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RESPONDING TO A RADIOLOGICAL OR NUCLEAR TERRORISM INCIDENT: A GUIDE FOR DECISION MAKERS

National Council on Radiation Protection & Measurements

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Responding to a Radiological or Nuclear Terrorism Incident: A Guide for Decision Makers

Recommendations of the
NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS

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[For detailed information on the availability of NCRP publications see page 182.]

Preface

A high priority for the U.S. Department of Homeland Security (DHS) is the preparation of emergency responders and decision makers for conducting rapid, efficient countermeasures to an act of radiological or nuclear terrorism. Several publications by the National Council on Radiation Protection and Measurements (NCRP) have provided guidance on effective responses to terrorism incidents, including Report No. 138 (2001), *Management of Terrorist Events Involving Radioactive Material*; Commentary No. 19 (2005), *Key Elements of Preparing Emergency Responders for Nuclear and Radiological Terrorism*; Report No. 161 (2008), *Management of Persons Contaminated with Radionuclides*; and the proceedings of the 2004 NCRP Annual Meeting on *Advances in Consequence Management for Radiological Terrorism Events* published in *Health Physics* in 2005.

This Report on *Responding to a Radiological or Nuclear Terrorism Incident: A Guide for Decision Makers* provides a comprehensive analysis of key decision points and information needed by decision makers at the local, regional, state, tribal and federal levels in responding to radiological or nuclear terrorism incidents. It provides a framework for preparedness efforts by describing in depth the information that should be acquired and communicated as a basis for the decision-making process. This Report is written with consideration of basic information that may be useful to planners developing local and regional response plans that in turn should be used to support training and exercise programs to prepare for acts of radiological or nuclear terrorism. The Report provides valuable supplementary information in support of the U.S. National Response Framework, the National Incident Management System, and other federal and state guidance that has been issued in recent years.

This Report was prepared by Scientific Committee 2-2 on Preparedness for Responding to the Aftermath of Radiological and Nuclear Terrorism: A Guide for Decision Makers. Serving on Scientific Committee 2-2 were:

John W. Poston, Sr., *Chairman*
Texas A&M University
College Station, Texas

Members

Brooke R. Buddemeier
Lawrence Livermore National Laboratory
Livermore, California

Abel J. Gonzalez
Nuclear Regulatory Authority of Argentina
Buenos Aires, Argentina

Robert J. Ingram
Fire Department, City of New York
Center for Terrorism and Disaster Preparedness
Bayside, New York

Cynthia G. Jones
U.S. Nuclear Regulatory Commission
Washington, D.C.

Kathleen Kaufman
County of Los Angeles Department of Public Health
Los Angeles, California

John J. Lanza
Florida Department of Health
Pensacola, Florida

Edwin M. Leidholdt, Jr.
U.S. Department of Veterans Affairs
Mare Island, California

Debra McBaugh
State of Washington, Department of Health
Olympia, Washington

Stephen V. Musolino
Brookhaven National Laboratory
Upton, New York

Tammy P. Taylor
Los Alamos National Laboratory
Los Alamos, New Mexico

Consultant
Jerrold T. Bushberg
University of California, Davis
Sacramento, California

NCRP Secretariat
Kenneth L. Groves, *Technical Staff Consultant*
Bonnie G. Walker, *Assistant Managing Editor*
Cindy L. O'Brien, *Managing Editor*
David A. Schauer, *Executive Director*

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Thomas S. Tenforde
President

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1. Executive Summary

The guidance presented here for local, regional, state, tribal and federal decision makers is intended to provide the most comprehensive summary to date of recommendations and key decision points for planners preparing responses to radiological or nuclear terrorism incidents. It is unique because it considers both forms of terrorism within one publication while accounting for their fundamental differences. It is not uncommon for radiological or nuclear terrorism incident planning preparations to be broadly addressed together in a single radiation-specific hazard response publication. The potential consequences of nuclear terrorism are radically different from those of radiological terrorism and therefore the planning and preparation must take into account these differences. This Report accounts for those differences, yet draws from the characteristics that are similar for the two basic incident scenarios.

The Report does not present a distillation of recommendations and key decision points in an executive summary. This is deliberate. NCRP strongly recommends that key decision makers use and understand this planning guidance in its entirety to adequately begin the planning process for response to radiological or nuclear terrorism incidents or to assess existing plans. It is incumbent upon key decision makers who use this guidance to understand the recommendations and decision points in the proper context. This can only be accomplished by studying the text and, for planners with less familiarity with the topic, the references supporting the Report.

2. Introduction

2.1 Purpose

Local and state emergency-response decision makers (*e.g.*, elected and appointed officials, emergency management officials, incident commanders) should be well prepared in the event of an act of radiological or nuclear terrorism. Terrorism preparedness is a high priority of the U.S. Department of Homeland Security (DHS).

Two National Council on Radiation Protection and Measurements (NCRP) reports offer advice for the planning of responses to radiological or nuclear terrorism incidents and discuss the critical roles of adequate planning, preparation and funding for the support of emergency-response actions (NCRP, 2001; 2005). Soon after the events of September 11, 2001, NCRP released Report No. 138, *Management of Terrorist Events Involving Radioactive Material* (NCRP, 2001). This report was followed by a more focused publication, NCRP Commentary No. 19, *Key Elements of Preparing Emergency Responders for Nuclear and Radiological Terrorism* (NCRP, 2005). The current Report is intended to support preparedness efforts by providing a framework of key recommendations and decision points needed by decision makers preparing for the response to a radiological or nuclear terrorism incident.

The purpose of this NCRP Report is to provide this framework by defining:

- preincident planning and preparation;
- essential policy recommendations;
- issues to be addressed and key decision points;
- actions to be taken to protect public health, safety and security; and
- critical information needed by decision makers to initiate appropriate actions during the early (emergency) response to an act of radiological or nuclear terrorism.

The Report has two primary components:

- information needed by decision makers to protect the health and safety of emergency responders and members of the general public; and

- consolidated recommendations on key decision points; levels of radiation doses; dose rates at which a response should be initiated; and the nature, timing and extent of the response.

This Report is consistent with, and builds upon, existing U.S. federal policy and guidance.

2.2 Target Audiences

This Report is intended for those organizations and individuals responsible for planning and executing a response to a radiological or nuclear terrorism incident. The intended audience of this Report is decision makers at the local, regional, state, tribal and federal levels who are responsible for decisions affecting public health, safety and security. These decision makers include:

- elected and appointed officials;
- incident commanders;
- planners across disciplines that support emergency response;
- leaders of emergency-response departments;
- managers of public health departments;
- managers of healthcare organizations; and
- managers responsible for providing assets.

2.3 Scope

The response to a radiological or nuclear terrorism incident is commonly divided into three phases (DHS, 2008; ICRP, 2005; NCRP, 2001). In the United States, these are referred to as the early, intermediate and late phases, although other organizations such as the International Commission on Radiological Protection (ICRP) give them more descriptive names: the rescue, recovery and restoration phases. These phases cannot be represented by exact time periods, and transitions from one phase to another are not likely to be distinct. Nevertheless, they are useful in emergency-response planning for radiological or nuclear terrorism incidents for describing the hazards present, decisions that should be made, and response actions necessary at various times following an incident.

The *early phase* (*emergency phase*) is the period at the beginning of an incident when immediate decisions for effective protective actions are required, and when actual field-measurement data generally are not available. Exposure to the radioactive plume, short-term exposure to deposited radionuclides, and inhalation of radionuclides are generally taken into account when considering protective actions for the early phase. The response during the early phase includes initial emergency-response actions to protect public health and welfare in the short term, considering a time period for protective action of hours to a few days. Priority should be given to lifesaving and first-aid actions. During this early phase, incident commanders and other decision makers must make decisions and direct operations with only limited information. In general, early-phase protective actions should be taken very quickly, and the protective-action decisions can be modified later as more information becomes available (DHS, 2008). The early phase following a radiological dispersal device (RDD) or improvised nuclear device (IND) incident may last from hours to days, likely lasting longer for an IND incident.

The *intermediate phase* may follow the early-phase response within as little as a few hours or in days. The intermediate phase of the response is usually assumed to begin after the incident sources and releases have been brought under control and protective-action decisions can be made based on measurements of exposure and radionuclides that have been deposited as a result of the incident (DHS, 2008). The main sources of exposure to people in this phase are irradiation by recently-deposited radionuclides, inhalation of resuspended material, and ingestion of contaminated food or water. Actions during the intermediate phase include detailed surveys to characterize the deposition of radionuclides and may include food interdiction and relocation of some members of the general public. The intermediate phase may last from weeks to many months, until protective actions can be terminated.

The *late phase* begins with the initiation of restoration and cleanup actions to reduce radiation levels in the environment to acceptable levels and ends when all the remediation actions have been completed. These phases are described in more detail in the references listed above (DHS, 2008; ICRP, 2005; NCRP, 2001).

This Report principally addresses recommendations associated with planning and preparedness associated with the early phase and the leading edge of the intermediate-phase response. It does not explicitly provide recommendations for planning during the intermediate-phase response, which will be managed with resources defined in the National Response Framework (FEMA, 2008a), nor does it address recommendations for the late-phase response which will be addressed in a subsequent NCRP report.[1]

[1]NCRP Scientific Committee 5-1 on Approach to Optimizing Decision Making for Late-Phase Recovery from a Radiological or Nuclear Terrorism Incident.

The Report draws on many publications, including previous NCRP publications addressing these issues. It should be recognized that there is a wealth of information available within the United States and internationally. NCRP has considered much of this information, both published and unpublished. Reports and guidance on this subject will continue to be issued by federal and state agencies, as well as some professional societies.

After a short summary of the types of terrorism-related incidents involving radioactive and/or nuclear material(s) included in this Report, Section 3 presents a discussion on the two main topics of the Report:

- establishing control zones around the incident site, and
- protecting emergency responders and members of the general public.

This is followed by a detailed discussion (Section 4) on response-plan development and implementation. Consideration of radiological or nuclear terrorism incidents is divided into two separate sections (Sections 5 and 6, respectively) to allow more effective discussion of these topics. Finally, Section 7 is intended to assist in planning and preparing the public health and medical response for managing these incidents.

2.4 Report Goals

The primary goal of this Report is to provide recommendations and decision points to be considered and implemented in the preparation of effective response plans well in advance of potential terrorism incidents involving radioactive or nuclear materials. This Report provides NCRP recommendations that can be used by local, regional, state and tribal planners to prepare response plans. Once response plans are developed, NCRP strongly recommends that communities periodically conduct tabletop and field exercises to ensure that the response to radiological or nuclear acts of terrorism is effective in meeting the challenges that such incidents may present.

2.5 Quantities and Units

This Report is focused almost exclusively on the early-phase response to radiological or nuclear terrorism incidents. During this early phase, the incident commander will attempt to manage the radiation levels that emergency responders receive during the conduct of their duties by: (1) establishing radiation control zones using observed exposure rates from external sources and surface contamination levels, and (2) making decisions regarding the cumulative absorbed dose to individual emergency responders for various emergency-response activities.

The primary radiation quantities and units used in this Report to implement (1) and (2) are those in common use in the United States for emergency response, and are listed below (also see the Glossary). NCRP has adopted the International System (SI) of radiation quantities and units for its reports (NCRP, 1985). Therefore, in the text the corresponding SI quantity and unit is displayed in parenthesis after the common quantity and unit.

For the radiation control zones (regarding exposure rate from external sources):

- *Common use*: exposure rate in milliroentgens per hour (mR h^{-1}) or roentgens per hour (R h^{-1}); and
- *SI system*: air-kerma rate in milligrays per hour (mGy h^{-1}) or grays per hour (Gy h^{-1}).

The quantities and units for exposure rate (or air-kerma rate) refer to photons only. For photon energies <300 keV, the actual air-kerma rate is 0.087 mGy h^{-1} (for 10 mR h^{-1}) [0.087 Gy h^{-1} (for 10 R h^{-1})]; the numerical value (0.087) is slightly different for higher energies (*e.g.*, 0.088 for ^{60}Co gamma rays). In this Report, the corresponding air-kerma rate is given to one significant digit [*e.g.*, 10 mR h^{-1} exposure rate (~0.1 mGy h^{-1} air-kerma rate)]. Neutrons are not expected to be present or will be a minimal contributor at the time emergency responders are present. Significant neutron exposure is expected only during the initial blast from an IND. The blast will be over before emergency responders arrive.

For the radiation control zones (regarding surface contamination):

- *Common use*: activity in disintegrations per minute per unit area (dpm cm^{-2}); and
- *SI system*: activity in becquerels per unit area (Bq cm^{-2}).

The quantities and units for surface contamination apply to alpha particles, beta particles and gamma rays from radioactive contamination.

For the control of cumulative absorbed dose to emergency responders [the decision dose (Section 3.2.2)] from exposure to external sources:

- *Common use*: cumulative absorbed dose in rads (rad); and
- *SI system*: cumulative absorbed dose in grays (Gy).

The quantities and units for cumulative absorbed dose to emergency workers from exposure to external sources refer to photons only, and the cumulative absorbed dose is treated as though it were a whole-body absorbed dose. Neutrons are not expected to be present or will be a minimal contributor at the time emergency responders are present. Alpha and beta particles will not penetrate the protective bunker gear of emergency responders, and the inhalation of radioactive material can be controlled by the respiratory protection used by emergency responders.

Additional quantities and units referred to in this Report in the context of other specific discussions are defined in the Glossary.

2.6 Types of Radiological or Nuclear Terrorism Incidents

The purpose of this section is to describe the characteristics and potential consequences of radiological or nuclear terrorism incidents. Radiological terrorism involves the use of radioactive material and nuclear terrorism involves the detonation of a nuclear device. The types of radiological or nuclear terrorism incidents that are considered in the context of this Report are:

- radiological dispersal devices (RDDs);
- radiation exposure devices (REDs);
- deliberate contamination of food, water, or other consumables with radioactive material;
- dispersal of radioactive material from fixed radiological or nuclear facilities or material in transit; and
- improvised nuclear devices (INDs).

These types of devices or uses of radioactive material will be discussed briefly below. Section 2.6.1 describes the first four and Section 2.6.2 describes INDs. More detail can be found in NCRP Report No. 138 (NCRP, 2001), NCRP Commentary No. 19 (NCRP, 2005), and ICRP Publication 96 (ICRP, 2005). The International Atomic Energy Agency (IAEA, 2004a) provides more information on specific radionuclides that could be used in radiological terrorism.

2.6.1 *Radiological Terrorism Incidents*

Radiological terrorism incidents can range from those involving small and localized consequences to those involving a more widespread impact to the environment with a footprint (*i.e.*, area of contamination) over large distances on the order of a few miles and greater (Harper *et al.*, 2007). It is possible that a terrorist organization could devise a means of radiological attack other than those described in this section. Therefore, preparedness measures should always be flexible and scalable.

Protective actions and other decisions in the first few hours after notification of a radiological terrorism incident will probably have to be made with few field measurements or before data are available. There will be little or no knowledge of the initial quantity of radioactive material and the aerosolized fraction at the time the incident is discovered. Deliberate contamination of food or water or the use of an RED may be revealed by a set of medical conditions from victims who report for medical treatment (*e.g.*, nausea, vomiting, skin injuries, and/or depressed white cell blood counts), which will initiate the response to consider an RED; by detection of radioactive material with radiation survey devices; or by announcement by the terrorists themselves. If internal contamination is suspected, one of the first priorities will be to identify the specific radionuclides involved.

A radiological terrorism incident may expose a few people or possibly several hundred to thousands of people to low-level contamination. These people will ultimately require some type of decontamination. Fear may cause many uninjured people to seek hospital care, hindering the ability of hospitals to provide care for those with severe injuries caused by the explosion and other nonradiological early health effects normally seen at the hospital emergency departments (EDs). A very large number of people might require screening for external contamination, bioassay for internal contamination (Section 7.7.1), consideration of decorporation therapy (administration of drugs to hasten the elimination of some radionuclides, and consideration for long-term health monitoring.

An incident involving a small amount of radioactive material likely will cause localized impacts on people and the environment. A large source of radioactive material that is poorly dispersed might also have minimal, localized consequences in terms of cleanup, such as a small footprint or ballistic fragments with little or no aerosol. This situation would be handled like the spill of any hazardous material (HAZMAT) that would be remediated, and the infrastructure rapidly restored. Conversely, a large quantity of radioactive material that is effectively dispersed could have wide-ranging impacts. Experiments with potential RDD materials have demonstrated that increasing the quantity of radioactive material in a radiological device may or may not lead to widespread dispersal because the environmental impacts are determined by the fraction of the material that is aerosolized by the device. Large particles will result in relatively-high local deposition, whereas small particles will travel further from the release point (Harper *et al.*, 2007).

The amount of material that is aerosolized and the resulting plume that affects the area over which these materials will be dispersed depend on the method of dispersal, the design of the device, atmospheric conditions, terrain, and the chemical and physical form of the radionuclide (Harper *et al.*, 2007). Few or none of these parameters will be known at the time of discovery of the incident. RDD aerosolization experiments have shown that, even if a very large quantity of radioactive material is dispersed, the potential for early health effects is bounded within an area of ~1,600 feet (500 m) in radius from the release point (Harper *et al.*, 2007). If it is known that the source used in such an incident had an activity <10,000 Ci (370 TBq) of any radionuclide, the initial radiation hazard zone boundary can be established at ~800 feet (250 m) (Musolino and Harper, 2006) from the point of the explosion. Based on experiments for an outdoor explosion of an RDD, the plume is likely to pass from the immediate area within ~10 to 15 min, which would reduce the risk of acute inhalation of airborne activity to emergency responders and members of the general public in this area (Harper *et al.*, 2007). Conversely, in a device that produces poor aerosolization, the material could result in dangerous localized hot spots and/or ballistic fragments that might create high external exposure rates. The potential for ballistic fragments is independent of the amount of radioactive material (Harper *et al.*, 2007).

2.6.1.1 *Radiological Dispersal Device*. A device that spreads radioactive material with malicious intent is called a radiological dispersal device (RDD). An RDD that uses explosives for dispersion of the radioactive material is commonly referred to as a "dirty bomb." An RDD may or may not effectively disperse the radionuclide. An RDD might fail to detonate or be discovered prior to being triggered. In the latter case, the device could be rendered safe by bomb disposal technicians with particular care exercised to not cause a release of radioactive material.

In any terrorism incident, there could be an attempt to use an improvised explosive device or other nonradiological secondary device to harm emergency responders and members of the general public. Therefore, response plans should consider this additional threat to personnel (*e.g.*, law enforcement, fire/rescue) and critical infrastructure (*e.g.*, medical facilities), both near the scene of the incident and other locations. Furthermore, a secondary device in conjunction with an RDD could significantly increase the number of persons with traumatic injuries.

In general, it is most likely that the consequences of an outdoor explosion of an RDD will impact only a small area consisting of a few city blocks, but, like a chemical spill, care is needed to limit the spread of the material into other areas and prevent uncontaminated people from entering. It is expected that most exposures would be too small to cause early health effects to people and, with the exception of severe injuries from the conventional explosion, the major consequence will be low-level external contamination and possibly large-scale psychosocial effects.

A malfunctioning IND could result in consequences similar to an RDD. In this Report, IND refers to any type of device designed to cause a nuclear yield using conventional explosives to create a supercritical mass of special nuclear material (*e.g.*, enriched uranium or ^{239}Pu).[2] A malfunctioning IND would occur if the conventional explosive detonates, but no nuclear yield is achieved. Such an incident might aerosolize and scatter a fraction of the special nuclear material from the weapon, create an airborne plume, and contaminate the environment. The effect of a nuclear device that detonates with a large nuclear yield is discussed in Section 2.6.2.

For an outdoor explosion of an RDD, high radiation doses and large intakes of radionuclides and their associated early health effects are unlikely for devices that incorporate only ^{241}Am, ^{252}Cf, ^{192}Ir, or ^{226}Ra because, typically, these radionuclides are not available in the range of kilocurie (~40 TBq) quantities, in contrast to some other radionuclides commonly used in industry, research and medicine (*e.g.*, ^{60}Co, ^{90}Sr, and ^{137}Cs). Because of the associated high security and the lack of use in routine commerce and industry, the availability of a large enough quantity of ^{238}Pu or ^{239}Pu to produce an incident comparable to one with 10,000 Ci (370 TBq) or greater of a beta and gamma emitter is considered improbable compared to one using ^{60}Co, ^{90}Sr, or ^{137}Cs (IAEA, 2004b; Musolino and Harper, 2006).

The number of people directly injured or killed by the force of an RDD could range from none to a few, or perhaps hundreds. An RDD using nonexplosive means of dispersal would likely not directly cause any injuries or deaths from trauma. In the case of an RDD using explosive means of dispersal, the number of deaths and injured persons would depend upon the amount of explosive, the design of the device, its placement, and the number of people in its vicinity at the time of detonation. An RDD detonated when people are not near would not directly cause any casualties from trauma.

[2]Nuclear yield is the amount of energy that is released when a nuclear weapon is detonated (see Glossary for more information).

An outdoor explosion of an RDD would not be likely to deliver sufficient doses to people to cause early health effects, except perhaps for a few people close to the explosion who inhale aerosols from the concentrated plume (Musolino and Harper, 2006). However, an RDD using a large amount of explosives and detonated near many people, or causing a building to collapse similar to the truck bomb that destroyed the Alfred P. Murrah Federal Building in Oklahoma City in 1995 could kill more than a hundred people from the explosive blast and cause traumatic injuries to additional hundreds (COCDM, 1996). While it is true that the number of people directly injured by the explosive force of an RDD would be small, if the incident is not handled promptly and correctly, the risk is a small increased probability of cancer from the radiation exposure.

2.6.1.2 *Radiation Exposure Device*. A radiation exposure device (RED) consists of a large quantity of radioactive material clandestinely placed to expose people to ionizing radiation. This form of terrorism would use an intact sealed source or radioactive material enclosed in a container to expose unsuspecting people instead of widespread dispersal of the material. An RED might go undetected for a relatively long time, complicating the assessment of the exposed population.

For substantial harm to occur, the exposed individuals would have to be in close proximity to the source of radiation for extended periods of time. The smaller the activity, the closer individuals would have to be and the longer they would have to be in its vicinity for significant effects to occur. Early clinically-significant radiation-induced health effects are not likely unless individuals receive doses exceeding 150 to 200 rad (1.5 to 2 Gy) to a substantial portion of the body. Such effects may include ARS, with exposed individuals exhibiting nausea, vomiting, fatigue, weakness, dizziness, disorientation, fluid imbalance, impaired production of blood cells, and suppression of the immune system, with increased risk of infection, and, at very-high doses, possibly death. People who are very close to the device for a significant time (*e.g.*, hours) may also exhibit local radiation injuries to the skin, such as redness and nonhealing burns. Unless the deployment of an RED is announced by the terrorists or the device is discovered by radiation detection instruments, the only evidence of an RED may be people seeking medical care for the signs and symptoms of ARS and perhaps radiation injuries to the skin. Early symptoms of high radiation exposure may not be recognized as an indication of radiation exposure unless medical personnel are specifically trained to include that in their diagnostic process. Vomiting is a sensitive prodromal (*early*) symptom of ARS and the time from exposure to the onset of vomiting has been used successfully to estimate the seriousness of the radiation dose [>100 rad (1 Gy)] received by individuals. However, vomiting can also be caused by many more common conditions including severe psychological stress. When the cause is a high radiation dose, individual variability in time-to-vomiting is considerable and thus it may serve only to provide upper and lower limits of the dose actually received (Goans and Waselenko, 2005). Because of the protracted radiation exposure caused by an RED, ARS-associated vomiting may not occur as soon after exposure or at dose levels as happens from prompt short-term exposures at similar dose levels. Most dose estimates for radiation-induced vomiting are based on the latter scenario (Goans and Waselenko, 2005). Beyond the early health effects noted above, long-term health effects of an RED include an increased risk of developing late radiation effects including cancer.

2.6.1.3 *Deliberate Contamination of Food, Water or Consumables*. The deliberate contamination of food, water, or other consumables with radioactive material is another possibility for an attack. This could range from contamination far from the point of consumption that could potentially affect a large number of people, but with only very small quantity of radioactive material being consumed by any individual, or contamination close to the point of consumption, which would likely affect fewer people, but with a larger quantity of radioactive material being consumed by each individual.

2.6.1.4 *Dispersal of Radioactive Material from Fixed Radiological or Nuclear Facilities or Materials in Transit*. For localities with fixed radiological or nuclear facilities that already have emergency-response plans in place for accident scenarios and unplanned releases of radioactive material, the emergency response to an attack or sabotage of such facilities is similar to the response necessary for an RDD. The general response plan to transportation accidents involving any HAZMAT would be adequate for the initial response to sabotage of any quantity of radioactive material in routine transport. All such plans should consider that such incidents could be a terrorism incident or an accident.

2.6.2 *Improvised Nuclear Device*

In the past, most civil defense scenarios from the Cold War involved an exchange of large numbers of high-yield thermonuclear weapons. Today, the most likely terrorism nuclear weapon scenario involves the use of a single, probably low-yield fission device. A nuclear weapon could be constructed from stolen nuclear weapon components or fabricated *de novo* from fissile material (*e.g.*, ^{239}Pu or uranium highly enriched in ^{235}U). This type of device is referred to as an improvised nuclear device (IND). Alternatively, a nuclear weapon could be stolen, bought, or otherwise obtained from a state with nuclear weapon capability. The effects of these devices are discussed in NCRP Report No. 138 (NCRP, 2001) and NCRP Commentary No. 19 (NCRP, 2005). Glasstone and Dolan (1977) treat nuclear weapons and their effects in detail.

A nuclear terrorism incident would result in large-scale consequences to public health and safety. The effects in the immediate area of the nuclear terrorism incident would be catastrophic and the emergency-response support capability in the immediate area would likely be destroyed or severely compromised. Response units in areas of heavy fallout within 10 to 20 miles (~15 to 30 km) of the detonation site may be sheltered for several hours to protect themselves from potentially lethal levels of radiation. Unlike the response to an RDD where the local response infrastructure is generally unaffected, emergency response to a nuclear terrorism incident would be from outside the region immediately impacted by the detonation.

Blast effects from a nuclear terrorism incident would include blown-in windows and doors; overturned vehicles; collapsed buildings; ruptured surface and subsurface utilities such as electric power, gas and water mains; collapsed tunnels; and loss of major communication facilities. Blast injuries to people would include lacerations and contusions from flying glass and other debris, crush and other traumatic injuries, and broken bones.

Thermal effects are caused by the emission of ultraviolet, infrared, and visible electromagnetic radiation from the explosion and would most likely lead to structural fires over a wide area. Thermal effects to humans would include temporary and permanent blindness, and skin burns.

Early health effects are caused by prompt x rays, gamma rays, and neutrons emitted from the point of detonation and from residual beta and gamma radiation from the subsequent fallout after the nuclear terrorism incident. These effects manifest themselves in signs and symptoms determined by the radiation dose received by each person. Effects from very-high radiation doses may include some or all of the following: nausea, vomiting, fatigue, weakness, dizziness, disorientation, fluid imbalance, impaired production of blood cells, suppression of the immune system with increased risk of infection, and, death. These observed symptoms depend on the total absorbed dose and the dose rate at which it is delivered. The time to onset of these symptoms will be a function of the absorbed dose as well as the health and ages of the individuals exposed. Those people exposed to sublethal levels of radiation may have an increased risk of developing cancer. A discussion of biodosimetry can be found in Section 7.7.2.

Radioactive fallout will contaminate the environment and the exteriors of buildings and unsheltered people, food and water. Extensive radioactive fallout is produced by surface and near-surface nuclear detonations. For air bursts at a sufficient altitude, the fission products and activated materials from the device may be so widely dispersed and carried away by winds that there will be little local fallout. Fallout contains many radionuclides with a wide range of half-lives. Because of this, the intensity of the radiation from fallout is highest and most dangerous initially; the intensity of the radiation decreases rapidly in the first minutes and hours after fallout deposition and decreases more gradually as time progresses.

A nuclear detonation creates an electromagnetic pulse (EMP) that may damage electrical and electronic equipment, and render some of it unusable either temporarily or permanently. EMP effects differ significantly as a function of the height of the nuclear detonation above the ground and the effects are not easily predicted.

3. Key Radiation Protection Principles

Radiation protection emergency-response plans *must* be in place before an incident to effectively manage the aftermath of radiological or nuclear terrorism. These include local and regional policies for:

- establishment of control zones:
  - hot zone; and
  - dangerous-radiation zone.
- protecting people:
  - recommendations for members of the general public;
  - recommendations for emergency responders; and
  - recommendations for public health and medical personnel.

These policies should be established, codified and promulgated to all agencies that have roles in response to radiological or nuclear terrorism incidents. Although national and state regulations exist for routine (nonemergency) occupational exposures and control zones, these regulations are not appropriate for emergency conditions including radiological or nuclear terrorism incidents.

NCRP (2005) recommends an approach based on two actions:

- establishment of radiation control zones; and
- control of absorbed doses to individual emergency responders.

Radiation control zones divide the incident site into areas of differing levels of radiation risk where specific exposure controls can be applied. The absorbed dose to each emergency responder governs decisions regarding duration (stay time) for various emergency-response activities.

3.1 Establishment of Control Zones

Establishing control zones is a quick way to delineate appropriate protective actions for both the response community and members of the general public before the incident is fully characterized. For this reason, a key preincident preparedness action is to develop a process for defining control zones and to develop the protective actions recommended within each control zone. Three zones are defined:

- cold [outdoor exposure rate ≤10 mR h^{-1} (~0.1 mGy h^{-1} air-kerma rate)];
- hot [>10 mR h^{-1} (~0.1 mGy h^{-1})]; and
- dangerous-radiation zone [≥10 R h^{-1} (~0.1 Gy h^{-1})].

The last two are discussed more fully below.

3.1.1 *Defining the Hot Zone*

This Report adopts the control zone *outer perimeter* definition described in NCRP Commentary No. 19 (NCRP, 2005), which is consistent with the *hot-line* definition described in the ASTM Standard E 2601-08 (ASTM, 2008). NCRP also adopts the American Society for Testing and Materials and National Fire Protection Association terminology of the hot zone, which is defined as the zone immediately surrounding a HAZMAT incident that extends far enough to minimize deterministic effects and reduce the risk of stochastic effects from the HAZMAT to personnel outside the zone and is demarcated by the hot line. In addition, this Report provides amplifying information on initial actions and implementation of control zones and the recommended actions for emergency responder and public safety within the control zones.

Recommendation: Establish the hot zone boundary if any of the following exposure rate or surface contamination levels is exceeded:

- 10 mR h^{-1} exposure rate (~0.1 mGy h^{-1} air-kerma rate);
- 60,000 dpm cm^{-2} (1,000 Bq cm^{-2}) for beta and gamma surface contamination; and
- 6,000 dpm cm^{-2} (100 Bq cm^{-2}) for alpha surface contamination.

It is important to recognize that boundaries are not to be determined precisely [*e.g.*, a boundary approximating 10 mR h^{-1} (~0.1 mGy h^{-1}) can be established for an instrument reading between 5 mR h^{-1} (~0.05 mGy h^{-1}) and 20 mR h^{-1} (~0.2 mGy h^{-1}) as these readings are essentially equivalent from the standpoint of health risk and operational flexibility]. Where practical, the hot zone boundary should be established to match physical boundaries (*e.g.*, streets and fences) that are close to the radiation levels identified above. There is a discussion on how to convert counts per minute to disintegrations per minute in NCRP Commentary No. 19 (NCRP, 2005) that will be useful when discussing methodologies for making measurements that will establish the boundary for the hot zone.

In addition, it will be necessary to perform an all-hazards assessment of the incident site and establish the control zones for the worst hazard(s) identified. Examples of other possible hazards include:

- unstable structures;
- fires;
- chemical, biological, and other toxic material hazards;
- damage to transportation infrastructure (*e.g.*, roads, rails, tunnels);
- damage to the electrical power system;
- natural gas releases from ruptured lines;
- water supply interruptions; and
- other terrorism actions (*e.g.*, improvised explosive devices).

3.1.2 *Defining the Dangerous-Radiation Zone*

Within the hot zone, a *dangerous-radiation zone* should be established where and if the exposure rate reaches 10 R h^{-1} (~0.1 Gy h^{-1} air-kerma rate). Exposure and activity levels within the dangerous-radiation zone have the potential to cause early health effects if doses to people are not controlled and thus actions taken within this area should be restricted to time-sensitive, mission-critical activities such as lifesaving (NCRP, 2005). The use of the term dangerous-radiation zone in the context of this Report, based only on radiation levels, is not meant to preclude that other significant nonradiological hazards might exist. Emergency responders should always be vigilant as to the existence of all hazards that could impact life safety. People may also be excluded from an area because it has been designated as a crime scene.

Recommendation: Actions taken within the dangerous radiation zone (*i.e.*, exposure rate ≥10 R h^{-1} (~0.1 Gy h^{-1} air-kerma rate) should be restricted to time-sensitive, mission-critical activities such as lifesaving.

Emergency responders who enter the hot zone should be equipped with radiation monitoring equipment that provides unambiguous alarms, based on predefined levels, to facilitate decision making. It is recommended that the instrument alarm when the exposure rate reaches 10 R h^{-1} (~0.1 Gy h^{-1}), corresponding to the recommended value for the perimeter of the dangerous-radiation zone, and when the cumulative absorbed dose reaches the decision dose of 50 rad (0.5 Gy) (NCRP, 2005). The term *decision dose* is discussed in Section 3.2.2.

3.2 Protecting People

There is a national and international consensus on the basic principles that should be followed when undertaking decisions on the protection of people against radiation exposure in the aftermath of a radiological or nuclear terrorism incident (IAEA, 2005; ICRP, 2005; NCRP, 2001). These principles, which apply to both emergency responders and members of the general public, can be summarized as follows:

- Undertaking protective actions should be *justified* to ensure that they produce more good than harm; in the aftermath of an incident, it is not always mandatory to intervene with protective actions.
- If the intervention with protective actions is justified, these actions should be *optimized* to select the best protective options under the prevailing circumstances.
- Decisions on justification and optimization should also consider *individual doses* so that these do not exceed levels established before an incident occurs:
  - emergency responders [*i.e.*, firefighters, police, and emergency medical services (EMS) personnel];
  - medical and public health personnel;
  - comforters (*i.e.*, those citizens who provide support to emergency responders after an incident), care givers, and other volunteers; and
  - members of the general public.

