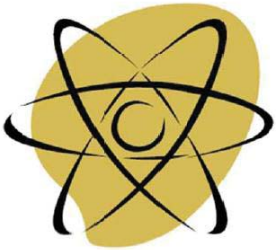
# Field Guide for Health and Safety Officers
# Radiological Incidents

## Part I - Operational Guidance
## &
## Part II - Background Information

*June 2014*



New York City Department of Health and Mental Hygiene with the NYC Securing the Cities Radiation Response and Recovery Committee and assistance from Domestic Nuclear Defense Operations and Lawrence Livermore National Laboratory. This project was supported by funding from the Urban Areas Security Initiative of the Department of Homeland Security.

NYC Health

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# Introduction to the Field Guide

In the event of a large-scale radiological or nuclear event it is likely that many NYC and other agencies will participate in response efforts. While overall radiation safety and health decisions will be made by the Command Element, the Citywide Incident Management System (CIMS) requires each agency to be responsible for ensuring the health and safety of its own workers. The Command Element and responding agencies will be supported by subject matter experts from advisory groups including the Radiological Advisory Committee (RAC) and/or the multiagency Health and Safety Workgroup convened to develop the incident health and safety plan (HASP) according to CIMS Annex D. This Field Guide is intended to provide guidance to Health and Safety Officers (HSOs) concerning radiological hazards and the recommendations to control potential exposures.

Radiation and radioactivity pose unique challenges and risks that are subject to local, State, and Federal regulations, including dose limits, requirements for posting radiological areas, and specifications on the use of radiation dosimetry. There is a minimum level of qualifications and/or experience that the HSO at the scene of a radiological emergency must possess to ensure staff is adequately protected and that regulatory compliance is achieved.

## Overview of Field Guide

This Field Guide consists of two major parts:

- Part I: Operational Guidance
- Part II: Background Information

**Part I: Operational Guidance**

Part I contains easy-to-use tables, charts, checklists, forms, and other tools that may be of immediate use during field operations. Part I also includes standardized forms that can be used without modification (if desired) to track radiation dosimeter use, record radiation instrument quality assurance checks, document radiation surveys, and so forth. All of the forms presented in Part I of this Field Guide were adapted from standardized materials developed by either the Federal Radiological Monitoring and Assessment Center (FRMAC) or by the Conference of Radiation Control Program Directors (CRCPD). Using standardized forms will help ensure that all agencies collect similar data and record it consistently and will facilitate data-sharing (particularly with radiological survey data) during and after the emergency response.

The other information, guidance, and tools found in Part I are either taken directly or adapted from other sources whenever possible. These sources include the National Council on Radiation Protection and Measurements (NCRP), the CRCPD, the New York City Radiological Response and Recovery Plan (RRRP), the International Atomic Energy

Agency, papers that have appeared in the scientific literature, and other sources of similar authority. The intent of Part I of this Field Guide is not to dictate specific work practices or procedures but, rather, to provide the HSO with a suite of forms, concise information, checklists, and other materials that have been vetted by reputable organizations and that can be used (with or without adaptation) to assist the HSO. Part I ***does not*** contain explanatory information about these materials – this information is found in Part II.

**Part II: Background Information**
Part II of this Field Guide is a primer that contains additional information to help the HSO, who is typically not a practicing radiation safety professional, to better understand the fundamentals of radiation science, radiation safety, and radiation safety work practices. Part II is intended to help the HSO to understand the principles behind the materials presented in Part I and to help answer the basic questions that might arise during the conduct of operations in a radiological area. The materials in Part II were developed, reviewed, and refined by radiation safety professionals from Brookhaven National Laboratory, Lawrence Livermore National Laboratory, the Nevada National Security Site, a variety of NYC agencies, and consultants.

## How to use this document

The HSO who is using this document ***during*** a radiological emergency will likely focus on Part I of this document. Several sections begin with a summary of the regulatory requirement and/or policy issues pertinent to that section (e.g. regulations regarding radiation dosimetry) and summarize the HSO's responsibilities in that particular area. All sections include tables of useful information, checklists, model procedures, and other information that can be used as-is or with minor modifications. An example of how an HSO might use Part I of this document is provided below.

The HSO who is ***not*** typically involved in a radiological incident response might wish to begin with reading Part II of this document to gain a better understanding of the basic principles and practices of radiation safety. This will help to provide a familiarity with the document itself, as well as to help build an understanding of the conditions that might be encountered during a radiological emergency response. This fundamental knowledge may not be directly applicable to field operations, but it provides a knowledge base that can help the HSO to plan effectively for a radiological emergency.

Example use of this document: *A group of responders is preparing to enter into a potentially contaminated area that is known to have radiation dose rates of up to 5 mR/hr and localized "hot spots" that reach 200 mR/hr.*

- Referring to Part I, Section 2.1 the HSO finds that entering an area with a dose rate of 5 mR/hr does not call for dosimetry, but that since there is the possibility of a worker exposure exceeding 500 mrem from working near hot spots it might be prudent to issue dosimetry to workers entering the Hot Zone. Also found in Sections 2.2, 4.2, 5.2 and 6.1 are lists of the HSO's responsibilities, including the

responsibility to ensure that workers are issued proper dosimetry, that they are trained in its proper use, and that they are reminded to check their self-indicating dosimetry regularly (if they are issued such dosimetry). Finally, the HSO will find the appropriate forms on which to log issuing dosimeters to personnel as well as to record the radiation exposure for these personnel.

- In Section 3, the HSO will find guidance on selecting the appropriate radiation survey instruments, guidance to help interpret the instrument readings, and forms on which to record radiation instrument quality control checks and radiation survey data in a standardized format.

- Section 4 helps the HSO to select appropriate Personal Protective Equipment (PPE) for personnel who enter the radiologically controlled area and it provides model procedures for donning and doffing PPE.

- In Section 5 the HSO will find guidance on how to work with responders to maintain radiation exposure As Low As Reasonably Achievable (ALARA), including formulas for calculating radiological stay time and radiation dose limits.

- Section 6 contains contamination control methods, including how to prioritize radiological versus medical concerns for contaminated injured personnel and the HSO will also find numerous suggestions for decontaminating personnel and equipment in this section.

- Section 7 contains generally accepted radiological work practices that may be relevant to the work being performed.

- Section 8 contains additional record-keeping requirements.

This is one hypothetical scenario that gives an example of how an HSO might choose to use this document – in reality each HSO is likely to use it in a manner that best suits the situation, the HSO's understanding of radiation safety, and the HSO's approach to emergency response in general.

# 1. General Information

**Table 1.1: Radiation quantities, units, and their uses**

| Measurement | Units reported | Most important information to record | Used for |
|---|---|---|---|
| **Radiation dose rate** | µR/hr, mR/hr, R/hr (rem or rad) | • Location,<br>• time,<br>• dose rate | • Determining risk to public and workers,<br>• Setting boundaries,<br>• Evacuation time and route<br>• Possible use in dose reconstruction and compensation claims |
| **SI Radiation dose rate** | µSv/hr, mSv/hr (Sieverts) | • Same as above | • Same as above; 100 rem = 1 Sv |
| **Radiation dose** | mR, R (rem or rad) | • Worker's name,<br>• date and time,<br>• dose | • Health records,<br>• Dose records,<br>• Dose reconstruction and compensation claims |
| **SI Radiation dose** | mGy Gy (Gray) | • Same as above | • Same as above; 100 rad = 1 Gr |
| **Contamination** | CPM, DPM | • Location,<br>• time,<br>• instrument reading,<br>• nuclide(s) and counting efficiency,<br>• person's name (if personal survey) | • Evacuation time and route<br>• Release of people, equipment, and areas for unrestricted use,<br>• Possible use in dose reconstruction and compensation claims<br>• Possible use in determining need for medical countermeasures (when surveying people) |
| **Internal radioactivity (from CRC or hospital)** | µCi | • Person's name<br>• nuclide(s)<br>• amount of activity<br>• mode of uptake (ingestion, inhalation, injection, etc.) | • Determine need for administering medical countermeasures<br>• Dose assessment / reconstruction and compensation |
| **Airborne radioactivity** | DAC, µCi/ml, pCi/ml | • location<br>• time<br>• nuclide(s)<br>• concentration | • PPE (respiratory protection)<br>• Evacuation time and route<br>• Dose assessment / reconstruction and compensation |

**Table 1.2: Activity of radioactive sources and its significance**

| Activity | Significance | Actions |
|---|---|---|
| microCurie | Not a significant health risk | Control as radioactive material |
| milliCurie | May be a minor health risk<br>Can cause skin burns if held in hand | Control as radioactive materials<br>Do not handle directly, use tongs |
| Curie | May be a health risk | Do not handle directly, use tongs |
| 1 < x <10 Curies | May be a health risk | Do not approach closely<br>Do not handle sources<br>Establish boundary at 2 – 10 mR/hr |
| 10s of Curies | May be a significant health risk | Do not approach without radiation dose and dose-rate monitoring equipment<br>Establish boundary at 2 mR/hr |

**Adapted from table 3.6 in NCRP Report 161**

## 1.1 Radiological HSO Qualifications

The scene of a radiological emergency will likely contain a variety of hazards, including the presence of radiation and radioactive contamination. Accordingly, an HSO at such a site must be fully qualified and, in addition, must also have some level of experience and training in radiation safety. Thus, the HSO at the scene of a radiological emergency must meet the following qualifications:

1. Minimum of 2 years in a job with safety operational or leadership responsibilities
2. Experience, training, and proficiency with radiation safety
    a. Qualification as a Radiation Safety Technician (or higher) in accordance with the requirements of ANSI/ANS Standard 3.1 (Selection, Qualification, and Training of Personnel for Nuclear Power Plants) **OR**
    b. Qualified to take the Registration Examination for the National Registry of Radiation Protection Technologists (NRRPT) **OR**
    c. Have earned at least a high school diploma or equivalent **AND**
    d. Through experience or training, have an understanding of the following areas:
        i. Types and properties of alpha, beta, and gamma radiation
        ii. Radiation units (e.g. rad, rem, Sieverts, Curie) and their significance
        iii. Biological effects of radiation exposure
        iv. Radiation detection and monitoring instruments, their proper use, and their proper selection
        v. Radiation dosimetry, its proper use, and regulatory requirements
        vi. Radiation safety practices (e.g. time, distance, shielding, ALARA, proper use of PPE, etc.)
        vii. Regulatory dose limits in emergency and non-emergency situations

## 1.2 Rules of thumb

**From NCRP Report 161, CRCPD, and Health Physics and Radiological Health Handbook**

- In explosions outdoors most airborne radioactivity settles to the ground within 10 minutes (CRCPD)
- Removing outer clothing may remove up to 90% of external contamination (NCRP 161)
- After 7 half-lives about 1% of the original radioactivity remains
- After 10 half-lives about 0.1% or the original radioactivity remains
    - If 1 Ci of Tc-$99^m$ (half-life = 6 hours) is spilled then
        - After 60 hours there will be 1 mCi of activity remaining
        - After 120 hours there will be 1 µCi of activity remaining
- Radiation dose rate from nuclear fallout drops by a factor of 10 for every factor of 7 increase in time
    - After 7 hours dose rates drop by a factor of 10 e.g., if at time = 0, exposure rate is100 R/hr, after 7 hours it is 10 R/hr
    - After 49 hours (2 days) dose rates drop by a factor of 100 e.g., if at time = 0, exposure rate is100 R/hr, after 49 hours it is 1 R/hr

- After 2 weeks (14 days) dose rates drop by a factor of 1000 e.g., if at time = 0, exposure rate is100 R/hr, after 14 days it is 0.1 R/hr

## 1.3 Simple (and necessary) calculations

- ***Effect of distance on radiation dose rate***
  - Radiation dose rate drops off with the inverse square of distance
    - Doubling the distance reduces dose rate by a factor of 4
    - Tripling the distance reduces dose rate by a factor of 9
    - Increasing distance by a factor of 10 reduces dose rate by a factor of 100
    - Inverse square Law: $I_1/I_2 = d^2_2/d^2_1$

  Radiation dose rate rises with the inverse square of distance as you approach a source

| Distance Decreased To _% of Original | Exposure Rate Increases By Factor of… |
|---|---|
| 50% | 4 |
| 25% | 16 |
| 10% | 100 |
| 5% | 400 |

- ***Calculating radiation dose rate*** from a radioactive source when you know the nuclide and the activity of the source
  - Dose rate at 1 meter = nuclide-specific gamma constant x activity of source
  - **Example:** the gamma constant for Co-60 = 1.14 so the radiation dose rate at a distance of 1 meter from a 1000 Ci Co-60 source = 1.14 x 1000 = **1140 R/hr**
    - Dose rate 2 meters away = 1140 / 4 = 285 R/hr
    - Dose rate 10 meters away = 1140 / 100 = 11.4 R/hr
    - Dose rate 1 foot away (1/3 of 1 meter; approximately 10x higher) = 1140 x 10 = 11,400 R/hr

- ***Converting CPM to DPM*** when the counting efficiency of the detector for the nuclide being monitored is known
  - DPM = CPM / counting efficiency
  - **Example**: a GM "pancake" probe has a counting efficiency of about 40% for Sr-90, so a reading of 10,000 CPM corresponds to 10,000 / 0.40 = 25,000 DPM

## 1.4 Nuclide summary table

**Table 1.3: Properties of nuclides likely to be used in a radiological terrorist attack**

| Nuclide | Radiation | Primary hazards | PPE |
|---|---|---|---|
| **Co-60** | Gamma | • External gamma radiation,<br>• Skin contamination | • No PPE provides protection against gamma radiation<br>• Cover skin (e.g. Tyvek, bunker gear, Level C or D PPE) to protect against skin contamination<br>• Respiratory protection (if airborne) |
| **Se-75** | Gamma | | |
| **Cs-137** | Gamma | | |
| **Ir-192** | Gamma | | |
| **I-131** | Beta, gamma | • Volatile<br>• Absorbs readily through skin<br>• Dose to thyroid | • Level C or D PPE to protect against skin contamination<br>• Potassium iodide (in the event of direct contact or uptake) |
| **Sr-90** | Beta | • Dose to bone from internal Sr-90<br>• Radiation (x-rays) from beta radiation passing through shielding | • Level C or D PPE to protect against skin contamination<br>• Respiratory protection (if airborne) |
| **Ra-226** | Alpha, gamma | • Inhalation<br>• Ingestion<br>• Injection<br>• Absorption via wounds | • Respiratory protection (if airborne)<br>• Cover open cuts, scrapes, and wounds<br>• Level D or Level C PPE to protect against skin contamination |
| **Pu-239** | Alpha | | |
| **Am-241** | Alpha, gamma | | |
| **Cf-252** | Alpha, neutron | | |

## 1.5 Short summary of radiation-induced health effects

**Table 1.4: Summary of radiation-induced health effects**

| Radiation dose (rem) | Expected health effects | Outcome |
|---|---|---|
| **< 1** | • No acute effect<br>• Possible very low additional cancer risk (< 0.1%) | No observable increase in cancer risk in the population |
| **1 – 10** | • No acute effects<br>• Possible low additional cancer risk (< 1%) | Possible observable increase in cancer risk in the population if > 100,000 people are exposed |
| **10 – 100** | • Bone marrow depression (and drop in blood cell counts) may occur<br>• Nausea and vomiting are possible towards the upper end of this range<br>• Additional cancer risk ~5-10% | Probable observable increase in cancer risk if a few hundred people are exposed |
| **> 100** | • Radiation sickness, bone marrow depression<br>• Risk of death increases significantly above ~ 400 rem<br>• Risk of cancer increases significantly | Observable increase in cancer risk |

**Adapted from Table 3.3 of NCRP Report 161**

# 2. Radiation dosimetry

Radiation dosimetry is the process of measuring a person's external exposure to ionizing radiation and is accomplished with a monitoring device that an employee wears while working in a radiation area. Two (2) common types of monitoring devices that some NYC agencies utilize are the Personal Monitoring Badge (such as thermoluminescent Luxel or Instadose dosimeters.) and the Personal Electronic Dosimeter (PED) (such as the Thermo RadEye PRD).

Personal Monitoring Badge

These are lightweight passive detectors that are clipped on to the worker's shirt or coat (similar to an ID badge). Badges typically need to be sent back to the manufacturer for processing. Some can be read using a computer using commercial software and an account with the manufacturer/vendor.

Personal Electronic Dosimeter (PED)

Battery-powered self-reading radiation detectors provide results of exposure (dose or dose rate) in real-time. They also can be programed to alarm at elevated exposure levels to warn workers. The Command Element and the RAC will review and if need be reestablish alarm levels for a site. PEDs need to be zeroed prior to initial use at a radiological emergency site; however, if the current reading is recorded prior to entering the site, it can be compared to the final reading. The recorded difference would suffice as the dose for the period of exposure. PEDs are not considered "dosimeters of record" because an impartial third party vendor is not performing the readout.

Group Personal Monitoring

When a large number of agency workers that don't have radiation dosimeters are involved in activities within a radiation area the Incident Commander, in agreement with the RAC, may assign one or two dosimetry badges and PEDs. The personnel must be conducting similar activities in the same area and are not likely to receive doses above 100 mrem during the entire work-period.

