CRCPD Publication 06-6

HANDBOOK FOR RESPONDING TO A RADIOLOGICAL DISPERSAL DEVICE

DIRTY BOMB

First Responder's Guide—The First 12 Hours

September 2006

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Conference of Radiation Control Program Directors, Inc.
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Announcement

Throughout this document there are references to Forms and Handouts being available on a CD.

For the Web version of this document, the Forms and Handouts are not on a CD—they are provided as attachments to the main file, accessible through the Navigation Pane, Attachments Tab.

This document has been developed by a working group of the Conference of Radiation Control Program Directors, Inc. (CRCPD) and accepted by the Board of Directors for publication. The contents contained herein, however, may not necessarily represent the views of the entire membership of the CRCPD or any federal agency supporting the work contained in this document. The mention of commercial products, their sources, or their use in connection with material reported herein is not to be construed as either an actual or implied endorsement of such products by the CRCPD or any federal agency.

The information contained in this document is for guidance. The implementation and use of the information and recommendations contained in this document are at the discretion of the user. The implications from the use of this document are solely the responsibility of the user.

Prepared by

CRCPD HS-5 TASK FORCE FOR RESPONDING TO A RADIOLOGICAL DISPERSAL DEVICE

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FOREWORD

The Conference of Radiation Control Program Directors, Inc. (CRCPD) is an organization made up of the radiation control programs in each of the 50 states, the District of Columbia, and Puerto Rico, and of individuals, regardless of employer affiliation, with an interest in radiation protection. The primary purpose and goal of CRCPD is to assist its members in their efforts to protect the public, radiation worker, and patient from unnecessary radiation exposure. CRCPD also provides a forum for centralized communication on radiation protection matters between the states and the federal government, and between the individual states.

CRCPD=s mission is Ato promote consistency in addressing and resolving radiation protection issues, to encourage high standards of quality in radiation protection programs, and to provide leadership in radiation safety and education."

The threat of the use of a radiological dispersal device (RDD) exists. This document was prepared as a training and reference tool for first responders with various degrees of radiological experience by radiation control program staff that bring with them the expertise in establishing zones, boundaries, and safe areas following radiological and nuclear incidents.

T. Pearce O'Kelley

Pearce O'Kelley, Chairperson
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PREFACE

This companion handbook to the "Radiological Dispersal Device (RDD) – Dirty Bomb – First Responder's Guide" (RDD pocket guide) was developed by the Conference of Radiation Control Program Directors Task Force for *Handbook for Responding to an RDD* as a training and reference tool for responders. The majority of the Task Force who prepared this report are radiation control program staff who bring with them the expertise in establishing zones, boundaries, and safe areas following radiological and nuclear incidents.

Many state and local responders expressed the need for assistance in identifying the most important activities that should take place when responding to an RDD. State and local responders are at various stages in their development of plans to deal with a radiological incident. Those who have not participated in national exercises or nuclear power plant exercises often do not have a basic flow chart of actions or lists of contact numbers. The authors hope that the RDD pocket guide and this companion handbook will provide such requested guidance. The handbook identifies generic tasks, gives initial guidance for the first 12 hours, and provides national, regional, and state/local agency contacts that can assist with radiological emergency response capabilities.

Before implementing the guidelines outlined in the RDD pocket guide and the companion handbook, however, state and local responders must ensure that an Incident Command System (ICS) has been established, and law enforcement is at (or soon to arrive at) the scene. The authors of this document have assumed that readers are already familiar with the need for an ICS and for the involvement of law enforcement and therefore did not attempt to describe these activities in detail.

In creating this document, the authors relied primarily on information currently available either in existing literature or on the Internet. A list of references that supplements the information presented in this handbook is included in Appendix 14.

Many responder groups and other partners were consulted during the preparation of the RDD pocket guide and this companion handbook. Their input helped us to design this product to best meet their needs. The authors wish to acknowledge their very valuable contributions.

Adela Salame-Alfie

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The authors wish to thank Mrs. Gena Gallinger of the New York State Department of Health for the preparation of the graphics used in the RDD pocket guide and in this document. We also want to acknowledge Robert Greger, CHP, California Department of Health Services and Mark Virgil, New York State Department of Health, for their contribution to the definition and validation of the methodology described in Appendix 4, "How to Distinguish Between Alpha, Beta, and Gamma Radiation Using a Pancake GM Survey Meter."

The authors acknowledge Ms. Lin Carigan of the CRCPD for her extensive technical editing, to assure uniformity and accuracy of this RDD Handbook. Her efforts transformed a draft document with robust technical content into a user-friendly training and reference resource that the authors hope will be of value to the responder community.

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Salame-Alfie, Adela, et.al. "Handbook for Responding to a Radiological Dispersal Device First Responder's Guide—the First 12 Hours," CRCPD Publication 06-6, September 2006, 88 pp.

This handbook has been designed to be used together with the "Radiological Dispersal Device – Dirty Bomb – First Responder's Guide" (RDD pocket guide) developed by the Conference of Radiation Control Program Directors, Inc.'s (CRCPD), HS-5 Task Force as a training and reference tool for responders. Its intended audience is state and local responders who may be called upon to respond to an explosive radiological dispersal device or "dirty bomb." It supplements and details the information provided in the RDD pocket guide.

This companion handbook does not attempt to address all situations that may be encountered by responders following the explosion of an RDD. However, many of the concepts introduced here can be applied to a variety of radiation incidents, and do not apply exclusively to dirty bombs. This handbook expands on the activities and concepts defined in the RDD pocket guide and provides state-specific radiation control program contact information. It does not replace the valuable technical information that can be obtained by contacting your local/state radiation control program.

Law enforcement and local/state radiation control staffs play a key role in the response to an RDD event. This handbook does not include descriptions of Incident Command or law enforcement activities since those are detailed elsewhere and are part of existing responder training.

The authors recognize that this is a living document, and therefore advise the users to check periodically for updates on specific information for their state.

INTRODUCTION

A radiological dispersal device (RDD) or dirty bomb is a mix of explosives, such as dynamite, with radioactive powder or pellets. When the dynamite or other explosives are set off, the blast carries radioactive material into the surrounding area.

Plans to deal with radiological incidents at the state and local level are at various stages of development. Representatives from jurisdictions that have not yet participated in national exercises or nuclear power plant exercises may lack critical information necessary for plan development, such as a basic flow chart of actions and a list of contact numbers.

The CRCPD has created this *Handbook for Responding to a Radiological Dispersal Device First Responder's Guide* as a training and reference tool to be used by state and local response officials in the event of a radiological incident. It is intended for use by responders (Fire, EMS, Police, HAZMAT), although the first receivers (EMS/EMT, medical staff at hospitals or other clinical settings) may also elect to use it as a guide when preparing to respond to an RDD event. To the greatest extent possible, the information has been kept simple and concise, and references for additional information have been provided.

The types of activities described in this document are presented as guidelines that could be modified depending on the specific incident. We strongly recommend that the users of this handbook become familiar with the handbook and the radiation guidelines specific to their state or local radiation program. Furthermore, readers are encouraged to contact their local/state radiation program official to obtain additional details on the information presented in these sections.

This handbook identifies generic tasks, gives basic initial guidance, and provides local responders with contact information for national, regional, and state agencies that can provide assistance during an event. More specifically, information in this handbook includes:

- A flow chart of suggested response activities when responding to an RDD;
- Information on effective use of basic radiation measuring equipment;
- Suggested radiation exposure decision points for defining the perimeters of access control zones;
- Guidance for rescuing victims;
- Instructions on how to conduct contamination surveys and a contamination survey sheet for recording the collected data;
- Guidance for quick assessment of internal contamination;
- Contact information for state and federal agencies for each region.

- Forms *(also available on the CD)*:
  - Guidance for Documenting Initial Site Survey
  - OSHA Incident Briefing – Form ICS201. This form is also downloadable from **http://www.osha.gov/SLTC/etools/ics/ics_forms.html**
  - OSHA Site Safety and Control Plan – Form ICS208. This form is also downloadable from **http://www.osha.gov/SLTC/etools/ics/ics_forms.html**
  - Contamination Survey Sheet
  - Suggested mass decontamination supplies list.
- Handouts *(also available on the CD)*:
  - How to Perform Decontamination at Home
  - Instructions for Workers Performing Contamination Survey
  - Instructions to the Public Waiting for Decontamination at the Scene of the Incident

Additionally, this document contains multiple appendices with more in-depth information, including:

- Flow Chart for Responding to a Radiological Dispersal Device
- Overview of the Types of Radiation
- Primer on Radiation Measurement
- How to Distinguish Between Alpha, Beta, and Gamma Radiation Using a Pancake GM Survey Meter
- Exposure vs. Contamination
- Guidance for Assessing Internal Contamination
- Health Effects of Radiation Exposure
- Acute Radiation Syndrome
- State and Local Radiation Control Program Contacts
- Federal Radiation Control Program Contacts
- Glossary of Radiological Terms

For ease of reference each major activity is presented in a separate stand-alone section. A companion CD has forms and handouts that can be modified to suit specific needs.

Note that this document does not discuss non-radiation emergencies, such as fighting fires, which are beyond the scope of this guide, and it should not be inferred that radiation issues should take precedence over these other activities. Responders need to integrate their routine response procedures with these radiation guidelines. Furthermore, the authors acknowledge that radiation guidance used in this document exceeds that used in routine radiation responses, such as traffic accidents involving radioactive material, since responding to an RDD event may require actions beyond those routinely encountered.

But before we go into detail about each of the steps in the flow chart, there are a few basics to remember:

- Rescuing victims and other lifesaving actions, such as putting out fires, take precedence over other activities;
- Make measurements, and set-up initial perimeters. Note that these perimeters may be relocated at a later time;
- Secure the area;
- Contact persons with radiation expertise. It is suggested you contact your state radiation control program immediately.

There are three cardinal rules of radiation protection for external radiation exposure from a radiation source: *reduce* time, *increase* distance, and *use* shielding.

- **TIME** — The less time you spend near the radiation source, the lower your exposure will be.
- **DISTANCE** — The greater your distance from the source, the less your exposure will be. Radiation exposure decreases with distance according to the inverse-square law. That is, if you triple your distance from the radiation source, your exposure will decrease by a factor of 9 (three squared).
- **SHIELDING** — External exposure to radiation can be partially blocked by the use of shielding. Traditionally, shielding is made of lead or concrete. However, staying behind vehicles, buildings, or other objects will also decrease exposure. In an RDD event, the radiation will likely be coming from the ground and other horizontal surfaces where the radioactive materials will have been distributed by the blast.

Note: Throughout this document, conventional units of measure are used. International SI units (Le Système International Unités, Sievert, or Sv) and a conversion table are provided in Appendix 3.

FLOW CHART FOR RESPONDING TO A RADIOLOGICAL DISPERSAL DEVICE (RDD)

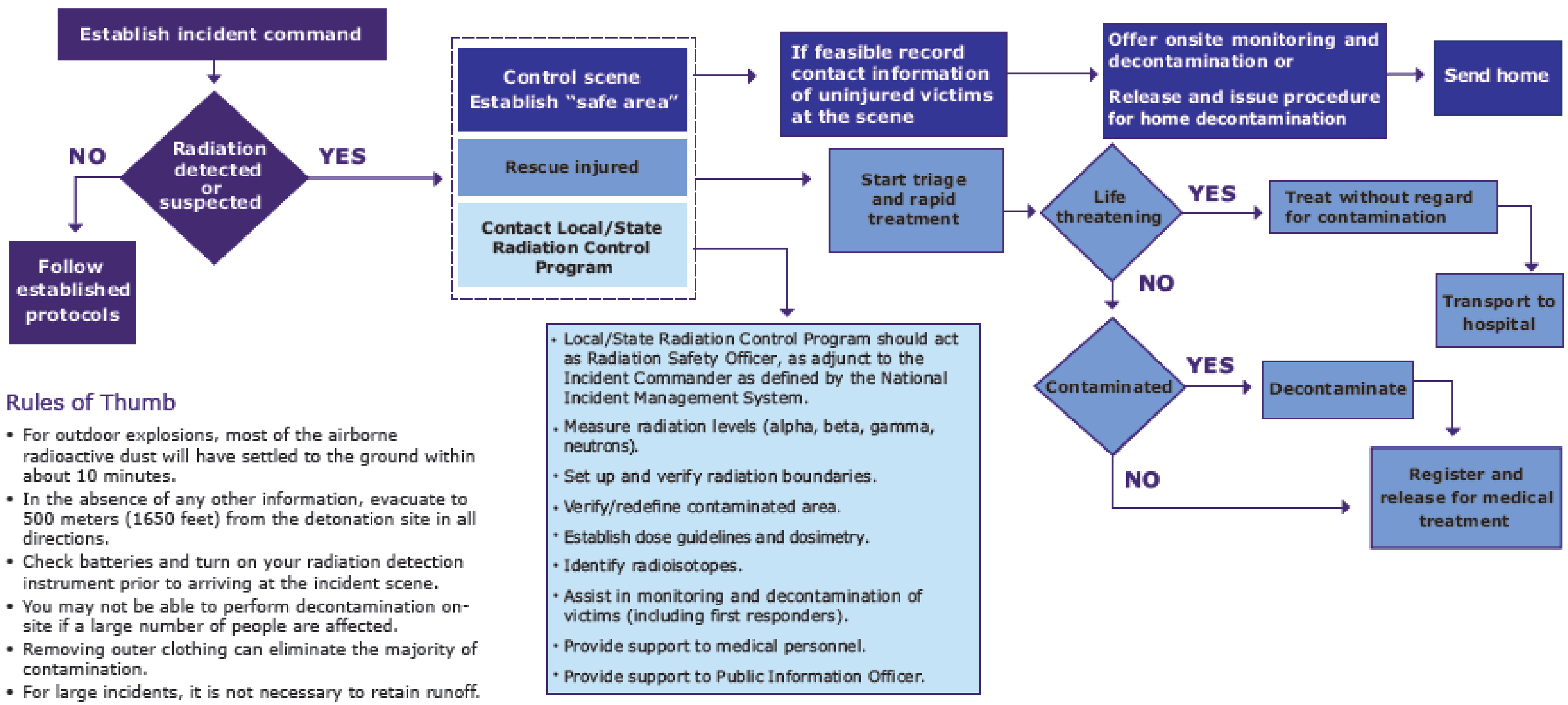


Figure 1. Flow Chart for Responding to a Radiological Dispersal Device (RDD)

The following sections in this document are intended to detail the actions presented in the flow chart above and to provide examples, when applicable. Among the specific actions detailed in the flow chart are to:

- Establish incident command.
- Contact local/state radiation control program *(contact numbers are provided in Appendix 9.)*
- Control the scene and establish safe area if radiation is detected or suspected.
- Rescue injured.
- Start triage and rapid treatment.
- If life threatening, treat without regard for contamination and transport to hospital.
- If not life threatening but contaminated, decontaminate.
- For individuals not injured, test for contamination. If contaminated, decontaminate or release and issue procedure for home decontamination. Record contact information of uninjured victims at the scene.

Expanded Rules of Thumb

- For outdoor explosions, most of the airborne radioactive dust will have settled to the ground within about 10 minutes. Individuals not wearing protective clothing and a respirator when entering a radiation hazard area should wear a dust mask and overshoes.
- In the absence of any other information, evacuate to 1650 ft (500 m) f rom the detonation site in all directions.
- Check batteries and turn on your radiation detection instrument prior to arriving at the incident scene.
- You may not be able to perform decontamination on-site if a large number of people are affected.
- Removing outer clothing can eliminate the majority of contamination.
- For large incidents, it is not necessary to retain runoff.
- Initial monitoring and decontamination efforts of individuals at the scene should primarily focus on preventing acute radiation effects to the affected individual. Cross contamination issues are a secondary concern, especially if the contaminated area and number of evacuees is large.
- Universal precautions should be used in any situation where the presence of radioactive materials is suspected to help prevent the spread of contamination from injured victims to emergency personnel.
- Protect yourself and others from:
- Direct exposure to radiation; most significant for high-energy gamma rays and beta particles. Keep as great a distance as possible from these radiation sources/areas. The public in the immediate areas should seek shelter indoors rather than stay outside.
- Inhalation/ingestion exposure, which is most significant for alpha emitters. A respirator for responders is advised. The public may hold a folded handkerchief over their mouths/ noses.
- Absorption in blood via cuts/ wounds in the skin. Cuts/ wounds should be covered with clean cloth or gauze to reduce contact with loose dust and debris.
- Suggested release levels (assuming using a pancake GM probe at 1 inch from the radiation source):
- With contamination up to 1 , 000 cpm, allow individuals to leave; instruct them to go home and shower.
- If the event is large and if adequate decontamination resources are not available, the release level can be increased to 10,000 cpm. Instruct people to go home and shower.
- Send people with contamination levels greater than 10,000 cpm to a designated decontamination area.
- People contaminated to levels greater than 100,000 cpm are likely to have internal contamination and should be identified as a priority for follow-up for internal contamination.
- Identify the region of suspected highest radiation, and control access to this area. Unless necessary to save lives, do not enter this region.
- Contact radiation professionals. A list of contact numbers for state radiation control programs is available in Appendix 9. The state radiation control program or state emergency management agency may also request assistance from the Department of Energy’s (DOE) Radiological Assistance Program (RAP). Contact numbers for the DOE regions are located in Appendix 10.

ESTABLISH INCIDENT COMMAND

Incident command unifies all emergency responders under a single command hierarchy. In the years following the development of the incident command concept, its acceptance had become widespread; state and local officials are now expected to integrate their resources into the Incident Command Structure (ICS), consistent with the National Incident Management System (NIMS) when responding to emergencies, whether natural or man-made in origin. ICS training is required for first responders and this document assumes that an ICS will be established following an RDD detonation.

> *A staff member of the radiation control program should function as the Radiation Safety Officer in the Incident Command upon arrival at the scene.*

If feasible, establish the Incident Command Post at a location upwind with background radiation levels. If this is not feasible, use an area of less than 2 mR/hr and contamination levels less than 1,000 cpm measured 1-2 inches from the ground with a pancake probe. Check with local/state radiation control personnel if it appears necessary to establish the Incident Command Post in a higher radiation/contamination area.

RADIATION DETECTED OR SUSPECTED

If radiation is suspected by the presence of labels, shielded containers, placards, etc., radiation surveys are needed to determine if it is present and the nature and extent of the hazards involved.

If you suspect radiation or your meter shows a positive reading (above background levels), assume you are in a radiation field. Always believe your instrument if it tells you radiation is present, but be cautious if the instrument indicates there is no radiation present. Some instruments saturate ("peg") and indicate low or no readings in a very high radiation field.

If possible, wrap the probe and instrument with plastic wrap or place in a plastic bag (unless you are measuring alpha radiation) prior to use, to minimize contamination of the instrument.

Some amount of radiation is always present in the environment. Radiation in the environment comes from both cosmic radiation, which originates in outer space, and from radioactive materials that occur naturally in the earth. This is known as background radiation. Background radiation does *not* require special safety controls. If radiation levels are at background levels, no special measures need to be taken. *Appendix 2 provides an overview of the types of radiation.*

When elevated radiation levels are suspected or detected, procedures should be established to control the scene to reduce radiation exposure to all individuals (including responders) and to reduce the spread of contamination. Responders will need to safely rescue and treat injured persons. Details about scene control and safe rescue are included in later sections of this handbook.

Personal radiation dosimeters should be worn by responders, and should preferably be donned before arrival at the incident site. If personal electronic dosimeters are available and have the capability of setting alarms at preset radiation levels, the alarming points should be established based on the magnitude of the radiation event as determined by radiation professionals, and the activities of the person wearing the device.

Alarm set points should be established before an event with input from your state/local radiation agency or during the event with the Radiation Safety Officer at the scene. *For the purposes of this document, assume 1 Roentgen (R) = 1 rad = 1 rem.* Suggested alarm setpoints for individuals going into the *medium* or *high* radiation zones (> 100 mR/hour) are 1,000 mR/hour and 5,000 millirem cumulative radiation dose. Suggested alarm set points for individuals not performing life saving or critical property protection activities are 100 mR/hour and 500 millirem cumulative radiation dose. Note that an alarm doesn't indicate the person needs to leave the area; it simply means the person needs to be aware of radiation levels in the area reaching a predetermined exposure rate, or that they've received a predetermined amount of radiation dose.