In addition to the international consensus on general principles, NCRP also recognizes that during a radiological or nuclear emergency, where conditions are extreme, routine exposure control concepts are not directly applicable because of the potential for doses of much greater magnitude than those that radiation workers or emergency responders normally accrue. However, the general principle of optimization can be used during extreme emergency situations. In these instances, applying the principle of optimization can be viewed as making every reasonable and practical effort to both maintain doses to radiation below the levels causing early health effects, and to reduce the risk of stochastic effects, so as to maximize lifesaving and protection of critical infrastructure (Musolino *et al*., 2008).

The potential benefits from the actions emergency responders take and the exposures they receive should be considered, judged on a case-by-case basis, and take into account the risks that would be incurred. During these types of emergencies, it may be allowable to expose personnel to high doses of radiation, but then the primary goal should be to ensure that early health effects are avoided and, as a secondary goal, that the risk of stochastic effects is minimized. Beyond keeping emergency responders below levels of dose that will cause early health effects, the incident commander will apply optimization principles.[3] These principles apply equally as well when used to control doses to personnel during emergencies as they do in routine operations (Musolino *et al*., 2008).

3.2.1 *Recommendations for Members of the General Public*

Current federal public protection guidance is based on the concept of *dose avoided*. For example, Table 8.5 of NCRP Report No. 138 (NCRP, 2001) identifies actions that should be considered *based on averted exposures*. In the initial minutes to hours of a radiological or nuclear terrorism incident, it will be difficult to predict public exposure, identify appropriate actions to avoid exposures, inform members of the general public, and execute the protective actions.

[3]For example, the incident commander can optimize the dose to personnel by distributing the work among several individuals [*i.e.*, 10 emergency responders each receiving 10 rad (100 mGy)], instead of one person receiving 100 rad (1 Gy), or by controlling the numbers of emergency responders undertaking a given function to minimize the overall collective dose. When large areas are highly contaminated, the incident commander can justify the authorization that emergency responders may receive doses up to 50 rad (500 mGy) or greater to rescue injured victims, but might not so authorize to protect property. DHS Protective Action Guides (DHS, 2008), allows the incident commander to exercise judgment on implementing the decision points (*i.e*., continue lifesaving, and/or protect property), if the decision dose must be exceeded to complete a task or the overall mission (Musolino *et al*., 2008).

Recommendation: NCRP recommends that the initial public protective action for both radionuclide dispersion incidents and nuclear detonations be *early, adequate sheltering followed by delayed, informed evacuation.* Until the level and extent of contamination can be determined, efforts should be made to avoid being outdoors in potentially-contaminated areas.

3.2.2 *Recommendations for Emergency Responder*s

Recommendation: *NCRP does not recommend a dose limit for emergency responders performing time-sensitive, mission-critical activities such as lifesaving.* Instead, decision points should be established by the incident commander based upon operational awareness and mission priorities.

The recommendation above is consistent with existing national and international guidance reviewed which identifies the conditions and activities in which higher levels of dose may be warranted. In all cases, appropriate measures should always be taken to keep doses to individual emergency responders as low as reasonably achievable (the ALARA principle), given the situation and response objectives. This can be accomplished by minimizing the time spent in hazardous areas, wearing appropriate personal protective equipment (PPE), staff rotation, and establishing dose and dose-rate decision points.

As an example, let us suppose there is a nearby child daycare facility with young children. After assessing the situation, it is determined that there are injured people inside the facility, some damage to the structure, and the dose rates outside the facility are ~10 rad h^{-1} (100 mGy h^{-1}). In this case, emergency responders may have to work for an extended time and could receive large doses in rescuing and providing first aid to the victims while evacuating uninjured children. Since there are many persons whose lives are at risk in this situation, the incident commander would certainly choose to protect these people's lives despite the fact that the emergency responders may receive absorbed doses greater than occupational limits. Provided that their absorbed doses are below the threshold for ARS, the incident commander might use 5, 25, and 50 rad (50, 250, and 500 mGy) or more as decision points (not limits) to control total dose (NCRP, 2001). With respect to protecting property, the incident commander sometimes may decide to continue fire suppression even though radiation levels are high. A case in point might be a fire in a building that threatens an adjacent critical facility, such as an electric power substation, the destruction of which could entail large-scale societal disruption from the loss of electrical power (Musolino *et al*., 2008).

There are a number of resources available that can be used to establish recommendations and criteria for managing emergency-responder doses. The recently published *Planning Guidance for Protection and Recovery following RDD and IND Incidents* (DHS, 2008) modifies previously issued guidance from the U.S. Environmental Protection Agency (EPA, 1992) by providing a description of justification for approaching or exceeding 50 rad (0.5 Gy) to a large portion of the body in a short time (an early exposure). Both NCRP (1993) and the Conference of Radiation Control Program Directors (CRCPD, 2006) recommend a 50 rad (0.5 Gy) *decision dose* to evaluate whether or not to remove personnel from continuing lifesaving operations. IAEA (2006) recommends 100 rem (1 Sv) personal dose equivalent (at 10 mm) (see Glossary) for lifesaving efforts and ICRP (2005) places no cap on lifesaving. In all cases, emergency responders should be made fully aware of the risks of both early and late (cancer) health effects from such large doses. The provision of this information to emergency responders is discussed later in this section.

Decision point: NCRP recommends, when the cumulative absorbed dose to an emergency responder reaches 50 rad (0.5 Gy), a decision be made on whether or not to withdraw the emergency responder from the hot zone. NCRP considers the 50 rad (0.5 Gy) cumulative absorbed dose a decision dose, not a dose limit.

NCRP identified the decision dose of 50 rad (0.5 Gy) with the assumption that additional dose would be accumulated as the emergency responder withdrew from the area (NCRP, 2005). If warranted by the mission and circumstances, continuing the mission could be a legitimate decision even after an emergency worker receives the 50 rad (0.5 Gy) decision dose. The 50 rad (0.5 Gy) decision dose was developed in an effort to keep an emergency responder's individual dose from *unintentionally* surpassing 100 rad (1 Gy), below which clinically-significant early health effects are *not* likely to occur. Early health effects are not likely unless individuals receive doses exceeding 150 to 200 rad (1.5 to 2 Gy) to a substantial portion of the body. Such effects may include ARS, with exposed individuals exhibiting nausea, vomiting, fatigue, weakness, dizziness, disorientation, fluid imbalance, impaired production of blood cells, and suppression of the immune system with increased risk of infection, and at very-high doses, possibly death.

While exposing emergency responders to an additional dose at a subsequent incident without regard for the elapsed time between events is discouraged, in some instances it may not be possible. In those instances where a response is required utilizing emergency responders who had received a previous dose, the incident commander may allow emergency responders to receive an additional dose using the same criteria as for all other emergency responders.

When possible, taking into account their other duties, and particularly when first entering an area, emergency responders should measure and report the exposure rates. This will help the emergency responders and their incident commanders identify and avoid areas of extremely high exposure rates and identify low exposure rate locations that may be used as staging areas. This will also assist the emergency responders and their incident commanders in controlling emergency responder exposures, determining the rough profile and extent of the radionuclide contamination, redefining the radiological hazard zone boundaries, and characterizing the overall incident.

Many federal agencies including EPA, the U.S. Nuclear Regulatory Commission (NRC), the Occupational Safety and Health Administration, U.S. Department of Energy (DOE), and many other expert advisory organizations recommend that emergency workers, whose duties during a radiological or nuclear terrorism incident may entail exceeding occupational dose limits (occupational dose limits are *not* applicable by law or regulation to emergency situations), do so as volunteers who have been provided information on the health risks of such exposures to allow them to make informed decisions (DHS, 2008; IAEA, 2006; ICRP, 2005; NCRP, 2001; 2005). However, NCRP recommends that, to the extent practical, informed consent of such emergency workers be obtained *in advance* of a radiological or nuclear terrorism incident and not when such an incident occurs. For individuals who are expected to perform as emergency responders (*e.g.*, firefighters, police, and EMS personnel), these responsibilities should be identified in job descriptions, conditions of employment, and other employment-related documents, as appropriate, and included in routine training and qualification. By doing so, these emergency workers will be provided with information on the potential health consequences of such exposures to allow them to make informed decisions before the radiological or nuclear terrorism incident. Details of both the responsibilities of the employer and the emergency responder are discussed in Appendix A.

3.2.3 *Recommendations for Public Health and Medical System Personnel*

Healthcare workers at hospitals and other medical facilities and public health system personnel, who may encounter contaminated victims of a radiological or nuclear terrorism incident for the purpose of treatment or assessment, are sometimes referred to as "first receivers" (Koenig, 2003; OSHA, 2005). NCRP considers such workers to be a category of emergency responders (NCRP, 2005). As is the case for other emergency responders, and because of their important roles in the response to a radiological or nuclear terrorism incident, NCRP recommends that the doses to these workers not be subject to dose limits. However, experience has shown that medical workers providing care to the contaminated victims of a radiological terrorism incident are unlikely to exceed the occupational dose limits for a radiation worker. Medical personnel near the Chernobyl nuclear reactor accident who treated contaminated workers accumulated doses <1 rad (10 mGy) (Mettler and Voelz, 2002).

3.2.4 *Building Design and Construction*

Building design and construction will play an important part in ensuring occupant safety after a radiological or nuclear terrorism incident. For example, a building designed for earthquake resistance is far more likely to survive the shock of a nuclear terrorism incident, and the higher standards for windows for hurricane protection in many coastal states may reduce injuries from broken windows. Building ventilation systems can incorporate features, such as filters, that protect occupants from outside HAZMAT. When a new public building is designed in a major metropolitan area or surrounding community, consideration should be given to building codes or design elements that help reduce potential blast effects and can help protect occupants from external hazards, particularly the radiation from fallout that might be deposited outside and on the building after an IND detonation. This recommendation applies particularly to buildings that will be directly involved in emergency response, such as fire, police, and EMS stations; emergency operations centers (EOCs); emergency dispatch centers; and hospital EDs.

3.2.5 *Building Ventilation Systems*

Recommendation: Methods to control ventilation systems in office/large apartment buildings should be considered as this action could reduce the inhalation dose to persons sheltering inside.

Ideally, the prompt shutdown and isolation of the air intake to a large urban building for 60 min post-release would reduce the inhalation of radionuclides by the occupants of the building. This action would also reduce the contamination of the components of the ventilation system. For this countermeasure to be effective, it would require the operator of the building to promptly be aware or notified that a radionuclide is associated with an explosion or have an automatic system with a radiation sensor. If the building is not equipped with a radiation detector, it is not likely that the management will know there is airborne activity in less than 10 min. In addition, most buildings do not have the ability to shut down an entire ventilation system with the push of a button. Conversely, in some circumstances, the efficiencies of the filters can be significant, removing greater than 90 % of the radionuclide, depending on the particle size, the condition of the filter, and its design (Musolino and Harper, 2006). It is advisable to keep away from the contaminated filters and not access their enclosures until health authorities perform a radiological assessment (Musolino and Harper, 2006).

Even if the building ventilation system can be promptly isolated, atmospheric conditions still could result in unfiltered air flowing into the structure from pathways that are normally secondary or precluded when the ventilation system is in routine operation. Therefore, for this countermeasure to be effective an engineering analysis of the ventilation system should be performed.

4. Response-Plan Development and Implementation

Decision makers will encounter many challenges in a radiological or nuclear terrorism incident. Many of these challenges will not be specific to response to a radiological or nuclear terrorism incident, such as law enforcement, security, and potential other possible terrorist threats such as improvised explosive devices. This Report will primarily address the key issues common to both radiological and nuclear terrorism incidents and identify the key elements that must be considered and addressed in a response plan for both types of incidents.

Emergency planners should review and augment existing plans and related documents necessary for achieving preparedness for a radiological or nuclear terrorism incident. Important elements of a response plan include hazard analysis, notifications, establishment of radiological control zones, emergency-responder decision doses, recommendations for managing emergency-responder dose, and a decontamination plan for members of the general public. Communications should also be addressed. It is critical to be able to communicate.

Methods and processes need to be developed to transfer information from the incident scene to appropriate local and state agencies. This includes determining what equipment (telephone, fax, email and radio) is available at each location. Processes are then needed for these agencies to coordinate their response activities and public communications. Testing and practicing these processes and methods should be included in all drills and exercises. Other necessary preparations include ensuring the availability of equipment such as radiation detection and monitoring equipment, dosimeters, PPE and replacement clothing; performing training; and conducting exercises.

4.1 Federal Guidance

Following the September 11, 2001 attacks, more urgent efforts were made to implement common incident management and response principles for terrorism incidents. In the United States, the National Response Framework (NRF) describes how an all-hazards response should be conducted. It is built upon scalable, flexible and adaptable coordinating structures to align key roles and responsibilities across the nation (FEMA, 2008a). It describes specific authorities and best practices for managing incidents that would include large-scale terrorist attacks and catastrophic natural disasters.

One of the key elements supporting NRF is the Nuclear/Radiological Incident Annex (NRIA) (FEMA, 2008b) which describes the policies, concepts of operations, and responsibilities of the federal departments and agencies governing the immediate response and short-term recovery activities for incidents involving release of radioactive material from inadvertent or deliberate acts. NRIA applies to two categories of radiological or nuclear terrorism incidents:

- inadvertent or otherwise accidental releases; and
- releases caused by deliberate acts such as radiological or nuclear terrorism incidents.

These incidents may include the release of radioactive material that poses an actual or perceived hazard to public health, safety, national security, and/or the environment.

The National Incident Management System (NIMS), which complements NRF, provides standard command and management structures that apply to response activities (FEMA, 2008c). NIMS provides a consistent, nationwide template to enable federal, tribal, state, regional and local governments, the private sector, and nongovernmental organizations to work together to prepare for, prevent, respond to, recover from, and mitigate the effects of incidents regardless of cause, size, location or complexity.

Supplementing DHS guidance, the Executive Office of the President released *Planning Guidance for Response to a Nuclear Detonation* (EOP, 2010). This interagency publication provides guidance and recommendations for public and emergency responder actions in the event of an urban nuclear detonation. The DHS/Federal Emergency Management Agency (FEMA) Planning Guidance adopted the use of EPA's Early and Intermediate Phase Protective Action Guides (PAGs) for RDDs and INDs, and provided an optimization process to develop cleanup goals in the late phase of an RDD or IND response.

U.S. requirements for food and water restrictions differ from international guidance discussed later in this Report. A contamination incident caused by the use of an RDD or an IND would direct the emergency responders to current RDD and IND guidance

(DHS, 2008). This guidance refers to the 1998 FDA recommendations and EPA proposed drinking water PAG, both guidelines recommend no more than 0.5 rem (5 mSv) effective dose to members of the general public during the first year after the incident. FDA has regulatory authority when products enter into, or are intended for interstate commerce. The regulation, which allows local, state and tribal authorities to detain products, refers to "adulteration" by some contaminant, but is not specific for radionuclides. In specific cases, FDA uses policy guidance and has adopted EPA derived intervention levels as a trigger (not a regulatory limit) for interdiction. FDA also has authority, under the Public Health Service Act, to interdict the movement of food as a precautionary measure when a Public Health Emergency has been declared (FDA, 1998).

Under the Safe Drinking Water Act of 1974, EPA (1974) sets national health-based standards for drinking water to protect against both naturally-occurring and man-made contaminants that may be found in drinking water. EPA, states, and water systems then work together to make sure that these standards are met. After a radiological terrorism incident, the proposed drinking water PAG may only apply for up to a 1 y time period during the intermediate phase. The fact that PAGs for water are designed for the intermediate phase, however, should not preclude reasonable precautionary measures (*e.g.*, closing water intakes and using available stored water) during the early phase. The goal is to keep the dose to members of the general public consistent with the ALARA principle (EPA, 1974).

4.2 Roles and Responsibilities

It is important to understand the roles and responsibilities of local, state, tribal and federal agencies. Response challenges resulting from radiological or nuclear terrorism incidents can quickly overwhelm local, regional and state resources and requests for federal assistance should be anticipated.

Decision makers should recognize that, in the early phase of the incident, state and federal resources will take time, perhaps days, to arrive. *Therefore, local organizations should be prepared to assume all roles and responsibilities in the earliest phase of an incident, relying entirely upon local resources.* The actions of local and regional emergency responders within the first 2 h, particularly for an RDD incident, will define the success of a response, and will significantly influence the public's confidence in their government's ability to provide an adequate response. In some incidents, local organizations retain ultimate authority when state and federal personnel arrive and should be prepared to direct and effectively utilize these resources, whereas in other situations command may be transferred to incoming state and federal resources.

It is important to understand the relationships among existing local, regional, state, tribal and federal response plans. Federal agencies can and will begin to provide assistance remotely *via* assets such as those listed in Table 4.1. NRIA (FEMA, 2008b) provided more information on federal assets that could be used remotely or that could be en route to the incident within hours of the incident to support local, state, and tribal authorities. Local and regional planning authorities should determine the roles and responsibilities of each organization that participates in response to radiological or nuclear terrorism incidents (Resources for nuclear and radiation disaster response (Maiello and Groves, 2006).

All potentially-affected organizations should jointly develop a regional, multi-agency response plan to ensure the issues that each organization will confront are addressed. Individual organizations may have existing plans that address radiological or nuclear terrorism incidents (FEMA, 2008b). The individual plans should be compared to remove conflicts and specify how the organizations will share responsibilities. The plans should specify which organization is in charge of each activity so that response will proceed efficiently. These plans should be consistent with the Incident Command System model and NIMS (FEMA, 2008c).

The state radiation control program can be contacted for assistance in developing a response plan. The most effective response will occur if local agencies jointly prepare their plans. In addition, once the plan is in place, agencies should conduct tabletop and field exercises, critique the exercises, and revise their plans, through lessons learned, in advance of an incident.

Each agency and organization whose staff is likely to become contaminated during a radiological or nuclear terrorism incident should establish procedures for surveys and decontamination of staff. This not only includes response organizations, such as fire, police and EMS, but also hospitals and organizations whose personnel may perform surveys of members of the general public for contamination.

Each organization should also establish procedures to limit the spread of radionuclide contamination within its facilities, such as fire stations, hospitals, buildings used for decontamination, community reception centers (CRCs), and alternative medical treatment sites (AMTSs). The procedures should recognize that contamination control will likely not be possible during the early (emergency) phase of an incident and that minor contamination of an area should not prevent its use. However, reasonable attempts should be

TABLE 4.1—*Partial list of federal assets available for a response to a radiological or nuclear terrorism incident in the early phase.*[a]

Asset	Activation Process	Services
RAP teams, FRMAC and other DOE assets	• Call DOE Watch Office at (202) 586-8100. • Requests for RAP teams may also be directed to the appropriate DOE Regional Coordinating Office.	• RAP provides initial radiological assessment and support to the incident commander. • FRMAC coordinates all environmental radiological monitoring, sampling, and assessment activities for the response.
IMAAC	Call IMAAC directly at (925) 424-6465 or DHS National Operation Center Watch at (202) 282-8101.	Produces and disseminates the federal consequence predictions for an airborne HAZMAT release.
Advisory Team for Environment, Food, and Health	Call the CDC Emergency Operations Center at (770) 488-7100.	Develops coordinated advice on environmental, food, health, and animal health matters.

[a]See Appendix E for a more complete list of DOE assets.

made to limit the spread of contamination. If an area, such as a room in a hospital ED designated for the reception of contaminated injured patients, becomes heavily contaminated, performing limited decontamination of the area will reduce the doses received by people working in the area and the spread of contamination to other areas.

Organizations with emergency-response vehicles, particularly ambulances, should establish procedures regarding the decontamination of vehicle interiors. The procedures should recognize that complete contamination control will likely not be possible during the early (emergency) phase of an incident and that *minor contamination of a vehicle's interior should not prevent or delay its use to respond to emergencies*. However, reasonable attempts should be made to limit the contamination inside a vehicle. Methods for minimizing contamination of the interior of an ambulance include:

- removing the outer clothing of a contaminated patient before loading the patient into an ambulance;
- placing two sheets on the gurney before placing a contaminated patient on the gurney; and
- folding the edges of the sheets over the patient.

Furthermore, reasonable attempts should be made to reduce the amount of radionuclide contamination inside a vehicle after a task, such as transportation of a contaminated injured patient to a hospital. These measures will reduce the doses received by people working in the vehicle.

In general, the removal of radionuclide contamination from outdoor areas is not an early (emergency) phase activity following a radiological or nuclear terrorism incident. However, there may be instances in which high dose rates from contamination deposited by a plume of radioactive material will impede or prevent the use of essential infrastructure, such as a fire station or a hospital ED. In such cases, washing the roof, other horizontal surfaces, and nearby paved areas with water may reduce the dose rate sufficiently to permit use of the facility. This may require assistance from the fire department and planning in advance of an incident. Similarly, emergency vehicles with heavily contaminated exteriors may be rendered usable by rinsing their exteriors with water. During lifesaving operations, do not waste valuable resources to contain contaminated wash water.

4.3 Response-Plan Requirements

Municipalities have been required by the Occupational Safety and Health Administration (OSHA, 2006) to develop and maintain emergency-response plans that address response to and management of incidents involving HAZMAT releases. In the past, these plans focused upon radioactive material released from transportation accidents and nuclear facilities rather than terrorism or other malevolent incidents.

The emergencies described above usually are highly localized releases with health risks to small numbers of people. Radiological terrorism incidents can be expected to produce a much wider dispersion of radioactive material and pose potential health risks to larger populations. This distribution of radioactive material over a greater area and the possibility that explosives may be used to disperse the material creates challenges that are very different from an accidental or nonmalevolent highly localized release.

As discussed in the next several sections, emergency planners should determine the specific requirements and elements for a response plan. The high level coordinated actions that should be addressed in the plan include the following:

- identifying key agency roles and responsibilities in responding to a radiological or nuclear terrorism incident;
- developing a "continuity of operations plan" and alternate emergency operations sites with a predetermined command succession, communications links and staffing including supplemental staffing as addressed in Section 7.11;
- describing how state and federal resources will be integrated into the local/regional emergency management system;
- identifying redundant communication systems for public messages immediately after a radiological or nuclear terrorism incident to provide clear, factual and timely guidance to members of the general public;
- establishing a notification process to request state and federal resources;
- establishing a community plan that addresses the needs of vulnerable populations (*e.g.*, hospitals, child daycare centers, prisons/jails, assisted living facilities, children at or en route to school);
- making timely damage assessments and providing for restoration of critical services, resources and infrastructure; and
- developing a recovery and restoration section of the plan to manage long-term health and environmental issues and the

local and state agencies that should be responsible for this mission, including possible relocation of people and businesses.

Before an incident occurs, communication should be established with the organizations listed in Table 4.1. This will be an important planning step to ensure the coordination needed during the actual incident response. The regional DOE Radiological Assistance Program (RAP) teams, DOE Federal Radiological Monitoring and Assessment Center (FRMAC), DHS Interagency Modeling and Atmospheric Assessment Center (IMAAC), and EPA National Response Team can assist in the development of response plans as well as support following a radiological or nuclear terrorism incident.

Recommendation: *Designate regional situational assessment centers* [these may be established *emergency operations centers* (EOCs)] that will collect and assess information from observations, instrument readings, weather, and computer modeling.

Communities should develop a complete list of entities to notify following recognition that an incident may involve radiological or nuclear terrorism. The contact lists should include subject matter experts with radiation expertise. Discussions should be held in advance with these subject matter experts to determine how best their expertise could be used in the event of a terrorism incident involving radioactive or nuclear material. State radiation control program personnel and DHS advisors and relevant federal agencies (*e.g.*, DHS, DOE, NRC, and EPA) should be included as well.

Planners should assess the community's requirements for radiation detection and monitoring equipment, dosimeters, and specialized PPE. Instruments should be calibrated and maintained in accordance with applicable standards, including recommended maintenance schedules of both the manufacturers and professional societies. FEMA (2002), NCRP (2005), and the American National Standards Institute (ANSI, 2006a; 2006b) provide guidance on this subject.

4.3.1 *Hazard Evaluations*

An evaluation of the hazards present in a work environment is the basis for the safe completion of tasks in that environment. This is true for planned special exposures that could result from incidents such as cleanup operations at a hazardous waste site (NRC, 1992). While all the hazards are not always known in advance, a hazard evaluation should also be performed during an emergency response to accidental and intentional release of HAZMAT.

While this Report focuses on radiation issues, planners should consider all hazards. Standard procedures for assessing the scene for all hazards should be used until the incident hazards are determined. In a terrorism incident, a secondary or follow-on attack is a possibility and response plans should address this. Emergency responders will follow their standard procedures for dealing with an explosion, recognizing the possibility of other terrorist threats such as improvised explosive devices during their response. Many HAZMAT training programs for both private and public organizations develop and use a process to conduct this hazard evaluation. One such example is "A-P-I-E" (analyze, plan, implement and evaluate) used by the International Association of Fire Fighters in their HAZMAT training programs (NFPA, 2005). Whether this specific one or another is used, it is the use of a process that is important.

This evaluation is an ongoing process of collecting information that begins before the incident occurs, continues during the response as new information is obtained, and stops after successful response to the incident and a final after-action review has been conducted. The information collected always begins with life hazards to victims and emergency responders, the hazards and materials involved, and resources available and needed.

As an example, in a transportation accident involving radioactive material in shipment, emergency responders not only collect information on any trapped or injured victims and the identity of the material and strength of the source, but they take an all-hazards approach. This includes the stability of the vehicle, other materials included in the load, fuel that may be leaking, downed utility wires, uneven terrain, wind conditions and weather, to give some examples. Emergency responders use this information to determine the actions necessary to control the release, best PPE to wear, and safest approach.

In a terrorism incident such as an RDD or IND, the same all-hazards evaluation should be performed. Life safety is a primary consideration with a large number of potential victims as well as the risk posed by the release of radioactive material or a nuclear detonation and fallout. There likely will be many other hazards present and information should be collected quickly to conduct a hazard evaluation. These may include: the modality of radiation exposure (RED) or release of radioactive material (RDD, IND); blast damage, building integrity, ruptured gas lines, broken glass, downed utilities; and damage to infrastructure including water systems and roads, fires, motor vehicle accidents, general debris, radioactive dust particles, hot spots, and fallout. The identity of the radionuclides present will be a critical piece of information to be collected to make the best decisions on how to protect emergency responders from the hazards of the radiation and will help the incident commander in determining the appropriate response. This is an example where preincident planning assistance provided by subject matter experts will improve the local/regional early response. In a radiological terrorism incident (RED, RDD), the radiation and radioactive material may not be the most significant hazard to emergency responders, whereas, after an IND detonation, the radioactive fallout will likely be the most significant hazard impacting large areas.

4.3.2 *Decontamination of Members of the General Public*

Regional plans should have a *common strategy for personal decontamination* methods and priorities. This is especially important for the injured, where inconsistent definitions and expectations among the emergency responders at the scene, ambulance companies, and the hospital could delay critical medical care.

Detailed planning guidance for personal decontamination is addressed in Sections 5.1, 6.6, and 7.6. The key point for radiological terrorism is that external contamination of people is *not likely to pose an immediate danger* to most contaminated individuals or the emergency responders providing assistance. This reduces the immediacy of the need for decontamination unless it is readily available and allows the emergency-response community greater flexibility in treating medical emergencies as well as selecting decontamination options (NCRP, 2005). Response plans should identify decision criteria and options for personal decontamination for a variety of potential situations.

4.3.3 *Control of Doses to Emergency Responders*

There will be a variety of organizations involved in response to radiological or nuclear terrorism incidents. All response agencies in each locality or region should adopt similar radiation exposure policies (*e.g.*, dose recommendations and decision doses) to ensure that critical missions can be accomplished with personnel who have the appropriate training and equipment. Section 3.2.2 provides recommendations regarding policies and procedures for controlling doses to emergency responders.

4.3.4 *Training and Exercises*

Lifesaving is one of the primary responsibilities following an RDD or IND terrorism incident. Training should emphasize the fact that with proper preparation, effective lifesaving actions can be taken after a radiological or nuclear terrorism incident, although in the case of a nuclear terrorism incident, radiation levels will likely preclude these efforts in large areas and not all emergency responders will be able to respond. Appropriate training and exercises can describe the hazards that would endanger the lives of emergency responders and members of the general public, and can minimize risks to emergency responders while they are performing those important lifesaving actions. Detailed training and exercise recommendations can be found in NCRP Commentary No. 19 (NCRP, 2005).

All emergency responders should be trained initially at a level corresponding to the duties and functions they would be expected to perform. In addition to the emergency-responder community, resource providers may be identified who should receive training and participate in exercises. Programs should be developed that include training for the staff as well as those outside the agency on whom they depend for support including physicians and those trained in radiation safety.

Training programs should include drills, exercises (including table-top exercises), and a system to identify lessons learned (FEMA, 2005). Refresher training should be given periodically and at least every 2 y. It may be useful to have just-in-time training modules available to be used at the time of an incident. For, example, one of the most important "just-in-time" training modules is on how to use radiation detection equipment. If emergency responders do not use these instruments frequently, they may forget important actions and how to use the different scales. Information relayed to EOC could be in error by a factor of 10 or 100 if an emergency responder does not adjust for the difference in scale, thereby misleading the decision makers.

Training programs should incorporate the use of radiation detection instruments and dosimeters to collect radiation data, establish protective-action zones, and identify risk-benefit decision points for incident commanders. Training programs would benefit from the expertise provided by technical authorities for the purpose of better understanding health and environmental recommendations (Brodsky *et al.*, 2004). Using visual training tools, those conducting training should define the zones based on damage and radiation levels defined in Sections 3 and 6. The following is a list of the topics to be covered in this training:

- local incident command system policies;
- basic principles of radiation, radiation safety, and effects on human health;
- protective-action guidance for emergency responders and members of the general public;
- operation of specific types of radiation monitoring instruments available to local emergency responders;
- analysis and integration of radiation monitoring instrument data into basic incident command system or NIMS concepts;
- dose guidance;
- the hot zone and dangerous-radiation zone, and how to establish operational working times based on radiation levels encountered;
- for a nuclear terrorism incident, the methods and criteria used to identify the *light-*, *moderate-* and *severe-damage zones* (these are defined in Section 6);
- crime scene and evidence management;
- treatment and decontamination strategies and priorities; and
- management of psychosocial issues.

4.4 Providing Information to Members of the General Public

In a radiological or nuclear terrorism incident, a major challenge that could face response authorities is public fear and confusion stemming, in part, from lack of understanding of radiation hazards and a lack of awareness of appropriate protective actions. The degree of success of a radiological or nuclear terrorism incident response will depend in part upon the public's awareness, *prior to an incident*, of protective actions it can take. Public awareness and use of protective measures such as sheltering will improve public safety, reduce the demand for emergency-response resources, and reduce response hindrances such as traffic congestion. These issues should be addressed in a preincident public information program.

Effective preparedness before an incident also requires the development of effective communication plans, including message templates prepared before an incident for use during the incident, and means to deliver the messages to those in the affected areas. There is a considerable body of information dealing with effective communication prior to or during a radiological emergency. For additional information on this subject the Centers for Disease Control and Prevention and NRC should be consulted (Becker, 2001; 2004; 2005; CDC, 2007b; EPA, 2007). Enough people should be trained to communicate to members of the general public to meet the predicted needs after an incident. A primary goal of radiological terrorism would be to elicit fear in members of the general public. A primary goal of a nuclear terrorism incident would be to kill and injure many thousands of people, as well as elicit fear. There are three main actions that will reduce the success of such a terrorism incident:

- a prompt and effective response to an incident by local/regional emergency responders in the first hours;
- provision of information to members of the general public before an incident, so that they understand the likely risks from such an incident, and the protective actions they should take; and
- prompt and effective provision of information to members of the general public after the occurrence of an incident regarding the nature of the incident, the consequences to members of the general public, and protective actions they should take.

For an IND detonation in particular, an effective preincident education program for members of the general public and prompt and effective provision of messages soon after the incident would likely save thousands of lives and reduce injuries of many more people.

4.4.1 *Preincident Public Information Program*

Recommendation: In advance of an incident, planning officials should work with local community leaders and the media to inform members of the general public about preparedness plans and protective actions members of the general public should take following a radiological or nuclear terrorism incident.

Such a program should address, at a minimum, the following topics:

- basic principles of radiation and its effects on health;

- likelihood of this type of incident compared to other hazards;
- similarities in preparedness actions for all-hazards planning;
- protective actions to be taken by members of the general public if informed of a radiological terrorism incident;
- protective actions to be taken by members of the general public if informed of a nuclear terrorism incident;
- planning and protective-action guidance for school and workplace locations;
- media outlets that will carry accurate and timely official incident information;
- guidance as to which local radio and television stations to monitor; and
- community-specific topics such as location of shelters.

The public information campaign should occur at multiple levels (*e.g.*, teaching in schools, providing take-home messages to students and employees, a local internet website, print distribution such as in the local newspaper and telephone directory, and radio and television public-service announcements). It will be helpful for local public affairs specialists to partner with representatives from the media in the development of the information to be distributed because they have extensive experience in effective communication for local populations. Furthermore, education of the media regarding radiation, health effects of radiation, radiological or nuclear terrorism incidents, and protective actions will help prepare the media to provide members of the general public with accurate information.

4.4.2 *Preparing for Post-Incident Messages*

Recommendation: Before an incident occurs, emergency planners should *prepare message templates* to be provided to members of the general public during the early (emergency phase) of the incident.

Message templates should be prepared in anticipation of radiological or nuclear terrorism incidents. This will greatly expedite providing important information to members of the general public and may help to reduce fear and inappropriate actions. The messages should answer the questions most likely to arise, such as:

- Am I safe where I am?
- Is my family safe where they are?
- Is it safe to get my children from their school?
- If I think I've been contaminated with radioactive material, what should I do?
- Is it safe for me to drink tap water?
- Is it safe for me to eat the food in my house or workplace?
- Is it safe for me to leave my house or workplace?
- How can I ensure the safety of my pet?
- Should I shelter or evacuate?
- Where should I shelter and for how long?
- Do I need to take further precautions because I have small children, or because I am pregnant?
- What was the location of the incident?

Examples of post-incident messages for both radiological and nuclear terrorism incidents are included in Appendix B (LA County, 2009). If a significant fraction of the population does not understand English, the messages should be translated into the languages spoken. DHS Office of Health Affairs provides sample messages that contain critical information for members of the general public in the first hour and additional message templates are available from the Centers for Disease Control and Prevention (CDC, 2007b) and EPA (2007).