## 2.1 Regulatory requirements

Under licensing circumstances radiation dosimeters are required by Article 175.03 of the NYC Health Code for:

1. Adults likely to receive a dose in excess of 10% of regulatory dose limits
    a. Radiation dose limits for radiation workers are:
        i. 5000 mrem to the whole body
        ii. 15,000 mrem to the lens of the eye
        iii. 50,000 mrem to the skin, to any internal organ, or to the extremities
    b. The radiation dose limit to those who are not radiation workers is 100 mrem to the whole body

2. Minors and declared pregnant radiation workers likely to receive a dose in excess of 10% of regulatory dose limits
3. Any individuals entering a High Radiation Area or a Very High Radiation Area
    a. A High Radiation Area is defined as an accessible area in which a major portion of the whole body can receive a radiation dose of 100 mrem in one hour
    b. A Very High Radiation Area is defined as an accessible area in which a major portion of the whole body can receive a radiation dose of 500 rad in one hour (500 rad to the whole body can be fatal).

## 2.2 HSO Responsibilities

1. Check with the Command Element or site Radiological Health and Safety Officer (RHSO)[1] to determine if there are any radiological areas at the site that require radiation dosimetry for workers entering the areas.
2. Ensure your agency personnel entering identified radiological areas are equipped with appropriate (as specified in the site-specific Health and Safety Plan (HASP)) and calibrated dosimetry devices (calibration must be within the previous 12 months).
3. Complete a Dosimetry Issue Log Form 2.1 (see section 2.4) and Record of Assigned External Dosimetry Badges Form 2.2 (see section 2.5) for each person assigned a badge and PED (forms 2.1 and 2.2 respectively).
4. Ensure personnel issued dosimetry devices are trained in proper wearing and use. See RHSO if your staff require training.
5. Remind personnel to periodically check their self-indicating PED to ensure it is still operating and to immediately exit area if device alarms.
6. Collect dosimetry results when appropriate (e.g. self-indicating PEDs or badges that are read on-site) from personnel exiting radiological areas.
7. Record return date, time and reading device on the attached Dosimetry Issue Log Form 2.1 in mrem, mrad or mR as appropriate for the dosimetry.
8. Provide original dosimetry log to RHSO on a daily basis and maintain a copy in your agency records.
9. Send dosimetry badges back to manufacturer for analysis as per frequency specified in site-specific HASP.
10. Provide copy of exposure results to RHSO and notify your agency staff in writing of their exposure levels.
11. Maintain records of personnel issued dosimeters (see Forms 2.1 and 2.2 below) and the radiation dose received.

[1] Sometimes referred to as Radiation Control Officer (RCO) or simply Radiation Safety Officer (RSO).

## 2.3 Recommended alarm settings for alarming dosimeters

**From NCRP Report 161, NCRP Commentary 19, and RRRP**

**Table 2.1**

| Alarm Point[1] | Alarm Type[2] | Usage |
|---|---|---|
| **Dose Rate (Normal Operations)** | | |
| **0.002 R/hr (2 mR/hr)** | Silenceable Intermittent | • Alerts responder to the presence of radiation above a level that could reasonably be expected from natural or legitimate causes.<br>• Identifies the Hot Zone boundary. |
| **1 R/hr (1,000 mR/hr)** | Non-silencing, Intermittent | Alerts user to the presence of a radiological Hot Spot. |
| **Dose Rate (Emergency Response Operations)** | | |
| **10 R/hr** | Silenceable Intermittent | Alerts user to an area where responder action should be restricted to only the most-critical, time-sensitive activities, such as the preservation of life. Identifies the Dangerous Radiation Zone (NCRP) boundary. |
| **100 R/hr** | Non-silencing, Intermittent | Victims who are in this area for more than a ***few hours*** may not survive their exposure. |
| **Total Dose** | | |
| **4 R or rem** | Silenceable Continuous | Administrative limit: Responder should request authorization from IC to continue activities. IC should consider changing out responder if replacements are available. Other methods should be considered to reduce responder dose (e.g., different approach vector, reduction of stay times, etc.). This administrative limit will help ensure that responders do not exceed Occupational Safety and Health Administration (OSHA) regulatory limit without considered action. |
| **50 R or rem** | Non-silencing Continuous | Responder should leave the area. In extreme life-saving situations, responder can continue if aware of the radiation risks and no alternative rescue method exists. |

[1]A dose or dose-rate-level alarm point of 80% can be used as an administrative level to notify a user that a predetermined set point is about to be reached.
[2]Alarm type: Silenceable indicates that users can acknowledge (silence) the alarm even if they remain in the area. Non-silencing indicates that the alarm will continue to sound while the user is in the specified dose rate.

## 2.4 Dosimeter issue log

For any self-indicating dosimeter (e.g. Rados, PRD, etc.) or for any permanent dosimeter that can be read on-site (e.g. Landauer InLight, Mirion InstaDose)

| Name | Individual ID number | Dosimeter type / ID number | Dosimeter calibration date | Date/Time Issued | Date/Time Returned | Initial Reading (mR) | Return Reading (mR) |
|---|---|---|---|---|---|---|---|
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**Source: FRMAC *Radiological Emergency Response Health and Safety Manual***

**Record maintenance:** Turn in original to Site Safety Officer daily, maintain copy in agency records. Records are to be maintained indefinitely unless otherwise authorized by DOHMH Office of Radiological Health.
**Dosimeter type**: note type of dosimeter (e.g. PRD, Rados, InstaDose, InLight, etc.)

**Form 2.1**

## 2.5 Record of Assigned External Dosimeters

**To be used for dosimeters that cannot be read on-site (e.g. Luxel, TLD, film badge)**

Date: _____ Location: _____

| Name | Dosimeter Badge | Electronic Dosimeter | Task(s) |
|---|---|---|---|
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Comments: _____

_____

_____

Radionuclides of concern: _____

Airborne Hazard ○ Y ○ N

Contamination Description: _____

_____

_____

Bioassays Required: _____

_____

**Source: Adapted from FRMAC *Radiological Emergency Response Health and Safety Manual***

**Form 2.2**

# 3. Radiation instruments and their use

## 3.1 HSO Responsibilities

1. Ensure radiation survey instruments are calibrated and operable
2. Conduct or supervise and document periodic radiation survey instrument checks daily, prior to use, or other periodicity as appropriate (e.g. battery check, response check)
3. Ensure personnel entering radiologically controlled areas are provided with appropriate radiation survey instruments
4. Ensure personnel issued radiation survey instruments are properly trained
5. Collect radiation survey maps and data forms and transfer to Incident Commander, Radiological Advisory Committee, and/or others as appropriate

## 3.2 Selecting radiation instruments

**Table 3.1: A guide to selecting appropriate radiation instruments**

| Survey type | Instrument type | Example instrument | Record results in |
|---|---|---|---|
| **Contamination** | Radiation meter with:<br>1. "Pancake" GM probe,<br>2. Alpha contam. probe,<br>3. Beta contam. probe,<br>4. Sodium iodide probe | Ludlum 2241-3 with:<br>1. Ludlum 44-9<br>2. Ludlum 43-5<br>3. Ludlum 44-142<br>4. Ludlum 44-1, 44-2 | CPM |
| **Radiation** | 1. Radiation meter with:<br>a. Energy-compensated GM<br>b. Sodium iodide<br>2. Ion chamber<br>3. MicroR meter | 1. Ludlum 2241-3 with:<br>a. Ludlum 133-7, Radeye G<br>b. Ludlum 44-2, PRD<br>2. Ludlum Model 9<br>3. Bicron MicroR meter | µR/hr<br>mR/hr<br>R/hr |
| **Nuclide ID** | Radio-Isotope Identifier (RIID) | 1. Thermo Identifinder<br>2. Canberra Inspector<br>3. ICS-4000<br>4. Exploranium | Nuclide (e.g. Cs-137) |

**Source: Adapted from Table 5.2 of NCRP Report 161**

**Table 3.2: Assessment of instrumentation for use in the aftermath of nuclear terrorism**

| Mission | Alarming Dosimeters & PERDs | Non-alarming PERDs | Survey Meter | PRD detection | Contamination monitors | Dosimeters | Aerial system |
|---|---|---|---|---|---|---|---|
| **Hot Zone activities** (use instruments that can function in exposure rates up to 10 R/hr) | | | | | | | |
| Worker dose assessment | ○ | ○ | — | — | — | ● | — |
| Worker safety for Hot Zone missions | ● | ○ | ○ Type II Only | — | — | — | — |
| Survey of Hot Zone | ● | — | ● Type II Only | — | — | — | ● |
| Establishing evacuation routes | ● | — | ● Type II Only | — | — | — | ● |
| **Activities outside of Hot Zone** (use instruments that can function in exposure rates up to 0.01 R/hr) | | | | | | | |
| Worker dose assessment | ○ | ○ | — | — | — | ● | — |
| Worker safety outside Hot Zone | ● | ○ | ○ | ○ | ○ | — | — |
| Locating Hot Zone boundary | ● | — | ● | ○ | ○ | — | ● |
| Monitoring medical care locations | ● | — | ● | ○ | ● | — | — |
| Monitoring at shelters (radiation levels) | ○ | — | ● | ○ | ● | — | — |
| External contamination detection (personnel) | ○ | — | ○ | ○ | ● | — | — |
| Internal contamination detection (personnel) | — | — | ○ | ○ | ○ | — | — |
| Equipment and facility contamination monitoring | ○ | — | ○ | ○ | ● | — | ○ |

**Legend:** ● Useful ○ Marginal — Not Useful

**Type II meters measure high levels of radiation (up to 10 R/hr or more). Type I meters are low level devices.**

**Table 3.3: Radiation instrument suitability for detecting various radionuclides**
**Adapted from IAEA TECDOC 1162**

| Nuclide | GM | PRD | RadEye G | Ion Chamber | MicroR meter | Identi Finder | Ultra Radiac | Ludlum 44-2 | Ludlum 43-5 |
|---|---|---|---|---|---|---|---|---|---|
| Co-60 | | | | | | | | | |
| Cs-137 | | | | | | | | | |
| Ir-192 | | | | | | | | | |
| Sr-90 | | | | | | | | | |
| I-131 | | | | | | | | | |
| Ra-226 | | | | | | | | | |
| Pu-238 | | | | | | | | | |
| Am-241 | | | | | | | | | |

**Adapted from IAEA TECDOC 1162**
**Green = recommended for all levels of activity**
**Yellow = recommended for higher levels of activity (mCi and higher)**
**Red = not recommended or unable to detect**

## 3.3 Radiation instrument readings and their significance

**Table 3.4: Significance of radiation dose-rate readings**

| Radiation dose-rate readings | | |
|---|---|---|
| **Dose rate** | **Significance** | **Actions** |
| **2 – 10 mR/hr** | 2 mR/hr is the regulatory limit for radiation dose rate in an uncontrolled area | • Evacuate public if practicable<br>• Establish control boundary<br>• Preferred Hot Zone boundary (RRRP) |
| **5 mR/hr** | Regulations require posting as Radiation Area | Entry requires wearing dosimetry |
| **100 mR/hr** | Regulations require posting as a High Radiation Area | • Entry requires double dosimeters (including 1 self-indicating dosimeter)<br>• Non-emergency turn-back limit |
| **10 R/hr** | Radiation workers will exceed annual dose limit (5 rem) in 30 minutes | Turn-back limit except for grave emergency or life-saving |
| **100 R/hr** | May develop radiation sickness with 1 hour exposure | • Turn-back limit except for life-saving<br>• Minimize time in these areas |
| **1000 R/hr** | • **May develop radiation sickness with 5-6 minute exposure**<br>• Will reach potentially life-threatening dose in 30 minutes<br>• Will receive lethal dose in 1 hour or less | **Do not enter area** |

**Source: Adapted from Table 3.1, NCRP Report 161 Volume 1**

**Table 3.5: Significance of radiation count-rate readings**

| Radiation count-rate readings | | |
|---|---|---|
| **Contamination (dpm/100 $cm^2$)** | **Significance** | **Actions** |
| **< 20 alpha<br>< 1000 beta/gamma** | **Contaminated, no restrictions** | • **None required** |
| **20 alpha<br>1000 beta/gamma** | **Limit for contamination in unrestricted area** | • **Establish control boundary**<br>• **Wear appropriate PPE (e.g. gloves, Tyvek, shoe covers)** |
| **2000 alpha<br>100,000 beta/gamma** | **Resuspended contamination may lead to inhalation or ingestion risk** | • **High controls required**<br>• **Wear appropriate PPE**<br>• **Consider respiratory protection** |
| **1,000,000 beta/gamma** | **Likely to lead to inhalation of significant amounts of radioactivity** | • **Very high contamination control procedures required**<br>• **Wear appropriate PPE and respiratory protection** |

**Source: Adapted from Table 3.2, NCRP Report 161 Volume 1**

## 3.4 Daily Instrument QC Checks

Event _____ Survey Team # _____

Performed by _____ Reviewed by _____ Page ___ of ___

| Inst. Serial Number[1] | Inst. Type[2] | Date and time meter checked out | Cal. Date[3] | Bat. Test[4] | QC check source type[5] | Check source ID[5] | Nominal check source reading[6] | Acceptable range[7] | Actual reading – checked out[8] | Date and time meter returned | Actual reading – returned[8] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 12345 | Ludlum 2241-3 with 44-7 | 1/1/12 0730 | 6/1/11 | OK | Button source | Attached to meter 12345 | 4000 cpm | 3000-5000 cpm | 4300 cpm | 1/1/12 1545 | 4200 cpm |
| | | | | | | | | | | | |
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(adapted from FRMAC RMMCF-9)

1. Instrument number is the serial number or other ID number of the instrument being used
2. Instrument type is the meter type and the probe being used (e.g. Ludlum 2241-3 with model 44-7 probe)
3. Calibration date – instrument must have been calibrated within one year of date of use
4. Battery must be checked prior to each use of an instrument
5. QC check source type and ID refer to check source used for the particular test (e.g. "button source attached to meter # 5")
6. Nominal check source reading is the expected reading for the meter and probe being used (e.g. 4000 cpm with GM pancake probe)
7. Acceptable range of readings is ±20% of the nominal reading
8. Actual reading is the actual check source reading on the instrument

Form 3.1

## 3.5 Radiation Survey Data Form

**Adapted from FRMAC form RMMCF-11**

**Date** _____ **Page** ___ **of** ___ **Event** _____

**Surveyor** _____ **Reviewed by** _____

| Time | Location | Inst. Type & ID | Reading[1] | Units[2] | Radiation type [3] | Surface [4] | Comments / sample ID and type [5] |
|---|---|---|---|---|---|---|---|
| 0813 | 253 Broadway, sidewalk in front of main door | Ludlum 2241-3 SN 12345 | 250 | µR/hr | Gamma | N/A (radiation survey) | Heavy damage to building, debris on sidewalk and street<br>Debris sample #25 taken<br>Smear wipe sample #132 taken |
| | | | | | | | |
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1. Reading is the instrument reading, including (if applicable) multiplier from switch setting (e.g. 2500 cpm on x10 scale = 25,000 cpm)
2. Units should be indicated on the instrument display or faceplate (e.g. mR/hr, cpm, etc.)
3. Radiation type is alpha, beta, gamma, neutron – depending on the meter and detector being used (see Table __ in this section)
4. Surface – is N/A for radiation surveys. For contamination surveys (measured in CPM) record the surface material and texture (e.g. glass covered with heavy dust; rough concrete piled with rubble)
5. Include relevant comments to help interpret the survey and indicate which samples (if any) were obtained at this location
6. Include map and/or sketches of survey/sample locations on back of this form to indicate the location of survey or sample points

**Form 3.2**

# 4. Personal Protective Equipment

## 4.1 General guidance for PPE

The presence of radioactive material will warrant the use of PPE. If an area was contaminated with radioactive dusts, liquids, or an airborne spray, PPE is highly recommended. The emergency phase of the response may call for full turnout gear, full face, forced air or self-contained breathing apparatus. In the recovery phase, coveralls, gloves, shoe covers and a nuisance mask may suffice.(NCRP 161). Recommended levels of PPE are shown in Table 4.1.

