDG</td>
<td>Clinical Decision Guide</td>
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<tr>
<td>CMV</td>
<td>Cytomegalovirus</td>
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<tr>
<td>CNSC</td>
<td>Canadian Nuclear Safety Commission</td>
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<tr>
<td>CPM</td>
<td>Counts per minute</td>
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<td>CPS</td>
<td>Counts per second</td>
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<tr>
<td>CRC</td>
<td>Community Reception Centre</td>
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<tr>
<td>CRS</td>
<td>Cutaneous Radiation Syndrome</td>
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<tr>
<td>CT</td>
<td>Computerized tomography</td>
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<tr>
<td>CTAS</td>
<td>Canadian Emergency Department Triage and Acuity Scale</td>
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<tr>
<td>DCA</td>
<td>Dicentric chromosome assay</td>
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<tr>
<td>DNA</td>
<td>Deoxyribose Nucleic Acid</td>
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<tr>
<td>DTPA</td>
<td>Diethylene triamine pentaacetic acid</td>
</tr>
<tr>
<td>ED</td>
<td>Emergency Department</td>
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<tr>
<td>EMS</td>
<td>Emergency Medical Services</td>
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<tr>
<td>EPD</td>
<td>Electronic Personal Dosimeter</td>
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<tr>
<td>ER</td>
<td>Emergency Room</td>
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<tr>
<td>FERP</td>
<td>Federal Emergency Response Plan</td>
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<tr>
<td>FNEP</td>
<td>Federal Nuclear Emergency Plan</td>
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<tr>
<td>Acronym</td>
<td>Full Form</td>
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<tr>
<td>G-CSF</td>
<td>Granulocyte-Colony Stimulating Factor</td>
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<tr>
<td>GI</td>
<td>Gastrointestinal</td>
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<tr>
<td>GM-CSF</td>
<td>Granulocyte-Macrophage Colony Stimulating Factor</td>
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<tr>
<td>GVHD</td>
<td>Graft vs Host Disease</td>
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<tr>
<td>Gy</td>
<td>gray</td>
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<tr>
<td>HAZMAT</td>
<td>HAZardous MATerials</td>
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<tr>
<td>HLA</td>
<td>Human leukocyte antigen</td>
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<tr>
<td>HSV</td>
<td>Herpes Simplex Virus</td>
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<tr>
<td>IAEA</td>
<td>International Atomic Energy Agency</td>
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<tr>
<td>ICRP</td>
<td>International Commission on Radiological Protection</td>
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<tr>
<td>IgG</td>
<td>Immunoglobulin G</td>
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<tr>
<td>IND</td>
<td>Improvised Nuclear Device</td>
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<tr>
<td>ISO</td>
<td>International Standards Organization</td>
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<tr>
<td>KI</td>
<td>Potassium iodide</td>
</tr>
<tr>
<td>LD&lt;sub&gt;50/30&lt;/sub&gt;</td>
<td>Lethal Dose to 50% of a population in 30 days</td>
</tr>
<tr>
<td>LNT</td>
<td>Linear-No-Threshold hypothesis</td>
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<tr>
<td>LRI</td>
<td>Local Radiation Injury</td>
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<tr>
<td>METREPOL</td>
<td>Medical Treatment Protocols for Radiation Accident Victims</td>
</tr>
<tr>
<td>MSC</td>
<td>Mesenchymal stem cell</td>
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<tr>
<td>NBDRP</td>
<td>National Biological Dosimetry Response Plan</td>
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<tr>
<td>NCRC</td>
<td>National Calibration Reference Centre</td>
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<tr>
<td>NCRP</td>
<td>National Council on Radiation Protection &amp; Measurements (USA)</td>
</tr>
<tr>
<td>OSL</td>
<td>Optically Stimulated Luminescence</td>
</tr>
<tr>
<td>PAD</td>
<td>Personal Alarming Dosimeter</td>
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<tr>
<td>PPE</td>
<td>Personal Protective Equipment</td>
</tr>
<tr>
<td>RDD</td>
<td>Radiological Dispersal Device</td>
</tr>
</tbody>
</table>
REAC/TS  Radiation Emergency Assistance Center and Training Site
RED  Radiological Exposure Device
REMPAN  Radiation Emergency Medical Preparedness and Assistance Network
SI  Système international d’unités (International System of Units)
Sv  sievert
TLD  Thermo-Luminescent Dosimeter
VSV  Varicella-zoster virus
WHO  World Health Organization
5-HT3  5-hydroxytryptophan
\( \alpha \)  Alpha radiation
\( \beta \)  Beta radiation
\( \gamma \)  Gamma radiation
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