Recommendation: Plans should provide for establishing a *joint information center* (JIC) and determining who will be the primary spokesperson before and after a JIC is established. These activities should be practiced in drills and exercises to ensure they operate as designed.

Providing prompt, accurate and concise information to members of the general public will be important during the response to an incident. Initially, information will most likely come from a local government official or designated *public information officer*. As the incident response progresses past the first hours or days, and state and federal resources arrive on-scene, a transition should occur from the local public information officer to a JIC. Establishing a JIC helps to avoid multiple spokespersons giving conflicting information and guidance to the media and members of the general public. It will be imperative to have at least one trusted official spokesperson and avoid conflicting information from multiple official sources which may lead to confusion. Bringing many agencies together to establish a JIC will be a challenge because most agencies do not routinely work together on public information matters. This challenge can be overcome through training and tabletop exercises that bring the agencies together prior to an actual incident.

Local emergency management organizations should include the use of the media in the public information program planning prior to an incident. Multiple delivery methods, all providing the same guidance, should be used. Reporters and media spokespersons should be trained in common radiation terminology and know where they can contact local authorities for accurate and timely updates.

4.5 Mutual-Aid Agreements

Recommendation: It is strongly recommended that local, regional, state and tribal governments and organizations involved in response to a radiological or nuclear terrorism incident establish written *mutual-aid agreements* with each other prior to such an incident.

For a large-scale radiological or nuclear terrorism incident, particularly an IND detonation, assistance from surrounding communities and perhaps even nearby states will be essential because local resources will be insufficient. Mutual-aid agreements can be effective tools to assist in sharing information, supplies, equipment and personnel for the purpose of protecting public health. Local, regional, state and tribal governments and private nonprofit organizations enter into mutual-aid agreements to provide assistance to each other in the event of disasters and other emergencies. These agreements usually are written, but occasionally are arranged orally after a disaster or emergency occurs. Among other issues, these agreements usually address liability and reimbursement.

States commonly have mutual-aid agreements with other states. The Emergency Management Assistance Compact is a congressionally-ratified organization that provides form and structure to interstate mutual aid (NEMA, 2009). Through the Emergency Management Assistance Compact, a disaster impacted state can request and receive assistance from other member states quickly and efficiently. NIMS maintains that states should participate in mutual-aid agreements and establish intrastate agreements that encompass all local jurisdictions (FEMA, 2008c; 2009).

4.6 International Agreements

A number of international agreements exist that could, in principle, be applicable in the aftermath of terrorism incidents involving exposure to ionizing radiation. Some of these international agreements have been agreed upon by the U.S. government and may be considered to be legally binding. Others have received the consent of U.S. representatives and embody an international *de facto* commitment. However, many only represent international scientific consensuses on particular issues. Federal decision makers should plan in advance whether and how to comply with these instruments.

International agreements could be applicable to consequences arising from terrorist attacks that occur in locations under the jurisdiction of the U.S. government, especially if the attack may produce consequences on places under jurisdiction of other national governments. They could also be applicable in cases where a terrorist attack occurs outside the jurisdiction of the U.S. government, but which may affect the U.S. territories.

The more important international agreements are the two Emergency Conventions that have been ratified by the United States: the Notification and the Assistance Convention (see below and Appendix C). The Emergency Conventions assign specific response functions and responsibilities to IAEA and the Parties, which include, in addition to a number of countries, the World Health Organization (WHO), World Meteorological Organization, and the Food and Agriculture Organization (FAO) of the United Nations. However various international organizations have (by virtue of their statutory functions or of related legal instruments) general functions and responsibilities that encompass aspects of preparedness and response (*i.e.*, WHO). WHO international health regulations requires international notification of radiation emergencies [*e.g.*, Member Countries must notify WHO in a timely way of any threat that qualifies as a public health emergency of international concern (whether infectious, chemical, biological or radiological)]. In the United States, CDC determines whether an emergency is a public health emergency of international concern and the U.S. Department of Health and Human Services (DHHS) notifies WHO (CDC, 2007a).

Pursuant to the obligations placed on it by the Emergency Conventions, IAEA regularly convenes the Inter-Agency Committee on the Response to Nuclear and Radiological Accidents, whose purpose is to coordinate the arrangements of the relevant international intergovernmental organizations for preparing for and responding to nuclear and radiological emergencies. Currently its members are representatives from the European Commission, European Police Office, FAO, IAEA, the International Civil Aviation Organization, the International Maritime Organization, the United Nations Scientific Committee on the Effects of Atomic Radiation, the International Criminal Police Organization, the Nuclear Energy Agency of the Organization for Economic Cooperation and Development, the Pan American Health Organization, the United Nations Environment Programme, the United Nations Office for the Coordination of Humanitarian Affairs, the United Nations Office for Outer Space Affairs, WHO, and the World Meteorological Organization. It is chaired by IAEA and meets periodically. The United States is a Member State of all these organizations except the European Commission and the European Police Office.

The relevant international agreements can be classified as:

- legally-binding international obligations (*i.e.*, *de jure* commitments, which are usually expressed in "international conventions");
- international *de facto* commitments, which are usually described in "basic safety standards;" and
- international scientific consensuses, which are explained in publications such as "international estimates" or "international recommendations."

Appendix C describes in more detail the relevant international instruments and the obligations that can arise from their application.

The purpose of these agreements is to arrange for notification of other countries when an incident occurs. Decision makers at the local and state level likely will not be involved, since the U.S. Department of State has responsibility for making formal notifications. However, some states that border on Mexico or Canada may develop relationships with their counterparts, which can come into play in an incident. This is particularly important if a nuclear terrorism incident occurs whose effects will almost certainly extend beyond the borders of the country.

Appendix D describes and addresses issues that arise from consumer products being transported between countries after a radiological or nuclear terrorism incident.

5. Radiological Terrorism Incident

5.1 Radiological Terrorism Incident Response Plan

As discussed in Section 2.6.1, some forms of radiological terrorism may not be known at the time of occurrence whereas other incidents, such as an explosive dispersal of radioactive material, may be obvious shortly after the explosion and may result in a variety of injuries that require emergency medical care. Preincident planning, therefore, should consider situations where the knowledge that there are victims unfolds slowly as well as those caused by an explosive dispersal. When there are victims who require urgent medical care, the first priority of the emergency responders is rescue and lifesaving medical treatment, taking precautions to protect themselves from other hazards, particularly secondary terrorist attacks.

Recommendation: Medical emergencies and lifesaving take priority over radiological monitoring and the concern for the presence of radionuclide contamination. Radiation monitoring equipment, although desirable, *is not required* to begin lifesaving operations.

The planning should clearly recognize that the radiation levels are unlikely to be immediately life threatening to emergency responders, unlike those expected from a nuclear terrorism incident. Monitoring of radiation levels should be initiated as soon as possible.

Recommendation: The geographic deposition of the radionuclide on the ground should be estimated initially from field measurements with instrumentation and displayed on a map; additional measurements should be made as soon as possible to improve the data quality of this map. Data collection and management should be a coordinated joint task by all agencies who will respond with monitoring equipment: DOE Radiological Assistance Program (RAP), Federal Radiological Monitoring and Assessment Center (FRMAC), EPA on-scene coordinators, EPA special teams, and other local, regional, state and federal resources.

The radiological terrorism incident response plan should set the second highest priority after lifesaving actions as beginning to map the footprint of the dispersal using radiation monitoring equipment. The plan should provide for coordination between all agencies that will respond with monitoring equipment to *jointly develop plans* before an incident to obtain, collect and map this information. This map will identify "hot spots" and "protective zones" and help the emergency responders reduce doses to themselves and others. Furthermore, mapping of the area will assist in defining the magnitude of the incident and developing evacuation plans. Field data can be converted to a dose assessment of the affected populations if these data can be rapidly collected and provided to local subject matter experts, if available, and early responding outside resources such as National Guard civil support teams, RAP regional teams and Consequence Management Home Team (CMHT), and IMAAC.

The response plan should coordinate all the various local/regional agencies with radiation monitoring capability (*e.g.*, fire, HAZMAT, police, and EMS) to report data to a regional assessment center for consolidation and analysis. From this regional assessment center, these data should be shared within the Unified Command if established and to the extent possible with the state EOC, DOE CMHT, and the regional RAP team. CMHT can respond within 1 h during normal business hours and 2 h after close of business. When activated, the coordinator establishes a telephone bridge and can invite local, regional, state, tribal and federal agencies to participate in the call. Additionally, an assessment scientist, geographic information system scientist, and web administrator may join the call and prepare for requests for assistance.

In addition to the state EOC, DOE Consequence Management Response Team (CMRT), and RAP assets can jointly provide remote health-physics support and dose assessments in real-time to the local health officials making protective-action decisions for emergency responders and members of the general public. Planning in advance for the use of these and other capabilities will greatly enhance the effectiveness of the local response in the first few critical hours. See Appendix E for more information on the DOE radiological emergency-response assets.

Recommendation: DOE regional coordinating office should be involved in the development of plans, tabletop exercises, and field exercises for the *early (emergency) phase* to ensure Radiological Assistance Program (RAP) and Consequence Management Home Team (CMHT) support during the first critical hours of the incident.

5.2 Radiological Terrorism Incident Hazard Zones

Section 3 provides NCRP recommendations for defining the hot zone and dangerous-radiation zone based on radiation measurements at the scene. However, an RDD incident is not likely to produce a large dangerous-radiation zone in terms of the exposure rate. While a large source of radioactive material that is poorly dispersed may cause exposure rates >10 R h^{-1} (~0.1 Gy h^{-1} air-kerma rate) in a limited area, this would be treated like any large spill of HAZMAT. As such, the area is generally manageable by the emergency responders as opposed to a dangerous-radiation zone from a nuclear terrorism incident, which will be a much larger area. The initial hot zones can be established with only qualitative measurements from instruments (*i.e.*, a simple association of an explosion with a radiation signature from personal radiation detectors). Emphasis should be put on the concept of dose avoidance by measuring the radiation levels and establishing operational working times based on the radiation levels that exist within the incident scene.

Recommendation: For an RDD, an initial hot zone boundary should be established ~1,600 feet (500 m) in all directions from the point of dispersion until measurements are made. If it is known that the source used in the incident had an activity <10,000 Ci (370 TBq), then the initial hot zone boundary can be established at a radius of ~800 feet (250 m). Decisions should not be based on the perceived wind direction, especially in an urban setting in which the wind field can be very complex. Projections with environmental models will not provide accurate predictions of consequences on a distance scale of ~1,600 feet (500 m). Adjust the location of the hot zone boundary as radiation measurements become available. This boundary definition is appropriate for both alpha and beta and gamma emitting radionuclides (Musolino and Harper, 2006).

5.3 Protective Actions for Emergency Responders and Members of the General Public

5.3.1 *Sheltering versus Evacuation in the Emergency Phase*

In Section 3, NCRP recommended immediate sheltering followed by delayed, informed evacuation. People who are outdoors in the immediate area should enter adequate shelter, and people indoors should remain indoors until the plume of airborne radioactive material has passed. Informing members of the general public of this protective action before an incident occurs will reduce exposure.

Sheltering during the passage of the plume of airborne radioactive material will lower exposure, but sheltering beyond that time could result in an additional exposure if radioactive air concentrations inside the buildings become higher than the outdoor concentrations. This scenario could occur due to the intake of material from the passing plume by the ventilation system of an urban building so that, afterwards, when the outdoor concentrations have significantly decreased, higher levels of particulates may remain inside the building. Although a wide range of variability is expected, estimates suggest that the concentrations inhaled inside the building could be ~5 % of those in the outside environment. Evacuation should be delayed until after the plume passes. The optimal time for evacuation subsequent to this depends upon building protection factors (PFs), routes of exit from the hot zone, and other factors. Authorities will inform members of the general public regarding when to evacuate (Musolino and Harper, 2006).

Based on the actual experience after the attacks on the World Trade Center, the plan for managing evacuees should presume an orderly mass self-evacuation. With that assumption, having advance community planning efforts in place that direct self-evacuees to avoid crossing the hot zone are important. At the appropriate time initial emergency responders should be prepared to guide evacuees along designated evacuation routes which have established egress locations far away from the immediate area where the source was dispersed (Musolino and Harper, 2006).

5.3.2 *Postemergency-Phase Protection of Members of the General Public*

Planning and communication with members of the general public should assume that the EOC or the unified command will likely redefine the size of the evacuation area after ground deposition of radioactive material are more accurately mapped with additional measurements, likely within a 12 to 36 h period after the incident.

Although there are some local regions that have plans to quickly map the ground deposition, detailed surveys and mapping will probably occur after the outside emergency-response personnel and resources arrive, likely in 12 to 24 h in accordance with NRF (FEMA, 2008a). For the intermediate phase, the existing EPA relocation PAGs of 2 rem (20 mSv) effective dose in the first year and 0.5 rem (5 mSv) effective dose in any subsequent year are considered appropriate for RDD and IND incidents (DHS, 2008). The evacuation area may extend several miles from the point of release in some cases, but, regardless, it is likely to occur at some distance beyond the hot zone established in the early (emergency) phase (Musolino and Harper, 2006).

5.3.3 *Improvised Respiratory Protection*

Recommendation: Using improvised respiratory protection by breathing through a dry cloth reduces the exposure from inhalation of airborne activity in the passing plume and from resuspension.

Improvised respiratory protection as a countermeasure is possible only if a member of the general public is informed before an incident occurs or before individuals are exposed to a passing plume. This issue is a topic for discussion with members of the general public in the planning stage rather than an emergency recommendation to be issued by the local health authorities after an incident occurs. This countermeasure can be used to reduce internal dose from inhalation of particles during the ~10 to 15 min of the plume passage. For improvised respiratory protection, the mouth and nose should be covered with a dry cloth or handkerchief. A wet cloth, although it would tend to absorb water-soluble particles such as cesium chloride and keep them out of the respiratory tract, would increase difficulty breathing and might induce the person not to use any respiratory protection. Discontinue use of the temporary respiratory protection 30 min after the radiological terrorism incident (Musolino and Harper, 2006).

5.3.4 *Management of Concerned Citizens*

Recommendation: Following a radiological terrorism incident, hospitals should plan for large numbers of uninjured people ("concerned citizens," previously known as "worried well") seeking medical evaluation and/or decontamination. Management of these persons outside the hospital *emergency department* (ED) or diversion to *community reception centers* (CRCs) for monitoring and decontamination should be addressed in the planning process.

The large numbers of people who self-evacuate may put themselves in danger and will impede the efficient movement of emergency responders. Although radionuclide contamination on the ground is not a significant health risk in most cases, many uninjured people will not believe that is the case and will seek medical attention. Because of this, hospitals may be overwhelmed by people who do not need medical treatment or decontamination and by people who need only decontamination. Consequently, hospitals may have difficulty providing care for patients who require urgent medical treatment. The term that has been used extensively in the past for these individuals is *worried well*; CDC and other federal agencies prefer to use the term *concerned citizens*. In order to be consistent with current terminology, this Report will use the term *concerned citizens*.

5.3.5 *Protection of Emergency Responders*

At the scene of an RDD incident, standard protective clothing (*e.g.*, firefighting/bunker gear) and respiratory protection devices are sufficient to protect emergency responders from contamination by radioactive material (NCRP, 2005). The wearing of PPE should be based on the hazards of the mission assigned (*e.g.*, by detection with radiation survey devices or as a consequence of intelligence information). Firefighting hazards require full firefighting PPE.

Because the initial plume will likely pass beyond the hot zone within 10 to 15 min, most emergency responders will not be exposed to high airborne concentrations of radioactive particulates because they will arrive after the plume has passed or first encounter the plume downstream when concentrations have become diluted. Therefore, the remaining levels of airborne activity, along with any contribution from resuspension, are expected to be relatively low, but should be confirmed with equipment for measuring airborne radioactive material as soon as available from a follow-up response organization if not available from the initial emergency responders. Air-purifying respirators are sufficient to protect emergency responders from resuspension outdoors (Musolino and Harper, 2006).

Recommendation: Assess the inventory of radiation detection and measuring instruments to ensure that a sufficient number of instruments of each capability are available. Radiation monitoring instruments should be available to alert emergency responders [*i.e.*, firefighters, police, and emergency medical services (EMS) personnel] to the presence of radiation and possible exposure.

Instruments should be set to alert the emergency responders when the exposure rate reaches 10 mR h^{-1} (~0.1 mGy h^{-1} air-kerma rate), corresponding to the recommended value for establishing the hot zone boundary.

If emergency responders are issued integrating personal dosimeters such as thermoluminescent, optically-stimulated luminescent, or other passive dosimeters, they should be worn during the response. Emergency responders who are assigned electronic dosimeters for monitoring doses received should have them turned on at all times.

Emergency responders should promptly measure and record exposure rates to determine and map the rough profile of the contamination and mark hot spots and control zone boundaries. The former is important information that the local EOC will need to begin to assess the scope of the incident; the latter will assist emergency responders in controlling their own doses in the first critical hours (Musolino and Harper, 2006).

5.4 Triage for Inhaled Radionuclides

Recommendation: Identify persons who were outdoors and potentially in the path of the passing plume during the first 15 min after an explosion involving an RDD. These persons should be screened to determine the need for medical treatment for inhaled activity as a medical priority.

The planning process should develop procedures to identify people who need medical evaluation for internal contamination. A person is not likely to have received a significant dose from inhalation without presenting gross external contamination at triage. People with upper-body contamination, particularly of the shoulder, head and hair, should be identified as possibly having significant internal contamination. Assume that individuals with contamination only on the lower portions of their bodies were not likely exposed to the passing plume and did not inhale large quantity of airborne radioactive material. People with significant upper-body contamination may require evaluation for follow-up medical treatment because they may have inhaled radioactive material. Countermeasures, such as decontamination or decorporation should be considered if indicated, but are not a highly urgent action. Serious medical conditions (*e.g.*, traumatic injuries, heart attacks, or strokes) have precedence over all contamination-related issues (Musolino and Harper, 2006). Evaluations for external and internal contamination are discussed in detail in Section 7.

5.5 Management of the Crime Scene

When an incident is caused by a terrorist action, the site will also become a crime scene and so the emergency response plan should incorporate law-enforcement responsibilities and response actions. The Federal Bureau of Investigation manages, leads and coordinates all law-enforcement and investigative activities with regard to the response to terrorist acts or threats, including tactical operations, crime-scene investigation, crisis negotiation, and intelligence gathering and dissemination (FEMA, 2008b). Public health and security will still be the primary responsibility and focus of the local authorities but they must accommodate evidence collection and other law-enforcement activities. The local/regional emergency responders must keep the scene as intact as possible while performing their duties (FBI/CDC, 2009).

6. Nuclear Terrorism Incident

Decision makers and others will face many challenges in a nuclear terrorism incident. This section amplifies the policies of Section 3 and the planning guidance of Section 4 to discuss challenges and provide recommendations specific to a nuclear terrorism incident. A key difference between an IND and an RDD is that an IND results in a nuclear yield whereas an RDD does not (Ansari, 2009). Nuclear yield is measured in kilotons. A kiloton (kT) is the explosive energy equivalent of a thousand tons of TNT. Nuclear detonations are capable of producing impacts far surpassing that of any conventional explosive.

The descriptions and planning factors provided in this Report are based on the *National Planning Guidance for Response to a Nuclear Detonation* (EOP, 2010), which describes a nuclear device yield of 10 kT detonated at ground level in an urban environment and suggested response actions. The effects of a nuclear explosion <10 kT would be less. However, this yield is the current planning basis for the federal government and this Report (IOM, 2009b).

A significant effect of a nuclear explosion is the blast that it generates. The blast originates from the rapidly expanding fireball of the explosion, which generates a pressure wave moving rapidly away from the point of detonation. Initially, near the point of detonation (also referred to as *ground zero*) for a surface nuclear burst, the overpressure is extremely high. With increasing distance from ground zero, the overpressure and speed of the blast wave dissipate to a point at which they cease to be destructive. A 10 kT nuclear terrorism incident could destroy most of the buildings in several city blocks and would severely damage infrastructure within 0.5 miles (~0.8 km) or more of the explosion (Glasstone and Dolan, 1977).

Glass breakage is an important factor in assessing blast damage, but different kinds of glass break at widely varying overpressures. The glass dimensions, hardening, thickness, and many other factors influence glass breakage although most windows within a few miles of ground zero will be broken by a 10 kT nuclear terrorism incident.

The cold war civil defense concept of "duck and cover" can provide protection from flying debris, particularly glass. There will be a bright flash that can be seen for very long distances (tens to hundreds of miles) which can alert members of the general public to take protective action. At 1 mile (~1.6 km), a 10 kT device has the brightness of 1,000 mid-day suns (Glasstone and Dolan, 1977). Windows were broken at a radius of 10 miles (~15 km) from Hiroshima, Japan (BMA, 1983). The air-blast shock wave takes several seconds to travel to areas a few miles away, thus providing people an opportunity to move away from windows and protect themselves from flying glass by "ducking" (*i.e.*, crouching or lying down) and "covering" (*i.e.*, ducking under tables, moving into doorways, or covering vulnerable areas like the neck and face with the hands and arms).

The thermal pulse from the nuclear terrorism incident can cause skin burns to those within a few miles of the nuclear terrorism incident who have a line-of-sight view of the fireball. The potential for fire ignition in modern cities from thermal effects is poorly understood but remains a major concern. Fires may be started by the initial thermal burst igniting flammable materials in buildings, or by the ignition of gas from broken gas lines and ruptured fuel tanks.

Secondary fires are expected to be prevalent following a nuclear terrorism incident. Secondary fires will result in medically-routine burns, but the health threat will be compounded by other injury mechanisms associated with a nuclear terrorism incident. Fires destroy infrastructure, pose a direct threat to survivors and emergency responders, and may threaten people taking shelter or attempting to evacuate. If fires are able to grow and coalesce, a firestorm[4] could develop that would be beyond the abilities of firefighters to control.

Another significant effect from a nuclear explosion is ionizing radiation. Intense radiation is produced by the nuclear fission process that creates the explosion and from the decay of radioactive fission products (radionuclides resulting from nuclear fission). During a nuclear explosion, fission products are created that attach to particles and debris to form fallout; these particles are the main source of radionuclide contamination produced by a nuclear explosion. Fission products emit primarily gamma and beta radiation. The various fission products have widely differing radioactive half-lives. Some have very short half-lives (*e.g.*, fractions of a second), whereas others emit radiation for months or years. Radiation from a nuclear explosion is categorized as prompt radiation, which

[4]A firestorm is a conflagration, which attains such intensity that it creates and sustains its own wind system that draws oxygen into the inferno to continue fueling the fires.

occurs within the first minute, and latent radiation, which occurs after the first minute and is mostly emitted by radioactive fallout (NATO, 1996). Both can deliver lethal doses. Moderate to large doses that are not large enough to be lethal are known to increase long-term cancer risk.

For low-yield detonations, prompt radiation can be an important contributor to casualties. The prompt radiation, however, is of short duration and its intensity decreases with increasing distance from ground zero. This decrease is a result of the radial distribution of radiation as it travels away from the point of detonation, and the absorption and scattering of radiation by the atmosphere and buildings. Buildings help to block the direct path of prompt radiation. However, even if an individual is shielded behind buildings, scattered radiation from the atmosphere can still make people sick or prove fatal.

Nearly all the activity in fallout comes from fission products produced during a nuclear terrorism incident (*e.g.*, uranium or plutonium nuclei split apart in the fission reaction). A smaller contributor is the induced activity (activation) of local materials by neutron capture. In the fireball, the fission products and neutron activation products are incorporated into or condensed onto the particles generated from the explosion, which then descend as fallout. In a fallout zone, exposure to external sources of gamma radiation is the dominant health concern, but beta radiation will cause severe tissue damage if the material remains in contact with unprotected skin, resulting in "beta burns."

As a rule, fallout particles that are the most hazardous are readily visible as salt or sand-sized grains (Crocker *et al.*, 1966), but a lack of visible fallout should not be misinterpreted to mean activity is not present. Therefore, appropriate radiation monitoring should always be performed (Glasstone and Dolan, 1977). Fallout that is immediately hazardous to emergency responders and members of the general public will descend to the ground within the first few hours. The most significant hazard area will extend 10 to 20 miles (~16 to 32 km) from ground zero, but this area will decrease in size over a few days as the fallout decays (Buddemeier and Dillon, 2009). Figure 6.1 shows a hypothetical pattern of nuclear terrorism incident damage and fallout deposition. Fallout may contaminate only a part of the blast damage area.

Contamination from fallout will hinder response operations in the local fallout areas and may preclude some and will delay many actions before sufficient radioactive decay has occurred. Monitoring radiation levels is imperative for the response community. Combining the measured radiation levels with predictive plume

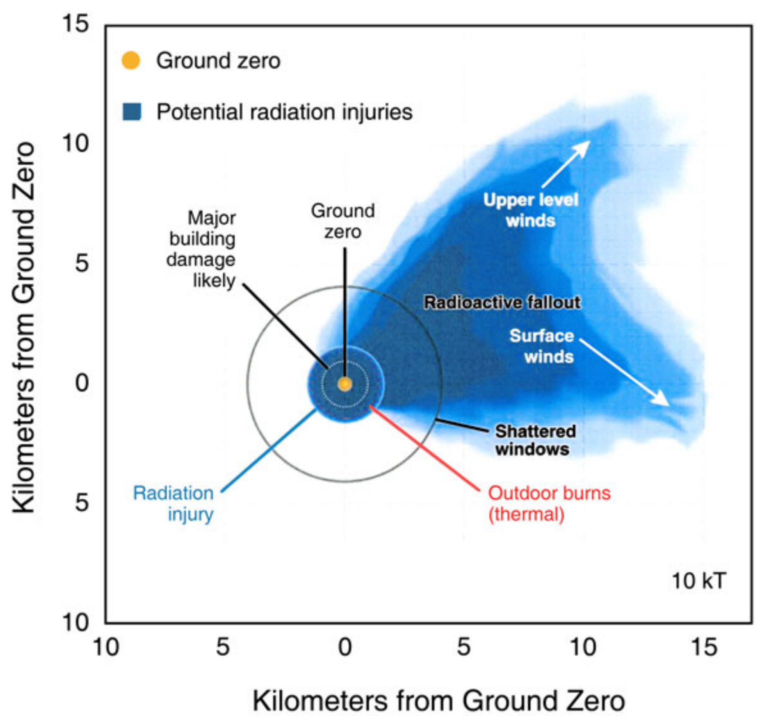

Fig. 6.1. Nuclear terrorism incident damage and fallout pattern. Significant differences in fallout patterns can result from varying wind directions and speeds at varying altitudes (Buddemeier and Dillon, 2009).

models and possibly measurements from aircraft can be valuable in determining response courses of action and making protective-action decisions (Buddemeier and Dillon, 2009; Yoshimura and Brandt, 2009).

A phenomenon caused by a nuclear terrorism incident called the electromagnetic pulse (EMP) poses no direct health threat, but can be very damaging to electronic equipment. EMP is a transient electromagnetic field generated by the nuclear terrorism incident that produces a high-voltage surge in conductors. This voltage surge can damage electronic components that it reaches. EMP phenomenon is a major effect for bursts at very-high altitude, but it is not well understood how it radiates outward from a surface level nuclear terrorism incident and to what degree it will damage the electronic systems that permeate modern society. Although experts have not achieved agreement on expected effects, there is general agreement that the most severe consequences of EMP would not occur beyond

2 miles (~3 km) from a surface level 10 kT nuclear terrorism incident (EOP, 2010). Stalling of vehicles and disruptions in communications, computer equipment, control systems, and other electronic devices could result. Because the extent of EMP effect is expected to occur relatively close to ground zero, other effects of the explosion (*e.g.*, blast destruction) are expected to dominate EMP effect. Equipment brought in from unaffected areas should function properly. It is not possible to make accurate recommendations on protection strategies for EMP damage to infrastructure or equipment needed for or affecting emergency response, such as two-way radios, telecommunications systems, and vehicles. Where possible, planners should incorporate EMP resistant equipment and consider redundancy with dissimilar means of communication.

6.1 Hazard Analysis and Zones

Situational awareness, achieved by quickly obtaining and disseminating information, will be critical for effective initial response and life safety. Planning activities should focus on identifying methods and organizations which will collect, analyze and disseminate the large amount of information, much of it incomplete in the early phase, that will be arriving from a variety of sources in the initial, critical hours of an incident.

A key regional planning aspect is ensuring that the various agencies responding to a radiological or nuclear terrorism incident have consistent definitions of hazard zones. Section 3 provides NCRP recommendations for defining the hot and dangerous-radiation zones based upon radiation levels. However, there are three additional "hazard zones" for a nuclear terrorism incident based on damage severity.

Blast damage extends outward from the nuclear terrorism incident in all directions, perhaps for several miles. This Report defines damage zones that are consistent with those used in the *National Planning Guidance for Response to a Nuclear Detonation* (EOP, 2010). Closest to the nuclear terrorism incident site will be the severe-damage zone where buildings are destroyed. Hazards and the unlikelihood of viable survivors make entry into the area unwarranted. Slightly further away would be the moderate-damage zone, where there will be significant building damage and rubble. However, there will also be a large number of persons with severe injuries who may survive if given prompt medical treatment. The light-damage zone, represented by the area that has broken windows as a primary effect, can extend for miles from the nuclear terrorism incident location (Figure 6.2).

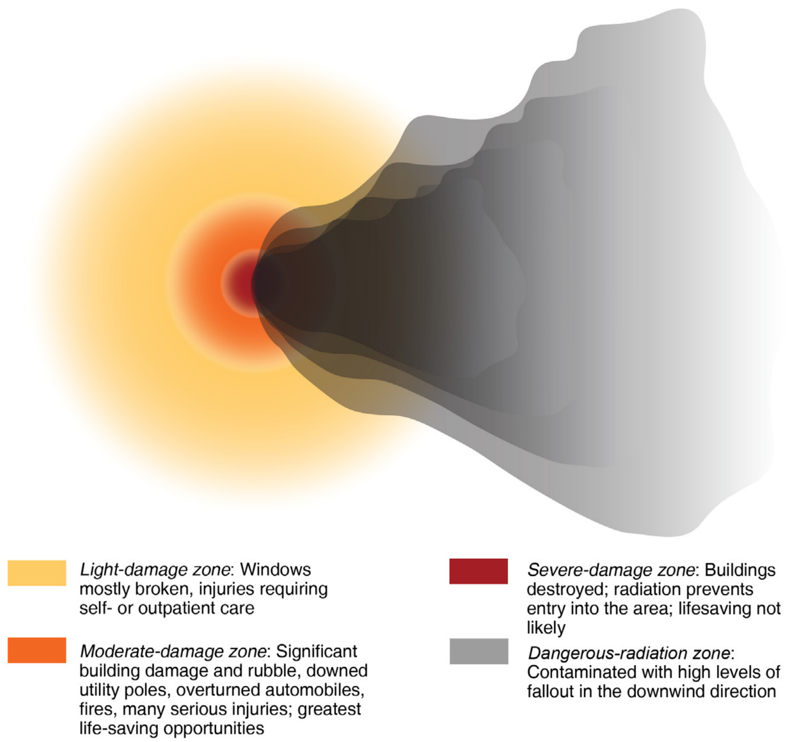

Fig. 6.2. Nuclear terrorism incident hazards zones. Terrain and other factors may cause these zones not to be circular. The grey cloud represents the dangerous-radiation zone resulting from fallout in the downwind direction (figure courtesy of the Brookhaven National Laboratory, Upton, New York).

Recommendation: After a nuclear terrorism incident, damage zones should be established. NCRP recommends the following: the light-damage zone is where windows are broken, the moderate-damage zone is the area of significant building damage, and the severe-damage zone is the area in which most buildings are destroyed.

There will be many hazards after a nuclear terrorism incident, including widespread fires and the presence of toxic materials, but one of the most significant, if it was a ground level or near ground level nuclear terrorism incident, will be the residual radiation from radioactive fallout and neutron activation of materials. Although the radiation levels are by far most hazardous in the first few hours, some areas within a few miles downwind may still be hazardous days after the nuclear terrorism incident. Rapid identification of these fallout areas for implementation of protective measures is one of the highest priorities of emergency management and public health authorities.

Identifying the dangerous-radiation zone [exposure rate ≥10 R h^{-1} (~0.1 Gy h^{-1} air-kerma rate)], as defined in Section 3, will have critical implications on response activities in or near fallout areas. The dangerous-radiation zone is an area where large doses could be delivered to emergency responders in a short period of time. After a ground level nuclear terrorism incident, the dangerous-radiation zone will be created by fallout that is deposited in the first few hours and have boundaries that may extend for 20 miles (~32 km), depending upon the yield and weather, but this dangerous-radiation zone will rapidly shrink as the fallout decays and may only be a mile or two long after a few days. As an example, an emergency responder working in an area with an initial 10 R h^{-1} exposure rate (~0.1 Gy h^{-1} air-kerma rate) 4 h after the nuclear terrorism incident will receive ~25 R (~0.25 Gy air kerma) in a 4 h work period.

The dangerous-radiation zone changes too rapidly in the first day to warrant physical marking of the perimeter. However, efforts should be made to secure a safe perimeter and dissuade people from entering. It is recommended that those working near dangerous-radiation zones have instruments that monitor the exposure rate.

As depicted in Figures 6.1 and 6.2, much of the moderate- and light-damage zones will not be in the dangerous-radiation zone and operations in the light and moderate-damage zones can safely proceed once the perimeter of the dangerous-radiation zone has been identified. The ≥10 mR h^{-1} (~0.1 mGy h^{-1} air-kerma rate) hot-line definition is useful for ensuring the staging areas and reception centers are outside of the hot zone, which will extend much further downwind but will also shrink in size over time as the radioactive fallout decays.

6.2 Response-Plan Considerations

Because the response to a nuclear terrorism incident will require extensive coordination of a large number of organizations, regional planning is essential to success. The following delineates consideration of roles and responsibilities, and essential elements of response planning. The establishment of mutual-aid agreements, essential for nuclear terrorism incident preparedness, was discussed in Section 4.