RADIATION DETECTION DEVICE BASICS

There are several concepts that are important for responders to learn before using a radiation detection device:

- Natural background radiation;
- Measurement units and scales;
- Calibration;
- Limitations of the device;
- Efficiency and units.

Understanding these concepts will allow responders to properly use radiation detection devices and to interpret the readings correctly.

Natural Background Radiation

Background radiation varies in different parts of the world, but almost every radiation detection device will indicate that radiation is present whenever (and wherever) it is operating. Over the course of a year, United States citizens are, on average, exposed to approximately 360 millirem of radiation, 80% - 90% of which is from background sources. Therefore, many radiation detection instruments, particularly those such as microR meters and pancake probes used to measure low levels of radiation, will indicate that radiation is present whenever they are operating.

To accurately detect an increase in the amount of radiation (and radioactive contamination) in an environment, it is important that responders turn on the radiation detection device (instrument) and establish and record a reading before beginning a survey. Take background radiation measurements in an area that you know is far from the radioactive source, and is free of contamination. For example, you may take a background reading at your base station before you leave, or even in your vehicle en route to respond.

When first responding to an RDD, always remember that accuracy of the radiation measurement is not as critical as verifying that radiation is present. Even if the initial reading is not precise, you may be able to make a quick determination of where the high and low radiation areas are, and determine which areas are most contaminated. Later, when more radiological support has arrived at the scene, more accurate measurements can be obtained.

Units

Radiation detection devices may provide readings in a number of different units, including counts per minute (cpm), Roentgen per hour (R/hr), milliRoentgen per hour (mR/hr), microRoentgen per hour (μR/hr), or millirem per hour (mrem/hr). *These units and prefixes are defined in the Primer on Radiation Measurements located in Appendix 3 of this handbook.* Since some radiation detection devices may have more than one scale on their faceplate, it is important to be aware of which set of measurements, or scale, you are reading. For emergency response purposes, the differences between rem and Roentgen (R) may be ignored. *For the purposes of* *this document, assume 1 Roentgen (R) = 1 rad= 1 rem.* Prefixes are important, however. Make sure you know whether the readings are in Roentgen (R), milliRoentgen (1/1000 Roentgen or mR), or microRoentgen (1/1,000,000 Roentgen, or μR).

Note: Throughout this document, conventional units of measure are used. International SI units and a conversion table are provided in Appendix 3.

Calibration

All instruments used to measure should be routinely calibrated, or checked, to determine the accuracy of their readings. To use a simple illustration, think of calibration as a way of making sure that your radiation detection device registers a reading of "five units" when you, in fact, have five units worth of exposure. Calibration of radiation detection devices can be done by the manufacturer or other licensed calibration facility and is usually performed at least every two years. Calibration frequency increases the confidence level in the reliability of the equipment. Radiation instruments are generally quite reliable over long periods of time.

A method for determining that an instrument is reasonably calibrated is to perform a field check of basic instrument operation using a small radioactive source, also known as a "check source," every time the instrument is turned on. The check source response should have been recorded shortly after calibration, but even if it was not, the field check will ensure the instrument is capable of detecting radiation. It is far better to have a simple instrument that indicates a potential presence of radiation, even if it doesn't accurately "measure" it, than to have no instrument at all.

Limitations of the Device

A variety of physical factors may limit the ability of your radiation detection device to provide accurate, consistent, and reproducible readings of the amount of radiation in a given environment. Examples of some of these limitations are described below.

- A pancake probe can only measure up to approximately 400 mR/hr (0.4 R/hr), and a sodium iodide (NaI) probe can only measure up to about 200 mR/hr (0.2 R/hr). When these probes are used in higher radiation fields, the instrument indication may "peg" (go off-scale), or may even indicate zero radiation. *Be very cautious if a radiation detection device indicates there is no radiation present.*

- Most routine ion chambers will measure to a maximum of 50 R/hr; more specialized equipment is required to measure higher exposure rates.

- Check the instrument manual or contact the manufacturer to find out how to operate the instrument in high radiation fields.

- Most instruments are calibrated using a Cs-137 source, so if Cs-137 is the nuclide being measured in the environment, the measurement provided by your radiation detection device would be the most reliable for that nuclide. If another nuclide is being measured, the measurement may be quite inaccurate. For example, a 1" x 1" NaI probe calibrated to a Cs-137 source may:

- Under measure the amount of radioactive cobalt 60 by about 50%;
- Over measure the amount of iodine 131 by about 500%; and
- Over measure the amount of thallium 201 by about 1000%.

Efficiency

Radiation detection instruments consist of two parts: the meter and the probe. Probes, which are held near the suspected source of radiation, vary in size and shape, as well as in the type of radiation they detect. Some probes detect particular radionuclides better than others.

No instrument detects all the radioactivity present; one must therefore correct the instrument reading using an "efficiency factor" in order to estimate the true amount of radioactivity present. The efficiency of a probe is the percentage of the radioactivity present that the probe is likely to detect. For example, if the efficiency of a pancake probe for cesium-137 (Cs-137) is 15%, that probe is only detecting 15% of the Cs-137 that is present. In an initial response situation, responders may only be looking to map contamination or to grossly locate a radioactive source. Therefore, knowing the instrument efficiency may not be necessary, and an instrument with even a 15% efficiency can be very effective in mapping or locating radiation.

The efficiencies given in the next section are typical for the type of probe noted, and apply to measurements made under "ideal" conditions; actual detection efficiency will likely be less for field measurements. Individual manufacturers can provide efficiencies for their probes for measuring various radionuclides under "ideal" conditions.

Efficiency and Units

The use of disintegrations per minute (dpm) (rather than counts per minute – [cpm]) is preferred because actual activity (quantity) of the radioactive material present can be calculated from dpm.

Many radiation detection instruments read in cpm. As the cpm reading varies from probe to probe, depending upon the efficiency, you may need to convert a cpm reading to dpm to accurately communicate radiation information outside your organization.

In any case, it is very important to indicate if the readings are in cpm or dpm to allow radiation control personnel to better understand the amount of radioactive material present. We illustrate below how to convert cpm into dpm and then calculate microcuries (μCi*) of activity from dpm.

dpm = cpm ÷ Instrument Efficiency

Activity (microcuries) = dpm ÷ 2.22×10^6
One (1) microcurie = 2.2×10^6 dpm

For example, if the efficiency for a Cs-137 source using a pancake probe is 15%:

dpm = cpm ÷0.15 and *μCi = dpm ÷ 2.22×10^6

*where μCi denotes microCuries (1/1,000,000 Curies (Ci))

RADIATION DETECTION INSTRUMENTS

Note that illustrations of a particular make or model instrument in this document are not to be construed as either an actual or implied endorsement of that instrument. Illustrations are offered simply to provide examples of what an instrument or probe may look like.

Meters

General Purpose Survey Meter

Some instruments allow various probes, including those shown in this section, to be attached to a general-purpose survey rate meter to allow them to measure different types of radiation. Some have an internal fixed detector. The scale of an instrument may read in milliRoentgen (mR), Roentgen (R), milliSievert (mS) or Sievert (S) per unit of time (typically per minute or second), or it may read in counts per minute (cpm or c/m). Some rate meters may have more than one scale.

Figure 2. General Purpose Survey Meter

Note that a survey rate meter may not be accurate unless the instrument was calibrated using the same radionuclide that is being measured, and with the same detector probe used during calibration. An instrument that can be used for measuring exposure rate without concern for compensating for the source used in calibration is the ion chamber described below.

Ion Chamber or Energy Compensated Geiger-Mueller (GM)

The ion chamber is the most accurate instrument for measuring radiation fields for radiation protection purposes. However, both an ion chamber and an energy compensated GM are good instruments for measuring exposure rates, because both are relatively insensitive to different radionuclide energies. This makes them a better choice than the pancake GM or Sodium Iodide (NaI) detector for measuring mR/hr. However, they are not as sensitive as a rate meter equipped with a pancake GM or NaI probe for detecting low exposure rates, and this makes them less desirable as a contamination monitoring instrument for individuals.

Figure 3. Ion Chamber

The ion chamber is the instrument of choice for setting up boundaries, and will measure gamma, x-ray, and beta if equipped with a beta window. A typical ion chamber will measure up to 20-50 R/hour, although there are also ion chamber instruments designed for very high radiation levels. An energy compensated GM is typically capable of measuring a broad range of radiation levels.

Probes

Pancake Probe (Pancake GM)

A Geiger Mueller (GM) pancake probe can detect alpha, beta, or gamma radiation, and is very efficient at detecting beta radiation. The probe begins to be less accurate as the count rate increases above 100,000 cpm, and around 400,000 cpm will respond low by a factor of about three, making their use at count rates greater than 400,000 cpm inadvisable.

The pancake probe is best used for detecting low levels of radioactive contamination on people or on surfaces. When it is used to detect gamma radiation using a mR/hr scale, it is possible to use it in a way that discriminates whether beta radiation may also be present. This is accomplished by taking a measurement with the open window, then turning the probe over and positioning its back toward the surface being monitored. Gamma radiation can penetrate the metal back of the probe, but the beta will be shielded, and a substantial difference between the two readings will indicate the presence of a mixed beta/gamma field.

Figure 4. Pancake Probe

A GM pancake probe is not energy compensated, meaning that it will only read mR/hr accurately for the radionuclide with which it was calibrated (normally Cs-137), but may be inaccurate by up to a factor of five for other radionuclides.

Typical background readings made with this probe will vary, but are generally in the range of 25-75 cpm. Under ideal conditions, and with the face of the uncovered probe held ½ to 1 inch from the surface being measured, some efficiencies for the probe used with the radionuclides shown are approximately:

Cesium 137	15%	Iridium 192	15%
Cobalt 60	10%	Strontium 90	30%

Alpha Scintillator

An alpha scintillator probe is used for detecting alpha radiation and is preferred over a Geiger Mueller pancake probe when alpha radiation is suspected. This is because a pancake probe has a much lower efficiency for alpha emitters and is of limited use. For americium 241, under ideal conditions, an alpha scintillator probe will only detect about 20% of what is present, and a pancake probe will be about 10 times less efficient.

Figure 5. Alpha Scintillator

An important note with respect to alpha radiation is that the measurement must be made as close as possible to a contaminated surface making sure that the probe is not in contact with the surface. Ideally, a measurement must be made with the probe surface held no more than about ⅛ to ½ inch away from a dry, relatively clean surface. This is because alpha particles will lose energy as they travel, and most will only travel a maximum of one to two inches. Alpha particles are easily shielded from measurement by a piece of paper, air, or wet, damp and dust laden surfaces.

Sodium Iodide Probe

A sodium iodide (NaI) probe will only detect gamma radiation. It is useful for detecting very low levels of gamma radiation, and can be used in radiation fields up to about 200 mR/hr.

The sodium iodide probe is useful for detecting the presence of low-level gamma radiation and for locating radioactive sources. In some cases, it is useful for surveying people, property, and the environment.

Figure 6. Sodium Iodide Probe

Background radiation can vary significantly from location to location, and these variations can be further impacted by the size of the sodium iodide crystal used in the probe. The range of "typical" background readings will depend on location and size and thickness of the crystal in the probe. Some examples of background measurement variation due to crystal size are:

- 1" x 1" crystal: 1,000-5,000 cpm
- 2" x 2" crystal: 5,000-25,000 cpm
- 1" x 1 mm crystal: 200-400 cpm.

While a pancake GM probe is better able to detect low levels of contamination on people and surfaces than a NaI probe, the NaI probe will nonetheless be a useful tool for contamination monitoring in an RDD event due to the anticipated levels of contamination that may be encountered.

Other Instruments

Radionuclide Identifier

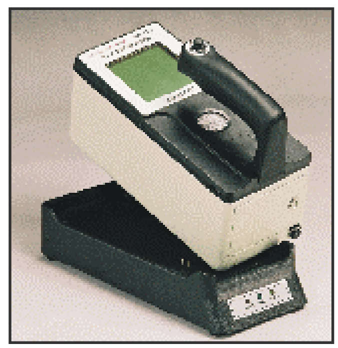


Figure 7. Radionuclide Identifier

A radionuclide identifier (also known as a multi-channel analyzer or MCA) can identify the gamma emitting radionuclide(s) present. It accomplishes this identification by analyzing characteristic energy peaks from a radionuclide and comparing it to a library of stored information. However, great caution is advised, because no identifier is correct 100% of the time, and further analyses may be necessary for proper identification of a source. Several radioisotopes emit gamma rays with energies that are similar or overlapping, or the radionuclide may not be available for comparison in the library. These are delicate instruments that are sensitive to abrupt changes in temperature and humidity. Additionally, radionuclide identifiers cannot identify a pure alpha or beta emitting radionuclide unless there is an associated gamma emitter from one of its decay products. Consequently, *radionuclide identifiers may sometimes misidentify the radioisotope*.

Electronic Dosimeters

Electronic dosimeters, also called personal dosimeters, or "pagers," can be used to measure an individual's exposure to radiation. They can also be used, to a limited extent, for detecting and measuring radiation. Generally, they may have a small sodium iodide, GM or solid state detector inside. Most can be used in either an exposure rate mode, which gives exposure per unit time, or in an integrated exposure mode, which will measure the accumulating exposure to the device until it is turned off or reset. Often they have an alarm that can be set to alert the user to a preset radiation level or a cumulative exposure. Note that many of these devices have limitations when worn in a high radiation field.

Figure 8. Electronic Dosimeters

Direct Reading Pocket Dosimeter

The direct reading pocket dosimeter is a charged ionization chamber designed to measure a total dose received from moderate to high levels of gamma radiation. These instruments use a small quartz fiber electroscope as an exposure detector and indicator. An image of the fiber is projected onto a film scale and viewed through the eyepiece lens. These are small simple devices that allow the user to effectively track their dose provided the dose(s) is recorded, the chamber is properly re-charged prior to its use, and is frequently monitored during use to avoid full discharge.

Figure 9. Direct Reading Pocket Dosimeter

Neutron Detectors/REM Ball

A REM ball is a relatively large instrument that measures neutron dose rates. They are usually only available to radiation control program staff. It is very unlikely that first responders will need to detect neutrons, because neutrons are not considered to be a significant threat in a "dirty bomb." Some radiation detection instruments also include a neutron detector; however they only provide information on whether neutron radiation is present or not, and do not provide dose rate measurements.

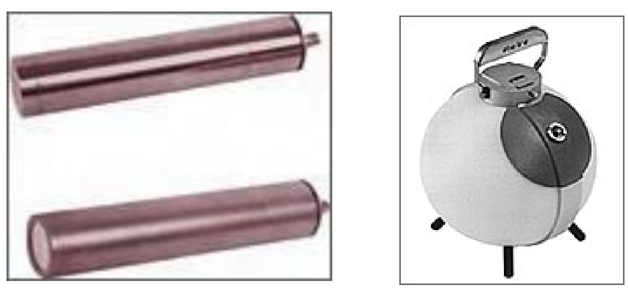


Figure 10. Neutron Detectors and REM Ball

Figure 11. Radiation Portal Monitor

Radiation Portal Monitor

A radiation portal monitor is a system designed for rapid screening of people in the event of a radiation incident. They are similar to the portal monitors that people walk through at airports, but these are designed to detect low levels of radiation. They are constructed so people can walk through them, or be in a wheelchair or on a stretcher. Some come with a vehicle adapter so vehicles can be driven through. They often use long plastic scintillation detectors that can generally detect less than one microcurie of cesium 137. The use of a portal monitor can significantly decrease the time needed to survey large numbers of people.

CONTROL THE SCENE AND ESTABLISH "SAFE" AREAS

Incident Command will need to quickly gain control of the scene of an RDD explosion and establish "safe" areas in order to protect responders and the public from unnecessary exposure to radiation. This will involve setting "decision area boundaries," controlling access, and surveying people and objects to determine if they are contaminated with radioactive materials. *(Included in the appendices are an Initial RDD Incident Form and instructions for workers performing a contamination survey, along with a form for recording contamination on individuals.)*

Unfortunately, no official guidance exists as to what levels of radiation should be used to demarcate one zone from the next. This document provides guidance for proposed values to be used when radiation control program staff are not yet at the site, and responders have limited or no radiation detection instrumentation. These are recommendations. Because individual states may adopt different values, it is important that responders consult with their local/state radiation control staff and become familiar with the specific values recommended by their state.

It is important to note that there may not be an orderly progression from low exposure to high exposure, especially near the blast area. It is likely that there will be multiple "hot" spots, which may result in higher radiation fields within areas that generally have lower radiation levels. The opposite may also occur. Because the deposition of the radioactive material is likely to be in a relatively uneven pattern, it may not be possible to have well-defined boundaries.

Responders will be extremely busy controlling the scene, rescuing victims, evacuating non-injured people, etc. Examples of data collection tools that can be used to rapidly document an initial site survey and initial details of the incident are provided. Completing these forms at the scene will be useful as they can provide your radiation control program staff with information to determine priorities and better provide assistance with zone re-definition, surveys, decontamination, etc. Examples of these forms can be found in the Forms and Handouts section of this document and also on the enclosed CD, to be adapted as necessary.

DEFINITION OF THE RADIATION AREA BOUNDARIES OR "DECISION POINTS"

In order to control the scene the first 12 hours following the detonation of an RDD, responders must define their radiation boundaries or decision points. These radiation decision points are demarcations of various radiation levels, which will be helpful in defining the types of activities and the time limitation that responders can stay in order to limit their radiation exposure. They will also help prioritize activities. The location and exposure rates of the radiation decision points will depend on the physical size of the impacted area.

The guidelines for radiation exposure following the detonation of an RDD are anticipated to be greater than those traditionally used when responding to transportation accident involving radioactive materials. The number of radiation areas or zones will depend on the event. It is possible that some events will result in the definition of only two areas, while others may require more.

The proposed boundaries or decision points presented in Figure 12 are provided for guidance. For a very large area, it may be difficult to set up a Low Radiation boundary at values smaller than 10 mR/hr within a reasonable distance of the epicenter of the blast, but if possible it should be set as low as practical. Note that the shape of the zones presented in Figure 2 is for illustration purposes only, since, as previously stated, the distribution of contamination may not follow an even pattern.

To better control activities at the scene, responders may define additional boundaries at 100 mR/hr and 1000 mR/hr. If necessary, an *extreme caution* zone should be established within the *high* radiation zone, to highlight the fact that there may be situations where the radiation levels near the epicenter of the blast may be higher than 10,000 mR/hr (10 R/hr). If responders need to enter this area to rescue people, their time should be limited to the most critical activities and dosimetry should be provided. Time spent in this area must be limited, in order to avoid Acute Radiation Syndrome *(see Appendix 8)*.

SETTING UP ZONES WHEN INSTRUMENTATION IS NOT AVAILABLE

It is possible that first responders may respond to a dirty bomb event without radiation detection instruments. If that is the case, the following guidance should be used:

- Rescue all injured persons, using triage protocols, moving personnel, as feasible, from the immediate blast area/explosion epicenter in an upwind direction;

- Evacuate all non-injured persons as soon as possible, preferably to a location up-wind from the immediate blast area /explosion epicenter for follow-up;

- Establish an evacuation zone of about 500 meters in radius centered on the explosion center (1650 feet or approximately 2.5 city blocks).

- Minimize time within this zone to lifesaving and critical property mitigation activities.

- Request radiation detection teams from nearest jurisdiction to assess radiation levels and establish decision area boundaries.