## 4.2 HSO responsibilities:

1. Prepare supplies of PPE equipment in a variety of sizes
2. Be aware of PPE requirements for entry into radiologically controlled areas
3. Ensure PPE that is set out for use is in good condition (e.g., no holes, not ripped, etc.)
4. Ensure all personnel are trained in donning and doffing the PPE they are required to wear
5. Inform personnel of PPE requirements prior to entry into radiologically controlled areas
6. Ensure that all personnel entering radiologically controlled areas are wearing proper PPE
7. Ensure that contaminated PPE from personnel exiting a radiologically controlled area is properly disposed of as radioactive waste
8. Spot-check personnel prior to entry to ensure they are wearing proper PPE
9. Spot-check personnel donning and doffing PPE to ensure the process is carried out properly
10. Address questions or problems (e.g., ripped PPE) as necessary

## 4.3 PPE Levels

**Table 4.1: Personal Protective Equipment Guidance**

| Recommended PPE Levels for RDD | | | |
|---|---|---|---|
| **Zone [a]** | **Potential Hazards** | **Typical Tasks** | **Recommended PPE [b, c, d, g, h]** |
| **Hot Zone**<br>(2mR/hr – 10mR/hr or greater than Warm Zone levels) | • High concentrations of airborne radioactive particles for the first 15 minutes after an RDD explosion in fires involving contaminated materials or in poorly ventilated areas/indoors<br>• Groundshine from fallen radioactive particles<br>• Removable surface contamination<br>• Hot spots around radioactive fragments | • Establish Hot Zone boundaries<br>• Perform Life Safety Operations<br>• Stabilize/remove injured people in accordance with triage flow sheet (*See Operational Strategy 6*)<br>• Assist self-evacuation through exit corridors<br>• Fight fires<br>• Control access<br>• Perform monitoring and site characterization<br>• Stabilize infrastructures | **Level B**<br>**or**<br>**Level C**<br>(if no fires or plume passed and all other hazards have been identified)<br><br>*Other specialized hazard-specific gear, as necessary for the hazards identified* |
| **Warm Zone**<br>(< 2mR/hr but may be higher depending on circumstances) | • Airborne radioactive particulates possibly due to re-suspension<br>• Loose dust and debris on people/clothing, ground and surfaces due to particle deposition and tracking from Hot Zones | • Set up access and exit corridors for responders and workers<br>• Continue to evaluate zone boundaries<br>• Support workers in Hot Zones and screening/decon areas | **Level C[f]**<br>(if assisting with screening and decontamination activities) |
| **Cold Zone**<br>(< 0.1mR/hr or near background level[1], if feasible) | • Background levels | • Setup location of Incident Command Post<br>• Set up Public Screening/Triage Areas<br>• Support workers and public in screening and decon areas<br>• Transport injured persons to hospitals<br>• Provide public self-decon instructions and radiation information | **None**<br>**to Level C**<br>(depending on the tasks) |
| **Environmental Assessment Area** | • Radioactivity can range from background to Hot Zone levels<br>• Potential long-term safety and/or environmental concern | • Obtain detailed radiological measurements to designate and prioritize areas for additional evacuation, areas for re-entry, remediation measures, and environment assessment | **Generally Level D or modified level D; Level C may be required in some circumstances** |

**Notes for Table 4.1**

| |
|---|
| a. During Early Phase response and before full event characterization is possible, initial zones will be established and may be redefined during later phases as more information becomes available. |
| b. The highest level of hazard, such as explosive or immediately dangerous to life and health (IDLH) atmospheres, must always be addressed first following OSHA and NIOSH standards and agency policies for Personal Protective Equipment. |
| c. PPE Definitions<br>I. Level B – Positive pressure, full face, NIOSH-approved CBRN SCBA; hooded chemically resistant coveralls; inner and outer chemically resistant gloves; chemically resistant steel or composite toe boots; optional outer boot covers, disposable<br>II. Level C – Full face or half mask, NIOSH approved air purifying respirator with P100 cartridges, non-ventilated goggles (if half face respirator), inner and outer chemically resistant gloves, Tyvek suit, chemically resistant steel or composite toe boots<br>Optional – Disposable P100 half mask respirator, Tyvek suit and booties, chemically resistant gloves and safety glasses or goggles<br>III. Level D - No respiratory protection and minimal skin protection. Level D protection is generally defined as standard work clothes and non-respiratory PPE. |
| d. Further guidance can be found at the Nuclear Regulatory Commission webpage at http://www.nrc.gov/reading-rm/doc-collections/cfr/part020/part020-appa.html and Article 175.03(h), Respiratory protection and controls to restrict internal exposure in restricted areas, and 175.03 Appendix A Protection Factors for Respirators, notes. |
| e. Based on Musolino SV, Harper FT. Emergency Response Guidance for the First 48 Hours After the Outdoor Detonation of an Explosive Radiological Dispersal Device, 2006. |
| f. It is not practical to rapidly quantify airborne particulate concentrations in these types of incidents. Instead, the guidance of Musolino and Harper will be used. This guidance applies where particulate concentrations are not expected to exceed the assigned protection factor (APF) of 10 for disposable half-face and elastomeric half-face respirators and an APF of 50 for full-face air purifying respirators. |
| g. Guidance assumes either qualitative and/or quantitative fit testing has been performed as per OSHA and NIOSH standards and agency respiratory protection policy. |
| h. The following Rules of Thumb are adapted from the "Handbook for Responding to a Radiological Dispersal Device - First Responder's Guide – The First 12 Hours" Conference of Radiation Control Program Directors (www.crcpd.org)<br>I. First Responders must follow agency respiratory protection policy (e.g., use of an approved respirator)<br>II. Absorption in blood via cuts or wounds can occur – cuts/wounds should be covered with clean cloth or gauze to reduce contact with loose dust and debris |

## 4.4 Generic procedure for donning/doffing PPE

**The information in this section is adapted from NCRP 161 Volume 1, Section 5**

***Perform the following checks prior to dressing in PPE:***

1. Examine gloves for holes, rips, tears, or split seams
2. Examine coveralls for rips, tears, or split seams
3. Examine shoe covers for holes and for proper size

4. Verify proper operation of respiratory protection
    a. Ensure nuisance masks or N95 filters do not have holes
    b. Ensure all masks fit tightly around nose and chin
    c. Confirm sufficient air supply in force-air masks;
    d. Examine all hoses for damage and leaks
5. Remove watches, jewelry, rings, etc., to reduce the risk of making holes in PPE

***PPE should be donned in this order:***

1. Turnout gear or coveralls
2. Shoe covers (tape at ankles if necessary and possible), wear two pair of shoe covers or booties over rough terrain
3. Gloves (tape inner gloves at wrist if necessary)
4. Respiratory protection (if advisable)
5. Hood or head covering (if applicable). Tape hood to respiratory protection; and
6. Dosimeter (should be easily accessible)

***PPE should be removed in this order:***

1. Outer gloves
2. Give dosimeter to health and safety personnel
3. Tape at ankle, wrists
4. Coveralls (coat and pants)
5. Head cover, helmet, and or hoods
6. Respiratory protection
7. Shoe covers (step to clean area)
8. Inner gloves

***After removing PPE, NCRP Report #161 recommends the following actions:***

1. Perform whole-body contamination survey
2. As it is removed, survey and dispose of contaminated PPE or set aside for decontamination as warranted. Disposable PPE is usually deposited in waste containers without survey
3. Place contaminated PPE and clothing into designated radioactive waste receptacles. If required, package each person's removed PPE in a separate bag before placing into waste receptacle
4. Survey hands after handling PPE
5. Wash hands and face, shower if possible

# 5. ALARA and Radiation Dose Management

## 5.1 ALARA Policy

**(from Article 175.03 of the NYC Health Code)**

Each person who oversees a radiological organization or radiological operations must use, to the extent practicable, procedures and engineering controls based upon sound radiation protection principles to achieve occupational doses and public doses that are as low as reasonably achievable below the limits specified in regulations.

## 5.2 HSO Responsibilities

1. Be aware of overall site ALARA policy, including local dose limits
2. Determine – in conjunction with Incident Commander, Radiological Advisory Committee, Site Safety Committee, etc. as appropriate – radiation safety practices to help maintain exposures ALARA
    a. Adjust ALARA program as conditions on site change (e.g. ALARA practices and expectations for life-saving activities will likely differ from those during more routine cleanup activities)
3. Ensure that all workers are trained in ALARA and in site-specific ALARA requirements prior to entry into any radiologically controlled area
    a. Review and track individual and overall radiation doses to identify trends that might indicate a potential ALARA problem  For example, pre-plan work functions and estimated stay-times with workers to minimize total exposures before entering known radiation fields, particularly those in hot zones (see Table 5.1).Clearly establish goal of each work function
    b. Verify that calculated stay-time is compatible with work function goal
    c. Establish contingency for work functions that cannot be completed within stay-time duration e.g., consider a “tag-team” approach in which team members complete only one step of the work function thus minimizing individual total exposures
    d. Assure that work crew members understand the radiation hazard and are prepared to retreat to the support area when cumulative doses begin to reach established (or agreed-upon) limits. Account for time to reach the support zone.
4. Maintain list of investigational levels of radiation exposure i.e., that level of radiation exposure calling for investigation or for suspension of work in radiological areas and take appropriate actions when a worker reaches or exceeds these levels
5. Assess high levels of radiation exposure and take appropriate actions as necessary
6. Maintain records of radiation exposure for all persons issued dosimeters
    a. Original copies shall be turned over daily to the Incident Commander

b. One copy shall be maintained by the agency Safety Officer (or designee) indefinitely

## 5.3 Determining radiological stay times

Stay times are a tool used to help prevent personnel from exceeding radiation dose limits. They are based on radiological factors (e.g. radiation dose rates, concentrations of airborne radionuclides, etc.) and on protective equipment characteristics (e.g. respirator protection factor). NCRP Report 165 suggests using “Decision Points” – a total radiation dose at which a responder will decide (or request permission to) continue working on a task. In practice, radiation dose management typically includes a combination of decision points and stay times. Factors that determine stay times include:

1. Radiation dose limit or decision point for responder and the task being performed (See table in next section)
2. Radiation dose rate in the area(s) in which the responder is working
3. Difficulty of reaching and returning from work location
4. Time required to exit from work area
5. Safety margin to prevent exceeding a dose limit (e.g. the HSO may choose to assign a stay time based on 80% of a dose limit)
6. **Even with an assigned stay time workers must check their dosimeters (e.g. PRD) periodically to monitor their exposure and to ensure they do not inadvertently exceed a dose limit**
7. If a responder approaches a dose limit before their stay time is up, or if a responder reaches a decision point, they must contact the appropriate Safety Officer or the Command Element to receive positive permission to remain in the area. If this permission is not granted the responder must exit the area when their stay time expires OR when they reach a dose limit or decision point.

**To calculate stay time**

1. Use Table 5.1 below to determine total allowable radiation dose
2. Refer to radiation surveys to determine radiation dose in work area
3. Divide total allowable radiation dose by the radiation dose rate

**Example:**

1. The dose limit for an emergency responder engaged in activities to prevent major injuries or to avert serious property damage is 25 R
2. Radiation survey maps indicate radiation dose rate in the work area = 5-10 R/hr and the highest dose rate along the entry/exit pathway is 10 R/hr
3. **Stay time = 25 R / 10 R/hr = 2.5 hours**

**Table 5.1: Stay time (in minutes) based on measured radiation dose rates**

| Dose Rate (R/hr) | Regulatory Limits | | | | Health Effects | | | |
|---|---|---|---|---|---|---|---|---|
| | Regulatory dose limit for non-rad worker | Regulatory dose limit for radiation worker | RRRP property-saving guidance level | Upper Guidance Level for life-saving actions | Onset of acute radiation sickness | Lethal dose to 50% without medical treatment | Lethal dose to 50% with medical treatment | Lethal dose to 100% of those exposed |
| | **100 mR** | **5 R** | **10 R** | **50 R** | **100 R** | **400 R** | **800 R** | **1000 R** |
| **100mR/hr** | 60 | 3,000 | 6,000 | 30,000 | 60,000 | 240,000 | 480,000 | 600,000 |
| **1** | 6 | 300 | 600 | 3,000 | 6,000 | 24,000 | 48,000 | 60,000 |
| **10** | 0.6 | 30 | 60 | 300 | 600 | 2,400 | 4,800 | 6,000 |
| **20** | 0 | 15 | 30 | 150 | 300 | 1,200 | 2,400 | 3,000 |
| **50** | 0 | 6 | 12 | 60 | 120 | 480 | 960 | 1,200 |
| **100** | 0 | 3 | 6 | 30 | 60 | 240 | 480 | 600 |
| **200** | 0 | 2 | 3 | 15 | 30 | 120 | 240 | 300 |
| **500** | 0 | 0.6 | 1 | 6 | 12 | 48 | 96 | 120 |
| **1000** | 0 | 0 | 0.6 | 3 | 6 | 24 | 48 | 60 |

Red = stay time < 30 min Yellow = stay time < 10 hrs Blue = stay time > 10 hrs

**From Table P in RRRP**

**Table 5.2: Stay time (in hours) based on airborne radioactivity concentrations and respirator protection factor**

| Protection factor | Airborne Radioactivity Concentrations (# DAC) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **1** | **5** | **10** | **50** | **100** | **500** | **1,000** | **10,000** |
| **1** | 2,000 | 400 | 200 | 40 | 20 | 4 | 2 | 0.20 |
| **10** | 20,000 | 4,000 | 2,000 | 400 | 200 | 40 | 20 | 2 |
| **25** | 50,000 | 10,000 | 5,000 | 1000 | 500 | 100 | 50 | 5 |
| **50** | 100,000 | 20,000 | 10,000 | 2,000 | 1,000 | 200 | 100 | 10 |
| **100** | 200,000 | 40,000 | 20,000 | 4,000 | 2,000 | 400 | 200 | 20 |
| **1000** | 2,000,000 | 400,000 | 200,000 | 40,000 | 20,000 | 4,000 | 2,000 | 200 |
| **10.000** | 20,000,000 | 4,000,000 | 2,000,000 | 400,000 | 200,000 | 40,000 | 20,000 | 2000 |

Red = stay time < 10 hrs Yellow = stay time < 80 hrs Blue = stay time > 80 hrs

## 5.4 Total dose guidance levels for emergency responders

**Table 5.3**

| Activity | Do Not Exceed: | Dose Guide | Conditions |
|---|---|---|---|
| Support efforts not required to be in the Hot Zone | 0.002-0.01 R/hr (2 – 10 mR/hr) | Individual agency guidance | • None |
| 1. General response operations at a radiological emergency<br>2. Longer term recovery operations<br>3. Monitoring, sampling | • 10 R/hr<br>• Areas > 1 R/hr should be marked if possible | Up to 5 rem (5,000 mrem)[2] | • All reasonably achievable actions have been taken to minimize dose. |
| 1. Protecting major property/valuable property for public welfare<br>2. Implement urgent protective actions | 200 R/hr (200,000 mR/hr) | Up to 10 rem (10,000 mrem) | • All appropriate actions and controls have been implemented; however, exceeding 5 *rem* (0.05 *Sv*) is unavoidable.<br>• Responders have been fully informed of the risks of exposures they may experience.<br>• Dose >5 *rem* (0.05 *Sv*) is on a voluntary basis.<br>• Appropriate respiratory protection and other PPE is provided and used.<br>• Monitoring available to project or measure dose. |
| 1. Lifesaving or prevention of serious injury<br>2. Protection of a large population, or actions to avert a large collective dose (to all personnel)<br>3. Prevent the development of catastrophic conditions | 200 R/hr (200,000 mR/hr) | Up to 25 rem (25,000 mrem) | • All appropriate actions and controls have been implemented; however, exceeding 5 *rem* (0.05 *Sv*) is unavoidable.<br>• Responders have been fully informed of the risks of exposures they may experience.<br>• Dose >5 *rem* (0.05 *Sv*) is on a voluntary basis.<br>• Appropriate PPE is provided and used.<br>• Monitoring available to project or measure dose. |
| Lifesaving operation or avoiding extensive exposure of large populations (e.g., catastrophic event/conditions) | Although planned activities in areas above 200 R/hr can be done safely, victims who are in this area for more than a ***few hours*** may not survive | Up to 50 rem (50,000 mrem)<br><br>(When lower doses are not practicable) | • Emergency responders might receive an equivalent dose that approaches or exceeds 50 rem (0.5 Sv) to a large portion of the body in a short time.[3]<br>• If lifesaving emergency responder doses approach or exceed 50 rem (0.5 Sv), emergency responders must be made fully aware of both the acute and the chronic (cancer) risks of such exposure. |

**Based on information in NCRP Reports 138, 161, and 165; RRRP Table F; EPA PAG Manual (1992); and Table 3 of CRCPD Handbook (see references for complete citation)**

[2] Applies to doses after the end of the emergency phase

[3] The principle of ALARA applies during emergency operations and every effort shall be made to comply with radiation exposure limits. When this is not possible, doses of 50 rem or more may be authorized. For such operations emergency workers must be 1) experienced volunteers, 2) trained in radiation safety, and 3) must understand the risks (NCRP 138). NCRP recommends, when the cumulative absorbed dose to an emergency responder reaches 50 rad, a decision be made on whether or not to withdraw the emergency responder from the hot zone. (NCRP-165).

# 6. Contamination Control and Decontamination

## 6.1 HSO Responsibilities

1. Maintain adequate stocks of PPE, contamination control supplies, and decontamination supplies
2. Ensure personnel entering radiologically controlled areas are wearing appropriate PPE
3. Ensure personnel entering and exiting radiologically controlled areas properly don and doff their PPE
4. Brief personnel on appropriate contamination control practices prior to their entry into a radiologically controlled area
5. Ensure personnel exiting a radiologically controlled area are surveyed for contamination
6. Determine (or be aware of) contamination limits, beyond which personnel, areas, or equipment cannot be released without decontamination
7. Oversee the decontamination of contaminated personnel
8. Ensure documentation of appropriate personal information and survey results for contaminated personnel
9. Ensure documentation of appropriate information (including survey maps and data if applicable) for contaminated equipment and its disposition (e.g. decontaminated, disposed of, restricted to controlled area, etc.)
10. Following decontamination refer contaminated persons on as appropriate (e.g. for assessment of internal contamination)
11. Ensure that clean zone and “dirty” or hot zone in decontamination area is maintained.