Specific challenges that should be addressed in developing a response plan for nuclear terrorism incidents include (Buddemeier and Dillon, 2009; EOP, 2010):

- Many local response personnel will be unable to respond due to their proximity to the blast site and they will need to shelter-in-place for at least the first hour, after which radiation levels should be measured and evacuation routes determined.
- The blast and possibly an EMP will create infrastructure failures in electricity, communications, and gas and water distribution systems. The extent of this EMP effect is uncertain.
- Fires, caused by the thermal pulse and blast damage, may be a hazard for sheltered or trapped individuals.
- Rubble piles in urban canyons may hinder evacuation and response efforts.
- Flash blindness may cause car accidents that block roadways within ~6 miles (~10 km) of the incident.
- Secondary hazards (*e.g.*, chemical releases, flooding, hazardous gases and dust from building collapses) will also be present.
- There may not be a visible mushroom-shaped cloud. Low yield, ground detonations in an urban environment may generate a nonuniform, and chaotic debris cloud. Night or overcast skies can obscure the view of the cloud produced.
- It will be difficult to predict or avoid unsafe fallout areas. The tremendous heat of the fireball causes a buoyant rise that will push the fallout several miles high where upper atmospheric winds, which often travel at high speeds [>50 mph (>80 km h^{-1})], carry the fallout and it would be difficult to avoid exposure for those within its path. Even if the cloud is visible, fallout particles may fall in nearby areas due to lower atmospheric wind directions.
- Varying wind directions at different altitudes may result in fallout deposition in locations which are not in the direction of the surface wind.
- The extensive debris cloud caused by the blast may obscure visibility within a few miles of the nuclear terrorism incident.
- The primary hazard is the radiation from the fallout particles on the ground and other horizontal surfaces; inhalation is a minor concern (Glasstone and Dolan, 1977; Levanon and Permick, 2008).

In preparing to respond to a nuclear terrorism incident, decision makers may encounter terms and concepts with which they are not familiar. Lists of concepts useful to decision makers who are not radiation experts include the following:

- nuclear terrorism incident terms such as *yield*, *prompt effects*, and *fallout*;
- ionizing radiation and the types of ionizing radiation;
- exposure or dose to a person versus contamination with radioactive material;
- external and internal contamination of a person;
- quantities and units for describing radiation;
- dose limits versus decision doses; and
- radiation health effects and the ranges of exposures that cause them.

Preparedness actions that should be addressed in the plan include:

- developing a "Continuity of Operations Plan" and alternate emergency operations sites with a predetermined command succession, communications links and staffing;
- determining radiation PFs for buildings that may be used as public shelters;
- identifying alternative communication systems for public messaging immediately after a nuclear terrorism incident to provide clear, factual and timely guidance to members of the general public;
- making timely damage assessments and providing for restoration of critical services, resources and infrastructure;
- identifying key agency roles and responsibilities in responding to a nuclear terrorism incident;
- developing a patient referral plan for immediate and long-term treatment as a result of critical injuries and severe radiation doses; and
- developing a recovery and restoration plan to manage long-term health and environmental issues and the local, state, tribal and federal agencies that will be responsible for this mission, including possible relocation of people and businesses.

Regional plans should also include common understanding of personal decontamination methods and priorities for managing fallout contaminated populations after a nuclear terrorism incident. It is expected that the fallout particles will be easy to brush off or be removed by changing shoes and outer clothing. People who were outside when the fallout arrived may also consider washing their hair and exposed skin surfaces. Since fallout contamination decays rapidly, it is most hazardous in the first few minutes and hours after a person becomes contaminated. Given this time frame, the large number of potential victims, and resources necessary for a formal decontamination process, simple self-decontamination techniques should be provided for a nuclear terrorism incident as people leave the dangerous-radiation zone or enter shelters (Appendix F).

A key planning consideration for decontamination is the logistics of providing replacement clothing and shoes, especially if temperatures are cool and hypothermia is a consideration. See Section 7.6 for detailed planning guidance for personal decontamination.

For a large explosion whose cause is unknown, an emergency alert system message should be broadcast stating that people should shelter indoors. If a nuclear terrorism incident is suspected, provide specific information on protection from fallout. The detonation of a very large amount of explosive in a city may not be promptly distinguishable from a very low yield nuclear terrorism incident in a parking garage underground that would suppress the flash. This topic is discussed further in Section 6.3.

Recommendation: Establish communication with emergency responders in the affected area. Provide safety instructions to the emergency responders and collect information on the type of blast damage and the radiation level where the emergency responders are sheltering and, if it is safe to measure it, the radiation levels outdoors. Determine the exposure rates [cold (outdoor exposure rate ≤10 mR h^{-1} (~0.1 mGy h^{-1} air-kerma rate)], hot [>10 mR h^{-1} (~0.1 mGy h^{-1})], or dangerous-radiation zone [≥10 R h^{-1} (~0.1 Gy h^{-1})] at their locations.

Establish communication with emergency responders in the affected area. Radios outside of the major building damage area should still function, although communication repeaters may be inoperative. Use alternate communication methods if needed.

Recommendation: Use a regional situational assessment center to collect information from observations, instrument readings, weather, and computer modeling to produce integrated situational awareness products (maps and displays). Products and information should be disseminated to all regional *emergency operations centers* (EOCs).

Designate a regional situational assessment center that will collect information from observations, instrument readings, weather, and computer modeling. Identification of areas with hazardous fallout is a priority. Even before a disaster is declared, establishing lines of communication with the appropriate organizations will be important. RAP, National Guard civil support teams, EPA on-scene coordinators and special teams, FRMAC, and IMAAC can provide valuable information collection, coordination and dissemination support.

6.3 Public Information Program to Improve Response to a Nuclear Terrorism Incident

Section 4 identifies the key components of a public information program. Below is guidance specific to preparing members of the general public for issues they may face in a nuclear terrorism incident.

6.3.1 *Preincident Public Information Program*

Recommendation: Injuries from flying glass and other missiles can be prevented by recognizing the immediate signs of a large explosion (*i.e.*, the flash) and moving away from windows and using the "duck and cover" technique. The preincident public information should describe this protective action.

The amount of time between the "flash" and the "bang" (sound of the detonation) is sufficient to "duck and cover" which may protect people inside buildings, especially their eyes.

Recommendation: The most effective way to save lives is to reduce exposure from fallout. The preincident public information should emphasize the *initial public protective action of early adequate sheltering followed by delayed, informed evacuation*.

As discussed in Section 4, the success of the response to a nuclear terrorism incident will depend largely upon public awareness, prior to an incident, of protective actions it can take. Public awareness and use of protective measures such as sheltering will improve public safety, reduce the demand for limited emergency-response resources, and reduce response hindrances such as traffic congestion. In a nuclear terrorism incident, it is anticipated that the greatest challenge to response authorities will be public fear and confusion resulting, in part, from the lack of understanding of radiation hazards, particularly from the fallout created by the nuclear terrorism incident. This issue should be addressed in a pre-incident public information campaign.

The program should provide general information such as the types of radiation, sources of radiation, common terminology for describing radiation, health effects of radiation, and, specifically for a nuclear terrorism incident, information on radioactive fallout including how it travels and how people can protect themselves. Information should be made available on how to determine the PFs for the common types of shelters such as homes, places of employment, and schools.

With support from FEMA, local authorities should identify public shelters for people outside buildings in the event a nuclear terrorism incident occurs. Signs similar to the Civil Defense shelter signs should be posted and visible for civilians with information on the level of protection provided in terms of the length of safe sheltering time.

6.3.2 *Preparing for Post-Incident Messages*

Templates for messages providing protective-action guidance for members of the general public should be prepared in anticipation of a nuclear terrorism incident and plans should provide for the prompt release of such messages. See Appendix B for examples of message templates for an IND. This will expedite providing important information to members of the general public and may help to reduce fear and inappropriate actions.

> **Recommendation:** Protective-action guidance should be issued to members of the general public as soon as possible after any large explosion, even before confirmation that the detonation was nuclear.

Initial information should be provided to members of the general public within 10 to 15 min after a nuclear terrorism incident and released even before it has been confirmed that a nuclear terrorism incident occurred. People outdoors or in severely damaged buildings should be advised to immediately seek suitable shelter and remain there for at least the first few hours or until guidance is received from emergency-response personnel or other authorities. Multiple delivery methods, all providing the same guidance, should be used.

Local emergency-management organizations should include the media in the public information program planning prior to an incident. Reporters and media spokespersons should be trained in common radiation terminology and know where they can contact local authorities for accurate and timely updates.

6.4 Protective-Action Recommendations Specific to a Nuclear Terrorism Incident

Recommendation: NCRP recommends that the initial public protective action be *early, adequate shelter followed by delayed, informed evacuation*. Until the level and extent of contamination can be determined, efforts should be made to avoid being outdoors in potentially-contaminated areas.

Recommendation: The goal of response to a nuclear terrorism incident is to save lives while minimizing risks to emergency-response workers. Unless there is an impact on life-safety, no resources should be initially expended for the protection of property.

It is important to be in an adequate shelter when the fallout arrives (Ansari, 2009). Fallout arrival times vary with nuclear yield and weather, but people outside of the building collapse area (severe-damage zone) should have at least 10 min before fallout arrives. People who are outside or in cars should seek the nearest adequate shelter. People who are already in an adequate shelter should remain in the shelter.

Although some high-energy gamma rays from the fallout contamination will penetrate the walls of buildings, protective actions, including the use of shielding provided by thick walls, and increasing the distance from outdoor fallout, can reduce exposures to people by a factor of 10 or more (DOD, 1967).

The protection factor (PF) describes the amount of protection from fallout radiation provided by being in a specified area of a building or other structure. Similar to the sun protection factor (SPF) values for sunscreen, the higher PF, the lower the radiation exposure that a sheltered person would receive compared to an unsheltered person in the same area. To obtain the sheltered exposure, divide the outdoor radiation level by PF. Figure 6.3 shows presumed PFs for a variety of buildings and locations within the building. For example, a person on the top floor or at the periphery of the ground level of the office/large apartment building shown would have a PF of 10 and would receive only one-tenth (10 %) of the exposure that someone outside would receive. Someone in the core of the building, halfway up, would have a PF of 100 and receive only one one-hundredth (or 1 %) of the outdoor exposure. In fallout areas, sheltering in locations with adequate PFs could prevent lethal exposures. Section 7.2 discusses a hospital's response to possible fallout radiation.

An adequate shelter is a location that places dense material (*e.g.*, earth), building materials, or distance between the occupants and horizontal surfaces that will accumulate fallout. Using the PF nomenclature described above (Figure 6.3), a PF of 10 or more is considered an adequate shelter.

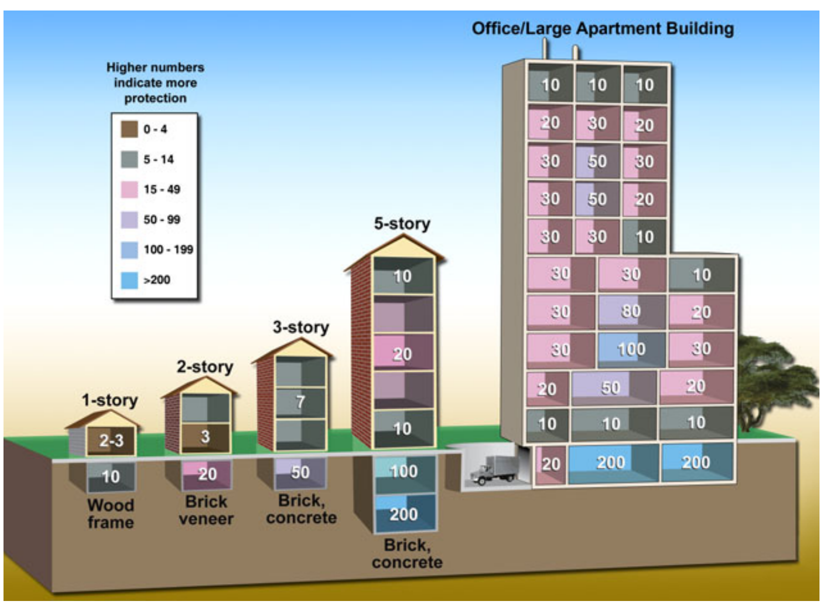

Fig. 6.3. Examples of PFs for a variety of building types and locations (Buddemeier and Dillon, 2009).

Examples of *adequate* shelters include:

- basements, particularly against a basement wall;
- multistory brick or concrete structures;
- office buildings (central core or underground sections);
- multistory shopping malls (away from the roof or periphery); and
- tunnels, subways, and other underground areas.

Examples of *inadequate* shelters include:

- outdoor areas;
- cars, buses, and above-ground rail systems;
- light residential structures such as mobile homes and single-story wood frame houses without basements; and
- single-story commercial structures without basements such as strip malls, retail stores, and light industrial buildings.

Buildings do not have to be "air tight;" broken windows do not greatly reduce the protection offered.

Recommendation: After the blast wave has passed, the most critical lifesaving action for emergency responders and members of the general public is to seek adequate shelter [with a protection factor (PF) of 10 or more] for at least the first hour, and then use radiation measuring instruments (if available), public messages, and shelter PFs to determine when to evacuate.

For a nuclear terrorism incident, survivors of the blast should seek shelter that can provide a fallout PF of 10 or more within 10 min of a nuclear terrorism incident. A major challenge for planners and emergency responders is to communicate with those in the shelters and convince them to remain there until it is safe to leave. The instinct to reduce one's exposure to radiation by fleeing the area or to reunite with family members must be recognized and overcome for safety. A strong public education and communication effort can help educate members of the general public and reduce this problem. But, it must be recognized that some people will evacuate, despite announcements to shelter in place.

Informed evacuation, after sheltering for at least the first hour, can begin in a phased process. Evacuation routes that take victims out of the fallout area as quickly as possible, using vehicular tunnels, subway tunnels, or other protected routes if available, should be identified. When traveling in contaminated urban areas, people should stay out of the middle of roadways. The lowest outdoor exposure areas are near the sides of large buildings. If roadways are clear, ambulatory victims can be directed to local collection points (always use adequate shelters for these) and picked up by designated transportation. Driving can be considered if the roads have been cleared and the number of evacuees can be accommodated.

Higher exposures can occur if people leave their shelters too early. Optimum shelter time depends on several key parameters:

- quality of the shelter;
- outside dose rate at that location;
- evacuation travel time through contaminated areas; and
- dose rates in the areas through which travel is required.

Recommendation: The dangerous-radiation zone should be identified within the first hour(s) to permit response planning and development of an informed, delayed evacuation strategy.

In the aftermath of the nuclear terrorism incident there are several populations that are early-phase priorities (*e.g.*, first few hours after a nuclear terrorism incident) those:

- experiencing medical emergencies;
- threatened by fire or toxic materials (not fallout);
- in danger from building collapse; and
- in *inadequate* shelters.

Except for those in good shelters (PF = 100+), those near the edge of the fallout area where travel times are short (<10 min) should consider evacuation when an informed evacuation route is available.

Populations that should be considered the next priority (*e.g.*, the first day after a nuclear terrorism incident) include those:

- threatened by fire or toxic materials (not fallout);
- in moderate shelters, such as two to three story buildings without basements;
- in danger from hot or cold weather;
- not in fallout areas, provided their evacuation does not hamper emergency-response operations or take them through fallout areas; and
- needing medication (*e.g.*, insulin).

Those that should be considered a late-phase priority (days after a nuclear terrorism incident) are those:

- in good shelters (large buildings or underground); and
- requiring evacuation assistance (*e.g.*, nonambulatory, elderly, hospital patients).

6.5 Planning for the Protection of Emergency Responders After a Nuclear Terrorism Incident

NCRP emergency responder protection policies discussed in Section 2 apply to a nuclear terrorism incident.

Recommendation: Radiation monitoring equipment is necessary for emergency responder dose control and safety while they are in their facilities and on emergency calls.

Recommendation: Radiation monitoring instruments should be available to measure exposure rates up to at least 10 R h^{-1} (~0.1 Gy h^{-1} air-kerma rate), corresponding to the recommended alert level for the dangerous-radiation zone. Additional instruments, in limited quantity, should be available to measure exposure rates up to 1,000 R h^{-1} (~10 Gy h^{-1}).

Fallout from a nuclear terrorism incident can generate very-high levels of radiation. As recommended in NCRP Commentary No. 19 (NCRP, 2005), radiation instruments should be available that can measure exposure rates up to 10 R h^{-1} (~0.1 Gy h^{-1} air-kerma rate). It may be necessary to support measuring exposure rates as high as 1,000 R h^{-1} (~10 Gy h^{-1}) for some emergency operations.

Recommendation: Emergency service facilities (*e.g.*, police stations, fire stations, EOCs) should be evaluated to determine the level of protection they provide against radiation from fallout. If a facility does not provide sufficient protection, an alternate shelter strategy should be developed.

Emergency service facilities will require evaluation to determine the level of protection they provide against the hazards of radioactive fallout. This is critical information that will be needed for determining the initial actions and length of shelter time for personnel in each facility. Water and food should be stored in facilities that provide high levels of shelter protection where it may be beneficial to stay for 24 to 48 h.

Recommendation: Prepare for backup communication that will survive the loss of communication repeaters and electrical power.

Communications systems in these facilities should be redundant, tested regularly, and maintained appropriately. Immediately after an IND incident, it will be critical to establish communications between each facility having emergency-response capabilities and the agency emergency managers to obtain information on the status within and outside the emergency-response facility shelter for transmittal to the local EOC.

6.6 Nuclear Terrorism Incident Recommendations for Emergency Responders

Recommendation: Emergency responders with radiation detection instruments should initially shelter using the instruments to monitor shelter conditions and not exit the shelter if it requires entering a dangerous-radiation zone [≥10 R h^{-1} exposure rate (~0.1 Gy h^{-1} air-kerma rate)]. Emergency responders without radiation monitoring equipment should shelter until informed that they are not in the dangerous-radiation zone.

The blast and fallout of a nuclear terrorism incident may affect large areas which contain a substantial portion of the community's response force. Emergency responders without radiation detection instruments should follow the public protection strategy. Emergency responders with radiation detection instruments should initially shelter using radiation detection instruments to monitor shelter conditions and not exit the shelter if it requires entering a dangerous-radiation zone [≥10 R h^{-1} exposure rate (~0.1 Gy h^{-1} air-kerma rate)]. If exposure rates permit, emergency responders should assess the immediate area for hazards, staying close to shelter locations and closely monitoring radiation levels, as it is important to immediately shelter if radiation levels increase rapidly.

Once emergency responder safety is ensured, performing a regional situational assessment is critical. Telephones and cellular systems may not be working or may be overloaded in the broken window blast area. However, two-way radio systems should work, although they may only function in point-to-point mode if communication repeaters have been damaged. If electronic equipment is not functioning, turning it off and then on may restore function. It is a high priority for emergency responders to establish communication with other response elements.

Recommendation: Emergency responders should record and report information on major hazards in their area and the location of cold [outdoor exposure rate ≤10 mR h^{-1} (~0.1 mGy h^{-1} air-kerma rate)], hot [>10 mR h^{-1} (~0.1 mGy h^{-1})], or dangerous-radiation zones [≥10 R h^{-1} (~0.1 Gy h^{-1})].

After establishing communication, emergency responders should report radiation levels at their location. Radiation readings will change rapidly with time. As a consideration for local and regional response plans, it may be more effective to report the zone that the emergency responder is in, such as cold [outdoor exposure rate ≤10 mR h^{-1} (~0.1 mGy h^{-1} air-kerma rate)], hot [>10 mR h^{-1} (~0.1 mGy h^{-1})], or dangerous-radiation zones [≥10 R h^{-1} (~0.1 Gy h^{-1})]. Local and regional emergency responders should record and report radiation levels at regular intervals. Identification of dangerous-radiation zones is a priority, but also important is reporting cold zone areas for the determination of safe evacuation routes and response staging areas.

The response needs from a nuclear terrorism incident can greatly exceed available response resources in the first few critical hours. Response will require the effective use of citizen volunteers to help manage and transport the injured and assist in evacuation. Such citizen volunteers are briefly discussed in Section 7.1.

In summary, priority actions for emergency responders within the blast damage area are:

- *Shelter*: The response force within the blast area should shelter until their radiation detection equipment can confirm that the exposure rates outside are <10 R h^{-1} (~0.1 Gy h^{-1} air-kerma rate).

- *Use radiation detection equipment*: Turn on survey and dose-rate instruments. If dosimeters are available, they should be prepared for use and distributed. Ensure detection equipment is operational; if a zero reading occurs in a known radiation area, there may be an EMP-induced malfunction.
- *Establish communication*: Emergency responder radio systems should work, although they may only function in point-to-point mode, if repeaters have been damaged. Point-to-point cellular phones may also function in this capacity. If radios appear to be nonfunctional turning them off and on again may restore the function.
- *Perform reconnaissance of the immediate area*: If outside exposure rates are <10 R h^{-1} (~0.1 Gy h^{-1} air-kerma rate), team(s) of two should proceed several blocks in each direction. Each team should be equipped with an exposure-rate meter and should turn back if it encounters exposure rates ≥10 R h^{-1} (~0.1 Gy h^{-1}). The team should record the locations of measured exposure rates.
- *Establish the approximate nuclear terrorism incident location*: Although this sounds simple, limited visibility, the effects of the positive and negative pressure blast wave, and blast wave reflection may create a confusing environment where areas of potential higher hazards may not be readily apparent to those within a few miles of the incident. This may be a good use for airborne assets, if available, to assess.
- *Identify and record the locations of fires*: Their extent and expected growth rate.
- *Identify and record the locations of other hazards*: (*i.e.*, chemical leaks, downed live electrical power lines, natural gas leaks, etc.).
- *Compile and report status and reconnaissance information*: If communication is limited, consider sending a volunteer to the nearest base of operations station in a direction away from the nuclear terrorism incident location. Potential dose to the volunteer should be considered.
- *Prepare for mass-casualty triage and extended operations*: Identify nearby locations that are safe to stage victims and evacuees.
- *Use citizen volunteers*: Since the magnitude of the incident will overwhelm all response resources. Life-safety will depend on citizen-run triage sites, litter bearers, and evacuation route clearing.

Recommendation: Lifesaving priority should be focused in the moderate-damage zone that is not in the fallout area.

Recommendation: Emergency responders should focus medical attention in the light-damage zone only on life-threatening injuries and life-threatening medical conditions.

The light-damage zone is where windows are broken, moderate-damage zone is the area of significant building damage, and severe-damage zone is the area in which most buildings are destroyed. A challenge for emergency responders will be to get to the lifesaving priority area (moderate-damage zone). This may require the emergency responders to bypass victims in the light-damage zone with minor, but compelling injuries. Expenditure of significant response resources and time in the light-damage zone could exhaust supplies desperately needed in the moderate-damage zone.

Once the general areas and magnitude of fallout have been determined, emergency responders who are not in danger should be assigned time-sensitive, high-priority missions. After the light-, moderate-, and severe-damage zones have been established, an initial priority is lifesaving in the moderate-damage zone that is not in the dangerous-radiation zone.

Recommendation: Emergency responder actions within the dangerous-radiation and severe-damage zones are not recommended within 24 h after a nuclear terrorism incident unless necessary for the life safety of large populations.

Although there will be injured individuals within the severe-damage and dangerous-radiation zones, the limited response resources of the first day should focus efforts on areas outside of the severe-damage and dangerous-radiation zones because these operations are less resource intensive to support. Missions into the severe-damage and dangerous-radiation zones should only be considered if they are necessary to support the life safety of a large number of people.

Recommendation: Decontamination plans should focus on self-decontamination performed as people exit the severe-damage and dangerous-radiation zones or enter shelters. The large number of potentially-contaminated citizens and the resources necessary for full decontamination will likely exceed the available response capabilities.

6.7 Considerations for Downwind Populations at Long Distances

Evacuation should only be attempted if the population can be out of the area *before* the fallout arrives; otherwise, sheltering is the best countermeasure for at least the first 2 h until the actual fallout hazard areas can be identified. Similar to hurricane impact area predictive models, the actual incident consequences can vary widely from the prediction. Protective actions should also be initially implemented in areas adjacent to the predicted fallout path. Even a well-behaved fallout cloud will spread out as it travels and deposit the fallout over a larger area (wider path), implying that:

- a large population likely will be impacted;
- longer travel times and distance will be needed to avoid the fallout; and
- later fallout arrival times are expected.

Although exposures will be much lower and early health effects (*i.e.*, radiation sickness) are not expected beyond 10 or 20 miles (~16 to 32 km) (nominally for a 10 kT explosion, though lower yields will produce shorter ranges), the protective action recommendations in *Planning Guidance for Protection and Recovery Following Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND) Incidents* (DHS, 2008) should be followed and shelter should still be considered to reduce the potential dose to outdoor populations in areas that may exceed 1 rem (0.01 Sv) total effective dose (sum of effective doses from external and internal radiation sources) which could include communities hundreds of miles downwind.

7. Preparing the Public-Health and Medical System Response

7.1 Public-Health and Medical Preparedness Overview

Recommendation: Review existing public-health and medical-response plans to ensure that radiological or nuclear terrorism incidents of any type and scope are addressed.

These preparations should address hospital preparedness, triage and treatment challenges, decontamination, population monitoring, radioactive waste, contaminated deceased persons, and recruitment and credentialing of supplemental staff.

Recommendation: The appropriate authority should develop a public-health and medical concept of operations scenario similar to that shown in Figure 7.1.

A radiological or nuclear terrorism incident will produce varying numbers of victims requiring a coordinated public-health and medical system response. The public-health and medical system response after such an incident is complex and would involve a variety of emergency responders who are defined in NCRP Commentary No. 19 (NCRP, 2005). Figure 7.1 shows a possible flow chart for public-health and medical operations after a radiological or nuclear terrorism incident. This section addresses many of the aspects (facilities, referral patterns, etc.) found in this figure. The concept of operations scenario presented in this Figure 7.1 should be scalable depending on the specific incident. For example, several hospitals may be involved during an incident, each with its own reception and triage center external to the ED. In addition, temporary decontamination centers (TDCs), community reception centers (CRCs), and alternative medical treatment sites (AMTSs) could be

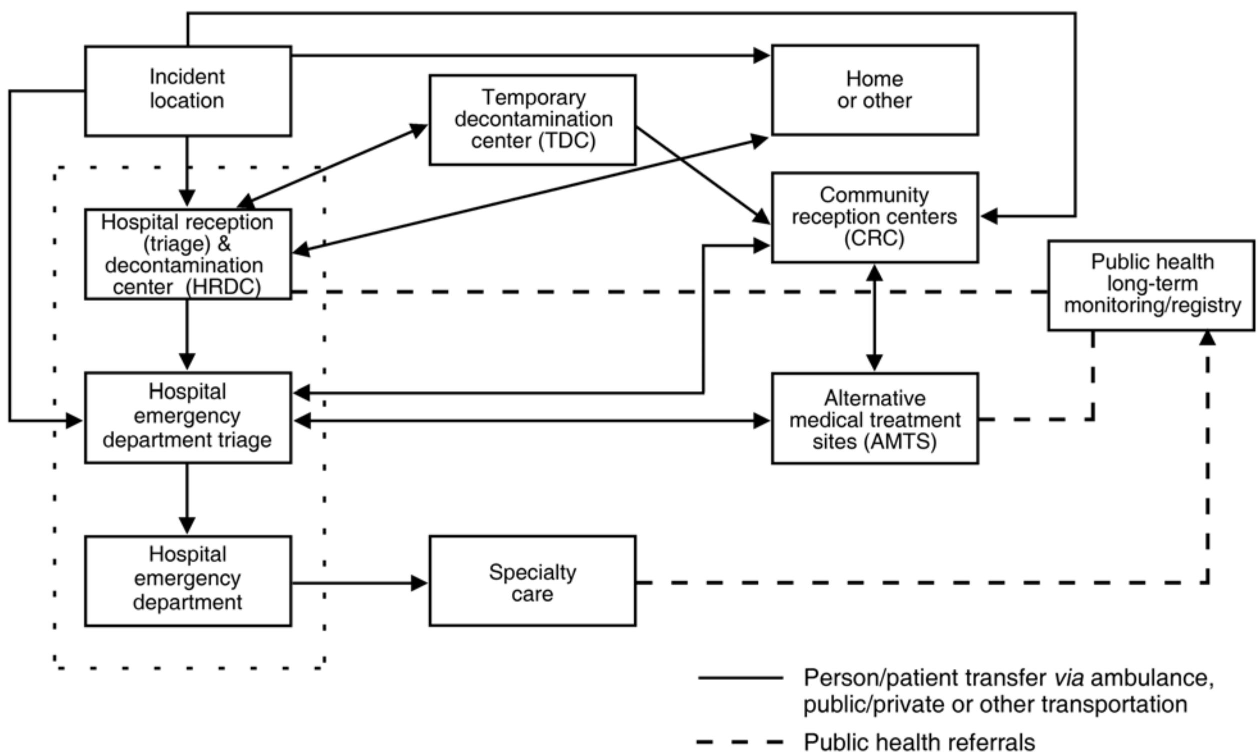

Fig. 7.1. Concept of operations for a public health and medical emergency-response system.

opened depending on the characteristics of the incident and particularly the number of individuals affected. In particular, a nuclear terrorism incident in a major metropolitan area would produce a catastrophic number of victims, quickly overwhelming the local public-health and medical system, and requiring regional, state, national, and perhaps international assistance. All regional hospitals not incapacitated by the nuclear terrorism incident would be involved in response activities. All of the various types of reception and decontamination centers and AMTSs should be opened in the region to handle the very large number of victims expected after a nuclear terrorism incident.

In addition to the components shown in Figure 7.1, casualty collection points will spontaneously open, staffed by citizen volunteers in relatively safe locations until sufficient numbers of emergency responders are available to begin triage, treatment and transport operations (EOP, 2010; Hrdina *et al.*, 2009). These citizen volunteers will be people in the area, including medical personnel, who choose to care for casualties, and, if available, members of community emergency-response teams.

Severely injured, but nonfatal victims would be transported by EMS or other means directly to a hospital ED triage site in the region for definitive care. As soon as possible after notification of a significant radiological or nuclear terrorism incident, each hospital should activate an onsite hospital reception and decontamination center (HRDC). The function of HRDC is to receive people who have arrived at the hospital but do not require ED care. These people may have minor injuries and radionuclide contamination and may be worried about radiation exposure. The function of an HRDC is described in more detail in Section 7.2.

AMTSs and CRCs (Figure 7.1) should be established as soon as possible after an incident. The primary function of an AMTS is to provide surge capacity for medical care outside of the hospital setting for noncritical patients, those triaged as having minor injuries, patients who are psychologically affected by the incident with no other injuries, and the concerned citizens who self-refer to medical facilities.[5] The primary function of a CRC is to provide population monitoring and decontamination services to large numbers of the affected population. AMTSs and CRCs are described in more detail in Section 7.3. A TDC(s) may or may not be established during an incident. If these centers are established, they would decontaminate some or all people without severe injuries (Section 7.6).

[5]"Concerned citizens" (see Glossary).

7.2 Hospital Preparedness

Recommendation: Every hospital should have plans to maintain operations during a radiological or nuclear terrorism incident of any type and scope, and to provide care for the victims of such an incident.

The EOC or other local or regional emergency-response organizations should maintain emergency contact information for all hospitals and other healthcare facilities in the local and regional healthcare system and should notify all these entities that a radiological or nuclear terrorism incident has occurred as soon as possible after the incident is suspected or recognized. Redundant and robust communications systems should be maintained between the local, regional, state and tribal authority, and between the local or regional authority and the local healthcare system (CDC, 2003).

Unless a hospital has sustained critical building structural and infrastructure damage, it should be prepared to remain functional to handle disaster victims. The victims may range from the critically injured and contaminated to the uncontaminated, concerned citizens.

Recommendation: Each hospital in or near a major metropolitan area should prepare for the contingency that it could be in the hot zone [outdoor exposure rate >10 mR h^{-1} (~0.1 mGy h^{-1} air-kerma rate)] from radioactive fallout after an improvised nuclear device (IND) detonation and possibly with a radiological dispersal device (RDD) detonated nearby.

Prior to an incident, each hospital should assess its buildings, as described in Section 6.4, to determine what portions of these buildings constitute adequate shelters from fallout radiation. Each such hospital should have at least one radiation survey meter, as described in Section 6.5, that can measure exposure rates up to at least 10 R h^{-1} (~0.1 Gy h^{-1} air-kerma rate). The hospital's emergency plan should include provisions, if radiation measurements or other information indicates that the hospital is in the hot zone, to perform radiation surveys of occupied areas within the hospital to determine if temporary relocation of patients and staff to other areas of the hospital is necessary. Performing these surveys and moving staff and patients out of areas with dangerously-high exposure rates becomes a matter of urgency if the hospital is in the dangerous-radiation zone [outdoor exposure rate $\geq 10\ R\ h^{-1}$ (~0.1 $Gy\ h^{-1}$ air-kerma rate)]. The emergency plan should take into account that the upper floor or floors may have to be temporarily evacuated because of radiation from fallout on the roof, unless the roof is decontaminated, as described in Section 4.2.

Each hospital's emergency operations plan should include provisions for responding to a radiological or nuclear terrorism incident, including handling victims presenting after such an incident. Each hospital should operate under the Hospital Incident Command System (EMSA, 2009). Hospital staff should receive training regularly on the hospital's radiological or nuclear emergency plan and drills and exercises should be conducted periodically.

The hospital plan should be integrated into the local or regional emergency operations plan under Emergency Support Function No. 8 (FEMA, 2008a). After an incident occurs, requests from the hospital for supplemental personnel, equipment and supplies are all made through the local or regional EOCs to state and federal partners. The hospital planning process should ensure the availability of adequate equipment including radiation survey meters, supplies, and supplemental staffing. Hospitals with nuclear-medicine and/or radiation-oncology departments, and larger hospitals with radiation safety organizations, will have radiation survey meters and staff trained in their use. Existing nuclear-medicine instruments may be useful in assessing internal radionuclide contamination, but this will require establishing protocols in advance of an incident and may include obtaining specialized software. Large medical centers with nuclear-medicine clinics should have instrumentation with the capability to identify the radionuclides from an RDD. These radionuclides are listed in Musolino and Harper (2006).

Planners should ensure that there is adequate hospital surge capability in case of a radiological or nuclear terrorism incident. Any incident will have at least a regional impact, so planners should ensure that there is more than a single hospital prepared to deal with persons injured from the incident, in case a specific hospital is incapacitated or overwhelmed by victims. Hospitals should *not* be the primary receivers of uninjured individuals after a significant radiological or nuclear terrorism incident. Therefore, regional plans should include measures to discourage people not needing urgent medical care from going to hospitals and direct them to CRCs for monitoring and decontamination.