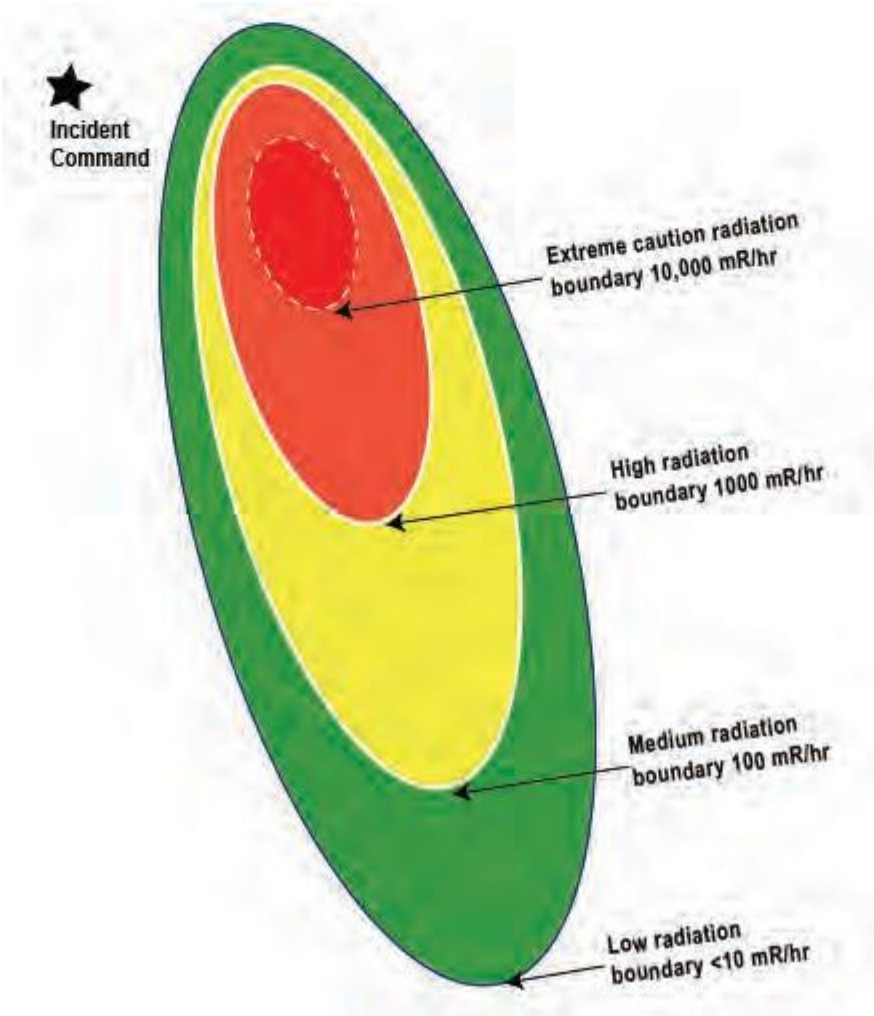


Figure 12. Radiation Zones

SETTING UP ZONES WHEN INSTRUMENTATION IS AVAILABLE

If radiation detection instrumentation is available, rescue and evacuate as noted above. Establish radiation zones as described below:

- Turn on and select the highest scale on the exposure rate meter (if using an instrument that doesn't auto scale).

> ***Starting on the highest scale is contrary to routine procedures, and is done to avoid saturating the instrument. A saturated instrument may not indicate the presence of radiation.***

If the meter doesn’t measure any radiation, go to the next lower scale, and continue going to a lower scale until radiation is detected or you are using the lowest scale. Make sure you wait for the instrument to stabilize when changing between scales.

- Survey the area and switch to a higher scale as needed, as you approach the blast vicinity;

- When the exposure rate approaches 100 mR/hr, establish a boundary for the *medium* radiation zone;

- Continue walking toward the blast vicinity, when the exposure rate approaches 1,000 mR/hr, establish a boundary for the *hig*h radiation zone;

- **Unless there is a critical need to gain access to an area (e.g., searching for victims for rescue and lifesaving, or assessing critical damage to a structure that may present a significant hazard to surrounding buildings or people), one should not conduct a radiation survey past the point where 1,000 mR/hour is measured. Surveys conducted in areas where exposure rates exceed 1,000 mR/hour should be performed with great caution, and surveys in areas exceeding 10,000 mR/hour should be conducted only when justified by great need;**

- Continue the radiation survey if there is a need to do so into the *high* radiation zone. If the exposure rate approaches 10,000 mR/hr, establish an *extreme caution* zone;

- If feasible, establish the Incident Command Post at a location upwind with background radiation levels. If this is not feasible, use an area of less than 2 mR/hr and contamination levels less than 1,000 cpm measured 1-2 inches from the ground with the pancake probe. Check with local/state radiation control personnel if it appears necessary to establish the Incident Command Post in a higher radiation/contamination area.

The following activities may be conducted by the state/local radiation control staff upon arrival at the scene:

- Conduct surveys and adjust radiation zone boundaries as necessary (verify/redefine contaminated area);
- Identify radioisotopes;
- Establish initial monitoring and decontamination guidelines for the responder contamination control point near the outer boundary of the *low* radiation zone;
- Provide guidelines for monitoring and decontamination of victims (including first responders);
- Provide guidelines for a remote monitoring and decontamination station for evacuees in a low radiation and contamination background area, preferably a background area, but at least in an area with less than 1,000 cpm contamination with a pancake GM, measured 1-2 inches from the ground, generally upwind of the epicenter of the blast zone;
- Provide technical support to medical personnel;
- Provide technical support to Public Information Officer;
- Perform dose assessments;
- Develop protective action recommendations.

CONTROLLING TIME IN THE RADIATION ZONES

In addition to defining the radiation decision points or boundaries, responders will need to define the various radiation zones. The goal of defining the zones is to simultaneously minimize unnecessary exposure to radiation and allow prompt, efficient rescue of victims and preservation of critical properties. Once the threat to critical infrastructures and human life is over, "exclusion" zones should be established at levels far lower than the ones indicated during the immediate response. Note that for most RDD scenarios, if one is outside the immediate blast zone, one is most likely to be outside of the most severe radiological conditions.

Controlling radiation exposure to responders should be the critical goal of emergency response planning. This goal may be achieved by developing strategies designed to limit the length of time that individual responders are exposed to elevated radiation levels. The maximum duration of exposure to radiation that a responder should have is termed "stay time." Stay time is calculated by dividing the total allowable dose by the exposure rate. *For the purposes of this document, assume 1 Roentgen (R) = 1 rad = 1 rem.*

For example, if the total allowed dose for lifesaving is 50,000 mrem, the total accumulated stay time in a 10,000 mR/hr field is 5 hours.

$$\frac{50{,}000 \text{ mrem}}{10{,}000 \text{ mR/hr}} = 5 \text{ hours}$$

The stay time calculation thus gives a quick estimate of the total amount of time that a first responder should spend in an area having a given, measured radiation level. The radiation zones and decision points (boundaries) are shown in Figure 12, and repeated here in a smaller version, and Table 1, and the radiation zones with suggested activities for each zone are shown in Table 2.

One should use either the maximum radiation exposure level allowed in the zone as the reference for stay times, or use actual measurements as the basis for stay times.

Note: Throughout this document, conventional units of measure are used. International SI units and a conversion table are provided in Appendix 3.

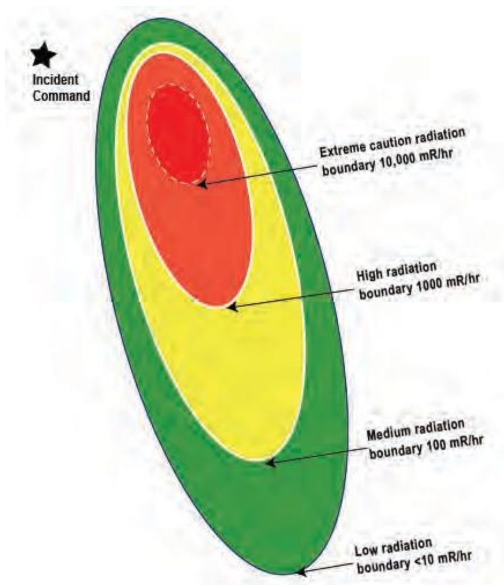


Table 1. Radiation Zones and Boundaries

Boundary Between Zones	Radiation Exposure Rates	
	mR/hr	R/hr
Extreme Caution and High Radiation	10,000	10
High and Medium Radiation	1,000	1
Medium and Low Radiation	100	0.1
Low Radiation	< 10	< 0.01

Table 2. Radiation Zones and Suggested Activities for Each Zone During the First 12 Hours

Decision Exposure Rate mR/hr	Radiation Zones mR/hr	Activities	Total Accumulated Stay Time for First 12 Hrs *
Background	Uncontrolled	No restrictions. The best location for Incident Command and decontamination activities.	Unlimited
< 10	Low-Radiation Zone < 10 -100	If feasible, restrict access to essential individuals. Initial decontamination of first responders should occur near the outer boundary of this area. Uninjured personnel within this zone at the time of the RDD explosion can be directed to proceed directly home to shower if resources do not permit contamination surveying at the scene. (For RDDs containing up to ~1000 Ci, this may be the only zone that exists.)	Full 12 Hours
100	Medium-Radiation Zone 100-1000	Restrict access to only authorized personnel. Personal dosimetry should be worn. Serves as a buffer zone/transition area between the high and low radiation zones. People within this zone at the time of the explosion should be surveyed for contamination before being released. (For RDDs up to ~ 10,000 Ci, this may be the highest radiation zone that exists.)	5 - 12 Hrs (12 Hrs for critical property and lifesaving activities)
1000	High-Radiation Zone 1000 - <10,000	Restrict access to authorized personnel with specific critical tasks such as firefighting, medical assistance, rescue, extrication, and other time- sensitive activities. Personal dosimetry should be worn. People within this zone at the time of the explosion should be surveyed for contamination before being released.	30 minutes – 5 Hours
10,000	Extreme Caution Zone ≥ 10,000	This area, located within the high radiation zone, is restricted to the most critical activities, such as lifesaving. Personal dosimetry required, although one monitor for several responders is acceptable if they remain near the person with the monitor. Limit time spent in this area to avoid Acute Radiation Sickness. People within this zone at the time of the explosion must be surveyed for contamination before being released.	Minutes to a few hours

Responders may find, in an extreme case, that a large source of radiation with radiation levels of 200,000 mR/hr (200 R/hr) or more is involved. ***Should you encounter radiation levels this high, immediately turn back and inform the Incident Commander. Entry into these areas should only be made at the direction of the Incident Commander in consultation with the Radiation Safety Officer for lifesaving activities, and only for very short time periods (minutes).***

* Total Stay Time is calculated by dividing total allowed dose by exposure rate. For example, if total allowed dose for lifesaving is 50,000 mrem, Total Stay Time in a 200,000 mR/hr field is 15 minutes.

$$\frac{50{,}000 \text{ mrem}}{200{,}000 \text{ mR/hr}} = 0.25 \text{ hour (15 minutes)}$$

NOTES:

- If feasible, Incident Command and other administrative control functions, triage area, and contamination monitoring area should all be located outside the *low* radiation zone. Preferably these functions will be located upwind of the RDD site in an area of natural background radiation and no contamination. If not practical, seek areas with minimum radiation and contamination levels, preferably with contamination levels less than 1,000 cpm using a pancake GM, measured 1-2 inches from the ground surface, and radiation levels near background for contamination monitoring, and less than a few mR/hr for other activities.
- Discuss other alternatives with local/state radiation control program staff.
- If staff resources allow, use a pancake GM probe to define the 10,000 cpm boundary (1,000 cpm if feasible) outside of the *low* radiation zone, and restrict nonessential personnel from this area. It is desirable to control access to this area, and to survey personnel leaving this area for contamination before being released for other activities in order to minimize nuisance contamination spread.

Personal dosimetry is also recommended for workers in the low radiation area.

Note: This table is also available in the Forms and Handouts section and on the CD.

DOSE GUIDELINES

The purpose of dose guidelines is to ensure that certain critical doses are not exceeded, thus providing some protection from serious harm from radiation, and also help manage doses to levels that are as low as reasonably achievable (ALARA). The dose guidelines presented here are recommended for instances where the radiation control program staff have not yet arrived to the scene, and may be modified by the radiation staff upon arrival.

If local and or state radiation control program staff are at the scene, they will help track and plan activities in high radiation areas to minimize doses to the responders. Radiation dosimeters should be worn for entries into all radiation zones. Exception can be made for the *low* radiation zone; however, if radiation dosimeters are not available, survey instruments and timekeeping must be utilized to track and record doses. The turn-back values have also been provided as general guidelines to minimize doses as much as possible.

The turn-back exposure rates and dose guidelines are given in Table 3. Table 3 also lists the emergency worker dose limit. The emergency worker dose limit is a concept that is used in radiological emergency response activities during an accident at a nuclear power plant. Emergency workers usually include law enforcement staff tasked with checkpoint control, bus drivers assisting with evacuation of the general public, etc. It is anticipated that following an RDD, in addition to the responders there will be other people assisting the victims. The emergency worker dose limits are provided here for completeness. Ideally, it is expected that other emergency responders will be available to assist in rescue operations, such that staff rotation can take place, and doses can be minimized. We encourage you to consult with your state/local radiation office to obtain specific guidelines.

Some form of recordkeeping of exposure should be maintained. This may include dosimetry records or basic recording of personnel assignments and time spent in various zones. If this is not feasible during the response phase, an effort to obtain this information should be made as soon as possible after critical needs are met and before personnel leave the site. At a minimum, contact information for responders should be recorded. If possible, this effort should be coordinated with the Radiation Safety Officer.

Table 3. Turn-Back Exposure Rates and Dose Guidelines

Activities	Suggested Turn-Back Exposure Rates	Guidelines for Total Accumulated Dose	Increased Cancer Risk [4, 5]
Emergency worker dose limit	Follow Radiation Safety Officer instructions	5,000 mrem[1]	0.4 %
Non-lifesaving activities (major critical property protection)	10,000 mR/hr	10,000 mrem	0.8 %
Lifesaving activities	200,000 mR/hr[2] **Extreme Caution**	50,000 mrem [3]	4 %

[1] Note that the 5000 mrem dose guideline represents the standard occupational dose limit for one year.

[2] Specific approval and controls required to exceed this turn-back exposure rate.

[3] The 50,000 mrem dose guideline is a level where minor effects from short-term radiation exposure are possible. Note that this guideline applies to a once-in-a-lifetime event.

[4] Increased lifetime risk of a fatal cancer. It does not mean that the person will get cancer. *For more information see Appendix 7.*

[5] NCRP Commentary 19, NCRP 138

Guidance on Radiation Exposure

This guidance may be used in the absence of specific instructions from the local or state radiation control program.

- Optimally, personnel dosimeters should be provided to all emergency workers.

- When responding to an RDD event, responders may find themselves in areas having radiation levels in excess of 1,000 mR/hr (1 R/hr). This is the point where the *high* radiation zone should begin. *Only authorized individuals assigned specific tasks and stay times, and preferably provided with alarming dosimeters, should conduct emergency response activities within this zone (or higher radiation zones).* These individuals should limit their time spent within this zone to accomplishing only their assigned duty or task.

- Some RDD events may involve large sources of radiation, or radiation sources that remain concentrated within a small area. This could result in radiation levels exceeding 10,000 mR/hr (10 R/hr). This is the point where the *extreme caution* zone begins. Responders may need to perform lifesaving or non-lifesaving (such as critical property protection) activities in such areas in order to protect large areas or populations outside the immediate disaster area. To minimize a responder's risk of developing Acute Radiation Syndrome, time spent working in the *extreme caution* zone must be strictly limited (minutes to a few hours).

- Responders working in an area where radiation levels are 10,000 mR/hr (10 R/hr) for a total time of one hour receive a total body dose of 10,000 mrem (10 Rem), the dose guideline for critical non-lifesaving activities presented in Table 3. Alternatively, the same responder could enter the same area for four 15-minute intervals, or for two 30-minute intervals before the critical non-lifesaving dose guideline of 10,000 mrem (10 Rem) is reached.

- Acute Radiation Syndrome (ARS) is caused by exposure of the entire body (or large portions of it) to high doses of radiation over a short period of time. The effects on the bone marrow, the gastrointestinal tract, and the nervous system will depend on the radiation dose received. One way to minimize the risk of developing ARS is to decrease the duration of exposure to radiation. *(See Appendix 8).*

- Responders may find, in an extreme case, that a large source of radiation with radiation levels of 200,000 mR/hr (200 R/hr) or more is involved. ***Should you encounter radiation levels this high, immediately turn back and inform the Incident Commander. Entry into these areas should only be made at the direction of the Incident Commander in consultation with the Radiation Safety Officer for lifesaving activities, and only for very short time periods (minutes).***

Note: Appendix 7 discusses health effects of radiation exposure.

RESCUE INJURED

For outdoor explosions area, most of the airborne radioactive dust will have settled to the ground within about 10 minutes. Individuals not wearing protective clothing and a respirator when entering a radiation hazard area should wear a dust mask and overshoes.

Assess and treat life-threatening injuries immediately.
Treatment of such patients takes priority over all other activities, including decontamination. Do not delay advanced life support to assess contamination status. Perform routine emergency care during extrication procedures.

Methods for handling contaminated victims will vary depending on the medical condition of the individual. Guidance for conducting lifesaving and rescue operations, and for personal protective equipment needed by responders, is provided at the U.S. Department of Energy Transportation Emergency Preparedness Program (TEPP) website:

http://web.em.doe.gov/otem/program.html

For patients with non-life-threatening conditions: decontaminate if not medically contraindicated, then treat. *Decontamination procedures are detailed in the next section*.

Uninjured contaminated persons should *NOT* be directed to a medical facility; contamination is NOT an immediate medical issue when there are no physical injuries. External contamination for an incident involving an RDD will not likely be a significant health risk.

Externally irradiated patients are not contaminated. Exposure without contamination requires no decontamination. *For more information on exposure versus contamination, see Appendix 5.*

Contaminated patients who do not have life threatening or serious injuries may be decontaminated on-site or at a designated decontamination center. If patients are not going to a medical facility for treatment, it is acceptable to decontaminate to 10,000 cpm on a Pancake GM (0.05 mR/hr using a gamma detector) and direct the patient to proceed directly home to shower/wash. *A "How to Perform Decontamination at Home" sheet is included in this document in the Forms and Handouts section and on the CD.* Establishing higher decontamination limits may be necessary depending on the number of patients and the decontamination resources available.

The following guidelines apply to responders tasked with emergency medical management and may include EMS staff.

- Rescuers (i.e., fire department) should move victims out of the hazard area to a low radiation area. Move victims away from the radiation hazard area using proper patient transfer techniques to prevent further injury. Stay within a controlled area if contamination is suspected.

- Victims should be monitored at the control line for possible external contamination only after they are medically stable. Radiation levels significantly above background are strongly suggestive of the presence of contamination.

- Irrigation or washing of skin with lukewarm water and a mild soap is effective for initial decontamination. It is not necessary to collect the water that was used for decontamination. However, if possible, do not let the water contaminate other persons or equipment.

- Expose wounds, decontaminate with gentle irrigation, and then cover with sterile dressings. Priority efforts should be directed to decontamination of open wounds by rinsing with ample water before applying the dressing. Do not use irritants or methods that may abrade the skin, as this could result in internal contamination.

- Flush eyes with water or sterile saline if there is indication of eye contamination.

- Removing the contaminated person's outer clothing may reduce external contamination by up to 90%. Holding one's breath while removing contaminated clothing over the head will reduce the possibility of breathing radioactive particles. Place such items in a plastic bag (double bag if possible to minimize the potential for bag breach) and label with the person's name and location (incident site). These items may be used later for dose assessment or legal evidence.

- To minimize contamination spread at hospitals, attempt to decontaminate to levels below 1,000 cpm using a Pancake GM, but only if such decontamination efforts do not interfere with patient medical treatment.

- Move the ambulance cot to the clean side of the control line and unfold a clean sheet or blanket over it. Place the victim on the covered cot and package for transport. Do not remove the victim from the backboard if one was used.

- Package the victim by folding the stretcher sheet over and securing the patient in the appropriate manner. This reduces the spread of contamination to the ambulance.

- If possible, the ambulance should be lined with plastic or "chux" (absorbent pad on one side, and plastic on the other), so that contamination can be more easily removed.

- Before leaving the controlled area, responders should remove protective clothing at the control line. If possible, victims should be transported by personnel who have not entered the controlled area. Ambulance personnel attending victims should wear gloves and a dust mask if available.

- Notify proper authorities in the hospital. Let the hospital know that you are dealing with radiation incident victims, and provide an estimate of the number of individuals, their medical conditions, any known radiological information, and an estimate of your arrival time. Ask for any special instructions the hospital may have. You may be directed to an entrance other than the routine emergency department entrance for the purposes of radiological contamination control.

- Transport the victim to the hospital. Follow the hospital's radiological protocol upon arrival. Hand-off patients in a manner that reduces the likelihood of spreading contamination. Wrap the patient in a second clean sheet for transfer at the hospital.

- The ambulance is considered contaminated until proven otherwise or decontaminated. (Optimally, a person with radiation expertise will perform this type of "clearance" survey.) However, you may be directed to use the same ambulance for additional trips to the same event site prior to being "clean-released" (cleared to acceptable background radiation levels).