## 6.2 Priorities in caring for persons exposed to radiation and/or radioactivity

**Table 6.1**

| Degree of Injury and Contamination Level | Actions |
|---|---|
| Life-threatening injuries and/or medical conditions | • Manage airway, breathing, and circulation<br>• Transport to hospital |
| High external radiation dose to individual | • Transport to hospital before decontamination<br>• Treat for acute radiation syndrome |
| High levels of internal contamination (thousands of CPM from nasal swabs or contaminated wounds) | • Administer medical countermeasures (e.g. Prussian blue, potassium iodide) if possible<br>• Begin immediate treatment with DTPA if uptake from plutonium or americium is confirmed or suspected<br>• Decontaminate if medical condition permits<br>• Admit to emergency facility for dose assessment |
| Serious injuries (non-life-threatening, but requiring prompt medical attention) | • Decontaminate<br>• Admit to Emergency Department |
| Evidence of contaminated wounds | • Gently flush with sterile water or saline |
| High levels of skin contamination (> 100,000 CPM) | • Decontaminate<br>• Admit to Emergency Department for treatment of radiation burns<br>• Evaluate for internal contamination and dose assessment |
| Moderate injuries (requiring medical attention) | • Decontaminate<br>• Admit to Emergency Department |
| Moderate levels of internal contamination (hundreds of CPM from nasal swabs or contaminated wounds) | • Decontaminate<br>• Admit to Emergency Department<br>• Evaluate for internal contamination and dose assessment |
| Moderate levels of skin contamination (>10,000 CPM) | • Decontaminate<br>• Evaluate for internal contamination |
| Mild injuries with low levels of skin contamination (>1000 CPM) | • Decontaminate to 2x background<br>• Discharge if no evidence of internal contamination |
| No injuries, low levels of skin contamination (<1000 CPM) | • Can be released |

**Adapted from Table 6.3 of NCRP Report 161 and CRCPD Handbook**

## 6.3 Skin contamination intervention levels

The values (e.g. CPM) provided in these tables are default values that can be used for any nuclide and any radiation detector. More precise values for the specific nuclide(s) and instrument(s) present may be calculated by the Radiological Advisory Committee and substituted for these values.

**Table 6.2: Skin contamination intervention levels when the nuclide and counting efficiency are known.**

| If the nuclide and the counting efficiency for that nuclide are KNOWN: Correct the instrument reading to determine dpm/cm$^2$ | | | |
|---|---|---|---|
| **Alpha (dpm/cm$^2$)** | **Beta/gamma (dpm/cm$^2$)** | **Beta/gamma (µR/hr)** | **Actions** |
| < 600 | < 6000 | Non-detectable | No actions required – release |
| 600-6000 | 6000 – 60,000 | Non-detectable | ***Intervention optional***<br>• Decontaminate or advise to shower and wash clothing<br>• No significant health risk |
| 6000-60,000 | 60,000 – 600,000 | 20-30 | ***Intervention advisable***<br>• Prevent inadvertent ingestion and inhalation<br>• Limit spread of contamination from contaminated person<br>• Decontaminate |
| > 60,000 | > 600,000 | 200-300 | ***Intervention required***<br>• Prevent inadvertent ingestion and inhalation<br>• Limit spread of contamination from contaminated person<br>• Decontaminate |

**Adapted from Table 7.2 of NCRP Report 161**

**Table 6.3: Skin contamination intervention levels when the nuclide and counting efficiency are not known**

| If the nuclide and counting efficiency for that nuclide are NOT KNOWN: use uncorrected instrument readings | | |
|---|---|---|
| **Instrument count rate** | **Number of affected** | **Action** |
| < 1000 cpm | Any number | • Release to home<br>• Advise to shower and change clothing |
| < 10,000 cpm | Large number affected | |
| | Small number affected | • Decontaminate and release to home |
| 10,000 – 100,000 | Any number | • Decontaminate and release to home |
| > 100,000 cpm | Any number | • Decontaminate<br>• Evaluate for internal contamination<br>• Consider medical countermeasures or further follow-up |

**Adapted from CRCPD Handbook**

## 6.4 Personal decontamination guidance

**Table 6.4: Guidance for decontamination of people**
**Note - All methods should be followed up by survey monitor re-screening to determine effectiveness**

| Contamination Area | Method | Technique | Remarks |
|---|---|---|---|
| **Skin** | Soap & Water | 1. Wash 2-3 minutes<br>2. Check activity levels.<br>3. Repeat washing 2 times. | Wash hands, arms and face in sink or tub, shower for rest of body |
| | Soap, soft brush, water, dry abrasives such as corn flour | 1. Use light pressure with heavy lather.<br>2. Wash for 2 minutes, 3 times, rinse and monitor.<br>3. Use care not to erode skin. | |
| | Soap powder or similar detergent, standard industrial skin cleaner | 1. Make into a paste.<br>2. Use with additional water and a mild scrubbing action.<br>3. Use care not to erode skin. | |
| **Eyes, Ears, Mouth** | Flush with water | 1. Eyes: Roll back eyelids and gently flush with water.<br>2. Ears: Clean opening of ear canal with cotton swabs.<br>3. Mouth: Rinse with water-do not swallow. | Be cautious not to damage ear drum; rolling back the eyelids should be carried out by medical or suitably trained personnel. |
| **Hair** | Soap and water | 1. Use light pressure with heavy lather.<br>2. Wash for 2 minutes, 3 times, rinse, and monitor. | Hair should be back washed to minimize ingestion via mouth or nose. |
| | Soap, soft brush and water | 1. Make into a paste.<br>2. Use additional water and a mild scrubbing action.<br>3. Do not erode the skin. | Hair should be back washed to minimize ingestion via mouth or nose. |
| | Haircut/shave head | 1. Remove the hair to decontaminate scalp.<br>2. Use skin decon methods. | Use only after other methods fail. |

**Adapted from Table D7, IAEA-TECDOC-1162.**

## 6.5 Equipment decontamination guidance

**Adapted from Section 5.3.5 of NCRP Report 161**

- Smooth surfaces (glass, plastic, metal) can be decontaminated by:
  - Wiping with cloth dampened with water or commercial cleaning products
  - “Tape press” using the stick side of tape (e.g. duct tape, masking tape)
  - Immersion in an ultrasonic cleaning sink
- Contamination that cannot be removed is considered “fixed”
  - If radiation dose from fixed contamination is low then essential equipment (e.g. emergency response vehicle) can continued to be used
  - If equipment with fixed contamination is used the contaminated portions should be covered (if possible)

- Porous or fibrous surfaces cannot be decontaminated by washing or wiping
    - Soft items (e.g. wood, lead) may be shaved with knife to remove contaminated portion
    - Contaminated sections of paper or fabric can be cut out with scissors and the remainder used
- Large areas (e.g. ambulance interiors or floors) may be decontaminated by wiping with sponge or rags soaked in soapy water, detergent, or other cleaners

## 6.6 Decontamination station recommended supplies list

**Adapted from Table 8.2 in NCRP Report 161 and CRCPD Handbook**

- Appropriate PPE for personnel performing decontamination
- Respirators (if contamination levels are very high)
- Personal dosimeters
- Clean clothing for person(s) being decontaminated
- Large towels
- Scissors (if required for removing clothing or protective equipment)
- Large plastic bags for collection of contaminated clothing and decon equipment
- Radiation tags for marking contaminated items or bags
- Radiation area signs
- Masking tape
- Blankets
- Notebooks, paper, pencils
- Survey and data forms (Form 3.2 & 8.2 of this document)
- Radiation survey meters
- White absorbent paper
- Plastic sheets
- Soap, detergent, and other decontamination supplies
- Waste containers (e.g. drums or boxes) for contaminated clothing and equipment
- Hair clippers
- Caution line tape and ropes to mark off perimeters and areas of operation
- Disposable absorbent towels
- 5 gallon buckets
- Hazardous waste containers, bags, or drums
- Tarps (*to be used for privacy and/or as wind break)*
- Redress "modesty" packs, which include surgical scrubs or "Tyvek" type suit in varying sizes, or other available post-decontamination clothing and slippers.
- Various sizes of "zip lock" bags for personal belongings
- Indelible black and red markers
- Preprinted numbered labels for tagging victims, survey forms and clothing/valuables bags
- Clipboards or tables to write on
- Water diversion or collection equipment if necessary
- Point of contact listing of local and state support assets

# 7. General radiation safety work practices

## 7.1 Example radiation safety briefing

Once situational awareness is obtained from the CBRNE or Haz-Mat Branch at the incident scene, it is necessary to inform responders of the current radiological conditions. A summary may be formulated using the following outline.

Initial radiological surveys have been performed by _____. They have identified the following conditions:

- The nuclide(s) of primary concern is _____
- The primary type of radiation is_____
- Radiation dose rates are _____ at the following locations _____
- Contamination levels are _____ at the following locations _____
- Airborne radioactivity concentrations are _____ at the locations _____
- Completing your assigned task is projected to result in a radiation dose of _____

Exposure to very high doses of radiation carries with it the possibility of radiation injury (for example radiation burns or radiation sickness). It is possible to receive locally high radiation doses from the handling of radioactive debris. It is important to remain aware of radiation levels. Should radiation levels increase unexpectedly, mark and inform the Incident Commander or Operations Chief of the hot spot locations and the radiation dose readings immediately.

Exposure to radiation also carries with it the risk of developing cancer later in life. If you adhere to your assigned dose limit (which will be mentioned shortly) the added cancer risk is less than ½% (0.5%), above a background risk of about 40%. Adhering to the following safety precautions will help to minimize radiation dose and the risk it poses.

**Appropriate PPE for your work area** (check those needed):

- o Radiation dosimetry (specify types, specify alarm levels for dose and dose rate if appropriate and if dosimetry is available)
- o Respiratory protection (specify type)
- o Gloves (specify type and number of layers)
- o Shoe covers
- o Anti-contamination clothing (specify type)
- o Other (e.g. taping seams)

**Other protective actions include**:

- o Dose and/or stay time restrictions (specify stay time)
- o Minimize the amount of time spent in the highest dose-rate areas

- Maximize distance from the highest radiation dose-rate areas
- Utilize shielding (e.g. existing walls) to reduce radiation dose rates
- Do not eat, drink, smoke, chew, apply cosmetics, or perform any other actions that increase the risk of radioactive materials ingestion
- Do not enter if you have any uncovered wounds (cuts, scrapes, abrasions)
- Do not pick up any materials without the direction of the Radiation Safety Officer or the Health and Safety Officer

**Exit the area immediately when**:
- You reach your assigned dose or stay time limit
- Your self-indicating dosimeter reads ___ mR
- You are injured in any way
- You are instructed to leave by the HSO or the RHSO

## 7.2 Radiation dose reduction practices

**Adapted from Strom, 1996 (*Ten Principles and Ten Commandments of Radiation Protection*)**

- **Time** - minimize time spent in highest-dose radiation field
  - Plan work to be accomplished
  - Rehearse complex activities prior to entry
  - Work in lower-dose areas as much as possible
  - Be efficient, but not reckless; use tag-team approach if applicable
- **Distance** – maximize distance to highest-dose-rate radiation sources
  - Moving even 1 or 2 meters from a high-activity source can reduce dose substantially
- **Shielding** – place as much material as possible between the worker and the radiation source
  - No shielding is required for alpha radioactivity
  - Heavy protective clothing will provide adequate shielding against beta radiation
  - Use “natural” shielding such as solid walls (e.g. brick, concrete, rock)
  - Stand behind vehicles (also remember that radiation can stream beneath a vehicle, exposing feet and ankles)
  - Consider installing shielding if practicable (but remember that those installing the shielding might be exposed to high levels of radiation)
    - Lead sheets or bricks
    - Soil, rock, or concrete (4” of soil, rock, or concrete provides about the same shielding as 1” of lead)
    - Water (12” of water provides about the same shielding as 1” of lead)
- **Source Barrier** – minimize the dispersal of radioactive materials into the air or beyond site boundaries
  - Take dust suppression measures (e.g. misting dusty surfaces)
  - Decontaminate personnel and equipment prior to release from contaminated areas

- **Source Reduction** – minimize the amount of radioactive material on the site as a whole and in any given area
    - Take rapid action to remove highly radioactive items from area
    - Collect and remove decontamination waste frequently
    - Collect and remove contaminated clothing, PPE, and equipment frequently
- **PPE** – wear appropriate PPE to minimize skin contamination and internal contamination (see Section 4)

## 7.3 Contamination control practices

**Based on Section 5.3 of NCRP Report 161 and Department of Energy *Radiological Controls Manual***

1. For workers in radiologically controlled areas
    a. Review survey maps to achieve familiarity with the location and extent of contamination in the work area
    b. Wear appropriate PPE prior to entry into area
    c. Don and doff PPE properly
    d. Ensure contaminated areas are clearly marked and delineated with radiological boundary tape or rope as appropriate
    e. Establish contamination control corridors from entry/exit point to work area
2. For injured and contaminated persons
    a. Contamination control measures should not interfere with caring for severely injured persons
    b. Contamination control measures may include
        i. Removing outer clothing
        ii. Wrapping in sheet, blanket, etc. (isolation)
        iii. Dressing in Tyvek or similar outer garment to contain contamination
        iv. Decontaminating the affected person
3. For emergency and medical responders
    a. Do not delay or deny treatment to contaminated persons on account of the presence of contamination
    b. Standard precautions provide adequate protection when caring for injured persons who are contaminated with radioactivity
    c. Removing PPE, using a step-off pad when exiting a controlled area, and showering at the end of a shift are sufficient to prevent the spread of contamination into “clean” areas

## 7.4 Establishing and operating in radiologically controlled areas

**Adapted from Section 5.3 of NCRP Report 161**

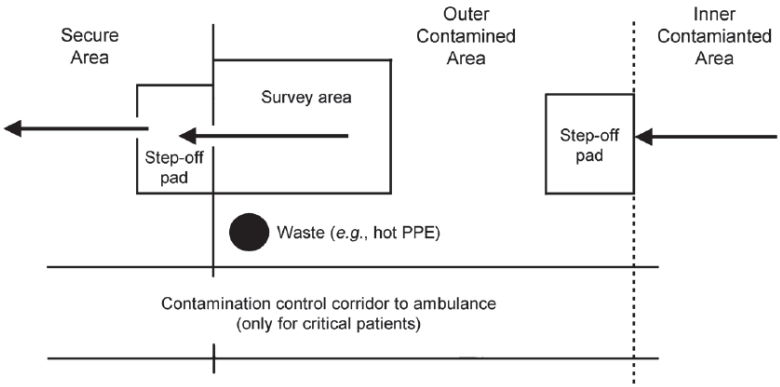
1. Established radiological boundaries should be at least waist-high with clearly defined entry and exit points at step-off pads
2. If possible, locate a table or designate an area with a barrier line separating clean and potentially contaminated surfaces at exit points
3. Tools and equipment can be placed on the table or in area for surveying prior to release from the contaminated area

4. Boundaries at designated exit points should be low to permit crossing without tripping or losing balance
    a. Persons should not enter or exit the controlled area except at designated points, such as the gates at step-off pads
5. Plastic sheeting (preferably textured to prevent slipping) should be used to cover the ground in the exit area
6. “Sticky mats” may be used as step-off pads to minimize the spread of contamination
7. “Hot” waste containers should be clearly marked “Radioactive” and lined with plastic bags
8. Step-off pads should be surveyed periodically for contamination and should be replaced, decontaminated, or renewed if found to be contaminated

## 7.5 Exiting a controlled area

**Adapted from Section 5.3 of NCRP Report 161**

1. Personnel should exit the controlled area ONLY at designated exit points
2. Badly injured persons should exit via the contamination control corridor and need not be surveyed or decontaminated if doing so will delay needed medical care
3. Enter the “hot” side of the exit point
4. Log the name of the person entering the exit point (or record the person’s exit on the entry/exit log form)
5. Survey outer gloves or hands for contamination
6. Survey coveralls, PPE, or outer clothing for contamination
    a. If the exit procedures call for removing outer clothing or PPE prior to all exits from controlled areas then this survey is not required; in these cases remove the outer clothing or PPE at the exit point and survey what is now the outer-most clothing
7. If contaminated, remove coveralls or outer clothing and place in radioactive waste container or plastic bag
8. Step to “cold” side of exit point
    a. Remove shoe covers while stepping over the boundary and place into radioactive waste container
9. Remove gloves inside out and place into radioactive waste container
10. Survey whole body, concentrating on hands, feet, face, knees, elbows, and seat of pants
11. Survey exit point and step-off pad(s) periodically and decontaminate as necessary




**Source: Figure 5.1 from NCRP Report 161**

# 8. Example Documentation and Record-keeping

## 8.1 Form for initial entry into a radiological area

Names of Entry Team #1:

_____
_____
_____
_____

Entry Team #1 Objective

_____
_____
_____
_____

Names of Entry Team #2:

_____
_____
_____
_____

Entry Team #2 Objective

_____
_____
_____
_____

Names of Backup Team:

_____
_____
_____
_____

Backup Team Objective

_____
_____
_____
_____

Names of Decon Team:

_____
_____
_____
_____

_____ _____ **FORM 8.1**

Health and Safety Officer or IC Date

## 8.2 Contamination Survey Sheet - CRCPD

**From CRCPD Handbook**

First Name: _____ Middle Initial: _____ Last Name:_____

Date of Birth: _____ Phone:_____

Address_____

Date/Time:_____ Drivers License #_____

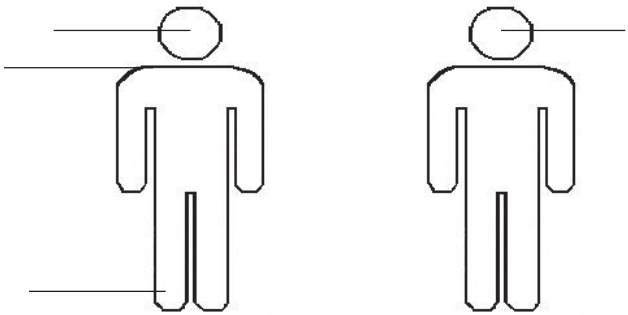
Location at time of incident:_____

Parent or Guardian (if child):_____

***Mark contamination locations and survey reading on the diagrams below.***

*Circle if readings are in cpm mR/hr µR/hr*

**FRONT** **BACK**



Survey results

<1,000 cpm_____ >1,000 cpm_____ >10,000 cpm_____

Comments:_____

_____

_____

Monitored by:_____

**Person sent to decontamination area: _____Yes _____No**

Clothing and valuable bag number: _____ Valuables returned: _____Yes _____No

Nasal area reading of 100,000 cpm or 0.5 mR/hr : ___Yes _____No

If Yes, refer to medical facility Person sent to medical facility: _____Yes ____No

**Form 8.2**

## 8.3 Contamination Survey Sheet - NYCDOHMH

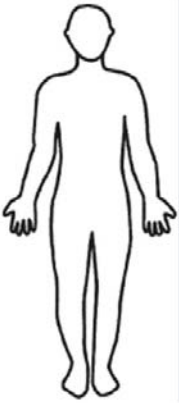
From NYCDOHMH DEOP-R

**Responder's Name** _____ **Date/Time** _____

**Survey taken on:** ☐ **Protective Clothing** ☐ **Personal Clothing** ☐ **Skin**

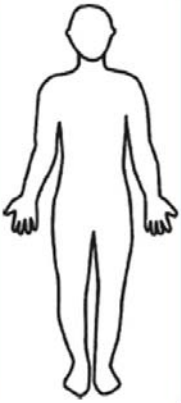
**Mark contamination locations on the diagrams below:**

**FRONT**



1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____

**BACK**



1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____

Comments:

---

---

---

---

**Monitored by:** _____ **Agency:** _____

**Instrument Type:** _____ **Instrument S/N:** _____

**Cal Due Date:** _____ **Probe Used:** _____

**Form 8.3**

## 8.4 Bioassay Sample Form

Last Name: _____ First Name: _____ Middle Iniital: ____

SSN / ID Number: _____ Organization: _____

Address: _____

Date (dd-mm-yy): _____ Work area or project: _____

Sample media: ___ Urine ___ Fecal ___ Thyroid ___ Lung
___ Wound ___ WBC ___ Nasal ___ Other (specify):___

Sample Number: _____ Time labeled (hhmm): _____

Comments: _____

Sample type: ___ Baseline ___ Routine ___ Post-work ___Possible exposure

___ Other (describe): _____

Time/Date of sample collection: Begin: _____ End: _____

---

### Chain of Custody

| Relinquished by (signature) | Date/Time relinquished | Date/Time received | Received by (signature) |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |

**Adapted from FRMAC *Radiological Emergency Response Health and Safety Manual*** **Form 8.4**

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## Appendix: Radiation Safety Considerations in a Hurry

If the emergency situation presses the HSO for time or an inexperienced HSO is on station at the incident, the following information may be of assistance jump-starting the radiation-safety considerations of the response. Essentially, these would be the bare minimum actions to implement until the situation evolves for a more refined response.