The role of a hospital in a radiological or nuclear terrorism incident is to provide medical treatment for persons with significant injuries from the incident, medically-significant internal contamination, life-threatening radiation doses, or a combination of these. Furthermore, the hospital still has responsibilities to care for those not involved in the incident. It is not the role of hospitals to decontaminate uninjured persons with external radionuclide contamination, except as noted below.

The hospital plan should include security precautions to protect the ED and other critical hospital locations from being overwhelmed by concerned citizens not requiring emergency medical care, as well as to deter terror activities directed at the hospital. Security personnel should be provided at all triage and reception locations, both in the ED and elsewhere, to maintain order.

Specific preparations must be made to handle the inevitable self-referrals of uninjured concerned citizens or slightly-injured people, who may or may not be contaminated. A method for dealing with such people would be to explain to them that, although they will ultimately be surveyed and decontaminated, if necessary, there will be considerable delays. Empower them by providing written instructions for self-decontamination (Appendix F), and encourage them to go home, or refer them to other locations, as determined by emergency management staff.

Each hospital's radiological or nuclear emergency plan should provide for the establishment of an HRDC separate from the ED that would be operational within 1 to 2 h after the hospital is notified of the incident. HRDC should be located away from the ED on or adjacent to the hospital campus to minimize the numbers of people and traffic in and around the ED. The triage function would continue screening persons for injuries or medical conditions requiring ED care, and will be the primary means of such emergent triage, and should not be concerned with handling the uninjured or those who are only contaminated.

The purpose of the HRDC is to receive persons who do not require care by the ED, but who may have minor injuries or medical conditions needing minimal treatment and who may be contaminated. Until CRCs are opened, this center would also receive persons who are concerned about contamination or radiation exposure. A major purpose of the HRDC is to protect the ED from being overwhelmed by people not requiring ED care, who if not redirected would limit or terminate its urgent care capability. The functions of HRDCs are to:

- provide triage for those persons not transported to the hospital by EMS but who may be injured or otherwise need medical evaluation;

- provide, or refer to another hospital location for, minor medical care to people not requiring care by the ED until the AMTS(s) is or are opened;
- survey and decontaminate people with external radionuclide contamination;
- provide radiological triage by performing an initial screening of people who may have internal contamination due to inhalation or ingestion of radionuclides; and
- provide information regarding the risks of radiation exposure.

Those not contaminated should be provided information stating so (including a wrist band, written documentation, or other means verifying that they are not contaminated) and given an opportunity for further follow-up, if necessary. Other services that might be provided by HRDC:

- crisis psychological counseling; and
- collection of samples from or referral to the appropriate locations of those persons needing bioassays for suspected internal contamination.

As part of the decontamination process, HRDCs should be able to provide replacements for contaminated clothing. In addition, the hospital should plan with local emergency management officials to provide transportation, if needed, for members of the general public to CRCs, AMTSs, or other locations.

Recommendation: Essential medical facilities, vehicles such as ambulances, and equipment such as radiation detection instruments should not be taken out of service because of low-level radionuclide contamination.

The threat posed by this contamination can be easily managed, does not pose a significant safety hazard and any radionuclide contamination risk is greatly outweighed by the need to have these critical medical assets available (Section 4.2).

Public announcements after an incident has occurred should provide guidance on self-decontamination and on the availability of TDCs, CRCs, AMTSs, and general and special-needs shelters, when they are ready for operation. However, public announcements should not mention the availability of HRDCs at hospitals to avoid overwhelming them with concerned citizens.

NCRP Commentary No. 19 (NCRP, 2005) defines all hospital staff as emergency responders who, as such, are subject to the occupational dose limits. In most circumstances, especially with an RDD, hospital staff doses should remain below the occupational dose limits. However, Smith *et al.* (2005) raised issues of dealing with the severely injured and those contaminated with radioactive debris including shrapnel. Since the shrapnel may be considered crime-scene evidence, consider the presence of law-enforcement and/or forensic evidence recovery personnel during the surgical removal. Their study showed that there are plausible situations in which special precautions for first receivers are necessary while handling the life-threatening injuries due to an RDD. More information on this subject is available in Smith *et al.* (2005). Of special concern is the potential failure to perform adequate radiation surveys of patients and miss a victim with embedded high-activity shrapnel. In this case the danger to staff from the high exposure rate may go unrecognized. In addition, if high-activity shrapnel is identified, the limited high exposure rate and spatial localization capabilities of current survey meters may limit the ability to locate and remove it in a timely manner. Section 3.2.3 provides recommendations on doses to hospital staff during a radiological or nuclear terrorism incident.

Plans for staffing the hospital during an incident should take into account the possibility that a fraction of the staff may not arrive or may leave because of concern for personal risk or the welfare of their families. The hospital plan should include an activation scheme for obtaining supplemental staff, equipment and supplies in case of an incident. The plan should also include facilities and supplies for feeding and housing hospital staff (and perhaps their family members, if the hospital is used as a staff shelter) who are unable to return home during an incident. Medical Reserve Corps (MRC) or other volunteers may be needed to supplement hospital staff until National Disaster Medical System or other replacements are available. Plans for supplemental staff should include obtaining people capable of using radiation survey equipment, interpreting the readings, and providing guidance regarding decontamination.

Syndromic surveillance systems are designed to capture and analyze health-indicator data to identify abnormal or unusual health conditions or clusters to enable early detection of disease outbreaks. An example of such a system is the CDC Electronic Surveillance System for the Early Notification of Community-Based Epidemics (Lombardo *et al.*, 2004). The implementation of a syndromic surveillance system in the ED, with participation by primary care and specialty physicians, would assist in the early detection of the signs and symptoms of ARS such as fever, nausea, vomiting and skin redness (erythema), especially in incidents involving REDs. The possibility of an RED should be considered if a number of individuals report to several different medical facilities with prodromal symptoms absent any obvious alternative medical diagnosis. Local public-health epidemiology staff could assist in implementing such a system at the hospital and would also be the recipients of this surveillance information.

Hospitals may quickly deplete their medical supplies and, thus, must maintain close contact with local and regional emergency management organizations so that the resources of CDC Strategic National Stockpile (SNS) 12-Hour Push Packages and Vendor Managed Inventory (VMI) can be made available. VMI contains countermeasures for large radiation doses and internal contamination by some radionuclides, addressed in Section 7.5.7, that could be used for some incidents.

The hospital plan should include operational training of the staff of the ED, the persons who will staff the onsite HRDC, and any other supplemental staff. The training should include information regarding management of contaminated patients; facility preparation and decontamination; the risks of radiation exposure and radionuclide contamination as well as methods for coping with the psychological stress of such incidents. The hospital plan should include periodic drills to test and reinforce training and to identify weaknesses in the plan. The staff of the nuclear-medicine department, the medical physics staff of the radiation-oncology department, and the staff of the radiation safety organization are trained in the use of radiation survey meters and should be used to assist the ED, and to assist in staffing HRDCs. The hospital plan should also include the provision of just-in-time training when an incident occurs.

Local and state public-health organizations and local and state chapters of professional organizations with expertise in radiation (*e.g.*, Health Physics Society, American Association of Physicists in Medicine, and Society of Nuclear Medicine) should assist hospitals in training the hospital staff, including those in the ED. Several references are available to assist in developing ED response plans and training aids (Bushberg *et al.*, 2007; HPS, 2008; Mettler and Voelz, 2002). Clinicians should be aware of the signs and symptoms of ARS and know where they could receive just-in-time training after an incident, such as at the Radiation Event Medical Management website (DHHS, 2010) and the 17 min video prepared by CDC entitled, *Radiological Terrorism: Just in Time Training for Hospital Clinicians* (CDC, 2007b).

7.3 Reception Centers Other Than Hospitals

Recommendation: Each community should establish *community reception centers* (CRCs) and *alternative medical treatment sites* (AMTSs) and should be prepared to handle large numbers of potentially-contaminated people, most of whom may have no injuries or noncritical injuries if the incident is not a nuclear explosion.

After an incident of radiological or nuclear terrorism, members of the general public will likely flee from the impacted area and seek assistance and/or shelter (Figure 7.1). Section 3 discusses the recommended actions for emergency responders and members of the general public following such an incident. Depending upon the severity of the incident, many members of the general public will go, or try to go, home and await further guidance from media sources. Others will attempt to go to a hospital to have their medical conditions assessed, whether or not they have actual injuries. Varying numbers of people without significant traumatic injuries may require surveys for radionuclide contamination, decontamination, radiological triage, crisis psychological services, and registration for long-term health monitoring.

CDC has developed the concept of a CRC that would be established to assess affected members of the general public for radiation exposure, perform decontamination, and enroll the victims in a registry for long-term health monitoring (CDC, 2007c). Local authorities should arrange, before an incident, to activate CRCs following an incident. These centers could be located near hospitals and in other community-wide locations. The reception centers should be organized along the lines of the incident command system. (This should not be interpreted as meaning that all components of the incident command system must be staffed).

Public-health and emergency management staff at CRCs will assess people for radiation exposure, survey them for radionuclide contamination, screen them for medical conditions requiring transfer to an AMTS or to a hospital, and enroll them in a community registry. The specific functions of CRCs include:

- provide initial registration of the victims of the radiological or nuclear terrorism incident;
- perform monitoring for external radionuclide contamination, using portal monitors if available;

- perform follow-up surveys of individuals found to be contaminated using hand-held survey instruments;
- provide external decontamination for those found to have radionuclide contamination;
- provide definitive registration for individuals found to have external and/or internal radionuclide contamination;
- provide initial psychosocial evaluations for victims including concerned citizens;
- answer questions and address the immediate concerns of the population;
- provide information and give instructions as to next steps;
- coordinate referrals to AMTSs or hospitals, depending on acuity of medical need;
- screen people for internal contamination due to inhalation or ingestion of radionuclides [may include initial collections of bioassay samples, such as urine (CDC, 2008a)]; and
- provide documentation indicating that a contamination screening has occurred and, if negative, or if the person has been decontaminated, stating so using a wrist band, a hand stamp, or written form.

While not their primary function, CRCs must be prepared to perform medical triage and identify persons who need urgent care, and to coordinate referrals of individuals to AMTSs or to hospitals. More specific details of the operation of a CRC can be found in *Population Monitoring in Radiation Emergencies: A Guide for State and Local Public Health Planners* (CDC, 2007c). In addition, NCRP Report No. 161 (NCRP, 2008) contains information for use by local authorities to develop plans to screen populations for internal contamination.

As soon as feasible, but within 6 to 12 h after a radiological or nuclear terrorism incident, CRCs should be opened in the affected community at safe distances away from the incident site (*i.e.*, for a nuclear terrorism incident, outside of the light-damage zone and not in areas of fallout) (CDC, 2007a; EOP, 2010). However, TDCs, discussed in Section 7.6, could be established in a smaller-scope incident to provide decontamination prior to CRC availability.

Before an incident, planners should identify suitable facilities for CRCs. Facility requirements for CRCs have been described by CDC (2007c). These characteristics include size, location, restroom facilities, shower facilities, accommodations for persons with disabilities, environmental controls against excessive heat or cold, adequate access and egress control (in case of emergency evacuation), security, and parking. Planners should obtain prior permission for use of the facilities in case of an emergency and arrange for access and use in an emergency, both during and outside normal working hours.

Arrangements should be made for multiple CRC sites, as is required for points of dispensing, separated by a distance and located so that an incident is not likely to incapacitate multiple centers. Locating reception centers at or near likely major relocation centers, or shelters is desirable, to facilitate the transport of persons between the relocation centers and reception centers.

CRCs could be co-located with the currently existing emergency preparedness *points of dispensing* for biological incidents. CRCs would be staffed by public-health personnel and trained volunteers such as members of the local community MRCs. Volunteer members with MRCs who are health or medical physicists or otherwise qualified would be essential to conduct the radiation monitoring and decontamination services provided at CRCs and other locations. CRCs may be needed to provide continuous services for several days after an incident, depending on the magnitude of the situation. In addition, AMTSs could also be conjoined or located close to CRCs to provide a specified level of medical care to the victims to keep them out of hospitals.

Because of the need to keep members of the general public away from hospitals, unless they are in need of urgent medical care, CRCs could be co-located with AMTSs. The co-location would be for convenience purposes, less transportation, better security, etc. AMTSs are designated to provide surge capacity for medical care outside of the hospital setting. The primary mission of AMTSs is to handle noncritical patients, those triaged with minor injuries, patients that are psychologically affected by the incident with no other injuries, and the concerned citizens who self-refer to medical facilities. AMTSs would keep those without serious illnesses or injuries from overwhelming hospital capabilities (Schenk, 2006). Well-prepared communities should be able to open AMTSs within 12 to 24 h after an incident. AMTSs would be staffed by federal National Disaster Medical System staff including disaster medical-assistance teams, other federal response teams, state medical-response teams or similar teams, medical and nursing members of MRCs, hospital staff, public health, home health agencies, and others. AMTSs may need to maintain operations for a week or more, depending on the significance of the incident. AMTSs could be replaced by federal medical stations or similar facilities when the federal assets are available (FMS, 2008).

Psychosocial issues will be a significant problem for the affected population and the reception centers should provide counseling and referrals services for large numbers of individuals. Reception center or AMTS staff should be supplemented by behavioral health experts from the local area or more probably from outside the affected area to address (Ansari, 2009; CDC, 2007a):

- post-traumatic stress;
- concern about exposure to radiation;
- stigmatization of those who received radiation exposure;
- anxiety about potential exposure; and
- depression and despair.

AMTSs will most likely be the location for providing more definitive radiological assessments of the victims of the incident including dosimetry for external as well as internal doses, and triage of the subgroup of exposed persons who need decorporation/blocking therapy. Those people are a medical priority but not a medical emergency. Bioassays may be performed by direct measurement such as whole- or partial-body counting; thyroid counting for radioactive iodine; lung counting for inhaled insoluble radionuclides; or by measurement of radionuclides in excreta, most commonly urine. This bioassay capability may be limited to those radionuclides most likely to be used for radiological terrorism. Section 7.7 and NCRP Report No. 161 (NCRP, 2008) provide guidance on such bioassays. Blood studies may also be useful in estimating the radiation doses of the victims. These are briefly described in Section 7.5.5.

Registry medical records would be kept on all AMTS patients that would later be transferred to the public-health department as part of the long-term population monitoring. AMTSs would provide definitive medical care unless hospitalization was required due to the level of radiation dose or for other reasons.

Planners should arrange for portal monitors, radiation survey instruments that can measure alpha and beta and gamma radiation, other equipment, and supplies for the reception centers in order to have the capability to monitor and evaluate contaminated people. This is a locale specific issue to resolve depending on the local capabilities and resources, and the size of the local population that might need to be monitored and evaluated. The supplies should include replacements for contaminated clothing and containers for radioactive waste such as exchanged clothing and discarded PPE worn by the staff. These instruments, equipment and supplies may be stored in stockpiles ready for use; may be obtained from other sources when an incident occurs; or may include limited stockpiles, with provisions for obtaining additional equipment and supplies. If radiation survey instruments are stockpiled, they should receive periodic calibrations, function checks, and replacement batteries.

SNS could be a source of supplemental medical supplies for AMTSs including VMI as a resource for radiological countermeasures. SNS Push Packages should be available anywhere in the United States within 12 h of an incident with VMI available after 24 to 36 h. Detailed plans on AMTS staffing as well as required equipment and supplies have been developed (Schenk, 2006).

Plans for staffing CRCs and AMTSs after an incident should take into account the possibility that a fraction of the staff may not arrive or may leave because of concerns of personal risk or concerns about the welfare of their families or relatives. To minimize this problem, training of staff should include information about the risks of radiation exposure and radionuclide contamination and of methods for preparing their families to cope with such incidents in their absence.

Planners should prepare in advance the text of messages to be released to the media and posted on the internet requesting that specific groups of people affected by an incident go to CRCs first and before being referred to AMTSs, or other appropriate facilities.

Planners should establish activation and deactivation schemes for CRCs and AMTSs. The activation scheme should include the notification of persons who are to staff these locations. Deactivation should include debriefing of the staff. After CRCs and AMTSs have closed, local public-health organizations with the assistance of CDC will continue the process of populating the registry and implementing the long-term health monitoring program (Section 7.7).

After most disaster situations, there are individuals who cannot or will not return to their homes. This may be due to infrastructure issues (*e.g.*, power outages), because their homes are damaged or destroyed, because of transportation issues, or other reasons. Most members of the general public could be accommodated in general shelters. However, certain members of the general public may have medical or other disabilities requiring them to seek assistance in *special-needs shelters*. Local and regional emergency managers must develop plans to open multiple general and special-needs shelters in the community. The American Red Cross and other organizations historically have staffed these shelters, commonly with the assistance of local and regional public-health organizations. In addition, *family-assistance centers* should be established by local and regional emergency management organizations to ensure family members of emergency responders have access to care and security.

7.4 Triage Challenges

Recommendation: Preincident planning is necessary to ensure appropriate triage of the victims of a radiological or nuclear terrorism incident despite possible hindrances such as large numbers of patients with traumatic injuries; medical facilities being overwhelmed by uninjured patients concerned about possible radiation exposure and radionuclide contamination; and medical staff's lack of experience in triage of, and possibly fear of, such patients.

While a radiological terrorism incident may not produce numbers of casualties beyond the range of trauma casualties incurred from the Oklahoma City incident, a nuclear terrorism incident in an urban area will produce mass casualties on the scale of tens of thousands, particularly blast, burn and radiation casualties. An outdoor explosion of an RDD is more likely to produce traumatic injuries, whereas REDs would produce only radiation injuries.

The guiding principle of medical and radiological triage is that treatment of life-threatening injuries is paramount over concerns for radionuclide contamination or radiation exposure (Smith *et al.*, 2005). In the case of an RDD, triage activities will begin at or near the scene of the incident, although many people will likely evacuate the highly contaminated area and those with injuries will require triage elsewhere. For an RED, on-scene triage would probably not take place because of the likelihood that individuals exposed would seek medical care at a variety of venues over an extended period of time. For an IND incident, initial triage should occur outside of the dangerous-radiation zone in the moderate-damage zone. The light-damage zone will have primarily injuries requiring self- or out-patient care (EOP, 2010).

For radiological or nuclear terrorism incidents, victims will likely consist of members of the general public as well as emergency responders. Medical and radiological triage will occur, depending on the situation, on-scene or nearby, and at TDCs, HRDCs, CRCs, and AMTSs. Treatment of life-threatening injuries should take precedence over efforts to assess radionuclide contamination or exposure.

In a mass-casualty situation, there is a paradigm shift in care philosophy from "do the greatest good for each individual" to "do the greatest good for the greatest number." Injuries of moderate severity rather than greatest severity should have priority, and victims are prioritized based on survivability. Until recently, this had been referred to as *altered standards of care* where the philosophy of *standard of care* is replaced by *sufficiency of care* (AHRQ, 2005; Schenk, 2008). However, a recent Institute of Medicine letter report (IOM, 2009a) describes *crisis standards of care* in which there is substantive change from normal healthcare practices due to a pervasive or catastrophic disaster.

The U.S. military has four categories for field triage of patients:

- *Immediate*: A slightly-injured person who can be handled with simple management.
- *Urgent*: The person is at risk for poor outcome if treatment or transportation is delayed.
- *Delayed*: There is no risk to life or limb if specific care is not immediately given.
- *Expectant*: The person is expected not to survive to reach higher medical support without adversely affecting the treatment of higher-priority patients. Palliative care should be provided if feasible. When adequate resources are available, the expectant category does not exist (IOM, 2009a; U.S. Army, 2008).

Four categories of patients for medical and radiological triage will present to emergency responders and decisions will need to be made as to their disposition:

- *Exposed, contaminated, and injured*: Require medical and radiological evaluation, transportation to a medical facility and decontamination;.
- *Exposed and contaminated, but not injured*: Require decontamination and radiological and medical evaluation.
- *Not contaminated, but injured*: Require medical evaluation and transportation to a medical facility.
- *Not contaminated and not injured (concerned citizens)*: May require transport to a reception center and, at least, will need instructions on next steps.

All victims and emergency responders may require psychosocial evaluations at appropriate venues such as CRCs, AMTSs, private physician offices, or public-health facilities, so behavioral health professionals should be made available.

On-scene triage consists of stabilizing injuries and significant medical conditions and transporting the most seriously affected individuals to prepared medical facilities. Ideally, in situations where there are limited numbers of victims, an individual familiar with radiation protection principles should communicate with the receiving medical responders or if possible accompany the injured to provide radiological assistance to the receiving medical responders. The presence of radionuclide contamination may be determined at the scene, en route to the receiving medical facility, or at the medical facility depending on protocols (NCRP, 2001). If possible, decontamination should be performed at the scene of the incident (this may be possible in a small-scale incident), if it does not significantly impede medical care.

A significant proportion of members of the general public at or near the incident location will self-evacuate. They may have minor injuries and may or may not be contaminated. Many will go to their homes, but others will likely go to the nearest hospital, perhaps before the injured arrive *via* the emergency medical system (Smith *et al.*, 2005). TDCs (Figure 7.1) may be able to assist these individuals in a small-scale incident (Section 7.6). Hospital triage outside of the ED should be implemented as soon as possible after the hospital is alerted by the local or regional EOC that an incident with mass casualties has occurred. This is especially true in incidents where contamination concerns need to be addressed so that hospitals can prepare the ED to receive contaminated people.

NCRP Report No. 161 (NCRP, 2008) shows a modified Radiation Emergency Assistance Center/Training Site (REAC/TS) radionuclide exposure decision chart. This decision tree should be the basis of initial radiological and medical triage of victims of any radiological terrorism incident. A new triage model for responding to large-scale radiological or nuclear terrorism incident mass casualties has been developed and is called the *Real-Time Monitoring Response Medical Response System* (Hrdina *et al.*, 2009). This system is a scalable approach to be used to characterize, organize, and efficiently deploy personnel, equipment and supplies as physically close to victims as is safely possible.

Medical and radiological triage may be performed multiple times after an incident at or near the scene, at the designated, prepared and secured area outside a hospital ED (HRDC), inside the hospital ED, at CRCs, at AMTSs, or other facilities set up by emergency-management organizations. The triage hierarchy is as follows:

- *Primary triage*: First triage done at the scene or prehospital setting based on acuity levels of injury, illness or disease.
- *Secondary triage*: Reevaluation of a patient's condition after initial medical assistance at the scene. This may be done at HRDC, in the hospital ED, or at CRCs, AMTSs, or other locations.

- *Tertiary triage*: Reevaluation of a patient's situation after care is given and is ongoing at the hospital, AMTS, or other location.

Copies of all publications prepared by EMS, radiation health responders, or others at the scene of a radiological or nuclear terrorism incident should accompany any transported patients to the hospital, CRC, AMTS, or other locations.

7.5 Treatment Challenges

Recommendation: The local and regional public-health and medical systems should prepare to provide medical treatment to the victims of a radiological or nuclear terrorism incident despite possible hindrances such as inadequate resources for the number of patients, medical facilities being overwhelmed by uninjured patients concerned about possible radiation exposure and radionuclide contamination, and medical staff's lack of experience in and possibly fear of treating such patients. "Crisis standards of care," should be implemented if resources are insufficient to maintain normal standards of care.

7.5.1 *Medical Treatment of Victims*

The ability of a community to medically respond to radiological or nuclear terrorism incidents will depend on the number of casualties and the preparation of a community's public-health and medical-response infrastructure. Preincident planning and exercises with participation of all community partners and agencies are of paramount importance. Public-health and medical-response system planners should prepare for a medical surge; these preparations should address staffing, equipment and supplies.

The management of radiation and combined (radiation and traumatic) injuries can be divided into three stages:

- initial on-scene triage;
- emergency care; and
- definitive care (AFRRI, 2003).

Medical management of victims of an incident begins at the scene. Management of radiation issues is almost always secondary to any medical concerns. Medical triage is always the first phase of the care of any causality.

Emergency care includes medical evaluation and any surgical care required during the first 12 to 24 h after the incident. This emergency care, for an injured individual, begins at the scene, continues during transport, and resumes at the medical facility, most likely a hospital, but possibly an AMTS, depending on the severity of the injury.

Definitive care is usually provided in a hospital where short- and long-term treatment can be provided or the patient is stable enough to be transferred to another facility. Long-term care of radiation injuries would probably occur at specialty facilities designed to provide intensive care, such as cancer centers, burn centers, and trauma centers (Hrdina *et al.*, 2009).

The number of victims that a hospital could expect depends on the specifics of the radiological or nuclear terrorism incident. An RED is likely to produce a variable number of radiation injuries and adequate care of the injured can likely be provided in a well-prepared hospital emergency system, assuming that it takes precautions against being overwhelmed by the uninjured concerned citizens. Depending on the amount of explosives and the type and amount of radioactive material used, an RDD incident could produce no or minimal traumatic and radiation injuries. However, a large-scale RDD incident, especially if there are secondary explosive devices, could produce dozens or even hundreds of traumatic casualties, and perhaps a few radiation injuries that would stress even a well-prepared hospital emergency system. An IND could produce tens of thousands of casualties consisting of blast, burn and radiation injuries.

For mass-casualty situations, *crisis standards of care* come into play due to the inherent limitations in resources that will occur (IOM, 2009a). In this situation, transfer, after stabilization, to another outlying medical facility will be required. As the number of traumatic injuries increases, the priority of treatment for internal radionuclide contamination decreases.

The number of people requiring medical care and/or radiological evaluations perhaps can be divided into the following categories:

- If less than 10 individuals are involved:
  - transport and evaluate/treat everyone at nearest hospital facility.
- If more than 10, but less than 100 individuals are involved:
  - initially transport those most significantly injured to the nearest hospital(s) or other facilities, transport those with no or minor injuries to outlying facilities or other locations;

    - evaluate and treat children and pregnant women at high risk as a priority; and
    - obtain demographics and histories on all in this category.
- If 100 or more individuals are involved (including the tens of thousands of casualties following an IND):
    - transport the most significantly injured but nonfatal to available healthcare facilities especially with priority for children and pregnant women;
    - transport or direct those with no or only minor injuries to HRDCs, CRCs, AMTSs, or other locations; and
    - obtain demographics and history on others.

7.5.2 *Radiological Assessment of Patients*

During the initial interventions by emergency responders after an incident, radiological assessments of patients should be performed. Preferably, these would be performed by individuals with radiological health training. Table 4.2 of NCRP Report No. 138 (NCRP, 2001) provides useful information on these matters.

An on-scene radiological assessment of casualties from a small to medium-scale radiological terrorism incident would follow medical triage, and would be the initial evaluation for radiation exposure and contamination. In radiological triage, an indicator of potential internal contamination is upper-body and/or facial contamination before or after decontamination. However, if the person has been decontaminated or has washed since the incident, absence of external contamination should not lead to the conclusion that the person was not contaminated by the incident. The recent history of when and where the person traveled is another indicator of the probability of internal contamination as some information about the contamination footprint should be known by the time the reception center begins operation.

If contamination is found and the injuries are not critical, the medical personnel should decontaminate the patients and transfer them to the appropriate receiving medical facility. NCRP Report No. 138 (NCRP, 2001), Section 4.3.2, provides guidance for patient radiological assessment.

REAC/TS can provide real-time advice on radiological evaluations and treatment. When requested, a response team including a physician, nurse, and a health physicist can activate within 2 h and deploy to provide on-scene consultation. Arrival time will typically be in the 6 to 12 h time frame depending on the incident location and weather. REAC/TS provides training and continuing education courses in radiation emergency medicine for physicians, physicians' assistants, nurses, emergency medical technicians, health physicists, and emergency responders in the medical management of a radiation incident.

NCRP Report No. 161 (NCRP, 2008) has modified a REAC/TS chart that shows the decision tree for evaluation and treatment of a radiation victim which will be useful in guiding decision makers in handling affected individuals. More information can be found at REAC/TS website (ORISE, 2010).

7.5.3 *Management of Individuals at Community Reception Centers*

In a small-scale incident, if TDCs are activated, uninjured members of the general public who require an evaluation for contamination after an incident should initially be referred to a TDC, given directions on how to self-decontaminate at home, or directly referred to a community reception center (CRC), when available. This would include the concerned citizens who may exhibit varying degrees of behavioral disturbances after such a traumatic incident. At CRC, contamination screening and registration for long-term population health monitoring would be performed, and information would be provided to answer questions from members of the general public such as 'What should I do next?' and 'Will I get cancer?'

External decontamination would be performed at a CRC and this process will be useful in initially categorizing those with possible internal contamination. Those individuals with a high probability of internal contamination include those who have:

- injury or illness due to the incident;
- documented contamination of face, anterior nares, neck, scalp, hair, or chest;
- persistent elevated survey meter count rate over chest and abdomen after decontamination (gamma-emitting radionuclides only);
- elevated count rate in laboratory analysis of urine sample;
- history of prolonged extrication from the severe-damage zone or area of high contamination;
- history of prolonged transit time from the severe-damage zone or area of high contamination without respiratory protection; and
- history of close proximity to the incident.

Those individuals with a lower probability of internal contamination include those who have:

- no detectable external contamination (provided they have not washed and changed clothes);
- no additional high-risk factors from list above; and
- showed external contamination only below the waist.

Those individuals who require special consideration for internal contamination include those who are:

- pregnant;
- children under 15 y of age; and
- shown to have contamination on the interior of the nose or mouth.

7.5.4 *Management of Individuals at Alternative Medical Treatment Sites*

Alternative medical treatment sites (AMTSs) would receive individuals of lesser medical severity than would hospitals and could serve as early as well as longer-term medical care facilities. Other than hospitals, AMTSs are the more likely initial locations where more definitive assessments would be performed for exposure from external sources and internal contamination.

7.5.5 *Diagnosis of Early Health Effects and Assessment of Internal Contamination*

An outdoor explosion of an RDD would not be likely to deliver sufficient doses to people to cause early health effects, except perhaps for a few people close to the explosion who inhale aerosols from the concentrated plume (Musolino and Harper, 2006). Early radiological injuries [*e.g.*, dose delivered in a short time (minutes to hours)] are possible from an incident with an RED. As described in Section 6, early radiological injuries on a large-scale will result from an IND. Time-to-vomiting determinations, making allowances for psychogenic etiologies, would be part of the diagnostic evaluation for external whole-body radiation doses. Serial lymphocyte counts for lymphocyte depletion (available in several hours using most clinical laboratories) as well as lymphocyte cytogenetics (available in several days from specialty laboratories) would also assist such a diagnosis (IAEA, 2001; Parker, 2007). Internal deposition of radionuclides could be determined by appropriate bioassay techniques but would depend on the availability of testing materials, equipment, and trained personnel (NCRP, 2008). Methods such as whole-body counting, lung counting, thyroid counting, and counting of urine samples may be useful after a radiological terrorism incident (Ansari, 2009). Hospitals and AMTSs would be the most likely venues to conduct these types of diagnostic evaluations or collect the samples for transfer to outside specialty laboratories. These evaluations are discussed further in Section 7.7.

7.5.6 *Hospital Management of Radiation Casualties*

Hospital accreditation organizations require all participating healthcare systems to develop plans to prepare for and respond to an incident (TJC, 2005). Many publications (AFRRI, 2003; NCRP, 2001; 2008; Waselenko *et al.*, 2004) provide comprehensive guidelines for the evaluation and treatment of victims with early radiological injuries. REAC/TS would also be available to advise clinicians in handling radiological injuries (ORISE, 2010). In addition, the REMM website (DHHS, 2010) is an online reference source for radiological patient management issues. The Radiation Injury Treatment Network (NMDP, 2010) provides comprehensive evaluation and treatment for victims of radiation exposure and educates specialty care clinicians regarding their potential involvement in a radiological or nuclear terrorism incident (NCRP, 2005; Parker, 2007).

Hospitals should consider how to handle the previously-triaged expectant patients that have been placed in this category due to traumatic and/or radiation injuries. In a mass-casualty situation, a reevaluation of these patients at the hospital could use the following criteria: If individuals are so severely injured that they will die of their injuries, possibly in hours or days (*e.g.*, severe large-area burns, severe trauma, lethal radiation dose), or in life-threatening medical crises (*e.g.*, cardiac arrest, septic shock) such that they are unlikely to survive given the resources available, they should be taken to a holding area and given palliative care, as required, to reduce suffering (Berger *et al*., 2009; IAEA, 2005; IOM, 2009a).

Specialty care would be needed for those with severe ARS or with significant internal contamination. Initially, care for severe ARS may be provided locally, but, subsequently, those requiring such care would probably need to be transferred to tertiary-care facilities out of the region such as cancer centers, burn centers, or trauma centers. Some persons with significant internal contamination, but without other major injuries, could be managed on an outpatient basis.

7.5.7 *Use of Countermeasures*

For high whole-body doses, colony stimulating factors are included in VMI and are available 24 to 36 h after a radiological terrorism incident (Ansari, 2009; CDC, 2008b). NCRP Report No. 161 (NCRP, 2008) provides comprehensive guidance on the use of countermeasures for the internal contamination of individuals with radionuclides. VMI also contains countermeasures, including potassium iodide, Prussian blue [ferric ferrocyanide or ferric(III) hexocyanoferrate(II)], and calcium and zinc DTPA (diethylenetriamine pentaacetic acid) for internal contamination by specific radionuclides.

7.5.8 *Medical Follow-Up of Individuals Exposed to Ionizing Radiation*

Long-term health monitoring of victims of a radiological or nuclear terrorism incident is the responsibility of the local, state or tribal public-health system perhaps with assistance from CDC, especially in developing the population registry. Several reports (CDC, 2007a; NCRP, 2001) provide information on long-term population monitoring for potential health effects caused by ionizing radiation.

7.6 Decontamination

Outside of the dangerous-radiation zone, medical stabilization of the patient is the first priority. The stabilization of life-threatening injuries should never be delayed to address radionuclide contamination of the patient or exposure to the healthcare provider from such contamination. This unequivocal statement differs significantly from the recommendations arising in the chemical and biological hazards communities.

Recommendation: The public-health and medical-response system must be prepared to assess and decontaminate the victims of an incident as soon as reasonably achievable.

It is usually not necessary to immediately decontaminate most victims from a radiological or nuclear terrorism incident, but it is done out of abundance of caution and to alleviate anxiety. Proper decontamination is important to reduce the exposure to the contaminated person; reduce the amount of external contamination that is taken into the person's body by inhalation, ingestion, or other means; prevent contamination of facilities and equipment; and reduce exposure to other individuals including emergency responders. It is also important for individuals who will undergo *in vivo* bioassay procedures (NCRP, 2005). Internal contamination from a radiological or nuclear terrorism incident is unlikely to be the most immediate health risk.