- Emergency Medical Technicians (EMTs) should be surveyed and decontaminated as necessary.

- For internal contamination, contact the Radiation Safety Officer and/or a Nuclear Medicine Physician at the hospital. Internal contamination requires assessment and treatment at a hospital *(See Appendix 6).*

DECONTAMINATION GUIDELINES

RADIATION SURVEY OVERVIEW

These guidelines may be followed in the absence of specific information on the type or magnitude of the radiation field.

- Establish the following **decontamination** areas:

  Area 1 Located upwind, near the *low* radiation zone outer boundary, for initial emergency worker staging at the scene along with victims leaving the radiation zones.

  Area 2 Located in an area upwind from the explosion area, and with measurements less than 1,000 cpm (preferably near background), for the evacuees and workers who will be monitored for contamination.

Remember to notify the local and or state radiation control programs through Incident Command for further specific information and guidance.

- If there is a *large* population to be evacuated in the *low* radiation zone (< 10 - 100 mR/hr), self-decontamination at home to the extent possible may be advised. Contingency planning for scanning and decontamination of the public needs to be considered. Following this recommendation will allow for easier handling of the large number of people potentially affected, and will allow them to go home instead of being detained. Large population refers to population numbers that would overwhelm your resources.

- If available, portal monitors that people can walk through can be used to quickly survey large numbers of people. The monitors should be wrapped in plastic wrap so that loose contamination can be easily and quickly removed.

- If the event is smaller and adequate decontamination resources allow, more restrictive guidelines may be adopted, as noted in the "Suggested Release Limits" below. Survey criteria will be established at the time of the response and may be different than "any detectable level."

- If individuals do not require immediate medical attention, they may be decontaminated on-site or allowed to go home to decontaminate. *(Instructions are provided in the Forms and Handouts section and on the CD.)* Proper decontamination is important to prevent contamination of facilities and equipment and to prevent exposure to other individuals. Remember that removal of outer clothing may reduce up to 90% of the contamination.

Suggested **release** levels (assuming using a pancake GM probe at 1 inch from the radiation source):

- With contamination up to 1,000 cpm, allow individuals to leave; instruct them to go home and shower. *("How to Perform Decontamination at Home" is available in the Forms and Handouts section and on the CD.)*

- If the event is large and if adequate decontamination resources are not available, the release level can be increased to 10,000 cpm. Instruct people to go home and shower. *("How to Perform Decontamination at Home" is available in the Forms and Handouts section and on the CD.)*

- Send people with contamination levels greater than 10,000 cpm to a designated decontamination area. *("Instructions to the Public Waiting for Decontamination at the Scene of the Incident" is available in the Forms and Handouts section and on the CD.)*

- People contaminated to levels greater than 100,000 cpm are likely to have internal contamination and should be identified as a priority for follow-up for internal contamination. (*"Instructions to the Public Waiting for Decontamination at the Scene of the Incident" is available in the Forms and Handouts section and on the CD.)* (*See Appendix 6 for Guidance for Assessing Internal Contamination.)*

For victims who wish to be surveyed or are in a radiation area that requires decontamination, you should hand out a form delineating the steps to be taken for decontamination. *("Instructions to the Public Waiting for Decontamination at the Scene of the Incident" is available in the Forms and Handouts section and on the CD.)*

Please remember that this may be a very stressful process for the victims; therefore, allowing people to become familiar with the decontamination process will help minimize delays while explaining the steps that they will have to go through to get decontaminated. If there are large groups of people in the area who are not fluent in English, it is recommended that the instructions be translated in advance, so they will be available in their native language.

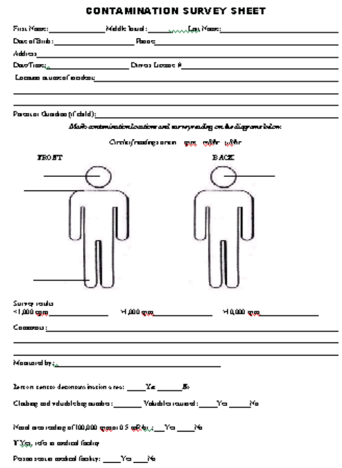
Note that if there are large numbers of people, you may need to perform a limited screening survey, rather than a more detailed survey, as described in the next section.

HOW TO PERFORM A RADIATION SURVEY FOR CONTAMINATION—INSTRUCTIONS FOR WORKERS

In performing a contamination survey with a hand-held instrument, first check to make sure the instrument is functioning properly. It is advisable to wrap the meter probe with plastic wrap to protect the probe from contamination (except if you are surveying for alpha contamination).

> ***Make sure that the instrument has batteries and that they work. To do this, turn your instrument to battery check. If the batteries are acceptable, turn the dial to a measurement mode and use a check source to verify the instrument is operating properly.***

A contamination survey sheet *(illustrated here and available in the Forms and Handouts section and on the CD)* should accompany anyone who is sent to a doctor or hospital for further follow-up.



Contamination Survey Sheet
(A full-size version is available in the Forms and Handouts section and on the CD)

Screening Survey

- *If a large population must be surveyed, it is acceptable to perform only a screening survey of the head, face, and shoulders, rather than a more detailed survey, since these are the most likely locations to become contaminated. You may also consider using portal monitors.*

  If only performing a screening survey, it is acceptable to hold the survey meter probe about 1-2 inches away from the body, and move it 2-4 inches per second. (If the probe is moved too quickly, its detection capability may be reduced.) Check with state/local radiation control personnel to determine the extent of contamination survey required.

- Return the probe to its holder on the meter when finished. *Do not set the probe down on the ground***.** The probe should be placed in the holder with the sensitive side of the probe facing to the side or facing down so that the next person to use the meter can monitor his/her hands without handling the probe or allowing contamination to fall onto the probe surface.

Complete Whole Body Survey

- If feasible, perform a complete, whole body contamination survey and record the findings on the Contamination Survey Sheet. To begin a body survey, the individual should stand with their legs spread and arms extended. First holding the probe about a ½ inch away from the surface to be surveyed, slowly (1-2 inches per second) move the probe over the head, and proceed to survey the shoulders, arms, and bottoms of the feet. Care must be taken not to permit the detector probe to touch any potentially contaminated surfaces.

  It is not necessary to perform the contamination survey in exactly the order listed below, but a consistent procedure should be followed to help prevent accidentally skipping an area of the body. Pause the probe for about five seconds at locations most likely to be contaminated.

  1. Top and sides of head, face (pause at mouth and nose for approximately five seconds; high readings may indicate internal contamination).
  2. Front of the neck and shoulders.
  3. Down one arm (pausing at elbow), turn arm over.
  4. Backside of hands, turn over (pause at palms for about five seconds).
  5. Up the other arm (pausing at elbow), turn arm over.
  6. Shoe tops and inside ankle area.
  7. Shoe bottoms (pause at sole and heel).

- As with the screening survey, return the probe to its holder on the meter when finished. *Do not set the probe down on the ground***.** The probe should be placed in the holder with the sensitive side of the probe facing to the side or facing down so that the next person to use the meter can monitor his/her hands without handling the probe or allowing contamination to fall onto the probe surface.

The most common mistakes made during the survey:

- Holding the probe too far away from the surface (should be about 1-2 inches away for a screening survey or about 1/2 inch or less for a detailed survey).
- Moving the probe too fast (should be about 2-4 inches per second for a screening survey or about 1-2 inches per second for a detailed survey.)
- Contaminating the probe. Probe background should be observed and compared to initial background. If within a factor of 2, it is acceptable to continue to use probe. Otherwise, check with radiation control personnel. Wrapping the probe in plastic wrap will help prevent surface contamination.

(These instructions for workers on how to perform a radiation survey for contamination are repeated in the Forms and Handouts section and on the CD.)

HOW TO DECONTAMINATE

- Immediate careful removal of the victim's *outer* clothing should remove up to 90% of the contaminant. When removing the clothing be careful of any clothing that has to be pulled over the head. Try to either cut the article off or prevent the outer layer from coming in contact with the nose and mouth area. The victim should also hold their breath while carefully pulling the article over the head. Holding one's breath while removing contaminated clothing over the head will reduce the possibility of breathing in radioactive particles. The bagged clothing (double bagged if possible to minimize the possibility of a bag rupture) should be sealed to prevent spread of contamination, and be retained for possible dose assessment or legal evidence. As much as possible, the names of the victims at the scene, and their contact information should be noted for follow-up.

- After clothing is removed, the victim's skin and eyes (if there is indication of eye contamination) may need to be decontaminated. In most cases, decontamination of the skin can be accomplished by gently washing with soap and lukewarm water followed by a thorough water rinse. It is important not to abrade the skin during washing or rinsing, as this can lead to internal radioactive contamination of the victim. For eyes, flush with plenty of water.

- While it is not anticipated that an RDD will result in internal contamination levels that will be health significant (at least not from other than alpha emitters), it may be desirable to perform a check for potentially significant internal contamination. Note that the victim's location during the event is likely to be the best indicator of concern about internal exposure. Individuals located within 1650 ft (500 meters) from the blast area should be a higher priority for internal contamination assessment than those located outside the 1650 ft perimeter of the blast. If the survey of the head, face and shoulder areas indicates high levels of contamination (greater than 100,000 cpm), you may assume that the person has internal contamination. It is not necessary to assess the levels of internal contamination at the site, since the need for treatment will be assessed and treatment will be administered by medical personnel at a hospital. *The procedure for determining internal contamination is detailed in Appendix 6.*

FORMS AND HANDOUTS

Throughout this document, there are statements that the forms and handouts are available on a CD. For this Web version of the document, that is not the case. The forms and handouts provided in this section are also included as attachments to this file. Most of them are available both as Word and Acrobat PDF documents. They can be printed/modified/adapted as necessary. Access to them is available through the Attachments tab on the Navigation Pane. This document opens with the Navigation Pane and Bookmarks visible and a Tab for Attachments. If the Navigation Pane is no longer visible, from the menu at the top of the screen select View and then Navigation Panels and select Attachments.

It is strongly urged that enough pre-printed copies of these forms and handouts (if adopted) be available and included in your emergency plan.

FORMS

Initial RDD Incident Form/Initial Site Survey
Incident Briefing (ICS 201 8/96)*
Site Safety and Control Plan (ICS 208 HM)*
Contamination Survey Sheet
Suggested Mass Decontamination Supplies List

HANDOUTS

How to Perform Decontamination at Home
How to Perform a Radiation Survey for Contamination—Instructions for Workers
Instructions to the Public Waiting for Decontamination at the Scene of the Incident
Radiation Zones and Suggested Activities for Each Zone During the First 12 Hours

*There are a number of Incident Command System forms available at the U.S. Department of Labor Occupational Safety & Health Administration website:

http://www.osha.gov/SLTC/etools/ics/ics_forms.html.

Initial RDD Incident Form

(Give this completed form to the state or local radiation control program team leader when they arrive on site.) (Complete as much as you can.)

Location and Time of Incident:	**Contact Person:**
D Residential D Commercial D Industrial D Other	On-site Incident Commander: Person completing this form: Cell phone/pager number:
Emergency Responders On Scene:	**Affected Members of the Public:**
D Police D Fire D HAZMAT D State/Local Radiation Control **D** Other Radiation Experts	**D** Estimated number of victims _______ D Estimated number of injured victims ______
Conventional Hazards:	**Radiological Hazards:**
D Fire **D** Chemicals **D** Explosives **D** Other (specify)	D Significant Radiation Dose D Release to the Environment D Inhalation Hazard D Contaminated Areas **D** Other (specify)
Meteorology:	**Is Access Controlled?**
At time of explosion: Wind Speed__________and Direction_______ Current: Wind Speed___________and Direction______	**D** No **D** Yes How?

Nuclide Identification (if possible)

Instrument Type___________________Model________________Serial # __________________
Nuclides:

Person(s) Interviewed:	**Phone Number**	**Affiliation**

Actions to prevent or reduce exposure of responders:

Actions to measure exposure of responders (dosimetry):

Initial Site Survey

Instrument Type______________________Model______________Serial # ________________________

Check Source Measurement____________________Background Measurement ___________________

Maximum measurement and distance from explosion site for:

Exposure rate (@ waist level):__________R/hr________yds

Contamination:__________cpm with Pancake GM________yds

Dose rate at IC:__________mR/hr

Contamination at IC:___________cpm with Pancake GM

Diagram of the Source and Surrounding Area

Include location of radiation area boundaries, relevant radiation readings, landmarks and distances

Comments:

Signature of person completing this form (Optional)

Date:
Time:

ICS 201 Incident Briefing Form

(This is a graphic of the PDF file available on the CD)
(Incident Command System Forms are also available online at **http://www.osha.gov/SLTC/etools/ics/ics_forms.html***)*

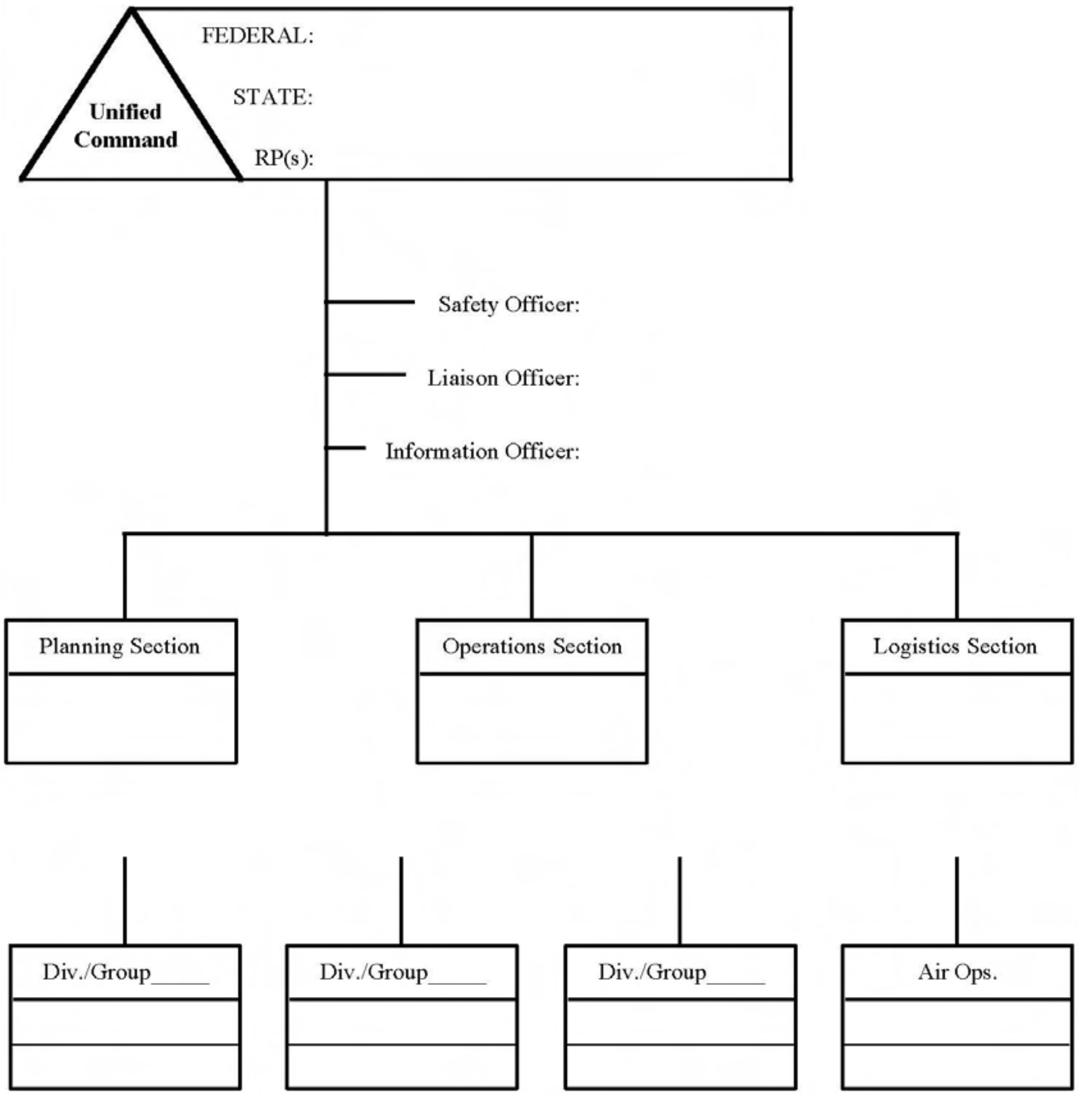
INCIDENT BRIEFING	1. Incident Name	2. Date Prepared	3. Time Prepared

4. MAP/SKETCH
(Could include maps showing the total Area of Operations, the Incident site, overflight results, trajectories, impacted shorelines, or other graphics depicting situation and response status.)

ICS 201 8/96	Page 1 of 4	5. Prepared By: (Name and Position)

6. Summary of Current Actions		
ICS 201 8/96	Page 2 of 4	

7. CURRENT ORGANIZATION



ICS 201 8/96	Page 3 of 4	

8. Resources Summary

Resource(s)/Identifier	Quantity	ETA	On Scene	Location/Assignment/Status

ICS 201 8/96	Page 4 of 4	

ICS 208 Site Safety and Control Plan Form

(This is a graphic of the PDF file available on the CD)
(Incident Command System Forms are also available online at **http://www.osha.gov/SLTC/etools/ics/ics_forms.html***)*

SITE SAFETY AND CONTROL PLAN ICS 208 HM	1. Incident Name:	2. Date Prepared:	3. Operational Period: Time:

Section I. Site Information

4. Incident Location:

Section II. Organization

5. Incident Commander:	6. HM Group Supervisor:	7. Tech. Specialist - HM Reference:
8. Safety Officer:	9. Entry Leader:	10. Site Access Control Leader:
11. Asst. Safety Officer - HM:	12. Decontamination Leader:	13. Safe Refuge Area Mgr:
14. Environmental Health:	15.	16.

17. Entry Team: (Buddy System) Name:	PPE Level	18. Decontamination Element: Name:	PPE Level
Entry 1		Decon 1	
Entry 2		Decon 2	
Entry 3		Decon 3	
Entry 4		Decon 4	

Section III. Hazard/Risk Analysis

19. Material:	Container type	Qty.	Phys. State	pH	IDLH	F.P.	I.T.	V.P.	V.D.	S.G.	LEL	UEL

Comment:

Section IV. Hazard Monitoring

20. LEL Instrument(s):	21. O_2 Instrument(s):
22. Toxicity/PPM Instrument(s):	23. Radiological Instrument(s):

Comment:

Section V. Decontamination Procedures

24. Standard Decontamination Procedures:	YES:	NO:

Comment:

Section VI. Site Communications

25. Command Frequency:	26. Tactical Frequency:	27. Entry Frequency:

Section VII. Medical Assistance

28. Medical Monitoring:	YES:	NO:	29. Medical Treatment and Transport In-place:	YES:	NO:

Comment:

ICS 208 HM   Page 1   3/98

Section VIII. Site Map

30. Site Map:

Weather ❑ Command Post ❑ Zones ❑ Assembly Areas ❑ Escape Routes ❑ Other ❑

Section IX. Entry Objectives

31. Entry Objectives:

Section X. SOP S and Safe Work Practices

32. Modifications to Documented SOP s or Work Practices:	YES:	NO:

Comment:

Section XI. Emergency Procedures

33. Emergency Procedures:

Section XII. Safety Briefing

34. Asst. Safety Officer - HM Signature: Safety Briefing Completed (Time):

35. HM Group Supervisor Signature: 36. Incident Commander Signature:

INSTRUCTIONS FOR COMPLETING THE SITE SAFETY AND CONTROL PLAN
ICS 208 HM

A Site Safety and Control Plan must be completed by the Hazardous Materials Group Supervisor and reviewed by all within the Hazardous Materials Group prior to operations commencing within the Exclusion Zone.