### Immediate HSO Radiation Safety Considerations

**Step 1:** Attempt to gather the following "situational awareness" information from the

Incident Command Center and "Haz-Mat" or "CBRNE Branch" for eventual transmission to field-level personnel and for safety decision making:

A. The radionuclide(s) of primary concern
B. The type of radiation of primary concern
C. Radiation levels (best estimates) in zones where (your) agency personnel will operate
D. Estimates of the levels of radioactive contamination in areas where (your) agency personnel will operate
E. Determine if airborne radioactivity can be present; consider re-suspension due to environmental conditions or man-made activities (debris removal)
F. In areas where radiation levels are high enough to restrict times of operation in those areas to a few hours, plan the operations to limit the doses.

**Step 2:** Assign/Distribute PPE
If possible, consult with other HSO personnel from first responder agencies for proper level of PPE or use observation of responding personnel as guidance. Consider the implementation of:

A. Radiation dosimetry (specify alarm levels for dose and dose rate if appropriate and if dosimetry is available)
B. Respiratory protection (specify type)
C. Use of Gloves (specify type and number of layers)
D. Shoe covers
E. Anti-contamination clothing (specify type)

**Step 3:** Issue or assure activation of all dosimetry devices (some agencies may use more than one device)

**Step 4:** Determine if stay time estimates are needed
Exposure to certain dose rates e.g., > 10 R/hr carries with it the possibility of radiation injury (radiation burns and/or radiation sickness) if the circumstances or the combination of exposure rate and time spent in the radiation field results in human doses that trigger such injury. Exposure to radiation also carries with it the risk of developing cancer later in life. If one adheres to assigned dose limits the added cancer risk is less than about 1 % above the background cancer risk (about 40%).

**Step 5:** Prepare to Assess/Reassess Radiological & Safety Status of Field Personnel
As the emergency evolves, HSO duties will unfold to meet the hazards identified. Field responders will check in remotely or in person back at the agency command area (or at IC). Analysis and assessment of the safety of response personnel should take advantage of the verbal and documented reports from the responders to continuously reassess the radiological and general safety environment. Another source of radiological information will be the Radiological Advisory Committee (RAC) which will stand up as the event evolves. The RAC may be located at the IC or CBNRE Branch.

**Down-Range Safety Considerations:**

A. Field personnel must exit the area they are working in if…

   a) Physical injury occurs
   b) Instructed to leave by the HSO or other first responders who have identified another hazard or need to perform activities with higher priority
   c) Instructed to leave by NYPD due to immediate threat e.g., active shooter or secondary explosive device discovered
   d) Assigned dose or stay time limit is reached

B. Verify situational awareness periodically; remain cognizant of other safety issues related to an incident such as:

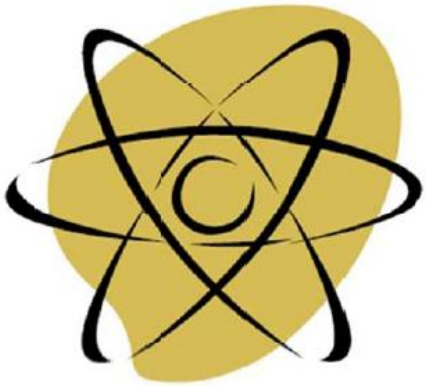
   a) Secondary terrorist devices or actions
   b) Other hazardous materials discovered
   c) Environmental conditions change (precipitation, temperature, wind)

C. Invoke time, distance and shielding rules of radiation safety where feasible
D. Caution against any actions that increase the risk of radioactive materials ingestion (consumption of food, insertion of contact lenses)
E. Prevent entrance to contaminated zones for personnel with uncovered wounds (cuts, scrapes, abrasions); seek medical attention first
F. Caution against handling of debris or other materials unless deemed “safe” by measurement and a subject matter expert

# Field Guide for Health and Safety Officers
# Radiological Incidents

## Part II - Background Information

*June 2014*



New York City Department of Health and Mental Hygiene with the NYC Securing the Cities Radiation Response and Recovery Committee and assistance from Domestic Nuclear Defense Operations and Lawrence Livermore National Laboratory. This project was supported by funding from the Urban Areas Security Initiative of the Department of Homeland Security.

NYC Health

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# Introduction to the Field Guide

In the event of a large-scale radiological or nuclear event it is likely that many NYC and other agencies will participate in response efforts. While overall radiation safety and health decisions will be made by the Command Element, the Citywide Incident Management System (CIMS) requires each agency to be responsible for ensuring the health and safety of its own workers. The Command Element and responding agencies will be supported by subject matter experts from advisory groups including the Radiological Advisory Committee (RAC) and/or the multiagency Health and Safety Workgroup convened to develop the incident health and safety plan (HASP) according to CIMS Annex D. This Field Guide is intended to provide guidance to Health and Safety Officers (HSOs) concerning radiological hazards and the recommendations to control potential exposures.

Radiation and radioactivity pose unique challenges and risks that are subject to local, State, and Federal regulations, including dose limits, requirements for posting radiological areas, and specifications on the use of radiation dosimetry. There is a minimum level of qualifications and/or experience that the HSO at the scene of a radiological emergency must possess to ensure staff is adequately protected and that regulatory compliance is achieved.

## Overview of Field Guide

This Field Guide consists of two major parts:

- Part I: Operational Guidance
- Part II: Background Information

**Part I: Operational Guidance**

Part I contains easy-to-use tables, charts, checklists, forms, and other tools that may be of immediate use during field operations. Part I also includes standardized forms that can be used without modification (if desired) to track radiation dosimeter use, record radiation instrument quality assurance checks, document radiation surveys, and so forth. All of the forms presented in Part I of this Field Guide were adapted from standardized materials developed by either the Federal Radiological Monitoring and Assessment Center (FRMAC) or by the Conference of Radiation Control Program Directors (CRCPD). Using standardized forms will help ensure that all agencies collect similar data and record it consistently and will facilitate data-sharing (particularly with radiological survey data) during and after the emergency response.

The other information, guidance, and tools found in Part I are either taken directly or adapted from other sources whenever possible. These sources include the National Council on Radiation Protection and Measurements (NCRP), the CRCPD, the New York City Radiological Response and Recovery Plan (RRRP), the International Atomic Energy

Agency, papers that have appeared in the scientific literature, and other sources of similar authority. The intent of Part I of this Field Guide is not to dictate specific work practices or procedures but, rather, to provide the HSO with a suite of forms, concise information, checklists, and other materials that have been vetted by reputable organizations and that can be used (with or without adaptation) to assist the HSO. Part I ***does not*** contain explanatory information about these materials – this information is found in Part II.

**Part II: Background Information**
Part II of this Field Guide is a primer that contains additional information to help the HSO, who is typically not a practicing radiation safety professional, to better understand the fundamentals of radiation science, radiation safety, and radiation safety work practices. Part II is intended to help the HSO to understand the principles behind the materials presented in Part I and to help answer the basic questions that might arise during the conduct of operations in a radiological area. The materials in Part II were developed, reviewed, and refined by radiation safety professionals from Brookhaven National Laboratory, Lawrence Livermore National Laboratory, the Nevada National Security Site, a variety of NYC agencies, and consultants.

## How to use this document

The HSO who is using this document ***during*** a radiological emergency will likely focus on Part I of this document. Several sections begin with a summary of the regulatory requirement and/or policy issues pertinent to that section (e.g. regulations regarding radiation dosimetry) and summarize the HSO's responsibilities in that particular area. All sections include tables of useful information, checklists, model procedures, and other information that can be used as-is or with minor modifications. An example of how an HSO might use Part I of this document is provided below.

The HSO who is ***not*** typically involved in a radiological incident response might wish to begin with reading Part II of this document to gain a better understanding of the basic principles and practices of radiation safety. This will help to provide a familiarity with the document itself, as well as to help build an understanding of the conditions that might be encountered during a radiological emergency response. This fundamental knowledge may not be directly applicable to field operations, but it provides a knowledge base that can help the HSO to plan effectively for a radiological emergency.

Example use of this document: *A group of responders is preparing to enter into a potentially contaminated area that is known to have radiation dose rates of up to 5 mR/hr and localized "hot spots" that reach 200 mR/hr.*

- Referring to Part I, Section 2.1 the HSO finds that entering an area with a dose rate of 5 mR/hr does not call for dosimetry, but that since there is the possibility of a worker exposure exceeding 500 mrem from working near hot spots it might be prudent to issue dosimetry to workers entering the Hot Zone. Also found in Sections 2.2, 4.2, 5.2 and 6.1 are lists of the HSO's responsibilities, including the responsibility to ensure that workers are issued proper dosimetry, that they are trained in its proper use, and that they are reminded to check their self-indicating dosimetry regularly (if they are issued such dosimetry). Finally, the HSO will find the appropriate forms on which to log issuing dosimeters to personnel as well as to record the radiation exposure for these personnel.

- In Section 3, the HSO will find guidance on selecting the appropriate radiation survey instruments, guidance to help interpret the instrument readings, and forms on which to record radiation instrument quality control checks and radiation survey data in a standardized format.

- Section 4 helps the HSO to select appropriate Personal Protective Equipment (PPE) for personnel who enter the radiologically controlled area and it provides model procedures for donning and doffing PPE.

- In Section 5 the HSO will find guidance on how to work with responders to maintain radiation exposure As Low As Reasonably Achievable (ALARA), including formulas for calculating radiological stay time and radiation dose limits.

- Section 6 contains contamination control methods, including how to prioritize radiological versus medical concerns for contaminated injured personnel and the HSO will also find numerous suggestions for decontaminating personnel and equipment in this section.

- Section 7 contains generally accepted radiological work practices that may be relevant to the work being performed.

- Section 8 contains additional record-keeping requirements.

This is one hypothetical scenario that gives an example of how an HSO might choose to use this document – in reality each HSO is likely to use it in a manner that best suits the situation, the HSO's understanding of radiation safety, and the HSO's approach to emergency response in general.

# 1. Overview and key points

- Radiological response ***rarely*** represents an immediate danger to the life and health of the responder ***except***:
  1) Directly handling a sufficiently high-activity radioactive source that has not been dispersed, and
  2) Fallout from a nuclear detonation, especially within the first few hours and close (< 20 miles) to the detonation location (Note: a Radiological Dispersal Device – also called a "dirty bomb" – is NOT a nuclear detonation).

- The primary health concern from exposure to relatively low doses of radiation (less than 10 rem) is a potentially slight increase (~1%) in the long term background (lifetime) risk of cancer (BEIR VII);
  - All else being equal older people are less susceptible to radiation effects,
  - Fetuses and young children are most susceptible to this effect.

- Penetrating gamma radiation (often the primary hazard) cannot be stopped by PPE, however dose control tools (such as survey meters and electronic dosimeters) can provide protection by warning the user of radiation levels that exceed safety guidelines.

- Contamination (often the secondary hazard) is not immediately life-threatening and can be controlled through respiratory protection and clothing that can be easily washed or discarded.

- Unlike many chemical and biological agents, radioactive contamination rarely[1] represents an immediate danger to the health of the victim or the responder. This reduces the immediacy of the need for decontamination and allows the emergency response community greater flexibility in selecting decontamination options.

- For the injured, lifesaving treatment and transport should always take precedence over radiological monitoring or decontamination.

- Even during emergency response activities, individual and group exposures should be kept as low as reasonably achievable (ALARA) within the constraints of the situation and mission objectives. The benefit of every mission must be weighed against the risk to the response force. This can be accomplished by:

  - Limiting the time spent in radiation fields

[1] Two notable exceptions are: (1) victims at the site of, or immediately downwind of a nuclear detonation (which may be several miles), as these are areas that may have radioactive material contamination levels high enough to be of immediate danger to the life and health of emergency responders, and (2) the very rare case of radioactive source-material shrapnel embedded in a patient. In such rare cases, the radiation dose control tools and guidelines in this document are still applicable (NCRP Commentary 19).

    - Limiting the number of responders on a mission to the minimum needed to accomplish the mission safely and effectively,
    - Maximizing the responders' distance from sources of radiation (if possible for the mission)
    - Using vehicles, buildings, or portable shielding (if available) to reduce radiation levels in working areas.

- Nausea and vomiting are the earliest clinical signs of Acute Radiation Syndrome (ARS). If these symptoms occur while conducting field activities, the affected individual(s) must be removed and a dose evaluation performed to ensure the operating environment is adequately characterized and responder exposures controlled. However, it must be recognized that such symptoms may also be caused by other agents (*e.g.*, a neurological agent), heat stress or by a psychosomatic reaction to the stress of a radiological emergency.

## 1.1 Types of Radiological Events

Any kind of emergency response involves health and safety issues that have to be addressed in accordance with the scale of the incident and the prevailing hazard. Planning and preparedness efforts should therefore provide adequate provisions to tackle health and safety problems that range from minor concerns to those that include critical lifesaving actions and the protection of major assets, infrastructure, and public property. This guide is issued to help Health and Safety Officers (HSOs) to provide sound protective measures to emergency professionals deployed at the scene of the incident and the surrounding areas. Table 1.1 lists some of the types of radiological incidents that may occur and the response activities that would be required.

**Table 1.1: Types of Radiological Incidents and Responses**

| Incident Type | Radiation Involved | Responsive Actions |
|---|---|---|
| **Threat of an incident** | None | 1. Evaluate as appropriate based on information available.<br>2. Possible need to collect survey measurements to evaluate veracity of threat[1]. |
| **Misplaced, Lost, or Stolen Source** | Source(s);<br>sealed or unsealed | 1. Evaluate as appropriate based on information available.<br>2. Survey to locate source[1]. |
| **Transportation Accident or Spill** | Source(s);<br>sealed or unsealed | 1. Secure radioactive material,<br>2. Restrict area as appropriate for the type and quantities of material involved (the Emergency Response Guidebook (ERG) provides recommendations for boundaries and actions). |
| **Radiation Exposure Device** | Sealed gamma source | 1. Secure area. Identify source with hand-held instrumentation or aerial survey.<br>2. Secure, shield, and transport source for disposal. |
| **Radiological Dispersal Device**<br>(RDD or "dirty bomb") | Radioactive materials dispersed<br>by conventional explosive or other means | 1. Secure area. Initial focus on direct effects of blast and emergency medical care.<br>2. Possible need for wide-area radiation monitoring.<br>3. Possible need for internal radiation monitoring.<br>4 Probable need to establish zones and decontamination stations.<br>5. Possible need to implement steps to reduce radiation dose to general public. |
| **Improvised Nuclear Device (IND)** | Special nuclear materials,<br>fission and activation products | 1. Initial focus: Communicate protective action to the public mainly to shelter in place; arrange safe evacuation; provide emergency medical care for victims of thermal and blast effects; determine the magnitude and extent of the plume and control zones in the affected area<br>2. Evaluate radiological conditions for long-term response. |

[1] Surveys may be conducted inconspicuously to ensure the safety of surveyors from threats against them

# 2. Radiation Hazards

## 2.1 Radiation Units and Terminology

The **rad** and **rem** are common units of radiation dose. In this guide, radiation dose is expressed in mrem (1000 mrem = 1 rem). Units of R (Roentgen) are sometimes used as well, although this is generally considered an obsolete unit of measure. For emergency response purposes, assume that R, rad, and rem are equivalent so that 1 R = 1 rad = 1 rem.