Decontamination is used to remove or reduce to an acceptable level radionuclide contamination of operational personnel and civilian victims. Protection of emergency responders, support personnel, and medical staff is the highest priority. The same decontamination process for potential or actual contamination also applies to members of the general public. Emergency responders should be aware that the decontamination of equipment may also be required. Precautions should be taken to avoid unnecessary spreading of contamination. Some contaminated objects may need to be preserved as evidence. Local, regional and state planners should develop decontamination action levels and protocols prior to an incident.

Emergency responders should be aware that some people arriving from areas with potential radionuclide contamination may require decontamination. The incident commander should establish a decontamination plan and procedures for decontamination of these people, as well as ambulatory- and nonambulatory-injured persons, and uninjured persons, as feasible. In the absence of other hazards (chemical, biological, explosive material, etc.), all reasonable efforts should be made to adequately remove radionuclide contamination from victims. Injured persons should be prioritized for treatment and transported as safely and expediently as possible (Smith *et al.*, 2005).

Emergency decontamination of ambulatory and nonambulatory victims can be accomplished by removing the outer clothing and wrapping or redressing the victim in clean garments. This action can remove most of the contamination on the person (Mettler and Voelz, 2002). Emergency responders should consider the use of sheets, blankets, and disposable clothing (paper or cloth) which allows for continued medical treatment in designated cold zone areas once emergency decontamination is completed.

A scalable approach is required for decontamination planning. Because radionuclide contamination is not likely to be an immediate health threat to the victims, the size of the incident will determine the type of decontamination procedures employed. For a small-scale incident, showering at the scene or at TDCs may be employed. For larger-scale incidents, dry decontamination (*e.g.*, waterless hand cleaner and paper towels) techniques and self-washing of exposed skin and hair may be sufficient for initial decontamination (until an individual is able to shower), which may occur at locations specified by authorities or at home with monitoring and decontamination validation at CRCs or other locations later when specified by authorities.

Ideally, all persons including emergency responders who have radionuclide contamination on the surfaces of their bodies would be decontaminated as soon as possible and in the vicinity of the incident. More than likely, depending on the particular situation, decontamination on-scene would not be feasible and a possible alternative would be self-decontamination at other sites such as at their homes. This would be the situation for large-scale incidents involving hundreds to thousands of individuals who would seek decontamination and whose numbers would overwhelm TDCs, HRDCs, and CRCs. The critical decision point involves reducing radiation exposures by minimizing time spent waiting for decontamination, which could lead to increased skin exposures due to the extended time a radionuclide resides on the skin, or increased quantity of radionuclides inhaled or ingested. Decontamination at home may be the best choice but could result in incomplete decontamination due to the lack of radiation detection equipment to monitor the effectiveness of decontamination efforts, an increased chance of contaminating others, and would probably result in the contamination of home and automobile interiors. Domestic pets and farm animals that may have been exposed to radionuclide contamination should be decontaminated using the same techniques that are applied to humans and plans for their decontamination should be developed. Some people may have their pets with them when they arrive at CRCs and may not agree to leave without their pets as demonstrated in recent mass evacuation events (Basler, 2006).

As discussed above, the ability to decontaminate most or all affected individuals near the scene of the incident decreases with the expanding scope of the incident. In addition to the numbers of people requiring decontamination, weather conditions, the number of personnel and equipment available to perform decontamination, the availability of sufficient and appropriately-sized replacement clothing, and the availability of suitable nearby facilities for decontamination also affect the ability to perform this function and where it should occur.

TDCs could be opened at the discretion of an incident commander or other emergency managers after a small-scale radiological terrorism incident to provide initial decontamination instructions and capability. Alternatively, a TDC could be opened after a large-scale incident to decontaminate a group of people believed to be highly contaminated. Such a facility would be open to handle the uninjured members of the general public who did not need a hospital evaluation and who either cannot, or does not want to go home, or who want an initial decontamination effort before they go home. A TDC would help divert individuals away from hospitals and would provide them with information on next steps such as immediate self-decontamination or home self-decontamination, until a CRC is opened to provide more definitive evaluations. TDCs should be located near the site of the radiological terrorism incident, but upwind, in a building located in a noncontaminated area. Examples of suitable structures include those with shower facilities such as gyms, transportation hubs such as bus or train stations, or other locations with access to water. It may not be feasible to prestock these locations with decontamination supplies but local emergency management organizations should have a list of such locations available for rapid supply of necessary materials. At a minimum, decontamination supplies and capabilities would include running water (preferred, but wet wipes could offer an alternative); printed instructions for self-decontamination; survey meters including pancake probes; and self-decontamination kits that would consist of temporary replacement clothing. If not already in place, these supplies would need to be transported to TDCs by an appropriate agency that may provide initial staffing for the facility such as fire, police, EMS, or public health. TDC should open within an hour of an incident where radionuclide contamination is known or suspected and would remain open until CRCs are established, up to 6 to 12 h after the radiological terrorism incident.

Those leaving the incident scene may go (self-refer) to the nearest hospital. Local and regional hospitals should quickly (in less than 2 h) establish HRDCs away from the EDs, as described in Section 7.2. HRDC will send significantly-injured individuals to the hospital ED. The uninjured, but potentially-contaminated individuals would be provided initial radiological monitoring and/or decontamination, or be sent to a TDC, or to their homes with instructions for self-decontamination. Subsequently, these individuals may be sent home or referred to a CRC or AMTS for further evaluation.

Communities surrounding major cities should plan for the contingency of their citizens, who work in or visit the main metropolitan area, returning in large numbers after a radiological or nuclear terrorism incident. In a large metropolitan area into which people commute using mass transit, mass-transit stations at the periphery of the urban area may be suitable locations to establish decontamination centers. If mass transit is functioning following an incident, decontaminating persons fleeing the incident at or near these stations would avoid contaminating the interiors of their automobiles and homes.

Whenever people are decontaminated away from their homes, they must be provided with replacement clothing. Large numbers of the previously described decontamination kits should be available in the community for rapid placement at decontamination locations. If people are decontaminated at a site other than their homes and the weather is inclement, the people may require sheltering or transportation to a safe location.

If available, portal monitors that people can walk through should be used to quickly survey large numbers of individuals. The monitors should be wrapped in plastic so that loose contamination can be easily and quickly removed (CRCPD, 2006).

It is recommended that planners consider any cultural and religious issues in the community that would affect decontamination of members of the general public. It is recommended that jewelry, personal effects, credit cards, etc., not be taken from victims (CDC, 2007c). These items are important for resumption of normalcy by the general population. It may be prudent to store them in plastic bags for future decontamination if the items are contaminated.

The progress of a potentially-contaminated person should begin in the decontamination zone, with the removal of clothing, and move to the cold zone, where he or she would be issued new clothing and given treatment if needed. Emergency responders should be aware of the potential for spreading contamination to themselves and other response or reception staff and the potential introduction of contaminants into the victim through open wounds and body openings. Once immediate medical treatment is rendered onsite, victims should be wrapped and/or clothed to allow for further evaluation and treatment. When possible, victims should be monitored to determine the level of contamination present. Emergency responders should record monitoring results on patients' available records for medical facility use and review. Victims receiving lifesaving procedures should not be monitored if the effort will significantly impede medical assessment and treatment (Smith *et al.*, 2005). Upon completion of treatment in the cold zone, and prior to rendering additional victim aid, emergency responders should follow standard protocols for self-decontamination prior to treatment of additional victims.

There is no universally-accepted level of external or internal activity above which a person is declared to be contaminated and below which they are deemed to be decontaminated to a safe level.

Recommendation: Decontamination (skin and clothing) should always be performed when the contamination level is >0.1 mR h^{-1} exposure rate (~1 μGy h^{-1} air-kerma rate) at 10 cm, >600,000 dpm cm^{-2} (10,000 Bq cm^{-2}) beta and gamma surface contamination, or >60,000 dpm cm^{-2} (1,000 Bq cm^{-2}) for alpha surface contamination.

The levels of contamination in the recommendation above could represent a hazard from direct irradiation of the skin and/or from intake by inadvertent ingestion, and could indicate that the person has already inhaled or ingested a significant quantity of radioactive material (IAEA, 2006).

Target levels for adequate decontamination should be in the local and regional emergency plans, but may be modified at the time of the response. These levels may be different than "any detectable level of contamination" and depending on the number of people to be monitored may make surveys with this level of detail impractical (CRCPD, 2006; NCRP, 2005). If the incident is smaller and decontamination resources allow, more restrictive guidelines may be adopted, whereas these levels may have to be relaxed for larger incidents if resources are insufficient. To maximize the efficiency of the decontamination process, individuals who have been decontaminated to the appropriate standard should be identified by a wristband, hand stamp, written form, or other convenient method so that there is a visible means of showing that they have been evaluated.

For many victims, decontamination will be psychologically stressful. Therefore, familiarizing people with the steps of the decontamination process will help minimize delays and alleviate their anxiety. People awaiting decontamination should be given a brief document describing the steps to be taken for decontamination. See "Instructions to the Public Waiting for Decontamination at the Scene of the Incident" in Appendix F (LA County, 2009). If there are large numbers of people in the community who are not fluent in English, it is recommended that the instructions be translated in advance, so they will be available in a language that is understood by the person or a family member with the person (CRCPD, 2006).

If there are large numbers of people (>100), emergency personnel should perform a limited screening survey rather than a more detailed survey. It is acceptable to perform only a screening survey of the head, face and shoulders rather than a more detailed survey. Contamination of the head, face and shoulders indicates the possibility of internal contamination (CRCPD, 2006).

The person's location during the incident is likely to be the best indicator of potential internal contamination. Individuals who were outside during the first 15 min, and, who were within the ~1,600 feet (500 m) hot zone described in Section 2 for an RDD are considered high priority to find and screen. Recommendations are the same for alpha-, beta- and gamma-emitting radionuclides. If the survey of the head, face and shoulder area indicates high levels of contamination (>100,000 cpm), it should be assumed that the person has internal contamination (CRCPD, 2006). 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 or other location such as an AMTS (CRCPD, 2006). Plans for the establishment of decontamination facilities should include protocols for radiological monitoring of the established decontamination areas (to ensure that they are not contaminated) and for moving the decontamination facility based on changing radiological conditions if needed.

Section 7.9 discusses handling of deceased persons contaminated with radioactive material. Contamination of deceased persons present special problems in the initial phase of an incident since decision makers must minimize doses to staff while respecting familial and cultural concerns. Special procedures are required for handling deceased persons who may be contaminated with radioactive material. Wood *et al*. (2007) provides guidance on this matter recommending each body be surveyed and, if there is a reading of ≥100 mR h^{-1} exposure rate (~1 mGy h^{-1} air-kerma rate) at 1 inch (2.54 cm), that the body should be moved to a refrigeration unit at least 30 feet (~9 m) from the work area. Bodies with levels less than this value could be sent to a field morgue. If the deceased person is believed to contain radioactive shrapnel, then this should be surgically removed as soon as possible. Since the shrapnel may be considered crime-scene evidence, consider the presence of law-enforcement and/or forensic evidence recovery personnel during the surgical removal. Decontamination may have to wait until forensic examination and victim identification is complete. Personal effects such as watches or rings can be decontaminated and returned to the family.

In summary, if individuals do not require immediate medical attention, they may be decontaminated on-scene, allowed to go home to decontaminate (Appendix F) or otherwise decontaminated depending on the scope of the incident and available resources. Proper decontamination is important to limit the radiation dose of the individual, prevent contamination of facilities and equipment, and to prevent exposure to other individuals. Removal of outer clothing may reduce most of the contamination and wet wiping or showering can remove the majority of the remaining contamination (CRCPD, 2006).

7.7 Bioassays for Internal Contamination and Biodosimetry

7.7.1 *Bioassays for Internal Contamination*

In this Report, the term *bioassay* refers to the assessment of radionuclides in a person's body, called *internal contamination*, either by direct (*in vivo*) means (*e.g.*, whole-body counting or lung counting) or by indirect (*in vitro*) methods (*e.g.*, assays of excreta). Bioassays permit estimation of intakes of radionuclides, the activity in the body, the distribution of a specific radionuclide in the body, and the absorbed doses imparted by the radionuclides. Bioassays can provide information to guide the decision whether to treat a person for an intake of radionuclides and can monitor the effectiveness of such therapy. Treatment for internal contamination is called decorporation therapy and is discussed in Section 7.5.7. This Report only addresses bioassays in the early (emergency) phase of an incident.

The behavior of a radionuclide in the body depends on its chemical and physical form and its route into the body (*e.g.*, inhalation, ingestion, or introduction through a wound). For example, the fraction of an inhaled radionuclide in the form of particles that is retained in the body depends upon the particle size distribution and solubility. Some radionuclides (*e.g.*, those of americium and plutonium in soluble form) are efficiently absorbed into the body if inhaled, whereas, if ingested, are poorly absorbed by the gastrointestinal tract and are almost entirely excreted.

In the early phase after an IND detonation, bioassays are not likely to be of significant utility. Although the number of people with potential internal contamination will likely be very large, the risk from internal contamination is dwarfed by other risks, particularly that of direct exposure to the gamma radiation from fallout. Early treatment guidance (primarily a recommendation that people with access to potassium iodide swallow it) can be issued without bioassays.

For radiological terrorism incidents involving an RDD or the deliberate contamination of food, water, or other consumables, NCRP recommends that plans address bioassays. Although samples of excreta may be collected during the early phase of a radiological terrorism incident for later analysis, the primary purpose of bioassays in the early phase of a radiological terrorism incident is to guide decisions regarding whether to initiate treatment for internal contamination. Treatment for internal contamination is not a medical emergency but is more effective if begun soon after the intake (NCRP, 2008). Highly accurate bioassays are desirable, but may not be possible in the early phase of an incident; prompt but less accurate bioassays may be of greater usefulness in the early phase.

Recommendation: In the early phase of a radiological terrorism incident, the goal of bioassays should be to rapidly provide information to decision makers regarding whether people have received sufficiently large intakes to justify decorporation therapy.

Currently, it is not likely that bioassays can be performed promptly on all or even most people who may have internal contamination from a large-scale radiological terrorism incident. Due to the relatively mild side-effects of most decorporation therapies, a possible strategy is to perform bioassays of a few people and use that information to guide the decision whether to initiate treatment of others whose exposure circumstances are similar. Examples of groups from which samples of people might be assessed by bioassay are people injured by an RDD, people with heavy external contamination on their upper bodies, people who were outdoors in the plume area within a specified distance [*e.g.*, ~1,600 feet (500 m)] when an RDD was detonated, and children and pregnant women who were in the plume area. Indirect bioassays will be useful for early decisions on therapy only if the sample processing turnaround time is short, which would require onsite or nearby processing of samples. Direct bioassay can provide data to support early therapy decisions for some radionuclides.

If the chemical and physical forms of a radionuclide are not known, a single bioassay of a person will not completely characterize the intake or predict the success of treatment. For example, a single-lung or whole-body count can provide an estimate of the activity of a radionuclide in the body following an intake by inhalation, but will not differentiate between an insoluble material, much of which will be retained by the lungs, and a soluble material which will rapidly enter the systemic circulation. The estimation of an intake from a urine count is based upon assumptions regarding the solubility and chemical behavior of the radionuclide.

Thus, in the early phase of a radiological terrorism incident, in which the radionuclide may be known but the chemical and physical forms are unlikely to be fully characterized, bioassays may be helpful in the decision to initiate treatment for internal contamination, but will not guarantee the success of treatment. Additional follow-up bioassays may be performed after the early phase of the incident to confirm the results of the initial bioassays, assess the effectiveness of treatment, and determine whether it should be continued. NCRP recommends that plans for bioassays in the early phase of a radiological terrorism incident focus on radionuclides most likely to be used in such an incident and for which treatments for internal contamination are available. IAEA (2004a) and Musolino and Harper (2006) provide information on radionuclides that are likely to be used.

NCRP recommends that resources available for bioassays, such as whole-body and organ counting systems, in and near each major metropolitan area be identified. Medical, research and nuclear facilities and national laboratories may have such resources. Hospital nuclear-medicine departments commonly have equipment that can be adapted for emergency bioassays for gamma-ray emitting radionuclides with large CDGs[6] such as ^{137}Cs. This equipment includes gamma well counters that may be used to assay samples of excreta, thyroid probes that may be used for lung counting, and perhaps gamma scintillation cameras. If this hospital equipment is to be used for bioassays in a radiological terrorism incident, it should be calibrated in advance for the radionuclides likely to be used in a radiological terrorism incident, bioassay procedures should be developed, and the nuclear-medicine technologist staff should be trained in them. A medical physicist or medical health physicist can perform such calibrations and develop bioassay procedures. Portable radiation survey instruments can be used to estimate the activities in the body of gamma-ray emitting radionuclides with large CDGs. NCRP Report No. 161 (NCRP, 2008) and a new unpublished NCRP report provide more detailed information on equipment that can be used for bioassays (NCRP, in press). A possible role for federal government agencies is to facilitate the availability of sources and phantoms to calibrate hospital equipment for these bioassays.

Performing bioassays for radionuclides with very small CDGs is far more difficult. For example, lung counting for inhaled ^{241}Am requires a sophisticated lung counter in a low background environment and bioassays of excreta for ^{241}Am or plutonium require a sophisticated radiochemistry laboratory and time-consuming sample processing. Where bioassay methods for identifying intakes require significant turn-around time or highly specialized and therefore rare analytical equipment (*e.g.*, chest counting or radiochemistry analysis for ^{241}Am and plutonium), the decision to administer

[6]The clinical decision guide (CDG) was defined to assist physicians in making decisions in treatments to enhance decorporation of radionuclides deposited in the body. CDG is the maximum once-in-a-lifetime intake of a radionuclide that represents: (1) an acceptable stochastic risk, in the range of those associated with dose limits for emergency situations; and (2) avoidance of deterministic effects. A more detailed discussion of CDGs and a table of CDGs for specific radionuclides may be found in NCRP Report No. 161 (NCRP, 2008).

therapy may need to be based on relatively subjective field indications. Radionuclides such as ^{137}Cs and ^{131}I are much more readily detectable using simple radiation surveys and thus lend themselves to more objective therapy decisions based on such measurements.

Problems with bioassays during the early phase of a radiological terrorism incident include contaminating the bioassay equipment; in the case of direct bioassays, mistaking radionuclide contamination on the surface of the body or clothing for contamination inside the body; and, in the case of indirect bioassays, contaminating a sample of excreta with radionuclides from the surface of the person's body or clothing. Thus, a bioassay may indicate much higher intake than actually occurred. Bioassay procedures should incorporate precautions to avoid these sources of error. Such precautions include ensuring the patients have been decontaminated, having clean sample collection kits, and collecting samples in areas free of contamination. If a bioassay indicates an unexpectedly-high intake, it may be wise to repeat it promptly, taking into account these possible sources of error.

Bioassays using urine samples collected within the first 2 h after an intake of radionuclides may significantly underestimate intakes because of urine collected in the bladder prior to exposure diluting the early sample concentration (NCRP, 2008). A more accurate measurement can be obtained by having the person void and collecting a sample later. However, an earlier and less accurate urine sample is better than no sample for guiding treatment decisions, particularly if it demonstrates a large intake.

Information obtained from bioassays in the early phase of an incident will likely have large uncertainties. For example, estimates of intakes from bioassays of urine samples collected within a day after the intake may be in error by a factor of three or more. Physicians using such bioassay data to make treatment decisions should be made aware of these uncertainties.

Therapy for internal contamination affects the behavior of radionuclides in the body and must be considered if performing bioassays after the initiation of treatment. For example, the administration of Prussian blue for ^{137}Cs internal contamination will increase the excretion of cesium into the feces.

NCRP recommends that mechanisms be developed in the planning process so that the limited bioassay information available in the early phase of an incident will be shared with all organizations and institutions assessing and treating people who may have internal contamination. The information to be collected and shared in the early phase should include the results of all bioassays, including bioassays showing no intakes; basic demographic information for each individual, particularly whether an adult or child; and the exposure circumstances of each person receiving a bioassay. Local public-health departments are likely the best organizations to collect and disseminate these data.

7.7.2 *Biodosimetry*

During the early-phase response to an IND, and possibly for an RDD, it is anticipated that some emergency responders could receive significant radiation doses during the conduct of their duties. In addition, members of the general public may experience large doses in an IND incident or as a consequence of exposure to an RED, although few if any would be likely to receive large doses from an RDD. This section provides a brief overview of the application and current capabilities for biological dosimetry, also known as "biodosimetry," (see Glossary) as part of the medical care of individuals exposed during a nuclear terrorism incident.

Methods of biodosimetry available today include: assessment of individuals' signs and symptoms, particularly the time from exposure to onset of vomiting; serial blood counts for lymphocyte depletion (available in several hours using most clinical laboratories); and assays of lymphocyte cytogenetics (available in several days from specialty laboratories) (IAEA, 2001; ICRU, 2002; Parker and Parker, 2007). The estimation of dose from time-to-vomiting is the least accurate and the cytogenetic assays are the most accurate.

The best estimate of LD_{50} (lethal dose for causing death in 50 % of exposed persons) within 60 d in humans is in the range of 300 to 450 rad (3 to 4.5 Gy) (Anno *et al.*, 2003). However, this value can be roughly doubled for people by the use of antibiotics, platelets and cytokine treatment (Anno *et al.*, 2003), so it is important that individuals who actually received whole-body doses >200 rad (2 Gy) be identified. LD_{50} is significantly reduced in people with major burns or other significant injuries. Most individuals, but not all, exposed in the 200 to 500 rad (2 to 5 Gy) dose range would be identifiable due to early nausea, vomiting, and acute fatigue. Biodosimetry could play an important role in this dose range.

There is a narrow dose window, ~700 to 1,000 rad (7 to 10 Gy) (Waselenko *et al.*, 2004), in which bone-marrow transplantation may be considered. For doses <700 rad (7 Gy), survival rates are good solely with medication, but patients receiving doses >1,000 rad (10 Gy) will generally have lethal gastrointestinal damage (Weisdorf *et al.*, 2007). Thus, it may be useful to know if a patient's dose is within this dose window to ascertain whether a bone-marrow transplant would be a useful option.

Mass radiological triage will be important after a large-scale nuclear terrorism incident because of the need to identify, as quickly as possible, those individuals who will benefit from medical intervention, and those who will not. Eliminating and reassuring those patients who do not need medical intervention will be equally important in what will be a highly resource-limited scenario.

Currently, however, the capabilities of biodosimetry are limited and there is no accurate *rapid assessment technique* available for use during the early-phase response to an IND incident. Other groups have recommended a prioritized, multiple-assay, biodosimetric strategy for use in response to a nuclear terrorism incident (Alexander *et al.*, 2007). While the usefulness of biodosimetry, as outlined above, is recognized by the scientific community as an important research and development area (Blakely *et al.*, 2009; Garty *et al.*, 2010; Pellmar *et al.*, 2005), it is also clear that the capability to conduct such a mass radiological triage during the early-phase response to an IND terrorism incident will be limited (perhaps wasteful of valuable resources) and could divert the attention of the emergency responders from their mission critical duties.

7.8 Population Monitoring

Recommendation: The public-health system must be prepared to monitor individuals and the community for exposure to or contamination from radioactive material, to prevent short- and long-term health effects.

Population monitoring, also known as public monitoring, describes the effort, after a radiological or nuclear terrorism incident, to identify, screen, measure and monitor affected people and perhaps their pets, for exposure to and contamination from radioactive material (NCRP, in press). Population monitoring begins essentially immediately after an incident with an initial on-scene evaluation and would continue at TDCs, HRDCs, hospital EDs, CRCs, AMTSs, and, subsequently, by local, regional, state or tribal public-health authorities as part of a long-term registry.

Specifically, population monitoring is instituted after a radiological or nuclear terrorism incident and continues until all potentially-affected members of the general public (and emergency responders) have been assessed (using the six action steps below) (CDC, 2007c):

1. needed medical treatment;
2. the presence of radionuclide contamination on the body or clothing;

3. possible internal deposition of radionuclides;
4. decontamination of external and/or internal radionuclides;
5. determination of possible radiation dose received from exposure to external and/or internal sources of radioactive material and an evaluation of immediate health risks; and
6. establishing protocols to monitor for potential long-term health effects.

Provision of the six action steps above should be implemented as rapidly as possible after a radiological or nuclear terrorism incident. Involvement of the public-health system is needed in the early phases of the response so that long-term health effects can be followed using a population registry and epidemiologic studies lasting for decades.

The population to be monitored is comprised of individuals in the immediate vicinity of an incident. In addition, those individuals at variable distances downwind of the incident site may require assessment and monitoring. Secondarily, monitoring may extend to the pets of these individuals who also may have come in contact with the radionuclide. However, the concept of population monitoring as prescribed by CDC does not include the assessment of facilities, farm animals, vegetation, or the food supply. These last four categories have existing plans and are under the authority of EPA, U.S. Department of Agriculture, and the U.S. Food and Drug Administration.

To provide population monitoring after an incident such as an RDD, specific monitoring instruments are needed to survey for radionuclide contamination on the human body (external contamination). To assess internal contamination bioassays using whole-body counters, organ-specific counters, or assays of excreta may be required. However, techniques are being developed in which readily available radiation survey equipment will be capable of providing an approximate estimate of internal contamination in a less clinical environment. It is unlikely that an RDD would deliver lethal or near lethal radiation doses to victims outside the ~1,600 feet (500 m) zone described in Section 2. For an RED, lethal or near lethal levels are possible depending on the specific situation. But, external or internal radiation monitoring techniques will not provide useful information. For an IND, those in the severe-damage zone will, in most cases, receive fatal radiation doses or fatal traumatic injuries. Further away from ground zero, there will be reductions in radiation doses from the initial release of radiation but consideration of downwind fallout exposures must be included. In these cases, additional assessments may be needed using available methods to determine external and internal doses (AFRRI, 2007; NCRP, 2008; Waselenko *et al.*, 2004).

CDC states that the following actions are required after a radiological or nuclear terrorism incident (CDC, 2007c):

- identify victims from the incident (emergency responders and members of the general public) whose immediate health may be in danger and who require care due to critical injuries or other significant medical needs, or require decontamination;
- determine affected individuals (emergency responders and members of the general public) who need medical care for internal and/or external radiation exposure/contamination, continued evaluation, or short-term health monitoring;
- counsel affected individuals regarding their risks for long-term health effects (*e.g.*, cancer); and
- implement, using public-health resources, a population registry to provide long-term health monitoring.

DHHS has designated CDC as the lead federal agency for population monitoring. The duties of this designation are described in NRIA (FEMA, 2008b). DHHS, through Emergency Support Function No. 8 (of NFR), Public Health and Medical Services and in consultation with the coordinating agency, coordinates federal support for external monitoring of people. Under NRIA, CDC is responsible for assisting local, state and tribal governments in monitoring people for internal contamination. CDC is also responsible for supporting local, state and tribal governments in decontaminating people who are internally contaminated by providing guidance on provision of countermeasures that can increase the rate of removal of radionuclides from victims (CDC, 2008a). CDC will also assist local, state and tribal health departments in creating a registry of people who might have been exposed to radiation from the incident and help determine how much dose they may have received.

7.9 Handling Contaminated Waste

A radiological or nuclear terrorism incident may generate large quantity of radioactive waste, which must be handled appropriately. This waste will likely include contaminated debris, clothing, waste water, and other material. Most is expected to be of the type classified as low-level radioactive waste. However, high activity waste materials may be present, for example, as shrapnel after an RDD. In the case of a nuclear terrorism incident (*e.g.*, IND detonation), after 2 d, the levels of activity in the contaminated material will have decreased significantly due to radioactive decay.

Initially, radioactive-waste issues are secondary to provisions of lifesaving and critical infrastructure sustainment activities by emergency responders. Concerns regarding contaminated water runoff from decontamination of people and critical equipment should not impede decontamination efforts (EPA, 2008a). This subsequently will become a significant problem whose solution must still be determined by governmental authorities.

Disposal of radioactive waste is a complex issue, not only because of the nature of the waste, but also because of the complicated regulatory structure for dealing with radioactive waste. There are a variety of stakeholders affected, and there are a number of regulatory entities involved. Federal agencies involved in radioactive-waste management include EPA, NRC, DOE, and the U.S. Department of Transportation. In addition, the states and affected tribes play a prominent role in protecting members of the general public against the hazards of radioactive waste (EPA, 2008a).

In cases in which no agency or state is responsible for the radioactive waste involved in a terrorism incident, EPA assumes the coordinating federal agency role from DOE for the environmental cleanup and site restoration phases of the response (EPA, 2008b; FEMA, 2008b). The U.S. Department of Defense and the U.S. Army Corps of Engineers may have some responsibility for environmental remediation after a radiological terrorism incident.

If possible, radioactively-contaminated clothing obtained from individuals during decontamination should be appropriately packaged and labeled (name, location, time and date, and marked clearly with: RADIOACTIVE – DO NOT DISCARD). This clothing may be needed later for criminal forensics and/or for a dose reconstruction project. The scope of the incident (*i.e.*, small- versus large-scale RDD or IND), and the resources available, will determine the feasibility of this action.

Packaging of radioactive waste should be addressed by planners. The question of who will handle the radioactive waste and what PPE they will require also should be addressed. Packaging of waste should occur at all locations where decontamination may take place such as on the scene of the incident, TDCs, hospital reception (triage) and decontamination centers, hospital EDs, CRCs, or other locations. In addition, many individuals will go home to decontaminate; in large-scale incidents this may be the preferred advice provided to members of the general public. In this event, written instruction on home decontamination should be distributed to individuals and through the media. Planning should address how to handle presumably contaminated clothes, automobiles and homes as the timeline of the incident unfolds. Possibly, commercial radioactive-waste handling companies could be contracted to dispose of the radioactive waste.

7.10 Handling Contaminated Deceased Persons

Recommendation: Planners should ensure that deceased victims of a radiological or nuclear terrorism incident, who may be contaminated with radioactive material, are handled safely and appropriately.

Radiological terrorism may produce a relatively small number of deceased persons with radionuclide contamination, whereas an IND explosion in a populated area will result in large numbers of contaminated injured and fatal casualties. For medical examiners and mortuary personnel, it is important to control contamination in the work area, thereby minimizing risk to these workers. Decision points are needed for handling deceased persons with loose surface contamination, internal contamination, or shrapnel on or in deceased persons (Wood *et al.*, 2007).

There are two federal Disaster Mortuary Operational Response Teams (DMORTs) under the National Disaster Medical System as part of DHHS:

- Office of Preparedness and Response, under Emergency Support Function No. 8; and
- Public Health and Medical Care (FEMA, 2008a).

The function of DMORTs is to provide victim identification and mortuary services (DHHS, 2008). DMORT responsibilities include:

- temporary morgue facilities;
- victim identification;
- forensic dental pathology;
- forensic anthropology methods;
- processing;
- preparation; and
- disposition of remains.

DMORTs are composed of private citizens, each with a particular field of expertise, who are activated in the event of a disaster. During an emergency response, DMORTs work under the guidance of local authorities by providing technical assistance and personnel to recover, identify and process deceased victims. Teams are composed of funeral directors, medical examiners, coroners, pathologists, forensic anthropologists, medical records technicians, transcribers, finger-print specialists, forensic odontologists, dental assistants, x-ray technologists, behavioral health specialists, computer professionals, administrative support staff, and security and investigative personnel (DHHS, 2008).

The FEMA Response Division, in support of DMORT program, maintains two disaster portable morgue units. A disaster portable morgue unit is a depository of equipment and supplies for deployment to a disaster site. It contains a complete morgue with designated workstations for each processing element and prepackaged equipment and supplies (DHHS, 2008).

Persons involved in radiological or nuclear terrorism incidents are likely to be contaminated, perhaps heavily, so their bodies may remain contaminated after their death. Although dose rates from even relatively-high levels of contamination are not likely to be significant, certain precautions are still recommended. High radiation levels from deceased persons after an IND will quickly decay allowing access to the remains after a matter of days. In particular, all persons handling contaminated bodies must take appropriate measures to minimize their doses using the ALARA principle, and the deceased persons should be treated in such a way as to minimize the spread of contamination (Section 7.6). Many of these precautions are similar to those that would be taken due to standard (blood-borne) precautions (NCRP, 2008).

Although there are laws regulating the medical use of byproduct material in patients (NRC, 2006), there are no federal regulations concerning radioactive material on or in human remains. Guidance is available on handling radioactively-contaminated deceased persons from medical sources (NCRP, 1991), from transportation accidents (DOE, 2000), and by the military (JCS, 1997). Each state has policies for transporting deceased persons and there are federal regulations for shipment of radioactive material (DOT, 1977). Guidelines are available for dealing with contaminated deceased persons from the National Association of Medical Examiners (NAME, 2006).

Radionuclide contamination can be found externally on clothes and skin, internally lodged in organs, or present as shrapnel in bodies. Most external radionuclide contamination is likely to be eliminated by removing clothes and rinsing the exposed skin (Hanzlick *et al.*, 2007). Section 7.6 discusses the issue of decontamination in greater detail. Internal contamination usually occurs in a living person by breathing contaminated air or ingesting contaminated foodstuffs. Intake of radioactive material stops upon the person's death. After death, the internal contamination cannot be removed from the body but is usually not hazardous to emergency responders such as the medical examiner's staff. However, small pieces of radioactive material embedded in tissue by the force of an explosion (shrapnel) could emit enough radiation to cause emergency responders including medical examiners and their staff to exceed occupational dose limits or experience deterministic effects (Smith *et al.*, 2005). NCRP recommends early surveying of the bodies for radiation levels and quantity of contamination so that this material can be surgically removed during initial evaluation by the medical examiner (Wood *et al.*, 2007).

NCRP Commentary No. 19 (NCRP, 2005) defines emergency responder to include healthcare staff involved in forensic investigations and who, as such, would be subject to the effective dose limit set for such workers (NCRP, 2005). Mortuary or funeral-director staff may be designated as emergency responders and would then be subject to an effective dose limit of 5 rem y^{-1} (50 mSv y^{-1}) (NRC, 1993).