Item Number	Item Title	Instructions
1.	**Incident Name/Number**	**Print name and/or incident number.**
2.	**Date and Time**	**Enter date and time prepared.**
3.	**Operational Period**	**Enter the time interval for which the form applies.**
4.	**Incident Location**	**Enter the address and or map coordinates of the incident.**
5 - 16.	**Organization**	**Enter names of all individuals assigned to ICS positions. (Entries 5 & 8 mandatory). Use Boxes 15 and 16 for other functions: i.e. Medical Monitoring.**
17 - 18.	**Entry Team/Decon Element**	**Enter names and level of PPE of Entry & Decon personnel. (Entries 1 - 4 mandatory buddy system and back-up.)**
19.	**Material**	**Enter names and pertinent information of all known chemical products. Enter UNK if material is not known. Include any which apply to chemical properties. (Definitions: ph = Potential for Hydrogen (Corrosivity), IDLH = Immediately Dangerous to Life and Health, F.P. = Flash Point, I.T. = Ignition Temperature, V.P. = Vapor Pressure, V.D. = Vapor Density, S.G. = Specific Gravity, LEL = Lower Explosive Limit, UEL = Upper Explosive Limit)**
20 - 23.	**Hazard Monitoring**	**List the instruments which will be used to monitor for chemical.**
24.	**Decontamination Procedures**	**Check NO if modifications are made to standard decontamination procedures and make appropriate Comments including type of solutions.**
25 - 27.	**Site Communications**	**Enter the radio frequency(ies) which apply.**
28 - 29.	**Medical Assistance**	**Enter comments if NO is checked.**
30.	**Site Map**	**Sketch or attach a site map which defines all locations and layouts of operational zones. (Check boxes are mandatory to be identified.)**
31.	**Entry Objectives**	**List all objectives to be performed by the Entry Team in the Exclusion Zone and any parameters which will alter or stop entry operations.**
32 - 33.	**SOP s, Safe Work Practices, and Emergency Procedures**	**List in Comments if any modifications to SOP s and any emergency procedures which will be affected if an emergency occurs while personnel are within the Exclusion Zone.**
34 - 36.	**Safety Briefing**	**Have the appropriate individual place their signature in the box once the Site Safety and Control Plan is reviewed. Note the time in box 34 when the safety briefing has been completed.**

Radiation Zones and Suggested Activities for Each Zone During the First 12 Hours

Decision Exposure Rate mR/hr	Radiation Zones mR/hr	Activities	Total Accumulated Stay Time for First 12 Hrs *
Background	**Uncontrolled**	**No restrictions. The best location for Incident Command and decontamination activities.**	**Unlimited**
< 10	**Low-Radiation Zone < 10 -100**	**If feasible, restrict access to essential individuals. Initial decontamination of first responders should occur near the outer boundary of this area. Uninjured personnel within this zone at the time of the RDD explosion can be directed to proceed directly home to shower if resources do not permit contamination surveying at the scene. (For RDDs containing up to ~1000 Ci, this may be the only zone that exists.)**	**Full 12 Hours**
100	**Medium-Radiation Zone 100-1000**	**Restrict access to only authorized personnel. Personal dosimetry should be worn. Serves as a buffer zone/transition area between the high and low radiation zones. People within this zone at the time of the explosion should be surveyed for contamination before being released. (For RDDs up to ~ 10,000 Ci, this may be the highest radiation zone that exists.)**	**5 - 12 Hrs (12 Hrs for critical property and lifesaving activities)**
1000	**High-Radiation Zone 1000 - <10,000**	**Restrict access to authorized personnel with specific critical tasks such as firefighting, medical assistance, rescue, extrication, and other time- sensitive activities. Personal dosimetry should be worn. People within this zone at the time of the explosion should be surveyed for contamination before being released.**	**30 minutes – 5 Hours**
10,000	**Extreme Caution Zone ≥ 10,000**	**This area, located within the high radiation zone, is restricted to the most critical activities, such as lifesaving. Personal dosimetry required, although one monitor for several responders is acceptable if they remain near the person with the monitor. Limit time spent in this area to avoid Acute Radiation Sickness. People within this zone at the time of the explosion must be surveyed for contamination before being released.**	**Minutes to a few hours**

Responders may find, in an extreme case, that a large source of radiation with radiation levels of 200,000 mR/hr (200 R/hr) or more is involved. ***Should you encounter radiation levels this high, immediately turn back and inform the Incident Commander. Entry into these areas should only be made at the direction of the Incident Commander in consultation with the Radiation Safety Officer for lifesaving activities, and only for very short time periods (minutes).***

* Total Stay Time is calculated by dividing total allowed dose by exposure rate. For example, if total allowed dose for lifesaving is 50,000 mrem, Total Stay Time in a 200,000 mR/hr field is 15 minutes.

$$\frac{50{,}000 \text{ mrem}}{200{,}000 \text{ mR/hr}} = 0.25 \text{ hour (15 minutes)}$$

NOTES:

- If feasible, Incident Command and other administrative control functions, triage area, and contamination monitoring area should all be located outside the *low* radiation zone. Preferably these functions will be located upwind of the RDD site in an area of natural background radiation and no contamination. If not practical, seek areas with minimum radiation and contamination levels, preferably with contamination levels less than 1,000 cpm using a pancake GM, measured 1-2 inches from the ground surface, and radiation levels near background for contamination monitoring, and less than a few mR/hr for other activities.
- Discuss other alternatives with local/state radiation control program staff.
- If staff resources allow, use a pancake GM probe to define the 10,000 cpm boundary (1,000 cpm if feasible) outside of the *low* radiation zone, and restrict nonessential personnel from this area. It is desirable to control access to this area, and to survey personnel leaving this area for contamination before being released for other activities in order to minimize nuisance contamination spread.

Personal dosimetry is also recommended for workers in the low radiation area.

Note: This table is also available in the Forms and Handouts section and on the CD.

HOW TO PERFORM A RADIATION SURVEY FOR CONTAMINATION—INSTRUCTIONS FOR WORKERS

In performing a contamination survey with a hand-held instrument, first check to make sure the instrument is functioning properly. It is advisable to wrap the meter probe with plastic wrap to protect the probe from contamination (except if you are surveying for alpha contamination).

> ***Make sure that the instrument has batteries and that they work. To do this, turn your instrument to battery check. If the batteries are acceptable, turn the dial to a measurement mode and use a check source to verify the instrument is operating properly.***

Screening Survey

- *If a large population must be surveyed, it is acceptable to perform only a screening survey of the head, face, and shoulders, rather than a more detailed survey, since these are the most likely locations to become contaminated. You may also consider using portal monitors.*

  If only performing a screening survey, it is acceptable to hold the survey meter probe about 1-2 inches away from the body (instead of half an inch), and move it twice as fast as the normal 1-2 inches/second. (If the probe is moved too quickly, its detection capability may be reduced.) Check with state/local radiation control personnel to determine the extent of contamination survey required.

- Return the probe to its holder on the meter when finished. *Do not set the probe down on the ground***.** The probe should be placed in the holder with the sensitive side of the probe facing to the side or facing down so that the next person to use the meter can monitor his/her hands without handling the probe or allowing contamination to fall onto the probe surface.

Complete Whole Body Survey

- If feasible, perform a complete, whole body contamination survey and record the findings on the Contamination Survey Sheet. To begin a body survey, the individual should stand with their legs spread and arms extended. First holding the probe about a half-inch away from the surface to be surveyed, slowly (1-2 inches per second) move the probe over the head, and proceed to survey the shoulders, arms, and bottoms of the feet. Care must be taken not to permit the detector probe to touch any potentially contaminated surfaces.

  It is not necessary to perform the personnel contamination survey in exactly the order listed below, but a consistent procedure should be followed to help prevent accidentally skipping an area of the body. Pause the probe for about five seconds at locations most likely to be contaminated.

  1. Top and sides of head, face (pause at mouth and nose for approximately five seconds; high readings may indicate internal contamination).
  2. Front of the neck and shoulders.
  3. Down one arm (pausing at elbow), turn arm over.
  4. Backside of hands, turn over (pause at palms for about five seconds).

5. Up the other arm (pausing at elbow), turn arm over.
6. Shoe tops and inside ankle area.
7. Shoe bottoms (pause at sole and heel).

- As with the screening survey, return the probe to its holder on the meter when finished. *Do not set the probe down on the ground***.** The probe should be placed in the holder with the sensitive side of the probe facing to the side or facing down so that the next person to use the meter can monitor his/her hands without handling the probe or allowing contamination to fall onto the probe surface.

The most common mistakes made during the survey:

- Holding the probe too far away from the surface (should be about 1-2 inches away for a screening survey or about 1/2 inch or less for a detailed survey).

- Moving the probe too fast (should be about 2-4 inches per second for a screening survey or about 1-2 inches per second for a detailed survey.)

- Contaminating the probe. Probe background should be observed and compared to initial background. If within a factor of 2, it is acceptable to continue to use probe. Otherwise, check with radiation control personnel. Wrapping the probe in plastic wrap will help prevent surface contamination.

CONTAMINATION SURVEY SHEET

First Name:________________Middle Initial:________ Last Name:__________________________________

Date of Birth:_______________________Phone:____

Address____

Date/Time:________________________Drivers License #____

Location at time of incident:____

____

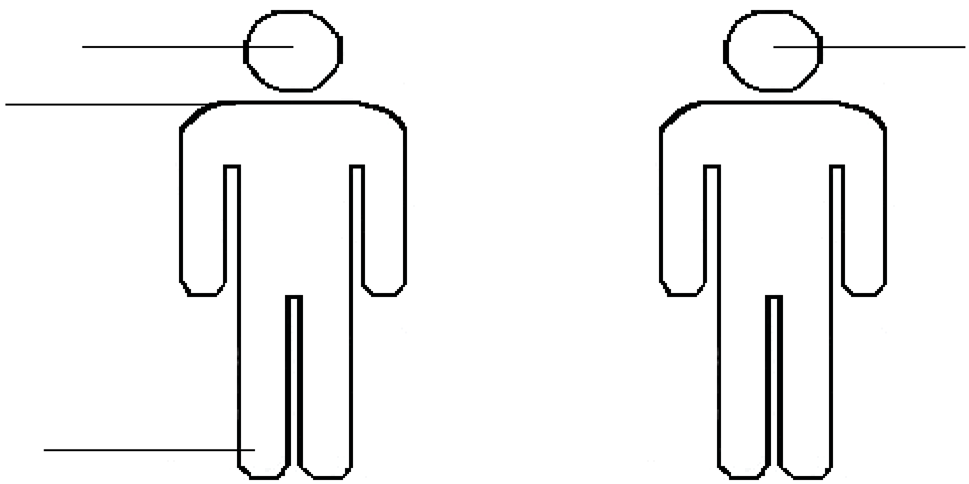
____

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

HOW TO PERFORM DECONTAMINATION AT HOME

You may have been exposed to low levels of radioactive particles. The particles may have settled on your hair, skin and clothing as dust. You are not in immediate danger from these small radioactive particles, however you do need to go home or to another designated area to decontaminate. Removal of outer clothing should reduce your contamination by up to 90%. In order to help protect your health and safety as well as others, please follow these directions.

Because radiation cannot be seen, smelled, felt, or tasted, people at the site of an incident will not immediately know if you have been exposed to radioactive materials. You can take the following steps to limit your contamination:

- Get out of the immediate area quickly. Go directly home, inside the nearest safe building, or to an area to which you are directed by law enforcement or health officials. *Do not go to a hospital unless you have a medical condition that requires treatment***.**

- If radioactive material is on your clothes, removing them will reduce the external contamination and decrease the risk of internal contamination. Prompt removal of outer clothing will also reduce the length of time that you are exposed to radiation. When removing the clothing be careful of any clothing that has to be pulled over the head. Try to either cut the article off or prevent the outer layer from coming in contact with the nose and mouth area. You may also hold your breath while carefully pulling the article over the head. Removal of clothes should be done in a garage or outside storage area if available, where the ground can be washed with a hose. If an outside area is not available, the removal of clothing should take place in a room where the floor can be easily cleaned, such as the tub or shower areas. ("Swiffers" are good for decontaminating smooth floor surfaces). Clothing should be rolled up with the contaminated side "in" to minimize cross contamination.

- If possible, place the clothing in a plastic bag (double bagging is best to reduce the chances of a rupture), and leave it in an out-of the-way area, such as the corner of a room or garage. Keep people away from it to reduce their exposure to radiation. You may be asked to bring this bag for follow-up readings or for disposal at a later time.

- Keep cuts and abrasions covered when handling contaminated items to avoid getting radioactive material in the wound.

- Shower and wash all of the exposed parts of your body and hair using lots of soap and lukewarm water to remove contamination. Simple washing will remove most of the radioactive particles. Do not use abrasive cleaners, or scrub too hard. Do not use hair conditioners. This process is called decontamination.

- If you are going to a monitoring location, it is best to change clothes and shower *before* being monitored.

Contact your local/state Radiation Control Program for additional guidance.

INSTRUCTIONS TO THE PUBLIC WAITING FOR DECONTAMINATION AT THE SCENE OF THE INCIDENT

You may have been exposed to radioactive particles. The particles from the explosion may have settled as dust on your clothes or body. In order to protect your health, you may be asked to go to a decontamination center. Do not panic, your health is not in immediate danger. You should follow these directions to prepare for decontamination:

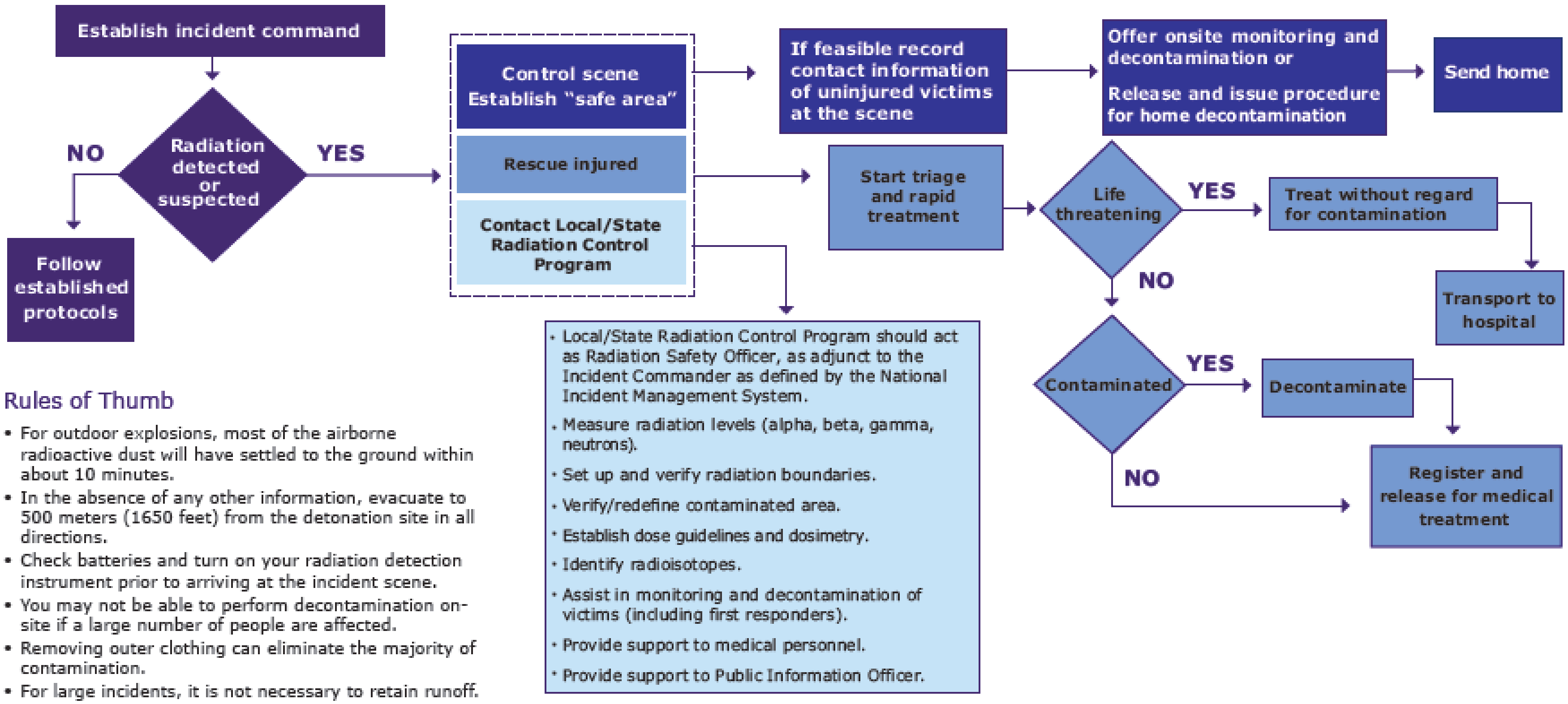
1. Go to the designated area.
2. Do not touch your face or put anything into your mouth.
3. Enter the screening area and stand for a screening (survey) of yourself with clothing, and provide the workers with necessary personal information.
4. After you are screened, you will be directed to leave if minimal or no contamination is present. If contamination is found, you will be directed to the wash area, or you may be sent home with instructions how to clean up (decontaminate) there.
5. If you are directed to enter the wash area, you will be segregated with individuals of the same gender. To the extent possible, families will be kept together through the decontamination process. Prepare to remove your outer garments behind a privacy curtain. If radioactive material is on your clothes, removing them will reduce the external contamination and decrease the risk of internal contamination. Prompt removal of outer clothing will also reduce the length of time that you are exposed to radiation. When removing the clothing be careful of any clothing that has to be pulled over the head. Try to either cut the article off or prevent the outer layer from coming in contact with the nose and mouth area. You may also hold your breath while carefully pulling the article over the head.
6. You will be provided with plastic bags. Place all of your clothing in one bag and your valuables in another plastic bag and seal them. You may be asked to double bag your belongings to minimize the potential for bag rupture. You will be instructed on how to handle these items at a later time when we know more about the hazards of the material used.
7. Pass through the wash area.
8. When you reach the end of the wash station you will be given clothing to put on, and then be directed to the final staging area.

SUGGESTED MASS DECONTAMINATION SUPPLIES LIST

- Caution line tape to mark off perimeters and areas of operation
- Survey meters
- Soap
- Disposable absorbent towels
- 5 gallon buckets
- Hazardous waste containers, bags, or drums
- Tarps (*to be used for privacy and/or wind break)*
- Redress "modesty" packs, which include a scrub or "Tyvek" type suit in varying sizes, or other available post-decontamination clothing and slippers.
- Gallon size "zip lock" bags for victims' belongings
- Indelible black markers for marking victims' belongings and hazardous waste bags
- Preprinted numbered labels for tagging victims, survey form and clothing/valuable bags
- Contamination survey forms
- Pens and pencils
- Clipboards or tables to write on
- Water diversion or collection equipment if necessary
- Point of contact listing of local and state support assets

APPENDIX 1

FLOW CHART FOR RESPONDING TO A RADIOLOGICAL DISPERSAL DEVICE (RDD)



Rules of Thumb

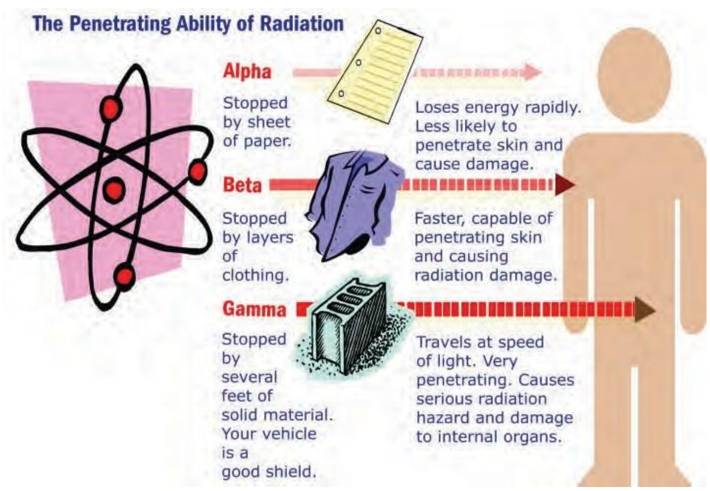
- For outdoor explosions, most of the airborne radioactive dust will have settled to the ground within about 10 minutes.
- In the absence of any other information, evacuate to 500 meters (1650 feet) from the detonation site in all directions.
- Check batteries and turn on your radiation detection instrument prior to arriving at the incident scene.
- You may not be able to perform decontamination on-site if a large number of people are affected.
- Removing outer clothing can eliminate the majority of contamination.
- For large incidents, it is not necessary to retain runoff.