International Units are the Sievert (Sv) and the Gray (Gy). 1 Sv = 100 rem, so 1 rem = 0.01 Sv = 10 mSv. Similarly, 1 Gy = 100 rad, which can be treated as equivalent to 100 rem.

Keep in mind the distinction between dose and dose rate. A dose (such as 5 rad) describes the total amount of radioactivity that a person has absorbed (or will absorb). A dose rate (such as 2 rad/hr) describes the strength of the radioactive field in a given location. By multiplying the dose rate by the time spent in a given location, the dose from that exposure can be calculated. For example, a person who spends 5 hours in a 1 R/hr radiation field will receive a total dose of 5 rads, the same dose as a person spending 1 hour in a 5 R/hr radiation field, or a person spending 20 hours in a 250 mR/hr (0.25 R/hr) radiation field.

The **Curie** (Ci) is a measure of the rate at which radiation is emitted from radioactive materials. A 1-Ci source, for example, will undergo 37 billion decays per second and a 1 microCurie source will undergo 37,000 decays per second. However, it is essential to keep in mind that the radioactive decay rate has very little to do with the physical quantity of radioactive material present – one gram of Ra-226 contains as much radioactivity as about three tons of depleted uranium, while one gram of tritium contains 10,000 times as much radioactivity as does one gram of Ra-226. The only ways to know how much radioactivity is present are via radiation measurements or by examining documentation associated with the source.

The International Unit for radioactivity is the Becquerel (Bq) and 1 Ci = 37 GBq (i.e. 37 billion Bq).

Units of radioactivity are frequently encountered in descriptions of the concentrations of radioactive substances (e.g. microCuries per cubic meter or picoCuries per gram). These units are also used to quantify the amount of radioactivity contained in shipments and in industrial or medical instruments. Unlike the rem, rad, and Roentgen, which relate to the amount of energy the radiation deposits in one's body, the curie measures the rate of radioactive decay of a material. Thus, the Curie cannot be used to directly estimate health risks or health effects.

Additional information on radiation units and their interpretation is found in Section 1 of the first part of this Field Guide.

## 2.2 Overview of Radiation Effects

Table 2.1 gives an overview of the expected health hazards at different exposure doses. These hazards are discussed further below. Note that, according to BEIR VII, the baseline lifetime cancer mortality risk for residents of the United States is ~40%. (That is, even in the absence of excessive radiation exposure, US residents have a 40% lifetime risk of dying of cancer). Therefore, a radiation dose predicted to increase cancer risk by 1% (for example) would increase that lifetime risk from 40% to 41%. Naturally, the risks to unborn children apply only when the dose is received by someone who is pregnant at the time of exposure.

**Table 2.1: Radiation Health Effects by Dose**

| EXPOSURE DOSE | Radiation Health Effect |
|---|---|
| **Up to 5 rem (5000 mrem)** | • No cases of birth defects reported among pregnant women<br>• No symptoms attributable to exposure<br>• Cancer risk likely does not increase |
| **10 rem (10,000 mrem)** | • Slightly increased risk of birth defects *in pregnant women exposed to this level of radiation*<br>• <1% increased risk of fatal cancer<br>• Exposure to unborn babies increases risk of childhood cancer |
| **25 rem (25,000 mrem)** | • Reports of temporary sterility with acute dose of 15 rem to pelvic area<br>• 1-2% increased risk of fatal cancer |
| **50 rem (50,000 mrem)** | • Slight loss of bone marrow cells; recovery is virtually 100%<br>• Risk of fetal birth defects or miscarriage<br>• 2-4% increased risk of fatal cancer |
| **100 rem** | • 10-30% of people experience nausea and vomiting.<br>• 10-50% have loss of appetite.<br>• Possible fever and increased risk of infection due to bone marrow syndrome.<br>• 5% increased risk of developing fatal cancer |
| **200 rem** | • Possible cataract formation (months or years later)<br>• 10% increased risk of developing fatal cancer |
| **450 rem** | • Many symptoms of acute radiation poisoning (ARS), including: skin reddening, loss of hair, bone marrow failure, bleeding, headache, radiation burns<br>• 50% mortality of exposed individuals within 60 days *without* medical treatment ($LD_{50/60}$ )<br>• Lifetime risk of fatal cancer increases to >40% |
| **800 rem** | • More severe ARS symptoms, confusion, loss of consciousness<br>• > 50% mortality within 2 to 3 weeks |

## 2.3 Risk of Cancer (Stochastic Health Effects)

Stochastic health effects are based on probability. Cancer and hereditary effects are the stochastic effects of concern with radiation. With stochastic health effects the risk of the effect increases with dose but the type or the severity of the effect is not altered by dose

(for example higher radiation exposure increases the risk of developing cancer but does not result in a more malignant cancer or a larger tumor).

Stochastic effects:

- Have a delayed onset- they can occur 2-3 decades after exposure
- Can occur at lower doses (less than 50 rem)
- Exposure to 100 rem of radiation increases the lifetime risk of cancer mortality by 5% (to 45% overall risk)
- However, there have so far been no hereditary effects on humans reported on scientific literature (that is, pre-conception exposure to radiation has not been shown to cause birth defects months or years later)

## 2.4 Non-Stochastic Health Effects

These effects are sometimes referred to as deterministic effects or radiation poisoning. Deterministic effects result from cell death; the higher the degree of cell death, the more severe is the effect. The total dose determines the amount of cell death:

- With an increased dose the following occur:
  - Number of cells affected increases
  - Biological effect is more severe
  - Types of effects increase

*Acute Radiation Syndrome* (ARS)- dose ≥ 75-100 rem

- Typical symptoms are nausea, vomiting, and weakness
- Onset can be delayed for up to a few months post-exposure
- As the dose increases, the number of organs involved increase
  - there will be more symptoms occurring
  - the time to onset of the symptoms decreases

*Cataracts*- dose ≥ 200 rem

- Usually a 2 year delay before onset following an acute exposure

*Skin burns and hair loss* – dose ≥ 300 rem

- Localized radiation burns (erythema) and loss of hair (epilation)

*Birth Defects*

- Effects only occur when an unborn baby is exposed *in utero*
- Outcome of the exposure depends on the radiation dose to the developing fetus and the post-conception age of the fetus at the time of exposure
- **No effects** have been seen for a fetal dose of less than 5 rem or for any exposure less than 2 weeks post-conception
  - in most cases (if the mother has no other risk factors) birth defects are highly unlikely for a fetal exposure of less than 15 rem

## 2.5 Recommended Dose Limits

Radiation dose limits are specified in regulations. National standards are established in 10 CFR 20[2] (Nuclear Regulatory Commission) and 29 CFR (OSHA), which have set an annual occupational dose limit of 5 rem (5000 mrem) for radiation workers working under controlled and routine conditions at licensed facilities.

Exceeding radiation dose limits is permitted under emergency situations if required to save lives, prevent injuries, or to protect facilities from extensive damage. However, regulatory bodies, professional organizations, and national advisory bodies recommend that all responders adhere to the regulatory radiation dose limits, even in emergency situations, ***unless it is necessary to exceed that level to complete lifesaving activities or efforts related to the protection of infrastructure and property***.

Radiation dose limits and decision points under a number of circumstances are summarized in Table 5.4 in Part I of this Field Guide.

## 2.6 Health Risks at Exposure Doses above 5 rem

The primary health effect from exposure to low dose radiation is the risk of cancer. At this time, cancer causes one in four deaths in the United States although this is an average and does not take into account individual risk factors (e.g. smoking, diet, genetic pre-disposition, etc.). Exposure to 100 rem increases the risk of developing fatal cancer by about 5% among the general population (BEIR VII).

Non-stochastic effects begin to appear at a dose of about 25-50 rem. The first such effect to appear is a loss of some of the normal function of the bone marrow and a drop in blood cell counts, but these effects are 100% reversible at doses of this level.

Consistent with the concept of ALARA all responders shall make every reasonable effort to keep their radiation exposures as low as reasonably achievable. However, it is necessary to keep the risks posed by radiation in perspective and to compare them to the risk(s) to be averted by emergency response efforts. For example, exposure to an addition 20 rem (increasing dose from 5 rem to 25 rem) will subject a responder to an additional 1-2% risk of cancer mortality over the following 20-30 years, which is a low – but not a trivial – added risk. This added exposure may be considered acceptable if the responder is engaged in saving the lives of those who are otherwise likely to be severely injured or killed. For this reason radiation workers are permitted to receive a one time total of 25 rem to save valuable property. The NCRP and Environmental Protection Agency (EPA) guidelines allow exceeding 25 rem for saving lives or averting high radiation exposures to large populations.

[2] New York State radiation regulations are found in Part 16 of the New York Code of Rules and Regulations. New York City radiation regulations are found in Article 175 of the New York City Health Code. Both New York State and New York City regulations are required to be compatible with 10 CFR 20.

## 2.7 Exposure Concerns for Pregnant Women

The data from animal studies, the Japanese atomic bomb survivors and pregnant women receiving diagnostic X-rays suggests that at a dose of 5 rem (5000 mrem) to the fetus results in a slightly increased risk of childhood cancer. There is no indication of induced birth defects at any fetal radiation dose of less than 5 rem (15 rem for a mother without additional risk factors such as smoking, alcohol use, etc.)[3].

Pregnant women who voluntarily declare their pregnancy are given lower radiation dose limits for the duration of their pregnancy. The occupational dose limit for declared pregnant radiation workers is 500 mrem for the entire pregnancy and may not exceed 50 mrem in any single month following the declaration of pregnancy.

## 2.8 General Considerations for Radiation Victims

An incident involving an uncontrolled release of radioactivity can produce several groups of affected people:

- Those who are seriously injured and radiologically contaminated
- Those who are seriously injured and have little or no radiological contamination
- Those who are contaminated and have minor or no injuries
- Those who are uncontaminated and were not injured by the event

Many radiological exposure scenarios involve exposure to materials capable of delivering external doses, (i.e., radiation emitted from sources external to the body) and resulting in radiation doses to the affected individuals. Sufficiently high external doses may cause skin burns, damage to the internal organs, or damage to the blood-forming organs (for example, causing bone marrow depression) and damage to other affected tissues. However, those who are subject to external radiation exposure do not become radioactive and they pose no threat to medical providers.

**Note: Victims of radiological exposures should have any trauma-induced injuries stabilized before any type of radiation decontamination is attempted.** The Health and Safety Officer or primary medical responder may evaluate the patient(s) for external radiation exposure and internal contamination if their medical condition permits.

Persons exposed to very high external gamma ray doses (more than 200 rem) may experience the onset of vomiting and diarrhea within 1 to 2 hours, and at higher doses (several hundred rem and higher) personnel might experience possible altered mental

[3] Brent, Robert L. The Effects of Embryonic and Fetal exposure to Ionizing Radiation: Counseling the Patient and Worker about These Risks. Chapter 3 of The Biological Basis of Radiation Protection Practice. Williams & Wilkins, 1992. Mossman KL and Mills WA eds.

status or even loss of consciousness for seconds or minutes. Radiation burns of the skin may evolve over several hours to days.

Appearance of any of these symptoms calls for dose assessment and aggressive medical care, which will initially include fluid resuscitation, administration of antibiotics/anti-virals, and stem cell stimulating medicine. Radiation burns will require burn treatment and care.

Radioactive contamination in wounds or burns can be absorbed, resulting in internal contamination and possibly the need for medical countermeasures (e.g. Prussian blue to increase the removal of cesium from the body). Initial treatment of the wound should include a contamination count or measurement of the radioactivity in the wound and specimen collection. Contaminated wounds should be flushed with copious amounts of saline or sterile water followed by debridement if the wound remains highly contaminated.

Some basic concepts for monitoring and treatment of victims with potential radiation exposure are summarized in the lists below. Additional information is found in Section 6 in Part I of this Field Guide.

## 2.9 Reminders for Medical Monitoring of Patients with Radiological Concerns

1. Medical needs should ***always*** take precedence over concerns for contamination on the patient.
2. Physicians, medical, ambulance staff and other responders should be reminded that direct exposure to gamma radiation does not cause a person to become radioactive or contaminated with radioactive material.
3. Normal sterile procedures will adequately control the unwanted spread of radioactive contamination.
4. Standard precautions will protect medical and emergency responders who are working on a contaminated person.
5. Release of radioactive material from a radiological dispersion device (RDD) is not likely to cause serious harm outside of the immediate blast area.
6. Early assessments of radioactive contamination can be made with portable monitoring equipment.
7. When medical and emergency responders are evaluating the medical impact of radiation exposure they must consider that the radiation exposures required to produce medical effects (e.g. radiation sickness, skin burns, etc.) are much higher than those to which radiation workers are normally exposed. Thus, a dose that might seem alarmingly high from the perspective of regulatory compliance (e.g. 50 rem) is still unlikely to cause serious medical problems.

8. If a patient requires further decontamination and follow-up after triage, these facts should be communicated to a single physician, rather than to multiple medical providers, to better allow for efficient decision-making and treatment.
9. Do not delay rescue and first aid operations in order to decontaminate vehicles, equipment, or personnel.
10. When decontaminating a person, up to 90% of the contamination may be removed by removing outer clothing.
11. When decontaminating skin contamination avoid taking actions that are painful or uncomfortable (e.g. do not use hot or cold water, avoid harsh soaps, etc.).

# 3. Radiation Dose Management

Many radiological incidents will not involve radioactivity levels high enough to cause an imminent health hazard. Nevertheless, it is always important to take all reasonable steps to minimize responder exposure, and to monitor and document all exposures that occur. A basic principle of radiation safety is to keep exposure ALARA in order to minimize risk. A number of practices, described in Section 3.2 below, will help responders to keep their radiation exposure ALARA. Additional information and good radiological work practices are found in Sections 5 and 7 of Part I of this Field Guide.

## 3.1 Emergency Responder Total Dose Guidance Levels

Routine occupational exposure limits are not applicable by law or regulation to radiological emergency incidents due to the potential for doses of much greater magnitude than those to which radiation workers and emergency responders are normally exposed[4]. However, even during extreme emergencies, the concepts of ALARA, justification, and optimization are still applicable. The potential benefit from emergency responder actions must be weighed on a case-by-case basis against the risk posed by the exposure, with every reasonable and practical effort made to both maintain doses to radiation below the levels causing early health effects and to reduce the risk of long term effects[5].

Two tools are available to help control radiation dose to emergency responders are turnback levels and decision points.

Dose rate turnback levels represent radiation dose rates at which emergency responders are required to stop advancing and to request instructions as to whether to continue advancing or to turn back. Turnback limits are intended to be used primarily in the early phases of emergency response when radiation levels are not yet well-characterized.

Another method for controlling radiation exposure and the activities of emergency responders is to use “decision points” based on a responder’s total radiation exposure. At each decision point an individual responder is required to halt their activities and to notify the Incident Commander of their exposure and their circumstance, requesting permission to elevate their allowable exposure to the next decision point. For example, an emergency responder reaching the 5-rem decision point who is intent on saving a person’s life would report having reached a dose of 5 rem and requesting permission to accumulate an exposure of up to (for example) 10 rem to save a life. If granted, the responder would continue working until completing their task (saving a life) or until

[4] NCRP Report 165 Responding to a Radiological or Nuclear Terrorism Incident: A Guide for Decision Makers
[5] Musolino et al., 2008

reaching the next decision point. If permission is not granted, the responder would pull back and turn over their work to another responder.

When possible, taking into account their other missions, first responders should measure and report exposure rates, particularly during initial area entries[6]. Once the radiation conditions are better defined, activities can be planned utilizing a combination of real-time total dose monitoring and stay time estimates.

The Incident Commander is responsible for defining the total dose and dose rate control levels for a specific incident, and authorizing responders to exceed a control level for a given type of action when reasonable alternatives do not exist. Emergency workers, whose duties during a radiological or nuclear incident may require exceeding the occupational dose limits, do so as volunteers who have been provided information on the health risks of such exposures to permit informed decision making[7]. It is recommended that, to the extent practical, informed consent of such emergency workers be obtained in advance of a radiological emergency (e.g., not when an incident has just occurred), that responsibilities and related risks be communicated in employment-related documentation, training and qualification.

Total radiation dose guidance levels for emergency responders are summarized in Table 5.3 in Part I, Section I of this Field Guide.

## 3.2 General Principles of Radiation Safety

The ALARA philosophy calls for taking all reasonable steps to minimize radiation exposure but it does not explain how this is to be accomplished. Over the century or so since the discovery of radiation and radioactivity health physicists and radiation workers have developed radiation safety principles and work practices that are quite effective at reducing both dose and risk to radiation workers. A respected health physicist, Dr. Daniel Strom, describes what he calls the “Ten Principles and Ten Commandments of Radiation Protection” which was published in the scientific journal *Health Physics* in 1996. Not all of Strom’s principles are relevant to a radiological event. Those that are relevant are summarized below.

**Time -** Minimizing exposure time within a radiation field will minimize the radiation dose. Responders can perform tasks in very high radiation fields with a minimal radiation dose by working quickly.