As stated above, there are no specific laws regulating the proper handling of deceased persons contaminated with radioactive material, nor is there a specific right or wrong procedure. Medical examiners, coroners, funeral directors, and health physicists will have to devise working methodologies for each situation. The objectives, in priority order, are (Wood *et al.*, 2007):

- *Deterministic effects will be avoided*: If workers keep their doses below the annual occupational dose limit (NRC, 1993) they will not incur any deterministic effects. Medical examiners or coroners will perform a professional medical and legal investigation to identify deceased persons scientifically and determine the cause and manner of death. Medical examiners will receive some radiation exposure performing their work both at the scene and in the morgue. They are classified as emergency responders and would be subject to appropriate dose limits set for this classification.
- *Human remains will be treated with dignity and respect*: Human remains will be processed as expeditiously as possible and released to the families. If bereaved family members want a funeral with a viewing or the religious practice of the decedent calls for a ceremonial washing, this will be allowed even though it causes some additional radiation exposure. Informed consent would be needed so that individuals, other than the emergency responder, were aware of the increased risk of these practices, as feasible.
- *Medical examiners will minimize the spread of contamination*: Deceased persons will be transported to a field morgue with clothing and personal effects intact, even though

this may spread contamination. However, the practices employed in the morgue will prevent any further spread.

- *Radiation exposures should be optimized for maximum protection of human health*: No one should receive a radiation exposure unless there is some benefit. Conducting a proper investigation is required by law, and respecting the religious or emotional needs of the bereaved family is a benefit.
- *The bodies of deceased victims may contain crime-scene evidence*: Law enforcement may be expected to work closely with the medical examiners to preserve vital crime-scene evidence.

7.11 Recruitment and Credentialing of Supplementary Personnel

Acquiring an adequate number of medical, nursing, radiation safety, and other professionals to staff TDCs, CRCs, AMTSs, hospitals, and other locations in a disaster situation may be quite challenging. Current planning calls for a variety of trained professionals and volunteers, both local and from outside the region, being utilized to cover staffing shortages. It is necessary to ensure that these individuals are properly qualified and *credentialed* for the work they will be asked to perform.

Recommendation: Ensure that physicians, nurses, radiation safety staff (radiologic technologists, nuclear-medicine technologists, medical physicists, and health physicists), and other professionals who will augment the staff at hospitals, AMTSs, CRCs, and other sites are credentialed and have identification documents.

All public-health and medical responders should be credentialed. Hospital, public-health, and other medical staff should have appropriate credentialing. However, supplemental staff should be credentialed based upon existing standards.

A credentialing process must be established with local access capability by administrative personnel at the victim receiving venues such as hospitals and with local, state and tribal public-health authorities. Many states have laws that waive certain credentialing requirements during disasters while others use gubernatorial disaster declarations to provide relief from some regulations governing staff qualification requirements.

The DHHS Office of the Assistant Secretary for Preparedness and Response has developed the *Emergency System for Advance Registration of Volunteer Health Professionals* to establish a national network of state-based programs that facilitate the use of health-professional volunteers in local, regional, state, tribal and federal emergency responses. Under this program, most states have developed emergency-health volunteer registries that are involved with the recruitment, advanced registration, licensure and credential verification, assignment of standardized credential levels, and mobilization of volunteers.

MRC, a component of DHHS Citizen Corps, is a readily available locally-sponsored entity found in many communities nationwide that provides preparedness and response training and increased capabilities for health professionals and others including radiation professionals (MRC, 2008). MRCs are commonly located within local public-health departments and, as such, the volunteers are, when activated, considered employees of that organization (Ansari, 2009). Training in the incident command system, public health preparedness, and other topics is available to MRC members. Just-in-time training would be provided as needed.

The healthcare accrediting organizations require facilities such as hospitals to have specific protocols for emergency credentialing. These systems, along with other credential verification procedures, should be used in the interim for any disaster activations. Federal assignees such as those with the National Disaster Medical System as disaster medical-assistance teams or as state medical-response teams or the like will be already credentialed. Local, state and tribal public-health and other government employees will likewise be credentialed through their sponsoring agency. At a minimum, the credentialing process should be able to verify the following information:

- name;
- address and contact information;
- agency affiliation;
- licensure;
- level of training;
- level of experience;
- any pending legal action, and
- qualification for assigned task.

Individuals arriving at the scene of an incident or to any specific venue requesting to assist should be directed to the incident command operations branch that handles these types of volunteers. If they are from the same state, then those who have registered with that state's emergency-health volunteer registry can be readily identified and credentialed onsite by contacting the state registry. The state licensure of those licensed by the same state but who have not registered can be verified by that state's health department or other licensing agency. Ideally, out-of-state volunteers who have registered with their own state's emergency registry could have their credentialing information verified by a state-to-state registry communication, if available. Currently, volunteers from other states who are not registered will be difficult to credential and their status will depend on individual state laws and local authority discretion until uniform credentialing procedures are adopted.

Because of the problems associated with credentialing interstate and even intrastate healthcare professionals after Hurricanes Katrina and Rita, the Uniform Emergency Volunteer Health Practitioners Act (UEVHPA, 2007) was developed by the National Conference of Commissioners on Uniform State Laws. This Act was developed to establish uniform procedures across all states who adopted this as law to facilitate the deployment and use of licensed health professionals to provide health and veterinary services in response to a declared disaster. The public and private sector healthcare professionals covered by this Act would be used to supplement the resources provided by local, state and tribal government employees and other emergency responders. The specific provisions of the Act:

- establishes a system for the use of volunteer health practitioners capable of functioning autonomously even when routine methods of communication are disrupted;
- provides reasonable safeguards to ensure that volunteer health practitioners are appropriately licensed and regulated to protect the health of members of the general public;
- allows states to regulate, direct and restrict the scope and extent of services provided by volunteer health practitioners to promote disaster recovery operations;
- provides limitations on the exposure of volunteer health practitioners to civil liability to create a legal environment conducive to volunteerism; and
- allows volunteer health practitioners who suffer injury or death while providing services pursuant to this Act the option to elect workers' compensation benefits from the host state if such coverage is not otherwise available (UEVHPA, 2007).

After verification of credentials, they would then be issued identification documents to facilitate access to the site where they are needed and integrated into the response. Documentation of individuals staffing facilities after a radiological or nuclear terrorism incident should be performed so that long-term health monitoring can occur following any work-related exposure.

Appendix A

Employer and Emergency Responder Responsibilities

Most personnel engaged in the response to a radiological terrorism incident (*i.e.*, the *emergency responders*) who may incur radiation exposures shall be considered occupationally-exposed *workers*. Organizations that employ them are termed *employers*. Both workers and employers should be subjected to requirements of occupational radiation protection standards. Examples of emergency responders include firefighters and examples of employers are firefighting departments. Voluntary *comforters* are usually not considered "workers" and are therefore not subject to the occupational requirements of radiation protection standards [they are subject to the dose limit for members of the general public [*i.e.*, 100 mrem y^{-1} (1 mSv y^{-1}) effective dose]. However, any dose to individual comforters incurred knowingly while voluntarily helping in the care, support or comfort of victims shall be specifically constrained to prevent or minimize radiation exposure.

In general, under routine, nonemergency-response operations, occupational radiation protection responsibilities of employers and emergency responders are as follows.

Employers shall be responsible for:

- protecting the emergency responders and complying with relevant requirements of the occupational radiation protection standards, ensuring in particular that:
  - occupational doses are limited as specified in the relevant requirements; and
  - occupational doses are consistent with the ALARA principle.

- ensuring that decisions regarding measures for occupational protection and safety be recorded and made available to emergency responders;
- establishing policies, procedures, and organizational arrangements for protection and safety to implement relevant requirements, with priority given to measures for controlling occupational exposures;
- providing suitable and adequate facilities, equipment and services for protection and safety, the nature and extent of which are commensurate with the expected magnitude and likelihood of the occupational exposure;
- providing necessary health surveillance and health services;
- providing appropriate protective devices and monitoring equipment and arranging for their proper use;
- providing suitable and adequate human resources and appropriate training in protection and safety, as well as periodic retraining and updating as recommended in order to ensure the necessary level of competence, keeping records of the training provided to individual emergency responders;
- consultation and cooperation with emergency responders with respect to protection and safety, about all measures necessary to achieve the effective implementation of requirements;
- promoting a safety culture, which is defined as the collective actions and attitudes of an institution and its workers which elevate the priority of safety issues to the proper level and encourage the adoption of the best available safety technology and standards-of-practice (NCRP, 2009);
- in consultation with emergency responders, developing and writing procedures as are necessary to ensure adequate levels of protection and safety, including values of any relevant dose level that require investigation or specific authorization and the procedure to be followed in the event that any such value is exceeded; making such procedures and their protective measures and safety provisions known to those emergency responders to whom they apply;
- supervising any work involving occupational exposures and ensuring that all reasonable steps are taken to ensure that the regulations, procedures, protective measures, and safety provisions are observed;
- providing information on the health risks due to potential occupational exposures that may occur during such responses, instruction and training on protection and safety,

and information on the significance for protection and safety of response actions;

- obtaining, as a precondition for engagement of emergency responders, the previous occupational exposure histories of such emergency responders and other information as may be necessary to provide protection and safety;
- taking administrative actions as are necessary to ensure emergency responders are informed that protection and safety are integral parts of a general occupational health and safety program in which they have certain obligations and responsibilities for their own protection and the protection of others, and in particular record any report received from an emergency responder that identifies circumstances which could affect compliance, and take appropriate action;
- arranging for the assessment of occupational exposures of emergency responders, on the basis of personal monitoring where appropriate, and ensuring that adequate arrangements are made with appropriate dosimetry services under an adequate quality-assurance program;
- arranging for appropriate health surveillance, if needed post-incident, based on the general principles of occupational health and designed to assess the initial and continuing fitness of emergency responders for their intended tasks;
- maintaining exposure records for each emergency responder, which shall include:
  - information on the general nature of the work in the response involving occupational exposures;
  - information on doses, exposures and intakes at or above the relevant recording levels and the data upon which the dose assessments have been based;
  - when an emergency responder is or has been occupationally exposed while in the employ of more than one employer, information on the dates of employment with each employer and the doses, exposures and intakes in each such employment; and
  - records of any doses, exposures or intakes due to other emergency interventions or accidents.
- providing for access by emergency responders to information in their own exposure records and for access to the exposure records by the supervisor of the health surveillance program and facilitating the provision of copies of emergency responders' exposure records to new employers when emergency responders change employment, and preserving such records during the emergency responder's

working life and afterwards; at least until the worker attains or would have attained the age of 75 y, and for not less than 30 y after the termination of the work involving occupational exposure; and

- facilitating compliance by emergency responders with the occupational radiation protection requirements.

Emergency responders shall be responsible for:

- following any applicable regulations and procedures for protection and safety specified by the employer;
- accepting such information, instruction and training concerning radiological protection and safety to enable them to conduct their work in accordance with the requirements of occupational radiation protection standards;
- using proper personal monitoring devices and protective equipment and clothing, as necessary;
- cooperating with the employer with respect to protection and safety and the operation of radiological health surveillance and dose assessment programs;
- providing to the employer information on their past and current work as is relevant to ensure effective and comprehensive protection and safety for themselves and others;
- abstaining from any willful action that could put themselves or others in situations that contravene the requirements; and
- reporting to the employer, as soon as feasible, circumstances that could adversely affect compliance with the standards, if for any reason a worker is able to identify such circumstances (*e.g.*, lifesaving activities involving radiation doses exceeding the occupational limits).

Conditions of service for emergency responders shall be independent of the existence or the possibility of occupational exposure. Special compensatory arrangements or preferential treatment with respect to salary or special insurance coverage, working hours, length of vacation, additional holidays, or retirement benefits shall neither be granted nor used as substitutes for the provision of proper protection and safety measures to ensure compliance with the requirements of the relevant occupational radiation protection standards. The notification of pregnancy or nursing shall not be considered a reason to exclude a female emergency responder from work, However, the employer of a female emergency responder who has notified her employer in writing of her pregnancy should ensure that the embryo or fetus, or the nursing infant is afforded the same broad level of protection as recommend for members of the general public.

For the extreme situations that may likely occur after a radiological or nuclear terrorism incident, the following actions are recommended:

- For emergency responders undertaking rescue operations that involve saving life, no dose restrictions are recommended. In these instances, applying the ALARA principle is viewed as making every reasonable and practical effort to both maintain doses to radiation below the levels that cause early health effects, and to reduce the risk of stochastic effects, so as to maximize lifesaving and protection of critical infrastructure.
- Otherwise, for rescue operations involving the prevention of serious injury or the development of catastrophic conditions, every effort should be made to prevent deterministic effects on health.
- For emergency responders undertaking other immediate and urgent rescue actions to prevent injuries or large doses to many people, all reasonable efforts should be made to keep absorbed doses consistent with the ALARA principle.

Rescuers undertaking actions in which the effective dose may exceed 5 rem (50 mSv) should be volunteers, and should be well prepared for dealing with the effects on the health of emergency responders (*i.e.*, they should be clearly and comprehensively informed in advance of the associated health risk) and, to the extent feasible, be trained in the actions that may be recommended, including the use of protective measures such as PPE, means of shielding, and use of medical countermeasures (if warranted) (IAEA, 1996).

Appendix B

Public Information Statements

B.1 In the Event of a Radiological Dispersal Device

RDD: Public Information Statement No. 1

(Can be used immediately after the explosion, as soon as the fire department arrives and detects radiation.)

There has been an explosion at __________ [*site of explosion*]. Fire and police personnel are on the scene. A radionuclide was spread by the explosion. People should stay away to facilitate response efforts and reduce the possibility of radiation exposure from this incident. We request that people avoid using telephones, including cell phones, to ensure lines are available for emergency responders.

We will provide a follow-up message on this issue in 1 h or sooner if additional information becomes available. This follow-up message is estimated to be issued not later than __________ [*e.g., give time as X:XX am/pm*].

RDD: Public Information Statement No. 2

(Can be used when additional information is available.)

There has been an explosion at __________ [*site of explosion*]. The fire, police and health departments are on the scene. A radionuclide was spread by the explosion. This was NOT a nuclear bomb. The highest levels of radionuclide contamination are in the area near the explosion, but we will be determining if the activity has traveled from the site of the explosion. Members of the general public should stay away to facilitate response efforts, and to reduce the possibility of radiation exposure from this incident.

Although we do not have evidence that radioactive material has spread beyond the area near the explosion, the wind may have carried small quantity away from the site of the explosion. As a precaution, people should stay indoors for their personal safety. If you are located [*north, south, east, west*] of __________, and within __________ miles of the explosion, you should close the doors and windows and turn off fans that bring in air from the outside. In-room fans that only recirculate air are OK to use. Air conditioning systems that do not bring in air from the outside may be operated. If you are in a large building [*office, retail, industrial or other*] you should move to the center of the building and the maintenance staff should put the system on "recirculation."

To minimize your risk of radionuclide contamination, those who were at the __________, [*explosion site*] or outdoors since __________ [*time of the explosion*] in the __________ area, are advised to change clothes and place the clothes you had been wearing in a plastic bag. As most of the contamination will be on your clothes, removing the clothing reduces any contamination by ~80 to 90 % depending on the amount of the body covered by clothing. Place the plastic bag in a garage, or other remote location. If possible, take a shower with warm, not hot, water and gently wash your body and hair with ordinary soap and shampoo that does not contain a conditioner. Do not apply conditioner after you have washed your hair. Children, if home, should also be given a shower or bath under supervision of a parent or other adult. Again, we recommend you stay indoors. If we determine that you would be safer in another location, we will advise you where to go. You should not go to a hospital unless you were injured in the explosion, or have another medical emergency requiring immediate treatment, such as a heart attack.

If you have a pet that was outside, the pet can be washed as you normally would wash the pet, but inside, either in your shower or bathtub, or in a tub. Be sure to take a shower yourself, after you have washed the pet.

You may drink or bathe in the water from your faucet. You may eat the food in your house. Food that was outdoors since __________ [*time*] today, within a few miles of __________ [*explosion site*] may need to be avoided.

We request that members of the general public avoid using telephones, including cell phones, to ensure lines are available for emergency responders. We also request that the media not fly over the scene so that airspace is available for emergency air responders, and to reduce air movement around the scene.

We will continue to monitor the area to establish the extent of radionuclide contamination to ensure the safety of members of the general public. You should listen to the radio or television for announcements; following the instructions from public officials will best ensure your safety. We will provide a follow-up message on this issue in 1 h or sooner if additional information becomes available. This follow-up message is estimated to be issued not later than __________ [*e.g., give time as X:XX am/pm*].

RDD: Public Information Statement No. 3
(Can be delivered within a few hours of the incident.)

There has been an explosion at __________ [*site of explosion*]. The fire, police and health departments are on the scene. A radionuclide was spread by the explosion. This was NOT a nuclear bomb. People should stay away to facilitate response efforts, and to reduce the possibility of radiation exposure from this incident.

Over the last hour we have determined that some radioactive material was carried __________ [*north, south, east, west*] of the explosion site by the wind. At this point, we do not know the extent to which the winds have carried the radioactive material, so we continue to advise people to stay indoors for their personal safety. As a precaution, if you are located within __________ miles (__________ km) __________ [*north, south, east, west*] of __________ [*explosion site*], you should close the doors and windows and turn off fans that bring in air from the outside. In-room fans that only recirculate air are OK to use. Air conditioning systems that do not bring in air from the outside may be operated. If you were at __________ [*explosion site*] when there was an explosion but have left and are not yet home, you may either continue home and shower there, or go to __________ [*evacuation location(s)*].

To minimize your risk of radionuclide contamination, those who were outdoors since __________ [*time of the explosion*] and within __________ miles __________ [north, south, west, east] of the __________ [*location of the explosion*] are advised to change clothes and place the clothes you had been wearing in a plastic bag, which will likely reduce any contamination by ~80 to 90 % depending on the amount of the body covered by clothing. If possible, take a shower with warm, not hot, water and gently wash your body and hair with ordinary soap and shampoo that does not contain a conditioner. Do not apply conditioner after you have washed your hair. Again, we recommend you stay indoors. If we determine that you would be safer in another location, we will advise you where to go. You should not go to a hospital unless you were injured in the explosion or have a medical emergency requiring immediate treatment, such as a heart attack. Right now, the safest place for you is indoors.

You may drink or bathe in the water from your faucet. You may eat the food in your house. Food that was outdoors since __________ [*time*] today, within a few miles of __________ [*explosion site*] may need to be avoided.

We have received questions about using potassium iodide (KI) pills. KI is not useful for the radionuclide used in this explosion and will not provide protection from radiation. Therefore, we do not advise the use of KI pills. Sheltering, or evacuation if public officials make that recommendation, provides the best protection.

We request that members of the general public avoid using telephones, including cell phones, to ensure lines are available for emergency responders. We also request that the media not fly over the scene so that airspace is available for emergency air responders, and to reduce air movement around the scene.

We will continue to monitor the area to establish the extent of radionuclide contamination to ensure safety of members of the general public. We will provide a follow-up message on this issue in 1 h or sooner if additional information becomes available. This follow-up message will be issued not later than __________ [*e.g., give time as X:XX am/pm*].

RDD: Public Information Statement No. 4
(Can be used after the presence of radioactive material has been confirmed and when recommending evacuation of designated areas.)

There was an explosion at __________ [*site of the explosion*]. The fire, police and health departments are on the scene. A radionuclide was spread by the explosion. This was NOT a nuclear bomb. Although the highest levels of radionuclide contamination are in the area near the explosion, radioactive material was carried by the wind in a __________ [*northern, southern, eastern, western*] direction from the site of the explosion. As a precaution, we are evacuating residents closer than __________ mile __________ [*north, south, east, west*] of the explosion site. That is, those within the area north of __________ [*street, avenue, etc.*], south of __________ [*street, avenue, etc.*], east of __________ [*street, avenue, etc.*] and west of __________ [*street, avenue, etc.*]. These residents should report to __________ [*name the evacuation center(s) and give address(es)*], where staff will determine if radionuclide contamination is present and provide additional decontamination if needed. ONLY the individuals within this designated area are advised to evacuate. If we determine that additional evacuations are advisable, you will be told when and where to go. If you do not have transportation, please call XXX-XXX-XXXX, and you will be given more instructions.

As a precaution, if you are located within __________ miles __________ [*compass direction*] of the __________ [*explosion site*], you should continue to stay indoors, keep the doors and windows closed and turn off fans that bring in air from the outside. In-room fans that only recirculate air are OK to use. Air conditioning systems that do not bring in air from the outside may be operated.

You may drink or bathe in the water from your faucet. You may eat the food in your house. Food that was outdoors since __________ [*time*] yesterday may need to be avoided.

We have received questions about using potassium iodide (KI) pills. KI is not useful for the radionuclide used in this explosion. Therefore, we do not advise the use of KI pills.

(This paragraph may not be needed by day two.) We request people avoid using telephones, including cell phones, to ensure lines are available for emergency responders. We also request the media not fly over the scene so that airspace is available for emergency air responders, and to reduce air movement around the scene.

We will continue to monitor the area to establish the extent of radionuclide contamination to ensure the safety of members of the general public. We will provide a follow-up message in 3 h or sooner if additional information becomes available. This follow-up message is estimated to be issued not later than __________ [*e.g., give time as X:XX am/pm*].

B.2 In the Event of an Improvised Nuclear Device

IND: Public Information Statement No. 1

(Can be used immediately after the explosion, as soon as the fire department arrives and detects radiation and it appears to have been a nuclear terrorism incident.)

There has been an explosion at __________ [*site of detonation*]. Fire and police personnel are responding. Because of the size and extent of the explosion, and the presence of significant radiation levels, this may have been a nuclear explosion, releasing a large quantity of radioactive material. People should stay away to facilitate response efforts and reduce the possibility of radiation exposure from this incident. If you are outside, go inside the nearest stable building. If you are inside a building, you should stay inside. If the building has a basement, you should go to the lowest level. If the building does not have a basement, you should get as close as possible to the center of the building and go up two or three floors if it is a multistory building.

We request that people avoid using telephones, including cell phones, to ensure lines are available for emergency responders.

We will provide a follow-up message on this issue in 1 h or sooner if additional information becomes available. This follow-up message is estimated to be issued not later than __________ [*e.g., give time as X:XX am/pm*].

IND: Public Information Statement No. 2
(Can be used when additional information is available.)

There has been a nuclear explosion at __________ [*site of the detonation*]. The fire, police and health departments are assisting injured people. The highest levels of radionuclide contamination are near the explosion, and downwind from the explosion, going from the __________ [*north, south, east, west*] to the __________ [*north, south, east, west*]. People should stay away from this area to allow response efforts to take place, and to reduce the possibility of radiation exposure from the incident. If you are outside, you should go to the nearest stable building. The building may have windows that have been blown out, but if that appears to be the only damage and the building appears to be structurally sound, go inside the building if no other building is nearby that still has windows. If you are inside a building, you should stay inside. If the building has a basement, go to the lowest level. If the building does not have a basement, you should get as close as possible to the center of the building and go up two or three floors if it is a multistory building. You need to stay in this location unless advised differently by authorities.

The radiation levels are expected to significantly decrease over the next 24 to 48 h. You will be endangering yourself and others if you try to leave the building you are in. We understand how difficult this will be, but you will endanger your children's lives, as well as your own, if you try to retrieve your children from school. Schools have prepared for taking care of the children, and children are safest staying in their schools. We also understand your desire to return home, and to gather your family. But taking that action could endanger everyone's lives. Please stay where you are. We will provide further instructions on reuniting with your family as quickly as we can.

Even if you are not downwind and do not appear to have any structural damage in your location, stay indoors for your personal safety. You should close the doors and windows and turn off fans that bring in air from the outside. In-room fans that only recirculate air are OK to use. Air conditioning systems that do not bring in air from the outside may be operated.

To minimize your risk of radionuclide contamination, people who were near the _________ [*explosion site*], or outdoors since _________ [*time of the explosion*] in the potentially-contaminated area, are advised to change clothes and place the clothes you had been wearing in a plastic bag. Because most of the contamination will be on your clothes, removing your clothing reduces any contamination by ~80 to 90 %. Place the plastic bag in a garage or other remote location. If possible, take a shower with warm, not hot, water and gently wash your body and hair with ordinary soap and shampoo that does not contain a conditioner. Do not apply conditioner after you have washed your hair. You should stay indoors. If we determine that you would be safer in another location, we will advise you where to go. You should not go to a hospital unless you were injured in the explosion, or have another medical emergency requiring immediate treatment, such as a heart attack.

You may drink or bathe in the water from your faucet. You may eat the food in your house. Do not eat food or water that has been outside.

We request that people avoid using telephones, including cell phones, to ensure lines are available for emergency responders. We also request that the media not fly over the scene so that airspace is available for emergency air responders, and to reduce air movement around the scene.

We will continue to respond and monitor the area to establish the extent of radionuclide contamination and structural damage to ensure the safety of members of the general public. We will provide an update in 1 h or sooner if additional information becomes available. This follow-up message is estimated to be issued not later than _________ [*e.g., give time as X:XX am/pm*].

IND: Public Information Statement No. 3

(Can be delivered within a few hours of the incident.)

There has been a nuclear explosion at _________ [*site of detonation*]. The fire, police and health departments are implementing their emergency-response plans. People should stay away to facilitate response efforts, and to reduce their radiation exposure from this incident.

We have determined that a radionuclide was carried _________ [*north, south, west or east; name neighborhoods, cities, towns, or other locations in addition to the compass direction, if possible*] of the explosion site by the wind. At this point, we do not know the extent to which the winds have carried the radioactive material, so we continue to advise people to stay indoors for their own, and others, safety. If you are located within __________ miles (__________ km) __________ of __________ [*explosion site*], you should close the doors and windows and turn off fans that bring in air from the outside. In-room fans that only recirculate air are OK to use. Air conditioning systems that do not bring in air from the outside may be operated. This applies to a residential home, not an office building. If you were outside and saw the explosion and are not yet home, you may either continue home and shower there, or go to one of the following __________ [*name the evacuation center(s) and give address(es)*].

To minimize your risk of radionuclide contamination, people who were outdoors since __________ [*time of the explosion*] and within __________ miles [*north, south, east, west*] of the __________ [*location of the explosion*] should change clothes and place the clothes you were wearing in a plastic bag, which will likely reduce any contamination by ~80 to 90 % depending on the amount of the body covered by clothing. If possible, take a shower with warm, not hot, water and gently wash your body and hair with ordinary soap and shampoo. Children, if home, should also be given a shower or bath under supervision of a parent or other adult. Again, we recommend you stay indoors. If we determine that you would be safer in another location, we will advise you where to go. You should not go to a hospital unless you were injured in the explosion, or have a medical emergency requiring immediate treatment, such as a heart attack. Right now, the safest place for you is indoors.

You may drink or bathe in the water from your faucet. You may eat the food in your house. Food that was outdoors since __________ [*time*] today, within a few miles of __________ [*explosion site*] may need to be avoided.

We have received questions about using potassium iodide (KI) pills. KI will only reduce the radiation dose to one organ, the thyroid, and should be taken as soon as possible after being exposed, as the KI pills' effectiveness decreases rapidly. Begin taking KI within the first hour or two after the explosion, or as soon as you can. Continue taking KI until told it is OK to stop. The dose of KI varies according to size in children and age in adults, and also is different for pregnant women.

We request that people avoid using telephones, including cell phones, to ensure lines are available for emergency responders. We also request that the media not fly over the scene so that airspace is available for emergency air responders, and to reduce air movement around the scene.

We will continue to monitor the area to establish the extent of damage and radionuclide contamination to ensure the safety of members of the general public. We will provide a follow-up message on this issue in 1 h or sooner if additional information becomes available. This follow-up message is estimated to be issued not later than __________ [*e.g., give time as X:XX am/pm*].

IND: Public Information Statement No. 4

(Can be used when evacuation of designated areas is recommended.)

There was a nuclear explosion at __________ [*site of the detonation*]. The fire, police and health departments have activated emergency plans. Although the highest levels of radionuclide contamination are within about a mile radius from the explosion, radioactive material was carried by the wind in a __________ [*northern, southern, eastern, western*] direction from the site of the explosion. We are evacuating residents closer than __________ mile __________ [*north, south, east, west*] of the explosion site. That is, those within the area north of __________ [*street, avenue, etc.*], __________ south of __________ [*street, avenue, etc.*], east of __________ [*street, avenue, etc.*], and west of __________ [*street, avenue, etc.*]. These residents may report to __________ [*name the evacuation center(s) and give address(es)*], where staff will be onsite to determine if contamination is present, and provide additional decontamination if needed. ONLY the individuals within this designated area are advised to evacuate. If we determine that additional evacuations are advisable, you will be told where to go.

As a precaution, if you are located within __________ miles __________ [*compass direction*] of the __________ [*explosion site*], you should continue to stay indoors, keep the doors and windows closed and turn off fans that bring in air from the outside. In-room fans that only recirculate air are OK to use. Air conditioning systems that do not bring in air from the outside may be operated.

You may drink or bathe in the water from your faucet. You may eat the food in your house. Food that was outdoors since __________ [*time*] yesterday may need to be avoided.

We have received questions about using potassium iodide (KI) pills. KI will only reduce the radiation dose to one organ, the thyroid, and should be taken as soon as possible after the exposure, as KI pills' effectiveness decreases rapidly. Begin taking KI within the first hour or two after the explosion, or as soon as you can. Continue taking KI until told it is OK to stop. The dose of KI varies according to size in children and age in adults, and also is different for pregnant women.

We request people avoid using telephones, including cell phones, to ensure lines are available for emergency responders. We also request the media not fly over the scene so that airspace is available for emergency air responders, and to reduce air movement around the scene.

We will continue to monitor the area to establish the extent of radionuclide contamination to ensure safety of members of the general public. We will provide a follow-up message in 3 h or sooner if additional information becomes available. This follow-up message is estimated to be issued not later than __________ [*e.g., give time as X:XX am/pm*].

Appendix C

Key Decisions for Federal Decision Makers (as they relate to international conventions and agreements)

C.1 Introduction

Should a radiological or nuclear terrorism incident occur in a territory under the jurisdiction or control of the United States, there would be a number of key international decisions to make. These would naturally be the responsibility of the federal government and therefore federal decision makers. Federal decisions would relate with compliance of obligations undertaken by the U.S. government in relevant international conventions. Conventions that could be invoked in such an incident are the Convention on Early Notification of a Nuclear Accident (so-termed Notification Convention), Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency (so-termed Assistance Convention), and the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (so-termed Joint Convention) would apply. The Joint Convention would apply in managing waste from cleanup after terrorism incidents involving radiological and/or nuclear material.

This appendix summarizes key decisions that federal decision makers should consider for ensuring that the U.S. government fulfills its international obligations undertaken in the above described international conventions in a timely manner.

Since these conventions were ratified at a time when possible malevolent use of ionizing radiation and radioactive material were not considered to be an international issue, it might be legally possible to exclude from the obligations of these conventions the safety implications of a terrorist attack. However, a decision to ignore the obligations of the U.S. government under the conventions, while possible from a legal viewpoint, may become politically unfeasible; particularly if the incident is located near a border with a neighbor party of the conventions (*e.g.*, Mexico or Canada) or has potential transboundary implications.

C.2 Notification

C.2.1 *Background*

Any radiological or nuclear terrorism incident may be considered a release of radioactive material that could be radiologically significant for another state and therefore be subject to the obligations undertaken by the U.S. government as a party of the *Notification Convention*. This Convention shall apply in the event of any accident involving facilities or activities of a state party or of persons or legal entities under its jurisdiction or control, from which a release of radioactive material occurs or is likely to occur and which has resulted or may result in an international transboundary release that could be of radiological safety significance for another state. WHO International Health Regulations require international notification of radiation emergencies [*e.g.*, Member States must notify WHO in a timely way of any threat that qualifies as a *public health emergency of international concern* (whether infectious, chemical, biological or radiological)]. In the United States, CDC implements these notifications for DHHS which are then passed on to WHO.

C.2.2 *Key Decisions*

The first and more important decision refers to the applicability of the Notification Convention. This could be made *a priori* of the incident, at the planning stage. There are three possible decisions, namely:

- U.S. government considers that the Notification Convention is always applicable to malevolent incidents involving significant releases of radioactive material;
- it will consider its applicability on a case-by-case-basis; or
- it will consider that the obligations under the Convention are not applicable to malevolent incidents.

It should be noted that this decision will have implications on the behavior of other parties to the Convention and can be a cause of *dispute*.

If the first decision is that the Notification Convention is applicable to the radiological or nuclear terrorism incident, then the major decision to make is to establish the mechanisms for:

- notifying, directly or through IAEA, those countries which are or may be physically affected, and IAEA, of the radiological or nuclear terrorism incident, its nature, the time of its occurrence, and its exact location.
- promptly providing those countries, directly or through IAEA, and IAEA, with such available information relevant to minimizing the radiological consequences in those countries. The information to be provided shall comprise the following data as then available to the U.S. government:
  - time, exact location where appropriate, and the nature of the incident;
  - activity involved;
  - assumed or established or foreseeable development of the incident relevant to the transboundary release of radioactive material;
  - general characteristics of the radioactive release, including, as far as is practicable and appropriate, the nature, probable physical and chemical form and the quantity, composition and effective height of the radioactive release;
  - information on current and forecast meteorological and hydrological conditions necessary for forecasting the transboundary release of radioactive material;
  - results of environmental monitoring relevant to the transboundary release of radioactive material;
  - offsite protective measures taken or planned; and the predicted behavior over time of the radioactive release.

  Such information shall be supplemented at appropriate intervals by further relevant information on the development of the emergency situation, including its foreseeable or actual termination. The decision maker shall decide whether the information conveyed to other countries of the Convention may be used without restriction, or is provided in confidence by the U.S. government.
- responding promptly to a request for further information or consultations sought by affected countries with a view to minimizing the radiological consequences in those states.
- making known to IAEA and to other countries, directly or through IAEA, its competent authorities and point of contact responsible for issuing and receiving the notification and information referred to heretofore. Such points of contact and a focal point within IAEA shall be available continuously.

(Note: a U.S. point of contact with IAEA already exists for radiological emergencies and nuclear accidents but it should be made clear whether this is the point of contact for malevolent incidents).

- concluding bilateral or multilateral arrangements relating to the subject matter of the Notification Convention in relation to malevolent incidents.

C.3 Assistance

C.3.1 *Background*

As in the case of the Notification Convention, any radiological or nuclear terrorism incident subject to the rights and obligations undertaken by the U.S. government are binding. This will imply both, rights to receive assistance from other countries and obligations to provide assistance to other countries.