APPENDIX 2

OVERVIEW OF THE TYPES OF RADIATION

Radioactive materials, also known as radionuclides or radioisotopes, are atoms that are unstable. In nature, there is a tendency for unstable atoms to change into a stable form. As they change form, they release radiation. This energy can be in the form of particles, such as ***alpha*** or ***beta*** particles, which are emitted from radioactive materials, or waves, such as light, heat, radio-waves, microwaves, x-rays and ***gamma*** rays.

Alpha particles are charged particles that are emitted from some radioactive materials such as radium and radon. The electric charge and mass of the alpha particle are the same as those of the nucleus of a helium atom. Alpha particles generally carry more energy than gamma or beta particles, and deposit that energy very quickly while passing through tissue. Alpha particles can be stopped by a thin layer of light material, such as a sheet of paper, and cannot penetrate the outer, dead layer of skin. Therefore, they do not damage living tissue when outside the body. When alpha-emitting atoms are inhaled or swallowed, however, they are especially damaging because they transfer relatively large amounts of ionizing energy to living cells.



Beta particles are charged particles emitted from the nucleus of a radioactive material. Beta particles have an electric charge and mass that are equal to those of an electron. Although they can be stopped by a thin sheet of aluminum, beta particles can penetrate the dead skin layer, potentially causing burns. They can pose a serious direct or external radiation threat and can be lethal depending on the amount received. They also pose a serious internal radiation threat if beta-emitting atoms are ingested or inhaled.

Gamma rays are electromagnetic energy that are emitted by a radioactive material. These rays have high energy and a short wave length. Gamma rays penetrate tissue farther than do beta or alpha particles, but leave a lower concentration of ions in their path to potentially cause cell damage.

See also:
- *Appendix 3:* *Primer on Radiation Measurement*
- *Appendix 4:* *How to Distinguish Between Alpha, Beta, and Gamma Radiation Using a Pancake GM Survey Meter*
- *Appendix 5:* *Exposure versus Contamination*
- *Appendix 6:* *Guidance for Assessing Internal Contamination*
- *Appendix 7* *Health Effects of Radiation Exposure*
- *Appendix 8* *Acute Radiation Syndrome*

APPENDIX 3

PRIMER ON RADIATION MEASUREMENT

In the aftermath of a radiological emergency the public will see radiation and its potential hazards described in many different and sometimes confusing ways. This primer is intended to help journalists and community leaders understand these terms.

Activity or radioactivity is measured by the number of atoms disintegrating per unit time. A ***becquerel*** is 1 disintegration per second. A ***curie*** is 37 billion disintegrations per second, which is the number of disintegrations per second in 1 gram of pure radium. A disintegrating atom can emit a beta particle, an alpha particle, a gamma ray, or some combination of all these, so becquerels or curies alone do not provide enough information to assess the risk to a person from a radioactive source.

Disintegrating atoms emit different forms of radiation: alpha particles, beta particles, gamma rays, or x-rays. As radiation moves through the body, it dislodges electrons from atoms, disrupting molecules. Each time this happens, the radiation loses some energy until it escapes from the body or disappears. The energy deposited indicates the number of molecules disrupted. The energy the radiation deposits in tissue is called the ***dose***, or more correctly, the ***absorbed dose***. The units of measure for absorbed dose are the ***gray*** (1 joule per kilogram of tissue) or the ***rad*** (1/100 of a gray). The ***cumulative dose*** is the total absorbed dose or energy deposited by the body or a region of the body from repeated or prolonged exposures.

Alpha particles, beta particles, gamma rays, and x-rays affect tissue in different ways. Alpha particles disrupt more molecules in a shorter distance than gamma rays. A measure of the biologic risk of the energy deposited is the ***dose equivalent***. The units of dose equivalent are ***sieverts*** or ***rem***. Dose equivalent is calculated by multiplying the absorbed dose by a ***quality factor***.

Sometimes a large number of people have been exposed to a source of ionizing radiation. To assess the potential health effects, scientists often multiply the exposure per person by the number of persons and call this the ***collective dose***. Collective dose is expressed as "person-rem" or "person-sieverts."

Abbreviations for Radiation Measurements

When the amounts of radiation being measured are less than 1, prefixes are attached to the unit of measure as a type of shorthand. This is called scientific notation and is used in many scientific fields. The table below shows the prefixes for radiation measurement and their associated numeric notations.

Prefix	Equal to	How Much Is That?	Abbreviation	Example
atto-	$1 X 10^{-18}$	.000000000000000001	A	aCi
femto-	$1 X 10^{-15}$	.000000000000001	F	fCi
pico-	$1 X 10^{-12}$	.000000000001	p	pCi
nano-	$1 X 10^{-9}$	.000000001	n	nCi
micro-	$1 X 10^{-6}$	.000001	µ	µCi
milli-	$1 X 10^{-3}$	.001	m	mCi
centi-	$1 x 10^{-2}$	.01	c	cSv

When the amount to be measured is 1,000 (i.e., $1 X 10^{3}$) or higher, prefixes are attached to the unit of measure to shorten very large numbers (also scientific notation). The table below shows the prefixes used in radiation measurement and their associated numeric notations.

Prefix	Equal to	How Much Is That?	Abbreviation	Example
kilo-	$1 X 10^{3}$	1,000	k	kCi
mega-	$1 X 10^{6}$	1,000,000	M	MCi
giga-	$1 X 10^{9}$	1,000,000,000	G	GBq
tera-	$1 X 10^{12}$	1,000,000,000,000	T	TBq
peta-	$1 X 10^{15}$	1,000,000,000,000,000	P	PBq
exa-	$1 X 10^{18}$	1,000,000,000,000,000,000	E	EBq

The above text "Primer on Radiation Measurement" is excerpted from CDC's website: **http://www.bt.cdc.gov/radiation/glossary.asp#primer**.

	Common Units	**SI Units**
Radioactivity	Curie (Ci)	Becquerel (Bq)
Absorbed dose	Rad	Gray (Gy)
Dose equivalent	Rem	Sievert (Sv)
Exposure	Roentgen (R)	Coulomb/Kilogram (C/kg)

Conventional/SI Units Conversion Table	
1 Curie = $3.7 x 10^{10}$ disintegrations/second	1 Becquerel = 1 disintegration/second
1 rad	0.01 gray (Gy)
1 rem	0.01 sieverts (Sv)
1 roentgen	0.000258 C/kg
1 gray	100 rad
1 sievert	100 rem
1 C/kg	3,880 roentgens

APPENDIX 4

HOW TO DISTINGUISH BETWEEN ALPHA, BETA, AND GAMMA RADIATION USING A PANCAKE GM SURVEY METER

This appendix describes a technique using a pancake GM meter (and if available, a sodium iodide or NaI meter) that may be employed by first responders to make a quick, initial determination of the type of radiation present at the scene (alpha, beta, or gamma). Many studies show that the most likely radionuclide(s) to be used in a dirty bomb would be either a gamma emitter or a beta-gamma emitter. However, it is possible that the radionuclide may be a pure beta emitter such as strontium 90 (Sr-90) or an alpha emitter such as plutonium 239 (Pu-239).

This methodology was developed to assist first responders in making an initial determination of the type of radiation present. This determination should be used to make decisions until radiation control staff arrive at the site with more sophisticated instrumentation to verify the type of radiation and identify the radionuclide(s).

Pancake GM survey meters will respond to beta, gamma, and X-radiation. They have very limited response to alpha radiation. Sodium iodide or NaI survey instruments will only respond to gamma radiation or x-rays. Do not be misled into thinking that radionuclides are not present by the lack of response from a NaI survey meter, since it can not detect alpha or beta radiation.

DETERMINING THE PRESENCE OF AN ALPHA EMITTING RADIONUCLIDE USING ONLY A PANCAKE GM METER

Although alpha emitters may not appear to be as hazardous as gamma emitters are, they are very harmful when inhaled or ingested. Therefore, it is important to check for the presence of alpha emitting radionuclides. Because the instruments normally available to first responders will not readily respond to alphas, it is important to use appropriate respiratory protection when monitoring for radionuclides.

Procedure

- Take readings at approximately 3 inches and about ½ inch (as close as possible without touching) above the ground with the window facing down. If the instrument reading increases by more than a factor of 3 at the ½-inch measurement (as compared to the 3-inch measurement), suspect alpha contamination (such as plutonium 239).
- Next, place a sheet of paper on the ground and take a reading with the window side down directly on top of the paper. The alpha radiation will not penetrate the paper, and the window down reading should significantly decrease to near background level. If the window down measurement taken over the paper does not significantly decrease, the nuclide is likely not an alpha emitter. (Please note that some alpha emitters, such as americium 241, also emit a low energy gamma which will not be stopped by a sheet of paper).

DETERMINING THE PRESENCE OF STRONTIUM 90 (OR OTHER PURE BETA EMITTERS) USING ONLY A PANCAKE GM SURVEY METER:

Strontium 90 is a pure beta emitter, and will not be detected by a sodium iodide instrument or other types of gamma identification survey meters. However, Sr-90 beta radiation can be easily detected and measured with a GM survey meter connected to an end-window, side-window, or a pancake probe (preferred). Suspect the presence of strontium 90 if a pancake GM meter reads between 1,000 and 10,000 cpm (20-200 times background), but there is no corresponding increase in readings using a NaI survey meter (still reads near background).

When Sr-90 is shielded by certain materials, the beta radiation can not be detected. However, the interaction of the beta radiation with the shielding materials can produce x-rays, which can be detected by GM, NaI, and other types of gamma identification survey meters.

Procedure

- Take a measurement with the window side of the pancake probe (mesh covered side) facing down at approximately 6 inches from the ground in an area that yields a meter reading between 500-1500 cpm. Then take another measurement with the window side facing up (away from the ground) at the same height.
- Compare the two measurements.
    - If only strontium 90 (or another pure beta-emitter) is present, the window up reading will be near background (depending on the model of the GM probe, background should be in the range of 25 to 75 cpm), and the window facing down reading should be 10 or more times greater than the window facing up reading. This is because the beta emissions are not able to penetrate the back side of the GM pancake probe.
    - If a gamma or beta-gamma emitter is present (e.g. cesium 137, iridium 192, cobalt 60), the window facing down reading at 6 inches, will be approximately twice the window up reading.
- Take another measurement with the window side of the pancake probe facing down at approximately 3 feet from the ground in an area that yields a meter reading between 500-1500 cpm. Then take another measurement with the window side facing up at the same height. Compare the two measurements. If a gamma emitting nuclide is present, both readings will be approximately the same.

APPENDIX 5

EXPOSURE VS. CONTAMINATION

External Radiation Exposure

Radiation exposure occurs when a person is near a radiation source. Persons exposed to a radiation source do not become radioactive. For example, an x-ray machine is a source of radiation exposure. However, you do not become radioactive when you have an x-ray taken.

There are three cardinal rules of radiation protection for external radiation exposure from a radiation source: *reduce* time, *increase* distance and *use* shielding.

- **TIME** — The less time you spend near the radiation source, the lower your exposure will be.

- **DISTANCE** — The greater your distance from the source, the less your exposure will be. Radiation exposure decreases with distance according to the inverse-square law. That is, if you triple your distance from the radiation source, your exposure will decrease by a factor of 9 (three squared).

- **SHIELDING** — External exposure to radiation can be partially blocked by the use of shielding. Traditionally, shielding is made of lead or concrete. However, staying behind vehicles, buildings, or other objects will also decrease exposure. In an RDD event, the radiation will likely be coming from the ground and other horizontal surfaces where the radioactive materials will have been distributed by the blast.

Internal Radiation Exposure

Internal radiation exposure comes from a person inhaling or ingesting radioactive particles. Depending on the type of radiation this can cause more damage than external exposure. During an RDD event care should be taken not to breathe particles when removing clothing over the head or entering dusty radiation zones. (Holding one's breath while removing contaminated clothing over the head will reduce the possibility of breathing radioactive particles.)

Note that it takes a considerable quantity of radioactive material, if not an alpha emitting nuclide, to result in internal contamination concerns.

Contamination

Radioactive contamination results when loose particles of radioactive material settle on surfaces, skin, or clothing. Internal contamination may result if these loose particles are inhaled, ingested, or lodged in an open wound. Contaminated people can distribute loose particles of radioactive material (dust), and should be decontaminated as quickly as possible to minimize contamination spread. However, the level of radioactive contamination on any individual(s) is unlikely to cause a health risk to another individual.

Radiation Exposure and Contamination Events

There are four types of radiation accident victims:

1. *External contamination of the body surface and/or clothing by liquids or particles.* External contamination is likely when responding to an RDD, also called "dirty bomb." In a dirty bomb event, the major hazard to health and safety is the explosion itself and/or injury from shrapnel. An exception would be when a fragment of a high activity radiation source pierces the victim. In that situation, an exposure hazard may exist.

   Patients are not likely to exhibit any symptoms related to radiological contamination. A person who is externally contaminated may have internal contamination from breathing contaminated dust/dirt/air. The amount of radioactive material expected to be on the surface of the victim is not likely to cause a radiation hazard to EMS or any first responder. In most cases, external skin contamination is not life threatening and can be usually removed with soap and water.

   Use of *Universal Precautions, also known as Standard Precautions* will help prevent the spread of contamination to emergency responders. ***Emergency responders should not delay treatment of victims due to fear of becoming contaminated with radioactive materials.*** However, the victim should be handled in a manner that will reduce the potential spread of contamination to other individuals and medical equipment (e.g., stretcher, ambulance).

2. *A person who has received a significant dose from an external source(s).* This includes an exposure to a large radiation source over a short period of time or exposure to a smaller radioactive source over a longer time frame. If the exposure is sufficiently high, symptoms may include nausea, reddening of the skin and fatigue. An extremely high exposure may result in death of the victim. These symptoms may not appear immediately; it may take several days or weeks before symptoms are observed. ***Externally exposed patients do not become radioactive and therefore do not pose a risk to EMS or other first responders. Never delay medical attention.***

3. *Internal contamination from inhalation and/or ingestion of radioactive material*. Patients who have inhaled radioactive materials will usually have detectable body, and in particular nasal contamination; however, they are not likely to exhibit any medical symptoms related to radiological contamination. Internal contamination needs to be assessed and treated in a clinical setting such as a hospital. It is extremely unlikely that the level of internal contamination would be sufficient to cause an external exposure hazard from the patient to EMS and other first responders. A person who has inhaled and/or ingested radioactive material will almost always have external contamination. Support for medical professionals in treating internal contamination is available from the Radiation Emergency Assistance Center/Training Site (REAC/TS) in Oak Ridge, TN (**http://www.orise.orau.gov/reacts/** or 865-576-3131).

4. ***A combination of any of these types.*** In this situation, using the guidance for external contamination is warranted.

APPENDIX 6

GUIDANCE FOR ASSESSING INTERNAL CONTAMINATION

To be performed by medical personnel at the hospital

While it is not anticipated that an RDD will result in internal contamination levels that will be health significant (at least not from other than alpha emitters), it may be desirable to perform a check for potentially significant internal contamination. This can be accomplished after facial decontamination by monitoring the nostril area for deposited contamination.

- If nasal area contamination is greater than 100,000 cpm using a Pancake GM or 0.5 mR/hr (for beta/gamma emitters), a nasal swab or nasal blow can be used to determine if the contamination is in the nose and therefore has likely been inhaled.
- The assistance of local/state radiation control program staff should be sought to evaluate the significance of the inhaled radioactive material. At these levels, it is anticipated that the person may have inhaled radioactive material near the radiation worker intake limit (5 rem).
- A gamma reading of approximately 0.1 mR/hr in contact with a person's decontaminated chest may also indicate the person has inhaled radioactive Cs-137 near the radiation worker intake limit.
- Medical intervention, if needed, can be performed to reduce the deposition of radioactive materials in the body, thus reducing potential damage to the individual.
- Local/state radiation control personnel will be able to assist in these evaluations.

For nasal swab collection first moisten the swab with a small amount of clean water. These swabs may then be analyzed on-site (or in some cases, sent to an off-site laboratory for analysis). Nasal swabs are useful because of their early availability, but it may be necessary to follow-up with more definitive tests, such as urinary excretion measurements and/or *in-vivo* measurements of radionuclides in the chest or whole body.

Radiation control program staff should be consulted to evaluate the significance of nasal swabs and the desirability of more definitive tests.

Additional guidance to determine internal contamination is available from the National Council on Radiation Protection (NCRP) guidance published in *Report No. 65, Management of Persons Accidentally Contaminated with Radionuclides (NCRP 65) available from* **www.ncrp.org***, and from the REACT/s site at* **www.orau.gov/reacts***.*

APPENDIX 7

HEALTH EFFECTS OF RADIATION EXPOSURE

The health effects associated with radiation exposure are divided into stochastic (probabilistic) effects, and non-stochastic (threshold) effects. Stochastic effects include the induction of cancer and hereditary effects. Non-stochastic effects include cataracts, burns, and acute radiation syndrome. The most serious effects result from very large doses received over short periods of time. Some effects, whether stochastic or non-stochastic (e.g., cancer and cataracts), may not appear until many years after exposure. Other effects, such as burns and acute radiation syndrome will appear within a few hours to a few days after a very large exposure. There will be variations in health effects seen among people receiving the same radiation dose, and the time frames for the individual responses will also vary.

The scientific consensus is that radiation doses above 20 rem, received in very short periods of time (1-2 days), will produce a reasonably clear risk of increased cancer incidence. For a 20 rem dose that risk is about 2%; that is, the risk will increase from a baseline risk of about 37% to a risk of 39% for women, and from a baseline risk of about 49% to a risk of 51% for men. This does not mean that persons exposed to this dose will get cancer, but that their risk is slightly increased over the baseline risk.

Doses below 20 rem, or doses of 20 rem received over extended periods of time, have not been clearly demonstrated to result in increased risks of cancer (although it is common practice to assume the risk is present). There is conflicting scientific data in this “low dose - low dose-rate” region. The bottom line is that the scientific community has not come to consensus on the potential effects of low dose - low dose-rate radiation, and any theoretical harm that might accrue must be balanced against the very real benefits of appropriately responding to an RDD, and saving lives.

Some large doses and their potential effects are:

Amount of Dose	Effect
5 rem	No detectable injury or symptoms
100 rem	May cause nausea and vomiting for 1-2 days and temporary drop in production of new blood cells
350 rem	Acute radiation syndrome can occur at these doses. Acute radiation syndrome is a serious illness caused by receiving a high dose of penetrating radiation in a short period of time. The earliest symptoms include nausea, diarrhea, and vomiting initially, which may be followed by a period of apparent wellness. There may be temporary hair loss. At 3-4 weeks, there is a potential for deficiency of white blood cells and platelets. Permanent sterility is possible. Medical care is required.
1000 rem	Likely to be fatal. Destruction of intestinal lining and internal bleeding. Medical care is required.

Note: Throughout this document, conventional units of measure are used. International SI units (Le Système International Unités, Sievert, or Sv) and a conversion table are provided in Appendix 3.

The object of any radiation control program is to prevent any deterministic effects and minimize the risk for stochastic effects. When a person inhales or ingests a radionuclide, the body will absorb different amounts of that radionuclide in different organs, so each organ will receive a different ***organ dose***. Federal Guidance Report 11 (FGR-11) from the Environmental Protection Agency (EPA) lists ***dose conversion factors*** for all radionuclides. This report can be downloaded from **http://www.epa.gov/radiation/pubs.htm**. The dose conversion factor for each organ is the number of rem delivered to that organ by each curie or Becquerel of intake of a specific radioisotope.

EXTERNAL, INTERNAL, AND ABSORBED DOSES

A person can receive an ***external dose*** by standing near a gamma or high-energy beta-emitting source. A person can receive an ***internal dose*** by ingesting or inhaling radioactive material. The external exposure stops when the person leaves the area of the source. The internal exposure continues until the radioactive material is flushed from the body by natural processes or decays.

A person who has ingested a radioactive material receives an internal dose to several different organs. The absorbed dose to each organ is different, and the sensitivity of each organ to radiation is different. FGR-11 assigns a different weighting factor to each organ. To determine a person's risk for cancer, multiply each organ's dose by its weighting factor, and add the results; the sum is the ***effective dose equivalent*** ("effective" because it is not really the dose to the whole body, but a sum of the relative risks to each organ; and "equivalent" because it is presented in rem or sieverts instead of rads or gray).