**Distance -** Increasing the distance from a radiation source will also lower the radiation exposure very quickly. Radiation exposure goes down by a factor of four if you double

[6] NCRP 165

[7] Dose rate levels are based on external exposure pathway, only. If internal exposure is not sufficiently mitigated through respiratory protection usage, these turnback levels may need to be adjusted.

the distance from a localized source. For example, if the exposure rate at 1 yard from a source is 8 mR/hour, the exposure rate at 2 yards from the same source will be 2 mR/hour. At four yards the exposure rate will go down to 0.5 mR/hr (500 µR/hr). Therefore, moving even a few yards further away from a localized source can reduce exposure levels dramatically. If the radioactive material is spread over a large area (several square yards) the exposure rate will not decrease as fast, but will still go down significantly as the distance increases.

**Shielding -** Properly shielding a radioactive source requires knowledge of the type of radiation emitted whether alpha, beta, or gamma radiation as defined below:

***Alpha particles*** are stopped with a sheet of paper, clothing, or a few inches of air. Thus radioactive materials that emit alpha radiation pose no risk from exposure outside of the body. These materials would have to enter the body by ingestion, inhalation, or introduction to the bloodstream via wounds or embedded fragments to cause any harm.

***Beta particles*** are easily stopped with a quarter- to half- inch sheet of plastic, or a thin layer of wood, metal, or skin. Even very energetic beta particles can only penetrate the outer layer of skin to a depth of about ½ inch. Lower-energy beta particles may not penetrate heavy clothing at all. Thus, radioactive materials that emit beta particles pose little risk unless they enter the body by ingestion, introduction into the bloodstream or inhalation. Beta particles will also only penetrate at most a few yards of air before giving up all of their energy. However, direct exposure or contamination of the skin to energetic beta can cause beta burns.

***Gamma rays*** are referred to as “penetrating radiation” because they can pass through solid materials. Shielding for gamma rays depends on the density and thickness of shielding material. High density materials, such as lead, tungsten, steel, and concrete are best for shielding gamma rays. *Personal Protective Equipment such as anti-contamination clothing or firefighting gear does not provide protection against gamma radiation.* As the thickness of a shield is increased, the intensity of the gamma radiation will also decrease. Shielding can include materials that are brought to the scene (e.g. lead bricks), but emergency responders can also take advantage of materials found at the scene (e.g. existing walls, embankments, or structures) as well as non-traditional shielding materials (e.g. large vehicles or water bladders used by the Fire Department). *Note: Unless there is a need to get near a radioactive source, such as for rescuing injured victims, fire-fighting, repairing or stabilizing damage to utility lines, or retrieval and disposal of the radioactive source, first responders can more easily reduce their radiation exposures by increasing the distance from the source rather than by utilizing shielding.*

**Source barrier** – Take steps to minimize the dispersal of radioactive materials into the air or beyond the boundaries of a contaminated site. This can be accomplished through dust suppression, decontaminating personnel and equipment (including vehicles)

leaving a contaminated area, covering exposed contamination with some sort of sheeting, and similar actions.

**Source reduction** – Radioactive wastes will accumulate as radioactive and contaminated materials are removed from the scene and as contaminated objects and people are decontaminated. As these wastes accumulate they will contribute to elevated radiation dose rates. For this reason, periodic radiation surveys should be performed and radioactive wastes should be removed or relocated as necessary.

**PPE** – Wearing appropriate PPE (e.g. protective gloves, respiratory protection, etc.) will reduce the risk of skin contamination, ingestion, or inhalation. This, in turn, will reduce radiation exposure to workers and responders. In particular, the use of respiratory protection will reduce the risk of internal contamination. Respiratory protection and considerations accompanying its use are discussed in Section 5 of this Guide. Further information on PPE, including PPE selection and generic procedures for donning/doffing PPE is found in Section 4 of Part I of this Field Guide.

# 4. Operating Zones and Public Safety Measures

## 4.1 Zone Definitions

A variety of operational and public exclusion zones may need to be established in response to a radiological incident, depending on the magnitude and extent of the impact. Table 4.1 describes typical operational responder and public safety zones.

| Name | Description |
|---|---|
| **Hot Spot** | • Localized area of especially high activity, generally above 1 R/hr<br>• Responders in Hot Spots should be aware of ALARA and plan all tasks to minimize unnecessary exposures |
| **Hot Zone / Exclusion Zone** | • Boundary should initially be set at a distance where the measured radiation dose rate is 2 mR/hr using an appropriate radiation dose-rate meter<br>• Incident Commander has discretion to set a boundary at a dose rate of 10 mR/hr<br>  ○ When time and instrumentation permit performing a contamination survey, the boundaries should be adjusted to reflect a dose rate of 2 mR/hr of removable contamination using an appropriate radiation detector<br>• In the absence of accurate dose rate and contamination measurements, the initial boundary can be set based on a distance from an explosion or release depending upon operational circumstances and area<br>• Placement of Hot Zone boundaries should also take into account other potential hazards in addition to radiation (e.g., structural collapse, fires, etc.)<br>• Members of the public in the Hot Zone may be required to evacuate immediately or to shelter in place and await further instructions, according to the incident-specific circumstances |
| **Warm Zone** | • Areas in which monitoring and decontamination of personnel and equipment as well as Hot Zone support occur<br>• Personnel and equipment enter and exit the Hot Zone through the corridors in the Warm Zone<br>• Boundaries should be established to provide sufficient space for the tasks and equipment noted above<br>• May include control points for the decontamination corridor thus helping to reduce the spread of contamination. Personnel enter and exit the Warm Zone at designated entry/exit points<br>• Decontamination and triage of the public will be conducted here |
| **Cold Zone** | • Area outside of the Hot Zone<br>• Ideally the Command Post and other support functions should be located in an area where radiation levels are less than 0.1 mR/hr (100 µR/hr) and where radioactive contamination is at background level.<br>  ○ If not feasible, these functions should be located in secured areas in which radiological risks are minimized<br>• In the early phase, considered suitable (in terms of radiological hazards) for short-term occupancy by the public and emergency responders<br>  ○ Further investigation may reveal that some areas of the Cold Zone are not suitable for *long-term* occupancy pending some degree of remediation<br>• PPE may be required for some tasks performed in the Cold Zone, and changing conditions may cause the Command Element to change PPE requirements in some areas in the Cold Zone as events progress |

## 4.2 Restrictions on Activities by Zone

A. Support Area

- No personnel dosimetry required.
- Activities include all staging operations and support activities.
- Rest areas to be established in cold zones.
- If radioactive contamination is present or suspected, those working in Hot Zone must go through decontamination line and radiation screening before crossing from Warm Zone into Cold Zone.
- Radiation monitoring of the area should be continuous monitor for changes in radiation or contamination levels.

B. Hot Zone

- Working within this area will be restricted to emergency responders, subject matter experts, technical advisors, and necessary regulatory authorities during the emergency phase. Following the emergency phase, the Hot Zone may be part of a crime scene and access may be restricted to crime scene investigators until the area is released. Responders should avoid spending unnecessary time in this zone.
- No smoking, eating, or drinking will be allowed in the Hot Zone.
- Situation-appropriate PPE should be worn at all times (described in Table 4.3 in Section I of this Field Guide)
- Radiation monitoring equipment should be used to alert the user they have reached any dose or dose-rate guidelines. Recommended alarm settings are provided in Table 2.1 of Section I of this Field Guide.
- The Radiological Health and Safety Officer(s) (RHSO) should monitor radiation doses received by workers and responders, advising on time allowed at different levels, advising commanders of doses to be expected and recommending protective actions such as those noted in the previous section.
- Responders and other workers should maintain communication with the Incident Commander, the RHSOs, or another designated on-site supervisor during any activities within the Hot Zone
- The decontamination line will be set up at the outer edge of this zone, up-wind from the location of the attack if possible. An upwind location is especially important if there is the possibility of resuspended radioactivity that could spread contamination downwind.

Prior to initiating entry into a potentially contaminated zone, the HSO must work with the RHSO to evaluate the potential for other types of hazards, including chemical, biological, and physical, in addition to radioactive hazards.

# 5. Personnel Protective Equipment (PPE)

Although radiation and radioactivity can pose unique hazards (e.g. the penetrating nature of gamma radiation) they share some routes of exposure that are similar to other potential hazards – skin contamination, ingestion, inhalation, absorption through the skin, and contamination of open cuts or wounds. Because of this, PPE requirements for working in radiological areas are similar to those for working around other hazards: covering the skin to minimize skin contamination and wearing respiratory protection to minimize the risks of inhalation and ingestion. As noted in the previous section, selecting and wearing appropriate PPE is an important safety measure.

## 5.1 Recommended Personal Protective Equipment (PPE) in a Radiological Incident

Self-contained breathing apparatus (SCBAs); respirators, firefighter "turnout" or "bunker gear;" and Level A, B, or C HAZMAT suits provide protection against skin contamination and against alpha and beta radiation. They do not protect against penetrating gamma radiation. Accordingly, appropriate PPE is an important part of radiation safety practice but cannot be relied upon as the sole means of protection. Clothing worn for protection against particulate contamination will become contaminated itself and must be removed as an individual leaves a contaminated area. The way in which protective equipment is removed must be carefully supervised so personnel do not contaminate themselves during the procedure – PPE donning and doffing procedures are provided in Section 4.4 of Part 1 of this Field Guide.

## 5.2 Overview of PPE Levels

**PPE is divided into four categories (A, B, C, and D)** based on the degree of protection afforded, with Level A PPE providing the highest degree of protection. The highest level of hazard, such as the presence of explosives or conditions that are immediately dangerous to life and health (IDLH), must always be addressed first, in accordance with OSHA and NIOSH standards and agency policies for Personal Protective Equipment. A summary of the different PPE levels is provided below.

**Level D** – Use when the concentration(s) and type(s) of airborne substance(s) are known and the criteria requiring use of respiratory protection are not met. A work uniform providing minimal protection for nuisance contamination only, consisting of:

1. Coveralls or uniform
2. Gloves*
3. Boots/shoes, chemical-resistant steel toe and shank.
4. Boots, outer, chemical-resistant (disposable)*
5. Safety glasses*
6. Hard hat*

*Optional item to be worn if applicable with incident hazards

If more skin protection is required, Level D can be modified by adding chemical-resistant clothing, such as Tyvek, and additional layers of gloves.

**Level C** – At this level PPE should be selected when the types of airborne contaminants are known, the concentrations have been measured and the criteria for using respiratory protection are met. Level C requires the use of NIOSH approved full-face or half mask Air Purifying Respirators (APR) equipped with an organic vapor, dust, fumes and mists combination cartridge i.e., P100 combination cartridge.

If the results of air sampling show that a relatively low protection factor is acceptable Modified Level C PPE can be used. This consists of Level C with a disposable P100 half-mask respirator in place of the APR. The assigned protection factor (APF) for the disposable half-mask respirator is 10, compared to 50 for the full-face APR. Selecting appropriate respiratory protection is discussed in greater detail later in this section.

**Level B** – At this level PPE should be selected when the highest level of respiratory protection is needed, but a level of skin protection lower than Level A is required. Level B protection is the minimum level of protection recommended on initial site entries until the hazards have been further defined by on-site monitoring.

**Level A** – Not needed for radiological protection alone. This level may be needed for response involving certain chemical hazards.

Further information about PPE selection and use can be found in Section 4 of Part 1 of this Field Guide.

Note: The degree of respiratory protection (e.g. nuisance mask, SCBA, air-purifying respirators, etc.) required will depend on many factors, including the airborne radioactivity concentrations and the presence of other airborne contaminants.

## 5.3 Respiratory Protection

In a radiological incident, the primary purpose of respiratory protection is to protect against inhalation of radioactive air contaminants that may be present as either gases or particulates. In deciding whether to use respirators, protection against concurrent chemical and physical hazards must also be considered. Simple facemasks used in a variety of emergency response scenarios will usually provide protection against inhaling radioactive particulates while allowing sufficient air transfer for working at high breathing rates.

***Respirators should be used only if necessary*** because they subject the wearer to additional stress and increase the risk of injury by impairing vision, freedom of motion, and ability to communicate. Under many circumstances, these factors may increase the risk of physical injury to the wearer that far exceeds any potential risk associated with

the inhalation of a small quantity of airborne radioactive material. Use of respirators may also increase the time needed to accomplish tasks in a high radiation zone, and therefore result in a higher external radiation dose.

Guidance on assigning stay times based on airborne radioactivity concentrations and the respirator protection factor is summarized in Table 5.2 of Part I of this Field Guide.

## 5.4 Considerations for Respirator Use

As stated in Section 5.3 (above), respirators should be used in radiological response only if deemed necessary. Use of respirators may increase the time needed to accomplish tasks in a high radiation zone, and can actually result in a ***higher*** external radiation dose that can increase the total radiation dose a worker receives. If the radioactive contaminant is known, and its air concentration has been measured, calculations can be performed to estimate if the benefit of respirator use outweighs the cost. The calculation is described in detail below.

### *Air Monitoring*

Air monitoring data, in conjunction with surface monitoring data, are generated in various locations in the radiological response area to assess the need for respiratory protection. Measurements are taken in personal (breathing zone) areas, downwind from the affected area(s), and at upwind background locations.

Air sampling for radioactive materials has many similarities with conventional particulate contaminant sampling methods. Gross alpha and beta-gamma counting should be done as soon as possible to assess the presence of short-lived radionuclides as well as following a suitable decay period (typically five days) to quantify long-lived radioactivity. These screening level analyses should be possible without the use of a radioanalytical laboratory.

If possible, personal breathing zone (lapel) samples should be collected during initial response actions when the potential for airborne radioactivity exists. These consist of a battery operated pump calibrated for airflow in excess of three liters per minute pulling air across a Millipore™ or Nucleopore™ polycarbonate membrane.

Area air samples are collected within and at the boundary of radiologically controlled access areas. Samples are collected using electric powered sampling pumps, calibrated at airflows in excess of 20 liters per minute. The flow rate and sample duration will be determined in order to detect the desired limit for radioactivity. Samples should be counted for gross alpha and gross beta-gamma concentrations and the results should be corrected as necessary to account for the presence of radon and progeny nuclides (these corrections must be performed by qualified health physicists)

### *DACs and Action Levels*

NRC has published Derived Air Concentrations (DACs) for a very large number of radionuclides in 10 CFR Part 20 Appendix B, Table 1, Column 3. These tables can be viewed on the internet at http://www.nrc.gov/reading-rm/doc-collections/cfr/part020/appb/. The DAC is the concentration of radioactivity in the air which, if inhaled for one work year (2,000 hours), will give the worker an intake that will result in a 5,000 mrem dose to the whole body or 50,000 mrem to the target tissue or organ. Concentrations in air are expressed in terms of multiples of DAC (e.g. 2 DAC, 0.001 DAC). NRC has also developed default values to be used if the nuclide(s) present is unidentified.

***The number of DAC in the atmosphere at any instant in time is not a limit and*** no actions are required when atmospheric radionuclide concentrations reach the level of 1 DAC. The only regulatory limit associated with airborne radioactivity concentrations apply to the total number of DAC-hours to which a person is exposed. Specifically, radiation workers are limited to 2000 DAC-hours in one year under normal circumstances. Thus, it is permissible (for example) for a radiation worker to work *without* respiratory protection in an atmosphere of 100 DAC for 10 hours (accumulating a dose of 1000 DAC-hours or 2500 mrem) without violating any regulatory requirements.

When deciding whether or not to order the use of respiratory protection, one must consider not only the number of DAC but also the amount of time to obtain the total number of DAC-hours that a person will work in the area. The HSO must also consider additional risks that might result from the use – or the non-use – of respiratory protection. The presence of additional airborne hazards might mitigate in favor of wearing respiratory protection regardless of the anticipated number of DAC-hours to which a worker might be exposed. Similarly, other factors such as the need to have a full field of view, a shortage of respirators, the need to work for periods of time that exceed the duration of an air tank, etc. may favor working without respiratory protection provided the worker does not exceed 2000 DAC-hours and provided there are no other respiratory hazards present.

### *Calculation Method for Known Contaminants*

1. Determine airborne concentration, **C** (µCi/mL), present in the atmosphere
2. Look up the Derived Airborne Concentration (**DAC**) in 10 CFR Part 20 Appendix B, Table 1, Column 3 for the radionuclide of concern. DAC should be in units of µCi/ml). By definition, inhalation of air without respiratory protection at the DAC for 1 hour results in a 2.5 mrem dose.
3. Estimate the potential time of inhalation exposure (**t**) in hours.
4. Calculate the estimated inhalation dose without respiratory protection:

**D** (in mrem) = (**C** x **t** x 2.5 mrem/hr) / **DAC**.

In the above equation, C is the airborne concentration of the contaminant in µCi/ml; t is the time in hours; DAC is the DAC in µCi/ml. If the contaminant concentration is known in units of multiples of DAC, the equation simplifies to:

**D** (in mrem) = (**C** x **t** x 2.5 mrem/hr).

5. Use external dose rate data in the area to estimate the external dose to workers for the projected stay times with and without respiratory projection.
6. Base the decision to use respiratory protection on ALARA, (i.e., which approach with or without respiratory protection gives the lowest dose?) and the presence of other considerations such as those mentioned above to determine which approach results in the lowest overall risk to responders. Since the use of a respirator may increase the time required to perform a certain task, the total dose may be less without a respirator.

Sample calculation:

Assume the external dose rate is 50 mrem/hr and the airborne concentration of the radionuclide of concern is 4 times the published DAC. Assume further that responders would need to spend three hours in the hot zone without respirators or four hours with respirators to complete all required operations. An ALARA evaluation based on whole body dose equivalent can be done as follows:

**With Respirators**

External Dose: 4 hours x 50 mrem/hr = 200 mrem
Internal Dose: 0 mrem
Total Dose: 200 mrem

**Without Respirators**

External Dose: 3 hours x 50 mrem/hr = 150 mrem
Internal Dose: 3 hours x 4 DAC x 2.5 mrem/DAC-hr = 30 mrem
Total Dose: 180 mrem

Therefore, consistent with ALARA, the work should be done without respirators.