COMMITTED AND TOTAL EFFECTIVE DOSE EQUIVALENTS

When a person inhales or ingests a radionuclide, that radionuclide is distributed to different organs and stays there for days, months, or years until it decays or is excreted. The radionuclide will deliver a radiation dose over a period of time. The dose that a person receives from the time the nuclide enters the body until it is gone is the ***committed dose***. FGR-11 calculates doses over a 50-year period and presents the ***committed dose equivalent*** for each organ plus the ***committed effective dose equivalent*** (CEDE).

A person can receive both an internal dose and an external dose. The sum of the committed effective dose equivalent (CEDE) and the external dose is called the ***total effective dose equivalent*** (TEDE).

APPENDIX 8

ACUTE RADIATION SYNDROME

[From the Centers for Disease Control and Prevention's Website]

Radiation sickness, known as acute radiation syndrome (ARS), is a serious illness that occurs when the entire body (or most of it) receives a high dose of radiation, usually over a short period of time. Many survivors of the Hiroshima and Nagasaki atomic bombs in the 1940s and many of the firefighters who first responded after the Chernobyl Nuclear Power Plant accident in 1986 became ill with ARS.

People exposed to radiation will get ARS only if:

- The radiation dose was high (doses from medical procedures such as chest x-rays are too low to cause ARS; however, doses from radiation therapy to treat cancer may be high enough to cause some ARS symptoms),
- The radiation was penetrating (that is, able to reach internal organs),
- The person's entire body, or most of it, received the dose, **and**
- The radiation was received in a short time, usually within minutes.

The first symptoms of ARS typically are nausea, vomiting, and diarrhea. These symptoms will start within minutes to days after the exposure, will last for minutes up to several days, and may come and go. Then the person usually looks and feels healthy for a short time, after which he or she will become sick again with loss of appetite, fatigue, fever, nausea, vomiting, diarrhea, and possibly even seizures and coma. This seriously ill stage may last from a few hours up to several months.

People with ARS typically also have some skin damage. This damage can start to show within a few hours after exposure and can include swelling, itching, and redness of the skin (like a bad sunburn). There also can be hair loss. As with the other symptoms, the skin may heal for a short time, followed by the return of swelling, itching, and redness days or weeks later. Complete healing of the skin may take from several weeks up to a few years depending on the radiation dose the person's skin received.

The chance of survival for people with ARS decreases with increasing radiation dose. Most people who do not recover from ARS will die within several months of exposure. The cause of death in most cases is the destruction of the person's bone marrow, which results in infections and internal bleeding. For the survivors, the recovery process may last from several weeks up to 2 years.

If a radiation emergency occurs that exposes people to high doses of radiation in a short period of time, they should immediately seek medical care from their doctor or local hospital.

More Information

For more information about radiation and emergency response, see the Centers for Disease Control and Prevention's Emergency Preparedness and Response website at **www.bt.cdc.gov** or contact the following organizations:

The CDC Public Response Source	1-888-246-2675
Conference of Radiation Control Program Directors (CRCPD)	**www.crcpd.org** or 502-227-4543
U.S. Environmental Protection Agency (EPA)	**www.epa.gov/radiation/rert**
Nuclear Regulatory Commission (NRC)	**www.nrc.gov** or 301-415-8200
Federal Emergency Management Agency (FEMA)	**www.fema.gov** or 202-646-4600
Radiation Emergency Assistance Center/Training Site (REAC/TS)	**http://orise.orau.gov/reacts/** or 865-576-3131
U.S. National Response Team (NRT)	**www.nrt.org**
U.S. Department of Energy (DOE)	**www.energy.gov** or 1-800-dial-DOE

For more information, visit **www.bt.cdc.gov/radiation**, or call CDC at 800-CDC-INFO (English and Spanish) or 888-232-6348 (TTY).

APPENDIX 9

STATE AND LOCAL RADIATION CONTROL PROGRAM CONTACTS

(Please reconfirm before using in any emergency plan.)

State/Local Agency	Office Hour Number	24-hr or After Hours Phone	24-hr Phone Radiation Emergency Instructions
Alabama	334-206-5391	334-324-0076	Ask for Radiation Control
Alaska	907-334-2100	907-428-7200	Press 1
Arizona	602-255-4845	602-223-2212	Ask to page Radiation Regulatory Agency
Arkansas	501-661-2301	501-661-2136	
California	916-440-7942	800-852-7550	
Los Angeles County	213-351-7897	213-974-1234	Ask for Radiation Management Staff
San Diego County	619-338-2969	619-778-2889	
Colorado	303-692-3300	877-518-5608	
Connecticut	860-424-3029	860-424-3333	State – radiation incident/emergency
Delaware	302-744-4546	302-659-3362	DEMA/State Police, Ask to page Radiation Control – Public Health
District of Columbia	202-535-2320	202-727-1000	
Florida	850-245-4266	407-297-2095	
Georgia	404/362-2675	800-241-4113 404/656-4863	
Hawaii	808-586-4700	808-247-2191 808-348-0970	Ask for Russell Takata/Rad Response
Idaho	208-334-2235	208-334-2241	
Illinois	217-785-9868	217-782-7860	
Indiana	317-351-7190	317-233-1325	Say Radiation Emergency
Iowa	515-281-3478 515-371-2255 (Blackberry)	515-323-4360	State Radio, Ask for Homeland Security Duty Officer, leave callback #
Kansas	785-296-1595	785-296-3176	Say Radiation incident or event
Kentucky	502/564-3700	800/255-2587	
Louisiana	225-219-3041	225-765-0160	
Maine	207-287-5677	207-624-7000	Say – Radiation Control
Maryland	410-537-3301	866-633-4686	
Massachusetts	617-242-3035	617-242-3453	Identify it's a radiation emergency and ask for Nuclear Incident Advisory team (NIAT)
Michigan			
Minnesota	651-201-4545	651-649-5451	
Mississippi	601-987-6893	601-352-9100	

STATE AND LOCAL RADIATION CONTROL PROGRAM CONTACTS

(Please reconfirm before using in any emergency plan.)

State/Local Agency	Office Hour Number	24-hr or After Hours Phone	24-hr Phone Radiation Emergency Instructions
Missouri	573-751-6161	800-392-0272	
Montana	406-444-2868	406-841-3911	
Nebraska	402-471-2168	402-471-4545	State Patrol, ask to page NEMA Duty Officer
Nevada	775-687-5394	888-438-7231 775-688-2830	
New Hampshire	603-271-4588	603-271-3636	State Police, ask to page Radiation Control
New Jersey	609-984-5462	877-WARNDEP 877-927-6337	
New Mexico		505-476-3232	
New York	518-402-7550	518-292-2200	
New York City	212-676-1550	212-350-4494	
North Carolina	919-571-4141	800-858-0368	
North Dakota	701-328-5188	701-328-2121	
Ohio	614-644-7860	614-644-2727	
Oklahoma	405-702-5100	800-522-0206	Refer to Radiation
Oregon	971-673-0499	971-673-0490 971-673-0515	
Pennsylvania	717-787-2480	717-651-2001	PEMA, ask to page DEP Bureau of Radiation Control
Rhode Island	401-222-7755	401-272-5952	Request Radiation Control
South Carolina	803-545-4400	803-253-6488	
South Dakota	605-773-3356	800-592-1861	
Tennessee	615-532-0364	615-741-0001	
Texas	512-834-6688	512-458-7460	State radiation emergency
Utah	801-536-4250	801-536-4123	
Vermont	802-865-7730	802-244-8727	
Virginia	804-864-8151	804-674-2400	State EOC, ask for the Radiological Health Duty Officer
Washington	360-236-3210	206-682-5327	
West Virginia	304-558-6772	304-558-5380	After office hours dial office number and press zero for emergency contact
Wisconsin	608-267-4792	800-943-0003	State -Radiation related emergency
Wyoming	307-777-7752		

APPENDIX 10

FEDERAL RADIATION CONTROL PROGRAM CONTACTS

(Please reconfirm before using in any emergency plan.)

Federal Agency	Office Number	24-hr Number
Federal Emergency Management Agency (DHS/FEMA) FEMA Operations Center	800-634-7084	
Region I (CT, MA, ME, NH, RI, VT)	617-223-9540	
Region II (NJ, NY, PR)	212-680-3600	
Region III (DC, DE, MD, PA, VA, WV)	215-931-5608	
Region IV (AL, FL, GA, KY, MS, NC, SC, TN)	770-220-5200	
Region V (IL, IN, MI, MN, OH, WI)	312-408-5500	
Region VI (AR, LA, NM, OK, TX)	940-898-5399	
Region VII (IA, KS, NE, MO)	816-283-7061	
Region VIII (CO, MT, ND, SD, UT, WY)	303-235-4800	
Region IX (AZ, CA, HI, NV)	510-627-7100	
Region X (AK, ID, OR, WA)	425-487-4600	
Nuclear Regulatory Commission (NRC) (24-hr recorded phone line)		301-816-5100
Environmental Protection Agency (EPA) **National Response Center**		1-800-424-8802
Department of Energy – Radiological Assistance Program (RAP Teams)		
Region I (CT, DC, DE, MA, MD, ME, NH, NJ, NY, PA, RI, VT)		631-344-2200
Region II (AR, KY, LA, MO, MS, PR, TN, VA, VI, WV)		865-576-1005
Region III (AL, FL, GA, NC, SC)		803-725-3333
Region IV (AZ, KS, NM, OK, TX)		505-845-4667
Region V (IA, IL, IN, MI, MN, ND, NE, OH, SD, WI)		630-252-4800
Region VI (CO, ID, MT, UT, WY)		208-526-1515
Region VII (CA, HI, NV, Pacific Rim Territory)		925-422-8951
Region VIII (AK, OR, WA)		509-373-3800
Oak Ridge Institute for Science and Education, Radiological Emergency Assistance Center Training Site (REAC/TS)	856-576-3131	856-576-1005

APPENDIX 11

SUGGESTED INTERNET SITES FOR ADDITIONAL INFORMATION

DHS FACT SHEETS

http://www.nae.edu/NAE/pubundcom.nsf/weblinks/CGOZ-6DZLNU/$file/nuclear%20attack%2006.pdf

http://www.nae.edu/NAE/pubundcom.nsf/weblinks/CGOZ-646NVG/$file/radiological%20attack%2006.pdf

EMERGENCY MANAGEMENT PROCEDURES

http://web.em.doe.gov/otem/initialresp.html

GENERAL REFERENCES

http://www.bt.cdc.gov/radiation
http://www.ncrp.com
http://www.ndu.edu/ctnsp/wmd_tipsheet.htm
http://www.rand.org/pubs/monograph_reports/MR1731/index.html
http://www.nae.edu/nae/pubundcom.nsf/weblinks/cgoz-642p3w?opendocument
http://www.hps.org/hsc
http://www.crcpd.org

MEDICAL PROCEDURES

http://www.phpreparedness.info/
http://www.afrri.usuhs.mil
http://orise.orau.gov/reacts

NATIONAL PLANS

http://www.dhs.gov/interweb/assetlibrary/NRP_FullText.pdf
http://www.ofcm.gov/atd_dir/pdf/erad.pdf
http://www.epa.gov/radiation/rert/rert.htm

PROTECTIVE ACTION GUIDANCE INFORMATION

http://www.epa.gov/radiation/rert/pags.htm
http://www.fda.gov/cder/guidance/4825fnl.htm
http://www.acr.org/s_acr/index.asp

PUBLIC PREPAREDNESS

http://www.phpreparedness.info
http://www.bt.cdc.gov/radiation/shelter.asp
http://www.bt.cdc.gov/radiation/index.asp
http://www.bt.cdc.gov/radiation/ki.asp
http://hps.org/documents/RDDPAGs.pdf
http://www.bt.cdc.gov/radiation/dirtybombs.asp
http://www.atsdr.cdc.gov/toxfaq.html
http://www.atsdr.cdc.gov/tfacts157.html
http://www.cdc.gov/nceh/ehs/ETP/default.htm
http://www.ready.gov

TRAINING RESOURCES

http://web.em.doe.gov/otem/program.html
http://www.fema.gov/compendium/print/compendium.pdf
http://www.fema.gov/compendium/index.jsp
http://www.training.fema.gov/emiweb/index.asp
http://orise.orau.gov/reacts
http://www.teppinfo.com/Tools/ModelProcedures/Model%20Decon%20Procedure.pdf
http://www.teppinfo.com/Tools/ModelProcedures/patient%20handling.pdf
http://www.teppinfo.com/Tools/ModelProcedures/MedicalExaminerCoroner.pdf

APPENDIX 12

STATE, LOCAL AGENCIES, AND PROFESSIONAL SOCIETIES THAT PROVIDED VALUABLE INPUT DURING THE DEVELOPMENT OF THIS PROJECT

Arizona:
Arizona Department of Public Safety, Arizona Department of Health Services, Arizona Radiation Regulatory Agency and Arizona Department of Environmental Quality, Chandler Fire Department, Gilbert Fire Department, Phoenix Police Department Bomb Squad, Gilbert Police Department, and Palo Verde Nuclear Generating Station Off-Site Emergency Planning.

California:
County of Los Angeles Fire Department; County of Los Angeles Department of Health Services, Radiation Management, and California Radiologic Health Branch.

Delaware:
City of Wilmington Police Department, Emergency Management Section; Delaware Department of Natural Resources and Environmental Control, State Emergency Response Team; Delaware Department of Health & Social Services, Division of Public Health, Office of Radiation Control, Office of Environmental Health Evaluation.

Iowa:
Iowa Department of Public Health; Iowa Homeland Security and Emergency Management; Fire Service Training Bureau (Division of State Fire Marshal), Iowa Department of Public Safety.

Massachusetts:
Amherst Fire Department, Greenfield Fire Department, Boston Fire Department, Massachusetts Department of Fire Services, Massachusetts Department of Public Health, Radiation Control Program.

Nevada:
Clark County Fire Department, Las Vegas Metropolitan Police Department; North Lake Tahoe Fire Protection District.

New Jersey:
New Jersey Department of Environmental Protection, Division of Environmental Safety & Health, Radiation Protection and Release Prevention Program.

New York:
New York Office of Fire Prevention & Control, Hazardous Materials Bureau, Homeland Security Program; New York State Department of Health, Bureau of Emergency Management Services; New York State Department of Health, Bureau of Environmental Radiation Protection; New York City Fire Department.

Texas:
Texas Department of State Health Services, Radiation Control

Washington:
Washington Department of Health, Office of Radiation Protection, Environmental Radiation Section

Centers for Disease Control and Prevention

Department of Homeland Security

Brookhaven National Laboratory

Health Physics Society

APPENDIX 13

GLOSSARY OF RADIOLOGICAL TERMS

Excerpted from the Centers for Disease Control and Prevention's Website
Note: This is a glossary of radiological terms, and not all of the terms in the glossary appear in this document.

Absolute risk: the proportion of a population expected to get a disease over a specified time period. *See also* **risk**, **relative risk**.

Absorbed dose: the amount of energy deposited by **ionizing radiation** in a unit mass of tissue. It is expressed in units of joule per kilogram (J/kg), and called "**gray**" (Gy). *For more information, see Appendix 3, "Primer on Radiation Measurement."*

Activity (radioactivity): the rate of decay of radioactive material expressed as the number of atoms breaking down per second measured in units called **becquerels** or **curies**.

Acute exposure: an exposure to radiation that occurred in a matter of minutes rather than in longer, continuing exposure over a period of time. *See also* **chronic exposure**, **exposure**, **fractionated exposure**.

Acute Radiation Syndrome (ARS): a serious illness caused by receiving a dose greater than 75 **rads** of penetrating radiation to the body in a short time (usually minutes). The earliest symptoms are nausea, fatigue, vomiting, and diarrhea. Hair loss, bleeding, swelling of the mouth and throat, and general loss of energy may follow. If the exposure has been approximately 1,000 rads or more, death may occur within 2 – 4 weeks. *For more information, see Appendix 8, "Acute Radiation Syndrome."*

Alpha particle: the **nucleus** of a helium atom, made up of two **neutrons** and two **protons** with a charge of +2. Certain radioactive nuclei emit alpha particles. Alpha particles generally carry more energy than **gamma** or **beta** particles, and deposit that energy very quickly while passing through tissue. Alpha particles can be stopped by a thin layer of light material, such as a sheet of paper, and cannot penetrate the outer, dead layer of skin. Therefore, they do not damage living tissue when outside the body. When alpha-emitting atoms are inhaled or swallowed, however, they are especially damaging because they transfer relatively large amounts of ionizing energy to living cells. *See also* **beta particle**, **gamma ray**, **neutron**, **x-ray**.

Americium (Am): a silvery metal; it is a man-made **element** whose **isotopes** Am-237 through Am-246 are all radioactive. Am-241 is formed spontaneously by the **beta decay** of plutonium-241. Trace quantities of americium are widely used in smoke detectors, and as neutron sources in neutron moisture gauges.

Atom: the smallest particle of an **element** that can enter into a chemical reaction.

Atomic number: the total number of **protons** in the **nucleus** of an atom.

Background radiation: **ionizing radiation** from natural sources, such as **terrestrial radiation** due to **radionuclides** in the soil or **cosmic radiation** originating in outer space.

Becquerel (Bq): the amount of a **radioactive material** that will undergo one decay disintegration) per second. *For more information, see Appendix 3, "Primer on Radiation Measurement."*

Beta particles: electrons ejected from the **nucleus** of a decaying **atom**. Although they can be stopped by a thin sheet of aluminum, beta particles can penetrate the dead skin layer, potentially causing burns. They can pose a serious direct or external radiation threat and can be lethal depending on the amount received. They also pose a serious internal radiation threat if beta-emitting atoms are **ingested** or **inhaled**. *See also* **alpha particle**, **gamma ray**, **neutron**, **x-ray**.

Bioassay: an assessment of **radioactive materials** that may be present inside a person's body through analysis of the person's blood, urine, feces, or sweat.

Biological half-life: the time required for one half of the amount of a substance, such as a radionuclide, to be expelled from the body by natural metabolic processes, not counting radioactive decay, once it has been taken in through inhalation, ingestion, or absorption. *See also* **radioactive half-life**, **effective half-life**.

Chronic exposure: exposure to a substance over a long period of time, possibly resulting in adverse health effects. *See also* **acute exposure**, **fractionated exposure**.

Cobalt (Co): gray, hard, magnetic, and somewhat malleable metal. Cobalt is relatively rare and generally obtained as a byproduct of other metals, such as copper. Its most common **radioisotope**, cobalt-60 (Co-60), is used in **radiography** and medical applications. Cobalt-60 emits **beta particles** and **gamma rays** during **radioactive decay**.

Committed dose: a dose that accounts for continuing exposures expected to be received over a long period of time (such as 30, 50, or 70 years) from **radioactive materials** that were deposited inside the body. *For more information, see Appendix 3, "Primer on Radiation Measurement."*

Concentration: the ratio of the amount of a specific substance in a given volume or mass of solution to the mass or volume of solvent.

Conference of Radiation Control Program Directors (CRCPD): an organization whose members represent state radiation protection programs. *For more information, see the CRCPD website:* **http://www.crcpd.org**.

Contamination (radioactive): the deposition of unwanted **radioactive material** on the surfaces of structures, areas, objects, or people where it may be **external** or **internal**. *See also* **decontamination**.

Cosmic radiation: radiation produced in outer space when heavy particles from other galaxies (nuclei of all known natural **elements**) bombard the earth. *See also* **background radiation**, **terrestrial radiation**.

Cumulative dose: the total dose resulting from repeated or continuous exposures of the same portion of the body, or of the whole body, to **ionizing radiation**. *For more information, see Appendix 3, "Primer on Radiation Measurement."*

Curie (Ci): the traditional measure of **radioactivity** based on the observed decay rate of 1 gram of radium. One curie of **radioactive material** will have 37 billion disintegrations in 1 second. *For more information, see Appendix 3, "Primer on Radiation Measurement."*

Cutaneous Radiation Syndrome (CRS): the complex syndrome resulting from radiation exposure of more than 200 **rads** to the skin. The immediate effects can be reddening and swelling of the exposed area (like a severe burn), blisters, ulcers on the skin, hair loss, and severe pain. Very large doses can result in permanent hair loss, scarring, altered skin color, deterioration of the affected body part, and death of the affected tissue (requiring surgery). *For more information, see Appendix 8, "Acute Radiation Syndrome."*

Decay chain (decay series): the series of decays that certain **radioisotopes** go through before reaching a stable form. For example, the decay chain that begins with uranium-238 (U-238) ends in lead-206 (Pb-206), after forming isotopes, such as uranium-234 (U-234), thorium-230 (Th-230), radium-226 (Ra-226), and radon-222 (Rn-222).

Decay constant: the fraction of a number of atoms of a **radioactive nuclide** that disintegrates in a unit of time. The decay constant is inversely proportional to the **radioactive half-life**.

Decay, radioactive: disintegration of the **nucleus** of an unstable **atom** by the release of **radiation**.

Decontamination: the reduction or removal of radioactive **contamination** from a structure, object, or person.

Deterministic effects: effects that can be related directly to the **radiation dose** received. The severity increases as the dose increases. A deterministic effect typically has a threshold below which the effect will not occur. *See also* **stochastic effect**, **non-stochastic effect**.

Dirty bomb: a device designed to spread **radioactive material** by conventional explosives when the bomb explodes. A dirty bomb kills or injures people through the initial blast of the conventional explosive and spreads radioactive **contamination** over possibly a large area - hence the term "dirty." Such bombs could be miniature devices or large truck bombs. A dirty bomb is much simpler to make than a true nuclear weapon. *See also* **radiological dispersal device**.

Dose (radiation): radiation absorbed by person's body. Several different terms describe radiation dose. *For more information, see Appendix 3, "Primer on Radiation Measurement."*

Dose equivalent: a quantity used in radiation protection to place all radiation on a common scale for calculating tissue damage. Dose equivalent is the **absorbed dose** in **grays** times the **quality factor**. The quality factor accounts for differences in radiation effects caused by different types of **ionizing radiation**. Some radiation, including **alpha particles**, causes a greater amount of damage per unit of absorbed dose than other radiation. The **sievert** (Sv) is the unit used to measure dose equivalent. *For more information, see Appendix 3, "Primer on Radiation Measurement."*

Dose rate: the **radiation dose** delivered per unit of time.

Dose reconstruction: a scientific study that estimates doses to people from releases of **radioactivity** or other pollutants. The dose is reconstructed by determining the amount of material released, the way people came in contact with it, and the amount they absorbed.

Dosimeter: a small portable instrument (such as a film badge, thermoluminescent dosimeter [TLD], or pocket dosimeter) for measuring and recording the total accumulated dose of **ionizing radiation** a person receives.

Dosimetry: assessment (by measurement or calculation) of **radiation dose**.

Effective dose: a dosimetric quantity useful for comparing the overall health affects of **irradiation** of the whole body. It takes into account the **absorbed doses** received by various organs and tissues and weighs them according to present knowledge of the sensitivity of each organ to radiation. It also accounts for the type of radiation and the potential for each type to inflict biologic damage. The effective dose is used, for example, to compare the overall health detriments of different **radionuclides** in a given mix. The unit of effective dose is the **sievert** (Sv); 1 Sv = 1 J/kg. *For more information, see Appendix 3, "Primer on Radiation Measurement."*

Effective half-life: the time required for the amount of a **radionuclide** deposited in a living organism to be diminished by 50% as a result of the combined action of **radioactive decay** and biologic elimination. *See also* **biological half-life**, **decay constant**, **radioactive half-life**.

Electron: an elementary particle with a negative electrical charge and a mass 1/1837 that of the **proton**. Electrons surround the **nucleus** of an **atom** because of the attraction between their negative charge and the positive charge of the nucleus. A stable atom will have as many electrons as it has protons. The number of electrons that orbit an atom determine its chemical properties. *See also* **neutron**.

Element: 1) all **isotopes** of an **atom** that contain the same number of **protons**. For example, the element uranium has 92 protons, and the different isotopes of this element may contain 134 to 148 neutrons. 2) In a reactor, a fuel element is a metal rod containing the **fissile material**.

Exposure (radiation): a measure of **ionization** in air caused by **x-rays** or **gamma rays** only. The unit of exposure most often used is the **roentgen**. *See also* **contamination**.

Exposure pathway: a route by which a **radionuclide** or other toxic material can enter the body. The main exposure routes are **inhalation**, **ingestion**, absorption through the skin, and entry through a cut or wound in the skin.

Exposure rate: a measure of the **ionization** produced in air by **x-rays** or **gamma rays** per unit of time (frequently expressed in **roentgens** per hour).

External exposure: exposure to radiation outside of the body.

Fission (fissioning): the splitting of a **nucleus** into at least two other nuclei that releases a large amount of energy. Two or three **neutrons** are usually released during this transformation.

Fractionated exposure: exposure to radiation that occurs in several small **acute exposures**, rather than continuously as in a **chronic exposure**.

Gamma rays: high-energy electromagnetic radiation emitted by certain **radionuclides** when their nuclei transition from a higher to a lower energy state. These rays have high energy and a short wave length. All gamma rays emitted from a given **isotope** have the same energy, a characteristic that enables scientists to identify which gamma emitters are present in a sample. Gamma rays penetrate tissue farther than do **beta** or **alpha particles**, but leave a lower concentration of **ions** in their path to potentially cause cell damage. Gamma rays are very similar to **x-rays**. *See also* **neutron**.

Geiger counter: a radiation detection and measuring instrument consisting of a gas-filled tube containing electrodes, between which an electrical voltage but no current flows. When **ionizing radiation** passes through the tube, a short, intense pulse of current passes from the negative electrode to the positive electrode and is measured or counted. The number of pulses per second measures the intensity of the radiation field. Geiger counters are the most commonly used portable radiation detection instruments.

Genetic effects: hereditary effects (mutations) that can be passed on through reproduction because of changes in sperm or ova. *See also* **teratogenic effects**, **somatic effects**.

Gray (Gy): a unit of radiation measurement for **absorbed dose**. It measures the amount of energy absorbed in a material. The unit Gy can be used for any type of **radiation**, but it does not describe the biological effects of the different radiations. *For more information, see Appendix 3, "Primer on Radiation Measurement."*

Half-life: the time any substance takes to decay by half of its original amount. *See also* **biological half-life**, **decay constant**, **effective half-life**, **radioactive half-life**.

Health physics: a scientific field that focuses on protection of humans and the environment from **radiation**. Health physics uses physics, biology, chemistry, statistics, and electronic instrumentation to help protect individuals from any damaging effects of radiation. *For more information, see the Health Physics Society website:* **http://www.hps.org/**.

Hot spot: any place where the level of **radioactive contamination** is considerably greater than the area around it.

Ingestion: 1) the act of swallowing; 2) in the case of **radionuclides** or chemicals, swallowing radionuclides or chemicals by eating or drinking.

Inhalation: 1) the act of breathing in; 2) in the case of **radionuclides** or chemicals, breathing in radionuclides or chemicals.

Internal exposure: exposure to **radioactive material** taken into the body.

Iodine: a nonmetallic solid **element**. There are both radioactive and non-radioactive **isotopes** of iodine. Radioactive isotopes of iodine are widely used in medical applications. Radioactive iodine is a **fission** product and is the largest contributor to people's **radiation dose** after an accident at a nuclear reactor.

Ion: an **atom** that has fewer or more **electrons** than it has **protons** causing it to have an electrical charge and, therefore, be chemically reactive.

Ionization: the process of adding one or more **electrons** to, or removing one or more electrons from, **atoms** or molecules, thereby creating **ions**. High temperatures, electrical discharges, or nuclear radiation can cause ionization.

Ionizing radiation: any radiation capable of displacing **electrons** from **atoms**, thereby producing **ions**. High doses of ionizing radiation may produce severe skin or tissue damage. *See also* **alpha particle**, **beta particle**, **gamma ray**, **neutron**, **x-ray**.

Irradiation: exposure to radiation.

Isotope: a nuclide of an **element** having the same number of **protons** but a different number of **neutrons**.

Latent period: the time between exposure to a toxic material and the appearance of a resultant health effect.

Local radiation injury (LRI): acute radiation exposure (more than 1,000 **rads**) to a small, localized part of the body. Most local radiation injuries do not cause death. However, if the exposure is from penetrating radiation (**neutrons**, **x-rays**, or **gamma rays**), internal organs may be damaged and some symptoms of **acute radiation syndrome** (ARS), including death, may occur. Local radiation injury invariably involves skin damage, and a skin graft or other surgery may be required. *See also CDC's fact sheet "Acute Radiation Syndrome" at* **http://www.bt.cdc.gov/radiation/ars.asp**.

Neutron: a small atomic particle possessing no electrical charge typically found within an atom's **nucleus**. Neutrons are, as the name implies, neutral in their charge. That is, they have neither a positive nor a negative charge. A neutron has about the same mass as a **proton**. *See also* **alpha particle**, **beta particle**, **gamma ray**, **nucleon**, **x-ray**.

Non-ionizing radiation: radiation that has lower energy levels and longer wavelengths than **ionizing radiation**. It is not strong enough to affect the structure of **atoms** it contacts but is strong enough to heat tissue and can cause harmful biological effects. Examples include radio waves, microwaves, visible light, and infrared from a heat lamp.

Non-stochastic effects: effects that can be related directly to the **radiation dose** received. The effect is more severe with a higher does. It typically has a threshold, below which the effect will not occur. These are sometimes called **deterministic effects**. For example, a skin burn from radiation is a non-stochastic effect that worsens as the radiation dose increases. *See also* **stochastic effects**.

Nucleus: the central part of an **atom** that contains **protons** and **neutrons.** The nucleus is the heaviest part of the atom.

Nucleon: a **proton** or a **neutron**; a constituent of the **nucleus** of an atom.

Nuclide: a general term applicable to all atomic forms of an **element**. Nuclides are characterized by the number of **protons** and **neutrons** in the **nucleus**, as well as by the amount of energy contained within the **atom**.

Pathways: the routes by which people are exposed to radiation or other contaminants. The three basic pathways are **inhalation**, **ingestion**, and direct **external exposure**. *See also* **exposure pathway**.

Penetrating radiation: radiation that can penetrate the skin and reach internal organs and tissues. Photons (**gamma rays** and **x-rays**), **neutrons**, and **protons** are penetrating radiations. However, alpha particles and all but extremely high-energy **beta particles** are not considered penetrating radiation.

Photon: discrete "packet" of pure electromagnetic energy. Photons have no mass and travel at the speed of light. The term "photon" was developed to describe energy when it acts like a particle (causing interactions at the molecular or atomic level), rather than a wave. **Gamma rays** and **x-rays** are photons.

Plume: the material spreading from a particular source and traveling through environmental media, such as air or ground water. For example, a plume could describe the dispersal of particles, gases, vapors, and aerosols in the atmosphere, or the movement of contamination through an aquifer (For example, dilution, mixing, or adsorption onto soil).

Plutonium (Pu): a heavy, man-made, radioactive metallic **element**. The most important **isotope** is Pu-239, which has a half-life of 24,000 years. Pu-239 can be used in reactor fuel and is the primary isotope in weapons. One kilogram is equivalent to about 22 million kilowatt-hours of heat energy. The complete detonation of a kilogram of plutonium produces an explosion equal to about 20,000 tons of chemical explosive. All isotopes of plutonium are readily absorbed by the bones and can be lethal depending on the dose and exposure time.

Prenatal radiation exposure: radiation exposure to an embryo or fetus while it is still in its mother's womb. At certain stages of the pregnancy, the fetus is particularly sensitive to radiation and the health consequences could be severe above 5 **rads**, especially to brain function. *For more information, see CDC's fact sheet, "Possible Health Effects of Radiation Exposure on Unborn Babies," at* **http://www.bt.cdc.gov/radiation/prenatal.asp**.

Protective Action Guide (PAG): a guide that tells state and local authorities at what projected dose they should take action to protect people from exposure to unplanned releases of **radioactive material** into the environment.

Proton: a small atomic particle, typically found within an atom's **nucleus**, that possesses a positive electrical charge. Even though protons and **neutrons** are about 2,000 times heavier than electrons, they are tiny. The number of protons is unique for each chemical element.

Quality factor (Q): the factor by which the **absorbed dose** (**rad** or **gray**) is multiplied to obtain a quantity that expresses, on a common scale for all **ionizing radiation**, the biological damage (**rem**) to an exposed person. It is used because some types of radiation, such as **alpha particles**, are more biologically damaging internally than other types. *For more information, see Appendix 3, "Primer on Radiation Measurement."*

Rad (radiation absorbed dose): a basic unit of **absorbed radiation dose**. It is a measure of the amount of energy absorbed by the body. The rad is the traditional unit of absorbed dose. It is being replaced by the unit **gray** (Gy), which is equivalent to 100 rad. One rad equals the dose delivered to an object of 100 ergs of energy per gram of material. *For more information, see Appendix 3, "Primer on Radiation Measurement."*

Radiation: energy moving in the form of particles or waves. Familiar radiations are heat, light, radio waves, and microwaves. **Ionizing radiation** is a very high-energy form of electromagnetic radiation.

Radiation sickness: *See also* **acute radiation syndrome** (ARS), *or the CDC fact sheet* "Acute Radiation Syndrome," *at* **http://www.bt.cdc.gov/radiation/ars.asp**.

Radiation warning symbol: a symbol prescribed by the Code of Federal Regulations. It is a magenta or black trefoil on a yellow background. It must be displayed where certain quantities of **radioactive materials** are present or where certain doses of radiation could be received.

Radioactive contamination: the deposition of unwanted radioactive material on the surfaces of structures, areas, objects, or people. It can be airborne, external, or internal. *See also* **contamination**, **decontamination**.

Radioactive decay: the spontaneous disintegration of the **nucleus** of an atom.

Radioactive half-life: the time required for a quantity of a **radioisotope** to decay by half. For example, because the half-life of iodine-131 (I-131) is 8 days, a sample of I-131 that has 10 mCi of activity on January 1, will have 5 mCi of activity 8 days later, on January 9. *See also:* **biological half-life**, **decay constant**, **effective half-life**.

Radioactive material: material that contains unstable (radioactive) atoms that give off **radiation** as they **decay**.

Radioactivity: the process of spontaneous transformation of the **nucleus**, generally with the emission of **alpha** or **beta particles** often accompanied by **gamma rays**. This process is referred to as **decay** or disintegration of an atom.

Radiogenic: health effects caused by exposure to **ionizing radiation**.

Radiography: 1) *medical:* the use of radiant energy (such as **x-rays** and **gamma rays**) to image body systems. 2) *industrial:* the use of radioactive sources to photograph internal structures, such as turbine blades in jet engines. A sealed radiation source, usually iridium-192 (Ir-192) or cobalt-60 (Co-60), beams gamma rays at the object to be checked. Gamma rays passing through flaws in the metal or incomplete welds strike special photographic film (radiographic film) on the opposite side.

Radioisotope (radioactive isotope): isotopes of an **element** that have an unstable **nucleus**. Radioactive isotopes are commonly used in science, industry, and medicine. The nucleus eventually reaches a stable number of **protons** and **neutrons** through one or more radioactive decays. Approximately 3,700 natural and artificial radioisotopes have been identified.

Radiological or radiologic: related to **radioactive materials** or **radiation**. The radiological sciences focus on the measurement and effects of radiation.

Radiological dispersal device (RDD): a device that disperses **radioactive material** by conventional explosive or other mechanical means, such as a spray. *See also* **dirty bomb**.

Radionuclide: an unstable and therefore radioactive form of a **nuclide**.

Radium (Ra): a naturally occurring radioactive metal. Radium is a **radionuclide** formed by the decay of **uranium** (U) and **thorium** (Th) in the environment. It occurs at low levels in virtually all rock, soil, water, plants, and animals. **Radon** (Rn) is a decay product of radium.

Radon (Rn): a naturally occurring radioactive gas found in soils, rock, and water throughout the United States. Radon causes lung cancer and is a threat to health because it tends to collect in homes, sometimes to very high concentrations. As a result, radon is the largest source of exposure to people from naturally occurring radiation.

Relative risk: the ratio between the risk for disease in an **irradiated** population to the risk in an unexposed population. A relative risk of 1.1 indicates a 10% increase in cancer from radiation, compared with the "normal" incidence. *See also* **risk**, **absolute risk**.

Rem (roentgen equivalent, man): a unit of equivalent dose. Not all **radiation** has the same biological effect, even for the same amount of **absorbed dose**. Rem relates the absorbed dose in human tissue to the effective biological damage of the radiation. It is determined by multiplying the number of **rads** by the **quality factor**, a number reflecting the potential damage caused by the particular type of radiation. The rem is the traditional unit of equivalent dose, but it is being replaced by the **sievert** (Sv), which is equal to 100 rem. *For more information, see Appendix 3, "Primer on Radiation Measurement."*

Risk: the probability of injury, disease, or death under specific circumstances and time periods. Risk can be expressed as a value that ranges from 0% (no injury or harm will occur) to 100% (harm or injury will definitely occur). Risk can be influenced by several factors: personal behavior or lifestyle, environmental exposure to other material, or inborn or inherited characteristic known from scientific evidence to be associated with a health effect. Because many risk factors are not exactly measurable, risk estimates are uncertain. *See also* **absolute risk**, **relative risk**.

Risk assessment: an evaluation of the risk to human health or the environment by hazards. Risk assessments can look at either existing hazards or potential hazards.

Roentgen (R): a unit of exposure to **x-rays** or **gamma rays**. One roentgen is the amount of gamma or x-rays needed to produce **ions** carrying 1 electrostatic unit of electrical charge in 1 cubic centimeter of dry air under standard conditions.

Shielding: the material between a radiation source and a potentially exposed person that reduces exposure.

Sievert (Sv): a unit used to derive a quantity called **dose equivalent**. This relates the **absorbed dose** in human tissue to the effective biological damage of the radiation. Not all radiation has the same biological effect, even for the same amount of absorbed dose. **Dose equivalent** is often expressed as millionths of a sievert, or micro-sieverts (μSv). One sievert is equivalent to 100 **rem**. *For more information, see Appendix 3, "Primer on Radiation Measurement."*

S.I. units: the Systeme Internationale (or International System) of units and measurements. This system of units officially came into being in October 1960 and has been adopted by nearly all countries, although the amount of actual usage varies considerably. *For more information, see Appendix 3, "Primer on Radiation Measurement."*

Somatic effects: effects of radiation that are limited to the exposed person, as distinguished from **genetic effects**, which may also affect subsequent generations. *See also* **teratogenic effects**.

Stochastic effect: effect that occurs on a random basis independent of the size of **dose**. The effect typically has no threshold and is based on probabilities, with the chances of seeing the effect increasing with dose. If it occurs, the severity of a stochastic effect is independent of the dose received. Cancer is a stochastic effect. *See also* **non-stochastic effect**, **deterministic effect**.

Strontium (Sr): a silvery, soft metal that rapidly turns yellow in air. Sr-90 is one of the radioactive **fission materials** created within a nuclear reactor during its operation. Stronium-90 emits **beta particles** during radioactive decay.

Teratogenic effect: birth defects that are not passed on to future generations, caused by exposure to a toxin as a fetus. *See also* **genetic effects**, **somatic effects**.

Terrestrial radiation: radiation emitted by naturally occurring **radioactive materials**, such as **uranium** (U), **thorium** (Th), and **radon** (Rn) in the earth.

Thorium (Th): a naturally occurring radioactive metal found in small amounts in soil, rocks, water, plants, and animals. The most common **isotopes** of thorium are thorium-232 (Th-232), thorium-230 (Th-230), and thorium-238 (Th-238).

Transuranic: pertaining to elements with **atomic numbers** higher than **uranium** (92). For example, **plutonium** (Pu) and **americium** (Am) are transuranics.

Uranium (U): a naturally occurring radioactive **element** whose principal **isotopes** are uranium-238 (U-238) and uranium-235 (U-235). Natural uranium is a hard, silvery-white, shiny metallic ore that contains a minute amount of uranium-234 (U-234).

Whole body count: the measure and analysis of the **radiation** being emitted from a person's entire body, detected by a counter external to the body.

Whole body exposure: an exposure of the body to **radiation**, in which the entire body, rather than an isolated part, is **irradiated** by an external source.

X-ray: electromagnetic **radiation** caused by deflection of **electrons** from their original paths, or inner orbital electrons that change their orbital levels around the atomic nucleus. x-rays, like **gamma rays** can travel long distances through air and most other materials. Like gamma rays, x-rays require more **shielding** to reduce their intensity than do **beta** or **alpha particles**. x-rays and gamma rays differ primarily in their origin: x-rays originate in the electronic shell; gamma rays originate in the **nucleus**. *See also* **neutron**.

APPENDIX 14

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