# 6. Radiation Protection Instrumentation

Selecting appropriate radiation instrumentation is vitally important to radiation safety because not all instruments respond correctly to all types of radiation – using the wrong meter can result in significantly over- or under-estimating the radiation dose rate in an area.

For use within the Hot Zone, instruments should be capable of measuring up to 10 R/h so that workers do not inadvertently stray into the Dangerous Radiation Zone. If entries above this level are required, instruments should measure both exposure rates up to 1000 R/h as well as track exposures. Alarming Dosimeters and Personal Emergency Radiation Detectors (PERDs) are particularly well suited for supporting response activities, although their alarm set points should be enabled to alert the user when additional protective measure or withdrawal from the area should be considered. Table 6.1 provides additional assessments of various radiation survey instruments and systems.

Tables 6.1 and 6.2 (below) are a modified version of the instrumentation information provided in the Federal *Planning Guidance* document (EOP, 2010). Examples include the types of instruments currently in use in the NYC. Inclusion of examples in this document does not represent an endorsement of specific products or vendors.

**Table 6.1: Assessment of radiation instruments for various tasks**

| Mission | Alarming Dosimeters & PERDs[1] | Non-alarming PERDs[1] | Survey Meter[2] | PRD detection[3] | Contamination monitors[4] | Dosimeters | Aerial system |
|---|---|---|---|---|---|---|---|
| **Hot Zone activities[6]** (use instruments that can function in exposure rates up to 10 R/hr) | | | | | | | |
| Worker dose assessment | ○ | ○ | — | — | — | ● | — |
| Worker safety for Hot Zone missions[7] | ● | ○ | ○ Type II[8] Only | — | — | — | — |
| Survey of Hot Zone | ● | — | ● Type II Only | — | — | — | ● |
| Establishing evacuation routes | ● | — | ● Type II Only | — | — | — | ● |
| **Activities outside of Hot Zone** (use instruments that can function in exposure rates up to 0.01 R/hr) | | | | | | | |
| Worker dose assessment | ○ | ○ | — | — | — | ● | — |
| Worker safety outside Hot Zone | ● | ○ | ○ | ○ | ○ | — | — |
| Locating Hot Zone boundary | ● | — | ● | ○ | ○ | — | ● |
| Monitoring medical care locations | ● | — | ● | ○ | ● | — | — |
| Monitoring at shelters (radiation levels) | ○ | — | ● | ○ | ● | — | — |
| External contamination detection (personnel) | ○ | — | ○ | ○ | ● | — | — |
| Internal contamination detection (personnel) | — | — | ○ | ○ | ○ | — | — |
| Equipment[7] and facility[9] contamination surveys | ○ | — | ○ | ○ | ● | — | ○ |
| **Legend:[10]** ● Useful ○ Marginal — Not Useful (**see notes on next page**) | | | | | | | |

**Table notes:**

[1] The American National Standards Institute is developing performance criteria for PERDs, ANSI N42.49A and ANSI N42.49B:

- Alarming PERDs for Exposure Control are alarming electronic radiation measurement instruments used to manage exposure by alerting emergency responders when they are exposed to photon radiation. The instruments provide rapid and clear indication of the level of radiation exposure and/or exposure rate and readily recognizable alarms. The alarms are both audible and visual, and distinguishable between exposure rate and exposure.
- Non-alarming PERDs for Exposure Control are ionizing photon radiation measuring detectors that provide a visual indication of exposure to the user, and are designed to be worn or carried on the body of the user. These detectors do not have audible or visual alarm. These detectors provide indications that decision levels based on recommended DHS Protective Action Guides have been reached or exceeded.

[2] ANSI N42.33 and ANSI N323 describe performance criteria for instruments used for detection and measurement of photon-emitting radioactive substances for the purposes of detection, interdiction, and hazard assessment. A survey meter is generally considered an ANSI N42.33 Type II instrument.

[3] Radiation detection systems deployed in support of law enforcement radiological / nuclear terrorism prevention missions are generally too sensitive to be used within the Dangerous Radiation Zone or Hot Zone; however, they can be of use outside the Hot Zone for the activities noted above.

[4] Contamination monitors are count-rate meters designed to measure activity (alpha, beta, photon, or alpha-beta) per unit surface area or activity of a localized source associated with the contamination of an examined object.

[5] Entry into areas with dose rates above 1 R/hr should be restricted to time-sensitive, mission-critical activities justified under the worker safety section of this document. Examples include investigation of underground evacuation routes, fire control, supporting a controlled evacuation, and restoration of critical infrastructure required for life-saving activities.

[6] Common missions within the Hot Zone include; fire-fighting, direct public notification of protective recommendations, life-saving or sustaining activities, supporting a controlled evacuation, road clearing, and restoration of critical infrastructure.

[7] Includes monitoring of vehicles and materiel being evacuated from the contaminated region.

[8] See Table 6.2 for definitions of Type I and II survey meters.

[9] Facilities include infrastructure and open-air structures.

[10] Definitions of the legend categories:

- **Useful** – This is a device that can effectively perform the designated mission or task without modification of the device or of its normal mode of employment.
- **Marginal** – The device can provide useful and relevant data in support of the designated mission or task, but with modification to the normal mode of employment. In addition, its use may create a potentially unsafe condition to the user of the device. This implies a need for care in the interpretation of the data produced by such a device under the circumstances.
- **Not Useful** – Although the device is capable of detecting nuclear radiation, its technical performance characteristics or conditions of use are such that it is unlikely to be able to provide useful information in support of the designated mission or task. In addition, its use may create a grossly unsafe condition to the user of the device.

## Table 6.2: Radiation Equipment Types & Mission Applications.

| Equipment | Description | Mission Applicability | Example |
|---|---|---|---|
| **Alarming Dosimeters & Personal Emergency Radiation Detectors (PERDs)** | Designed to be worn on the responder and to measure radiation dose absorbed by the individual. The dosimeter displays the dose and dose rate, and will alarm if pre-set thresholds for either are exceeded. | Used when significant exposure rates may be encountered and provide an alarm when preset **administrative and safety** levels have been reached or exceeded. PERD ranges allow use in the Hot Zone. | RADOS RAD-60 Canberra Mini-Radiac |
| **Non-alarming PERDs** [1] | Non-alarming PERDs provide a visual indication of exposure to the user and are designed to be worn or carried on the body of the user. These detectors do not have an audible or visual alarm. | Used when significant exposure rates may be encountered. These tools provide a visual indication when **safety** levels have been reached or exceeded, making them an excellent backup system for the DRZ. | Pocket Ionization Chamber SIRAD colormetric Dosimeter |
| **Personal Radiation Detectors** (PRDs) | Also known as "Radiation pagers," similar in appearance to electronic dosimeters; used to detect low levels of radiation. Although good for finding contraband radioactive material, these units do not (typically) have the range necessary for personnel protection (i.e., high dose rates) or distant detection. | Primary screening tool for law enforcement monitoring. Well suited for law enforcement or inspectors, these devices can alert the wearer to any unusual proximal radiation; however, they often "saturate" at relatively low radiation levels and cannot be used in the Hot Zone. | Polimaster 1703 (range: <1 – 7mR/hr) D-tect mini rad-D . |
| ***Special note:* Hybrid PRD / PERD** | Recently, PRD manufacturers have begun offering dual detector systems that allow the PRD to have an extended (high) dose rate range without sacrificing the lower dose rate sensitivity. | Polimaster PM1703-MO1 has an additional high-range detector capable of measuring up to 1000 R/hr, making it useful for both prevention and response missions. **Warning**: Alarm set points must be changed to match mission needs. | Polimaster 1703 MO-1 (range: <1 – 1000 R/hr) |
| **Survey Meter (Type I)** | Hand-held devices that detect low levels of radiation or contamination at and above background. Designed to operate in the 0 to 1 mR/hr range. May consist of a meter in conjunction with one or more interchangeable probes for detecting different types of radiation (alpha, beta, gamma, and/or neutron). | Used during initial detection to localize a radioactive source or detect the presence of contamination. Some survey meters may saturate or give false readings at levels that emergency responders may encounter in a radiological or nuclear event. | Civil Defense GM detector Ludlum Model 19 RadAlert50 |
| **Contamination Meter** | A special class of Survey Meters that have a detector capable of measuring contamination levels of alpha, beta, gamma or X-ray contamination. Typically reads out in "counts per minute" rather than a dose rate. | Measures surface contamination on people or objects. Measuring alpha contamination requires close proximity (< ¼ inch) to the surface. Used to survey people, areas, or objects. | SEI Inspector EXP Ludlum Survey |
| **Survey Meter (Type II)** | Hand-held devices used to quantify high radiation exposure rates. Detectors have a wide range for measuring gamma radiation, designed to operate in the range of 0.1 to 1,000 R/hr. | Primary detection device used by emergency responders for performing radiation hazard assessment and monitoring within the Hot Zone. | Civil Defense Ion Chamber (Various manufacturers) Thermo FH40-GL |
| **Passive Dosimeters** | These devices record the total exposure of the wearer over time, but do not provide immediate feedback to alert the wearer to possible over-exposure. These must be evaluated by special equipment to determine the wearer's exposure. | These tools are assigned to an individual **in addition to** the more active dose control tools above and are used to provide a legal record of the exposure. They do not alert the user to hazardous conditions. | OSL TLD |

## 6.1: Internal Dosimetry (Sample kits/laboratories)

Internal dosimetry is called for in cases of internal contamination due to inhalation of radioactive particulates or aerosols. The need for internal dosimetry may be estimated based on surface and air sample measurement data – for example, personnel working in a highly contaminated area without respiratory protection are likely to require internal dosimetry, as are persons who receive open wounds while working in a contaminated area. Once the need for internal monitoring has been established, a decision must be made related to the appropriate method of monitoring. For contaminant(s) with gamma-emitting radionuclides, direct bioassay measurements (e.g. placing a counter on the chest or back) may be employed. Direct bioassay measurements enable an immediate estimate of internally deposited radionuclides. Some radionuclides, such as Cs-137, distribute throughout the body, while others, such as radioactive iodine, tend to concentrate in one particular organ. The distribution of radionuclides in the body will determine the method of bioassay. Factors to consider include the type of radiation detector to be used (e.g. NaI or Geiger-Mueller tube) and the method of counting (e.g. whole body or tissue-specific). When responding to an emergency, health and safety personnel should consider requesting academic and Federal resources in addition to commercial analytical laboratories (through the chain of command) to provide direct bioassay equipment and expertise.

Other bioassay measurements usually involve analysis of urine samples to quantify the concentration of radionuclides in the urine and, indirectly, in the whole body. Samples of excreta are acceptable for measuring alpha, beta, and gamma radiation. Internal dose estimates from indirect bioassay data may be determined via the application of a metabolic model relating excreted material to body burden and body burden to dose. NCRP Reports #161 (*Management of Persons Contaminated with Radionuclides*) and #166 (*Population Monitoring and Radionuclide Decorporation Following a Radiological or Nuclear Incident*) provide a great deal of useful information relevant to performing and interpreting bioassay results.

The bioassay process involves some or all of the following steps:

- Sample collection (appropriate volume, suitable container, need to minimize cross contamination;
- Sample preservation if sample is not analyzed immediately;
- Transportation of sample to a radioanalytical laboratory;
- Sample preparation (benchtop chemistry);
- Sample analysis (counting and data reduction).

Samples should be packaged and shipped as dictated by the analytical method and the laboratory's receiving requirements.

Whenever samples are sent to a laboratory, it is essential that careful attention is paid to completing the chain-of-custody sheet as well as to packing, storing, and shipping samples in accordance with procedures provided by the receiving laboratory, and data management checklist (example checklists are provided in Section 8 in Part 1 of this Field Guide). The checklists are intended to be used to track bioassay samples, but

can be used for other types of samples, such as environmental samples, that may be sent to an offsite laboratory.

# 7. Decontamination

## 7.1: General Considerations

Exposure to external radiation alone does not require decontamination. Contamination of persons and equipment generally results from contact with radioactive materials, such as liquids or powders.

The majority of surface contamination (as much as 90 percent, depending on how a person is dressed) will deposit on the outside of the clothing, so simply removing contaminated clothes can accomplish a significant amount of decontamination and should be done as soon as possible. In general, care should be exercised in removing a person's contaminated clothing in such a way as to contain particulate contaminants. Contaminated clothing should be double bagged and labeled with **"CAUTION RADIOACTIVE MATERIALS"** tape if possible. Skin contamination can often be removed simply by repeated mild or gentle washing with warm water and mild soap. Care should be taken to prevent abrading the skin (enabling contamination to enter the bloodstream). Harsh soaps, hot or cold water, stiff brushes, and other painful decontamination methods should be avoided as well. If internal contamination is suspected, implement direct or indirect bioassay monitoring, as appropriate.

**Remember to always render medical care as a first priority. Concerns for contamination should not preclude actions to protect health and safety from other hazards such as fire, fumes, chemicals, physical injuries, etc. that may be life threatening. All other hazards to life should come before concerns for radiation.**

Following entry into contaminated areas, equipment and personnel must be surveyed with respect to maximum contamination levels. Equipment and protective clothing found to exceed the established levels should be decontaminated promptly. A personnel and equipment decontamination system must be implemented to control the spread of radioactive contamination. Positioning of the decontamination area should be upwind and upslope from the incident/accident scene. The decontamination facility should be located near an egress point out of the Hot Zone. A model decontamination procedure for emergency responders using SCBA is included in the following section.

## 7.2: Model Decontamination Procedure

The following decontamination procedure is not all-inclusive but was developed to meet the minimum guidance for decontaminating responders at a radioactive hazardous material incident. It is designed for use by trained and qualified emergency responders. The procedure assumes that responders are wearing SCBA, and is based on the assumption that all responders and equipment leaving a Hot Zone are potentially contaminated.

***Note: Different types and levels of personal protective clothing are worn by response organizations. When conducting decontamination you must adjust the decontamination process to satisfy the type and level of personal protective clothing being worn by responders. The procedure outlined below is appropriate for responders who are wearing protective clothing (e.g. a firefighter's turnout gear).***

1. Establish a Decontamination Corridor. Necessary barricades or identifying features of the decontamination system should be obvious to responders. Barricade tape, ropes, or traffic cones could be used for identifying the decontamination system.

2. Instruct responders to place equipment or tools in the designated drop area. This drop area should be made of some type of containment system. Examples of an equipment or tool drop area include a plastic cover placed on the ground that tools and equipment can be placed on or a lined can that equipment or tools can be placed in.

3. Have responders approach the hot zone line (identified by a step-off pad). Typical absorbent pads are acceptable to use as step off pads. Responder should step on the pad and wipe feet.
*Note:* Decontamination personnel should replace damaged step off pads as necessary. Replacement pads should be placed on top of existing pads.

4. If the responder plans on returning to the hot zone or is in need of an air supply change, the decontamination personnel will assist in conducting a hot bottle change.
*Note:* The decontamination personnel will assist the responder in changing the air supply. The hot bottle change process varies for the different types of Self-Contained Breathing Apparatus.

5. Radiation surveying. Decontamination personnel will conduct a full body survey of the responder. If detectable levels of radioactive contamination are observed, continue with **Step 6** of this procedure. If contamination is not found, continue with **Step 14**.*Note*: The radioactive contamination survey process, using a typical radiation contamination detection instrument, should take between five and ten minutes per responder.

6. With the assistance of the decontamination personnel, the responder will remove the SCBA harness and backplate; do not turn off the SCBA air supply.
*Note:* Decontamination personnel should ensure that the responder does not disconnect the regulator air supply or remove the SCBA face piece. Positive pressure within the face piece should be maintained.

7. With decontamination personnel assisting, have the responder remove gloves. The decontamination personnel will place the gloves in the designated collection device (plastic bag or lined can or ground covered area).

8. The decontamination personnel will assist the responder with putting on a new pair of latex gloves.

9. With decontamination personnel assisting, the responder will remove the helmet and hood. The decontamination personnel will place the helmet and hood in the designated collection device (plastic bag or lined can or ground covered area).

10. With decontamination personnel assisting, have the responder remove the coat, if any. The decontamination personnel will place the coat in the designated collection device (plastic bag or lined can or ground covered area).

11. With decontamination personnel assisting, have the responder step to next position in the decontamination process and remove pants and boots. The decontamination personnel will place the pants and boots in the designated collection device (plastic bag or lined can or ground covered area).
*Note:* If available, some type of temporary footwear should be provided (e.g. shoe covers).

12. The responder will remove the SCBA face piece and hand it to the decontamination personnel. The decontamination personnel will turn off the responder's SCBA. The decontamination personnel will place SCBA in the designated collection device (plastic bag or lined can or ground covered area).

13. The responder should step to next position in the decontamination process and remove latex gloves. Place gloves in disposal and proceed to designated staging area for contamination survey/monitoring.

14. If the responder was not contaminated, the next step in the decontamination process is to remove remaining protective clothing and report to designated staging area for a final contamination survey or monitoring.

15. The decontamination personnel will complete the decontamination process by conducting a self-decontamination using the aforementioned decontamination steps.
*Note:* Decontamination personnel will assist each other in removing protective clothing and placing removed clothing into the designated collection area.

16. Decontamination personnel should brief the RHSO or Decontamination Supervisor on the number, type and location of items (protective clothing, equipment, tools, etc.) needing decontamination.

# 8. References to Part II


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