It should be noted that even a country with powerful resources like the United States can benefit from assistance from other countries. For instance, a relatively simple radiological terrorism incident can overwhelm all biological dosimetry services in the United States. Under the rights given to it by being a part of the Assistance Convention, the United States can make use of such services from their countries.

C.3.2 *Key Decisions*

As in the case of the Notification Convention the first and more important decision refers to the applicability of the Assistance Convention to a radiological or nuclear terrorism incident. This could be made *a priori* of the incident, at the planning stage. In this case, however, the applicability is more obvious than in the case of the Notification Convention.

If the first decision is that the Notification Convention is applicable to the radiological or nuclear terrorism incident, then the major decision to be made is to establish the mechanisms for:

- calling for assistance in the event of a radiological or nuclear terrorism incident, whether or not such accident or emergency originates within U.S. territory, jurisdiction or control, from any other country, directly or through IAEA, and from IAEA, or, where appropriate, from other international intergovernmental organizations (hereinafter referred to as "international organizations").
- specifying the scope and type of assistance, recommending and, where practicable, providing the assisting party with such information as may be necessary for that party to

determine the extent to which it is able to meet the request. In the event that it is not practicable for the decision maker to specify the scope and type of assistance recommended, the decision maker and the assisting party shall, in consultation, decide upon the scope and type of assistance necessary.
- requesting assistance relating to medical treatment or temporary relocation into the territory of another country of people involved in a terrorist incident.
- for an assistance request made to the United States, promptly deciding and notifying the requesting country, directly or through IAEA, whether the United States is in a position to render the assistance requested and the scope and terms of the assistance that might be rendered.
- identify and notify IAEA of experts, equipment and materials that could be made available for the provision of assistance to other countries in the event of a terrorist incident as well as the terms, especially financial, under which such assistance could be provided.

If the United States is the provider of assistance, since the overall direction, control, coordination and supervision of the assistance shall be the responsibility within its territory of the requesting country, the decision maker should, where the assistance involves personnel, designate in consultation with the requesting country, the person who should be in charge of and retain immediate operational supervision over the personnel and the equipment provided by it. (The designated person should be expected to exercise such supervision in cooperation with the appropriate authorities of the requesting country.)

If the United States is the requesting country, the decision makers shall provide, to the extent of their capabilities, local and regional facilities and services, for the proper and effective administration of the assistance. It shall also ensure the protection of personnel, equipment and materials brought into U.S. territory by or on behalf of the assisting party for such purpose. Moreover, since ownership of equipment and materials provided by either party during the periods of assistance shall be unaffected, the decision maker should ensure the return of such equipment and materials.

C.4 Radioactive-Waste Management

C.4.1 *Background*

A radiological or nuclear terrorism incident will generate huge quantity of radioactive waste, mainly of the type termed *low-level* *radioactive waste*. The U.S. government has undertaken international obligations on the safety of radioactive-waste management, which are established in the Joint Convention. When and if, as a result of a radiological or nuclear terrorism incident, the need arises for the disposal of the resulting low-level radioactive waste, the U.S. government would be solely responsible for the identification of an appropriate disposal facility. The Joint Convention provides issues to be addressed and resolved (see details below).

C.4.2 *Key Decisions*

Since the Joint Convention's scope of application for radioactive waste, including discharges, is limited, the decision maker shall decide what radioactive waste generated by the radiological or nuclear terrorism incident shall be declared by the U.S. government as *radioactive waste and discharges* and who shall be the *regulatory body* for the purposes of the Joint Convention.

The decision maker shall plan for taking the appropriate steps to ensure that at all stages of *radioactive-waste management*, individuals, society and the environment are adequately protected against radiological and other hazards, in order to comply with the obligations under the Joint Convention. In particular, the decision maker shall plan for taking the appropriate steps to ensure that procedures are established and implemented for a proposed *radioactive-waste management facility*, including:

- evaluation of all relevant site-related factors likely to affect the safety of such a facility during its *operating lifetime* as well as that of a *disposal* facility after closure;
- evaluation of the likely safety impact of such a facility on individuals, society and the environment, taking into account possible evolution of the site conditions of disposal facilities after closure;
- making information on the safety of such a facility available to members of the general public; and
- fundamentally, consulting Contracting Parties of the Joint Convention in the vicinity of such a facility, insofar as they are likely to be affected by that facility, and provide them, upon their request, with general data relating to the facility to enable them to evaluate the likely safety impact of the facility upon their territory. (In so doing, the decision maker shall take the appropriate steps to ensure that such facilities shall not have unacceptable effects on other Contracting Parties of the Joint Convention by being cited in accordance with the general requirement of the Joint Convention.)

The decision maker shall particularly ensure that the design and construction of a radioactive-waste management facility provide for suitable measures to limit possible radiological impacts on individuals, society and the environment, including those from discharges or uncontrolled releases. Specifically, the decision maker shall take appropriate steps to ensure that discharges shall be limited to keep exposure to radiation consistent with the ALARA principle; and so that no individual shall receive, in normal situations, a radiation dose that exceeds national prescriptions for dose limitation which have due regard to internationally endorsed standards on radiation protection.

Appendix D

Controlling Consumer Products — Food, Water, etc. (international implications)

D.1 Introduction

Consumer products generally used by members of the general public, such as water, food, and other commodities of public consumption, can be deliberately contaminated with radioactive substances as a result of terrorist actions. The decision-making process for controlling such contamination is extremely difficult and controversial. However, experience from radiological accidents indicates that decisions are best made promptly, due mainly to public pressure. International radiation protection criteria for radionuclides in consumer products are available and could facilitate the decision-making process.

Consumer products always contain some amount of "contamination" by naturally-occurring radionuclides as a result of natural processes in the environment. This extant contamination is not perceived as such by members of the general public and may confuse the decision-making process in cases of deliberate addition. These naturally-occurring radionuclides deliver exposures that are essentially unamenable to control. However, in addition to "natural" contamination, consumer products can also contain radioactive material incorporated as a direct result of controllable human activities. This "human-introduced" radioactive material, which can be from both natural and artificial origins, may have been incorporated either as a result of the operation of regulated activities or as a result of radioactive residues from past regulated or unregulated activities or from radioactive material that were cleared of regulatory control and recycled into the market.

D.2 Radiation Protection Considerations

Specific and deliberate contamination of some products can conceivably lead to a large internal contamination of a few individuals, which can be sufficiently high as to be life threatening. However, massive contamination of consumer products is unlikely to lead to a significant internal contamination of a large number of people due to the large quantity of radioactive material that would be required to reach high levels of contamination in mass-produced or distributed supplies. One important timely challenge for decision makers will be a large number of people requesting monitoring for internal contamination, which in turn will lead to an impairment of the available monitoring facilities.

Ideally, decision makers should establish in advance "intervention exemption levels" for contaminated consumer products. Consumer products that are above such exemption levels would be subject to intervention and those that are below could be exempted from any intervention. These intervention exemption levels could in principle be decided on the basis of the anticipated situation. However, mainly due to the trade in consumer products and market globalization, the exemption levels may not be amenable to *ad hoc* decisions; they may not be established on a case-by-case basis but need to be standardized. The reasons are linked to obvious consumer reaction patterns. It is very unlikely that consumers would accept decisions that lead to levels of contamination higher than those established by other competent authorities and this will probably be the case, even in the aftermath of a terrorist incident.

The issue of how to regulate trade in consumer products containing a small quantity of radioactive material is not straightforward and has been subject to intense international debate. ICRP has dealt with the issue in a number of publications (ICRP, 1999; 2005; 2007; 2008) and the relevant international intergovernmental organizations have issued guidance on the relevant protection criteria (CAC, 2006; IAEA, 2004c; WHO, 2004). The exposure situations resulting from contaminated consumer products could be characterized as planned, emergency or existing, depending on the circumstances. Control measures could conceptually be implemented following ICRP recommendations for dealing with each type of situation. However, for the reason discussed before, it has been recognized that mainly due to the implications of any control on trade, regulation of radioactive material in consumer products cannot be established on a case-by-case basis but needs to be standardized.

It has been assumed that it is not likely that several types of consumer products would be simultaneous sources of high exposure to any given individual. On the basis of this presumption, it has been internationally recommended that a dose-based generic intervention exemption level of 100 mrem (1 mSv) for the maximum individual annual effective dose expected from a dominant type of consumer goods be established; drinking water however has been treated as an exception to this generic recommendation (see Section D.3.3 for guidance on drinking water levels).

On this basis, international intergovernmental organizations have established criteria for radionuclides in commodities of various types (ICRP, 1999).

D.3 International Intergovernmental Agreements

A number of recent international intergovernmental agreements have reached some consensus on radiological criteria for radionuclides in nonedible consumer products and also in foodstuffs and drinking water. Relevant U.S. local, state, tribal, and federal authorities may wish to consider such a consensus in deciding control measures on consumer products that could be contaminated as a consequence of a radiological terrorism incident. This international consensus establishes activity concentration values for radionuclides of artificial and natural origin in bulk quantity of material to be exempted from radiation protection control measures.

D.3.1 *Nonedible Consumer Products*

Following ICRP advice on consumer products, the policy-making organs of international governmental organizations tackled the issue of consumer products. In 2004, IAEA General Conference decided that IAEA, in collaboration with the competent organs of the United Nations and the specialized agencies concerned, should develop "radiological criteria for long-lived radionuclides in consumer products, particularly foodstuffs and wood" (IAEA, 2004a). The established levels for nonedible consumer products were issued as the international safety guide on the *Application of the Concepts of Exclusion, Exemption and Clearance* (IAEA, 2004a), which provides values of activity concentrations of radionuclides (both natural and artificial) in bulk quantity of nonedible materials that would be applicable to international trade. A graded approach consistent with the requirement of optimization of protection would be applied (IAEA, 1997) in the event of values exceeding the values prescribed.

It has been noted that perhaps it would have been appropriate to distinguish between the nonedible consumer products, which are the main subject of the above global intergovernmental agreement, and nonedible industrial consumer products that are extensively traded. Consumer products have greater potential for public exposure and are unrestricted in usage pattern. Industrial consumer products, on the other hand, are used for certain specific, limited purposes, usually in a workplace setting.

The agreement reached is an important step for international harmonization. Intergovernmental organizations have been encouraged to refine and expand the agreements already reached on nonedible consumer products and, in particular, to develop practical guidance on the recommended graded approach to regulation.

D.3.2 *Edible Consumer Products (other than drinking water)*

As for edible consumer products, in 1989, the Codex Alimentarius Commission (CAC) of the joint FAO/WHO adopted guideline levels for radionuclides in foods following accidental nuclear contamination for use in international trade (hereinafter referred to as the "Codex levels") (CAC, 2004), applicable for six radionuclides, namely ^{90}Sr, ^{131}I, ^{137}Cs, ^{134}Cs, ^{239}Pu, and ^{241}Am. It should be noted, however, that Codex Alimentarius defines a contaminant as follows: "Any substance not intentionally added to food, which is present in such food as a result of the production (including operations carried out in crop husbandry, animal husbandry and veterinary medicine), manufacture, processing, preparation, treatment, packing, packaging, transport or holding of such food or as a result of environmental contamination…" Whether radionuclides added deliberatively as a result of a terrorist action should be considered contaminants in the Codex language is a matter of legal debate.

Codex levels were adopted in the Basic Safety Standard (IAEA, 1996) and were originally designed to be applicable for 1 y following a nuclear accident or radiological emergency. The levels were intended to be maximum acceptable concentrations in the aftermath of a radiological accident, only to be tolerated under very exceptional circumstances and for a limited period of time. They were issued in the aftermath of the Chernobyl nuclear reactor accident, and were not proposed for application to regular circumstances and to the general exchange and consumption of foodstuffs, but remained applicable for 1 y following a nuclear accident. They were based on an effective dose of 100 mrem y^{-1} (1 mSv y^{-1}). Long-term exposures presume a mixing of contaminated foodstuffs with uncontaminated materials, which will result in a lower annual exposure in subsequent years. Therefore, it has been suggested that foodstuffs containing radionuclides in activity concentrations less than the Codex levels should be automatically regulated.

The Codex levels have evolved in recent years, taking account of improvements in the assessment of radiation doses resulting from the human intake of radioactive substances and the recognized need to establish wider guidance. In view of these developments, CAC considered broadening the scope, and referred the issue to the Codex Committee on Food Additives and Contaminants (CCFAC) for consideration. CCFAC agreed to request collaboration from intergovernmental organizations and governments to prepare a revised version of the Codex levels, and CAC approved the revision, including the development of guideline levels for long-term use. In response to this request, a meeting of experts was convened under the chairmanship of the ICRP chairman and including representatives of the United Nations Scientific Committee on the Effects of Atomic Radiation, the European Commission, and the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture. This resulted in revised Codex levels, which were transmitted for consideration by CCFAC together with a separate submission by the European Commission, which in turn agreed to forward the proposed revised levels to CAC for preliminary adoption.

CAC adopted the proposed revised levels and noted a number of reservations. Thus, draft revised Codex levels were considered by CCFAC along with written comments submitted by intergovernmental organizations and states, which decided that a further revision was required involving these organizations and all interested states. CCFAC finally agreed to forward the revised *Guideline Levels for Radionuclides in Foods Contaminated Following a Nuclear or Radiological Emergency for Use in International Trade* to CAC, which were adopted as a final Codex text at the 29th Session of the CAC. The revised, Codex levels were subsequently published in Schedule I, *Radionuclides of the Codex General Standard for Contaminants and Toxins in Foods* (CAC, 2006) and is the current standard for toxins in food.

D.3.3 *Drinking Water*

WHO developed specific guidance levels for radionuclides in drinking water and is responsible for international regulation. These levels have been incorporated into the third edition of *Guidelines for Drinking-Water Quality* (WHO, 2004). The drinking-water recommendations are based on 10 mrem (0.1 mSv) effective dose for 1 y consumption of drinking water, which is one order of magnitude less than the Codex Alimentarius criteria of 100 mrem y^{-1}

(1 mSv y^{-1}) effective dose (despite the fact that WHO is part of CAC). It has been recognized however that some of WHO guidance levels may exceed the target dose. Drinking water containing radionuclides in activity concentrations less than WHO guidance levels should not be automatically regulated but should be considered on a case-by-case basis.

D.4 Dealing with Consumer Products After Radiological or Nuclear Terrorism Incidents

ICRP has indicated that the above described international intergovernmental agreements provide a good basis for generic and universal radiological protection criteria for radionuclides in consumer products. In addition, in its recommendations on radiological protection in prolonged exposure situations in ICRP Publication 82 (ICRP, 1999), and in the aftermath of a terrorist attack in ICRP Publication 96 (ICRP, 2005), ICRP addressed the issue of a large amount of consumer products, including foodstuffs and water, remaining contaminated in the aftermath of a radiological emergency. With necessary changes these recommendations can be applied to the aftermath of a radiological or nuclear terrorism incident.

While recognizing that the international intergovernmental agreements on radiological criteria for consumer products described above would provide an adequate provisional basis for regulating the trade of commodities after such incidents, in ICRP (1999) recommended how to deal specifically with consumer products that are produced in an area affected by the emergency. This type of situation presents a particularly difficult problem; if the corresponding activity levels are higher than those in produce from neighboring areas, issues of market acceptance could arise if there are transboundary movements of the consumer products.

ICRP considers that if the annual doses in the area affected by the accident are acceptable because the protection strategy has been optimized, the situation outside the affected area may be acceptable. This is because the individual annual doses elsewhere from the use of consumer products produced in the affected area would not be higher than those in the affected area. However, the production of consumer products in areas affected by an emergency could commence some years after the incident; this possibility should be considered in any protection strategy applied after the incident. If the restrictions on consumer products produced in the area affected by an emergency have not been lifted, production of the restricted consumer products should not be restarted; conversely, if the restrictions have been lifted, production can be restarted. If an increase in production is proposed, it could proceed subject to appropriate justification. In circumstances where restrictions have been lifted as part of a decision to return to normal living, the resumption of and potential increase in production in the affected area should have been considered as part of that decision and should not require further consideration. It has been noted that economic and social conditions may be different inside and outside the area affected by a radiological or nuclear terrorism incident, and that this may legitimately lead to different decisions (as has in fact, occurred in real situations).

Therefore, decision makers may wish to consider a similar approach in a case of a radiological or nuclear terrorism incident. Measures for control of contaminated consumer products are expected to be initially applied within the area affected by the incident. Consumer products produced or subject to commerce within the area of influence of the incident would present an exceptionally difficult situation for decision makers. If the corresponding activity levels are higher than those in produce from neighboring areas, issues of market acceptance could arise, particularly if there are transboundary movements of the consumer products. If the annual doses in the area are below those established *a priori* in the intervention strategy; the situation outside the affected area should also be acceptable because the individual annual doses elsewhere from the use of consumer products produced in the affected area would normally not be higher than those in the affected area. If the restrictions on consumer products produced in the affected area have not been lifted, production of the restricted consumer products should not be restarted; conversely, if the restrictions have been lifted, production can be restarted. If an increase in production is proposed, it could proceed subject to appropriate justification. In circumstances where restrictions have been lifted as part of a decision to return to "normal" living, the resumption and potential increase of production in the affected area should have been considered as part of that decision and should not require further consideration.

D.5 Handling Situations Involving "Hot Particles"

In some scenarios, it can be imagined that radioactive residues may become very sparsely distributed in the environment (*e.g.*, as "hot particles"), giving rise to situations where there is the potential but not the certainty that the contamination of consumer products with such particles will actually occur. Building materials, in particular, could be affected by these situations. There are available international recommendations for dealing with potential exposure situations (IAEA, 1990; ICRP, 1993; 1997). Protection in situations involving hot particles is not a new issue (IAEA, 1998). For these situations, ICRP has issued criteria of acceptability, as follows: action levels should be derived on the basis of the unconditional probability that members of the general public would develop fatal stochastic health effects attributable to the exposure situation. That probability should be assessed by combining the following probabilities:

- being exposed to the hot particles;
- incorporating a hot particle into the body as a result of such exposure;
- incurring a dose as a result of such incorporation; and
- developing a fatal stochastic effect from that dose.

(These probabilities should be integrated over the full range of situations and possible doses). In establishing such action levels, consideration should be given to the possibility that localized deterministic effects may also occur as a result of the incorporation of hot particles.

Appendix E

Resources of the U.S. Department of Energy

Below is a list of DOE Radiological Emergency-Response Assets with a brief description of each. Figure E.1 is a timeline describing the approximate activation time after initial notification.

E.1 Radiological Assistance Program

The Radiological Assistance Program (RAP) mission is to provide first response radiological assistance to protect the health and safety of members of the general public and the environment. They

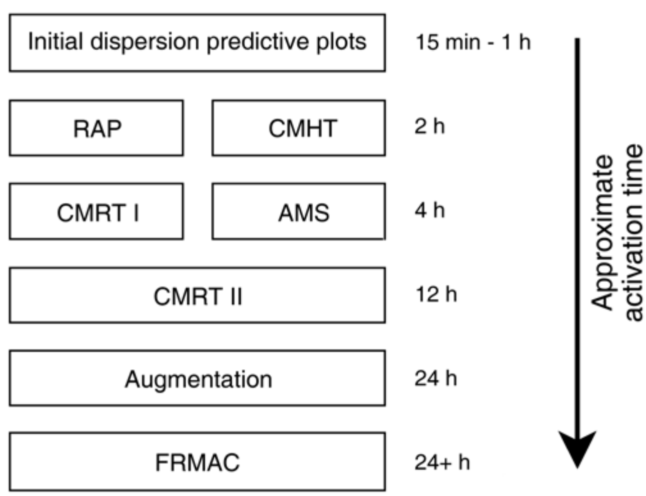

Fig. E.1. DOE radiological emergency-response asset timeline (DOE, 2010).

assist local, state, tribal and federal agencies in the detection, identification, analysis, and response to incidents involving the release of radiological materials in the environment. RAP advises decision makers and assists local authorities to minimize the hazards of a radiological terrorism incident. RAP is implemented on a regional basis, with coordination between the emergency-response elements of local, state, tribal and federal agencies.

Each region has a minimum of three RAP teams. Teams can coordinate with one another when assistance is necessary. Each RAP team consists of six to eight team members, which includes a DOE team lead, a team captain, and health-physics support personnel.

If a radiological or nuclear terrorism incident has occurred, other DOE assets will be activated as per NRF, and RAP will coordinate with them in conjunction with local emergency responders.

E.2 Consequence Management Home Team

The primary role of the Consequence Management Home Team (CMHT) is to support the incident response while Consequence Management Response Team Phase I (CMRT I) is en route to the incident scene. CMHT provides analysis and interpretation of the initial source term and early data, along with predictive map products. CMHT is operational and ready to assist within 2 h of notification. CMHT will receive data from RAP and local emergency responders who collect radiological data. CMHT support includes analyzing incident data (*e.g.*, monitoring data), evaluating hazards, and providing incident information and data products (*e.g.*, plume maps) to protective-action decision makers. CMHT can provide assistance and data products to RAP team(s) that have been deployed to support the response until CMRT assets are established at the incident. In coordination with DHS, the consequence management federal team leader approves release of information to authorized local, state and tribal officials.

CMHT can communicate to the CMRT I in real-time while they are en route to provide status information. Generally, CMHT data assessment capability will be transferred to CMRT I once those assets have been established at the incident.

E.3 Consequence Management Response Team Phase I

DOE will respond to a request for assistance by deploying the Consequence Management Response Team (CMRT). CMRT uses a phased approach to deploy personnel and resources into the field in a timely fashion. CMRT I, consisting of technical and management personnel, is ready to deploy within 4 h of notification and can be operational and gathering data within 3 h of establishing a base of operations. CMRT I initiates all technical aspects of a FRMAC response and serves as the command and control element of FRMAC initially. CMRT I includes 200 cubic feet (2,500 pounds) of equipment and 24 on-call personnel. The team will incorporate all the disciplines necessary to support operations but only on a limited scale. These disciplines include radiation monitoring, sampling, analysis, assessment, health and safety, and support and logistics functions. CMRT I is capable of sustaining 24 h operations for up to 72 h.

E.4 Consequence Management Response Team Phase II

Consequence Management Response Team Phase II (CMRT II) follow the Phase I resources within 12 h of activation and provides a more robust response team by providing additional personnel and equipment. CMRT assets along with the interagency resources that respond form a fully-operational FRMAC 24 to 36 h after the initial request for assistance. CMRT II includes 32 personnel and an additional 2,400 cubic feet (39,000 pounds) of equipment. CMRT II response team deploys with consumables to support operations for 96 h without resupply and is prepared to support 24 h d^{-1} operations for several weeks. CMRT II will focus on extensive field monitoring (collection, assessment, compilation and archiving of data) and initial sample collection and sample processing for characterization.

E.5 Consequence Management Response Team-Augmentation/Federal Radiological Monitoring and Assessment Center

If requested, DOE can call upon trained professionals from DOE facilities and national laboratories, RAP regions, and additional personnel and equipment will be deployed to augment and assist federal radiological monitoring and assessment center (FRMAC) operations. FRMAC is established "at or near the scene of an incident to coordinate radiological assessment and monitoring." FRMAC is a federal interagency center responsible for coordinating offsite monitoring and assessment activities with the affected local, state and tribal agencies. FRMAC protective actions focus on accurately defining areas where contamination levels of air, water, crops, forage and livestock may lead to concentrations in excess of nationally-accepted guidelines. The response during a FRMAC focuses on extensive sampling, sample processing and analysis, and further collection, assessment, compilation and archiving of data in order to characterize the radiological conditions as specified by NRIA. FRMAC is prepared to support 24 h d^{-1} operations for several weeks as determined by the severity of the emergency.

E.6 Aerial Measuring System

The Aerial Measuring System characterizes ground-deposited radiation from aerial platforms. These platforms include fixed- and rotary-wing aircraft with radiological measuring equipment, computer analysis of aerial measurements, and equipment to locate lost radioactive sources, conduct aerial surveys, or map large areas of contamination.

E.7 National Atmospheric Release Advisory Center

FRMAC has access to the National Atmospheric Release Advisory Center (NARAC), which provides tools and services that map the probable spread of HAZMAT accidentally or intentionally released into the atmosphere. NARAC has access to full scale atmospheric modeling with real-time meteorological data. NARAC is co-located with the IMAAC. NARAC provides atmospheric plume predictions in enough time for an emergency manager to decide if taking protective action is necessary to protect the health and safety of people in affected areas.

E.8 Radiation Emergency Assistance Center/Training Site

FRMAC has access to Radiation Emergency Assistance Center/Training Site (REAC/TS) physicians, nurses, health physicists, radiobiologists, and emergency coordinators specializing in assisting local and regional medical personnel in treating and diagnosing radiation effects on human health.

Appendix F

Decontamination of People

This appendix contains information for instructing people to self-decontaminate at home or while waiting for decontamination at the scene of an incident (LA County, 2009).

F.1 Instructions on How to Perform Decontamination at Home

Radioactive materials from the incident may have settled on your hair, skin and clothing as dust, sand or ash. Because radiation cannot be seen, smelled, felt or tasted, you and others will not know if you have radioactive material on you, unless radiation detection equipment is available. *You are not in immediate danger from this radioactive material*. However, you should go home or to another designated area to decontaminate (clean off the radioactive material). Removal of outer clothing should reduce your external contamination by up to 90 %. Washing exposed skin and hair will remove most of the rest.

To protect your health and safety as well as others, please follow these directions.

- Leave 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*.
- Remove your clothes (*read all of the instructions below before starting this process*):
  - if radioactive material are on your clothes, prompt removal of your clothing will also reduce the amount of radiation you receive.

- removal of clothes should be done in a garage or outside storage area if possible. If not, remove clothes in a room where the floors can be easily cleaned, such as a laundry room or a bathroom (in the tub or shower). Clothing should be rolled up with the contaminated side "in" to avoid spreading contamination.
- when removing clothing, be careful of any clothing that has to be pulled over the head. Try to either cut it off or prevent the outer layer from touching your nose and mouth. You may also hold your breath while carefully pulling the article over your head.
- if possible, put 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 a garage, outside location, the corner of a room, or a closet. Keep people away from it. You may be asked to bring this bag for 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.

• Wash yourself and your valuables:
  - shower and wash your body and hair using lots of soap and lukewarm water to remove contamination. Washing will remove most of the radioactive material. Do not use abrasive cleaners or scrub too hard. Do not use hair conditioners.
  - gently blow your nose and wash out your eyes, ears and mouth.
  - put on clean clothes.
  - wash valuables and identification cards that may have been contaminated and wash your hands again.
• If you cannot shower or remove all of your clothes, removing your outer clothing and washing exposed parts of your body, such as your head and neck, hair, hands, and arms, will remove most of the contamination.
• If you are going to a monitoring location, it is best to shower and change clothes *before* being monitored.

F.2 Instructions to Members of the General Public Waiting for Decontamination at the Scene of an Incident

You may have been exposed to radioactive material. The radioactive material may have settled as dust, sand or ash on your clothes or body. To protect your health, you may be asked to go to a decontamination center. *Your health is not in immediate danger.* At the decontamination center, you will be checked for radioactive material on your clothes, skin and hair. If you have a lot of radioactive material on your body, you will wash it off and be given clean clothes to wear. This process is called *decontamination*.

Follow these directions to prepare for decontamination:

- go to the designated area.
- do not touch your face or put anything into your mouth.
- enter the screening area and stand for a screening (survey) of yourself while clothed, and provide the workers with necessary personal information.
- after you are screened, you will be directed to leave if little or no contamination is present. If contamination is found, you will be directed to a wash area, or you may be sent home with instructions on how to cleanup (decontaminate) there.
- if you are directed to a wash area, you will be grouped with people of your gender. To the extent possible, families will be kept together. Prepare to remove your outer clothes behind a privacy curtain. If radioactive material is on your clothes, removing them will reduce the amount of radiation you receive.
- when removing clothing, be careful of any clothing that has to be pulled over the head. Try to either cut it off or prevent the outer layer from touching your nose and mouth. You may also hold your breath while carefully pulling the article over your head.
- you will be given plastic bags. Put 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 allowed to keep your valuables. If your clothing is contaminated, we will keep it. If there is any chance your valuables may be contaminated; remove items from the bag they are in carefully while wearing gloves and clean your valuables with soap and water when you get home.
- pass through the wash area.
- when you reach the end of the wash station, you will be given clothing to put on, and then be directed to the exit.

Glossary

absorbed dose: The energy imparted by ionizing radiation to matter per unit mass at the point of interest. In SI, the unit is joule per kilogram (J kg^{-1}), with the special name gray (Gy) (see *rad* and *cumulative absorbed dose*).

activity: The average number of spontaneous nuclear transformations occurring in a radioactive material per unit time. The unit for activity in the SI system is reciprocal second (s^{-1}) (*i.e.*, one nuclear transformation per second), with the special name becquerel (Bq). The special unit previously used was curie (Ci); 1 Ci = 3.7×10^{10} Bq. In this Report, activity is also expressed as disintegrations per minute per unit area (dpm cm^{-2}) with regard to surface contamination.

acute radiation syndrome (sickness) (ARS**):** A broad term used to describe a range of early signs and symptoms that reflect severe damage to specific organ systems that can lead to death within hours or several weeks.

air kerma (kerma in air): Kerma (kinetic energy released per unit mass) is the sum of the initial kinetic energies of all the charged particles liberated by uncharged particles per unit mass of a specified material. The SI unit of kerma is joule per kilogram (J kg^{-1}), with the special name gray (Gy). Kerma can be quoted for any specified material at a point in free space or in an absorbing medium (in this case air).

as low as reasonably achievable (ALARA**):** A principle of radiation protection philosophy that requires that exposures to ionizing radiation should be kept as low as reasonably achievable, economic and social factors being taken into account. The ALARA principle is satisfied when the expenditure of further resources would be unwarranted by the reduction in exposure that would be achieved.

becquerel (Bq**):** (see *radiation units and names*).

bioassay: A technique used to identify, quantify and/or specify the location of radionuclides in the body by direct (*in vivo*) or indirect (*in vitro*) analysis of tissues or excretions from the body.

biodosimetry: A technique used to determine radiation dose to people using the assessment of individual biological data such as assessment of individuals' signs and symptoms, particularly the time from exposure to onset of vomiting, serial blood counts for lymphocyte depletion, and assays of lymphocyte cytogenetics.

bunker gear: A firefighter's protective clothing. Bunker gear usually consists of boots, pants, coat, gloves, hood, helmet, and self-contained breathing apparatus (also called personal protection equipment).

calibration: The act of standardizing an instrument to a known source, or a laboratory procedure to a known result.

combined injury: Radiation injury exacerbated by other types of bodily injury (*e.g.*, skin burns, open wounds).

concerned citizens: The term that has been used extensively in the past for these individuals is "worried well"; the Centers for Disease Control and Prevention and other federal agencies prefer to use the term "concerned citizens." Concerned citizens may well overwhelm the capabilities of hospital emergency rooms when they do not have traumatic injuries, but are concerned because they may have been exposed to radiation or contaminated with radioactive material.

contamination (radionuclide): Radioactive material that is present in undesired locations such as on the surface of or inside structures, areas, objects or individuals.

cumulative absorbed dose: In this Report, a real-time integration of absorbed dose to the whole body from photons.

curie (Ci**):** (see *radiation units and names*).

decision dose: In this Report, a cumulative absorbed dose to the whole body (from photons) of 50 rad (0.5 Gy) to a specific emergency responder. At that whole-body absorbed dose, the decision at the command level is whether the emergency responder should be withdrawn from the radiation control zones.

decontamination: The removal of radionuclide contaminants from surfaces (*e.g.*, skin) by cleaning and washing.

detector: A device or component designed to produce a quantifiable response to ionizing radiation, normally measured electronically.

deterministic effects: Effects that occur in all individuals who receive greater than a threshold dose; the severity of the effect varies with the dose above the threshold. Examples are radiation-induced cataracts (lens of the eye) and radiation-induced erythema (skin).

dose: In this Report, used as a generic term when not referring to a specific quantity, such as absorbed dose.

effective dose: The sum over specified tissues of the products of the equivalent dose in a tissue or organ and the tissue weighting factor for that tissue or organ. The tissue weighting factor represents the fraction of the total radiation detriment to the whole body attributed to that tissue when the whole body is irradiated uniformly. The SI unit for effective dose is joule per kilogram ($J\ kg^{-1}$), with the special name sievert (Sv).

equivalent dose: A quantity used for radiation protection purposes that takes into account the different probabilities of stochastic effects that occur with the same absorbed dose delivered by radiations with different radiation weighting factors (the factor by which the mean absorbed dose in a tissue or organ is modified to account for the type and energy of radiation in determining the probability of stochastic effects). The SI unit of equivalent dose is joule per kilogram ($J\ kg^{-1}$), with the special name sievert (Sv) (also see *stochastic effects*).

mean absorbed dose: The total energy imparted to an organ or tissue divided by the mass of the organ or tissue. The SI unit of mean absorbed dose is joule per kilogram ($J\ kg^{-1}$), with the special name gray (Gy).

exposure: In this Report, exposure is used often in its general sense, meaning an irradiation. When used as a defined radiation quantity, exposure is a measure of the ionization produced in air by x or gamma radiation. The SI unit of exposure is coulomb per kilogram (C kg^{-1}). The special unit for exposure is roentgen (R), where 1 R = 2.58×10^{-4} C kg^{-1}. Air kerma is often used in place of exposure. An exposure of 1 R corresponds to an air kerma of 0.87 rad (8.7 mGy) (also see *rad*, *roentgen*, *gray*, *air kerma*).

exposure rate: The exposure per unit time [*e.g.*, 1 R h^{-1} (8.7 mGy h^{-1}) (~10 mGy h^{-1} air-kerma rate)].

fallout: Radioactive material falling from the atmosphere to the Earth's surface after a nuclear incident, such as a weapons test, accident, or detonation of an improvised nuclear device.

footprint: Refers to the area contaminated with radioactive material from the radiological or nuclear terrorism incident.

gamma rays: (see *radiation types*).

gray (Gy**):** (see *radiation units and names*).

instrument: A complete system consisting of one or more assemblies to quantify one or more characteristics of radiation or radioactive material.

monitoring: Means provided to indicate continuously or intermittently the level of activity or radiation exposure.

neutrons: (see *radiation types*).

nuclear yield: The amount of energy that is released when a nuclear weapon is detonated, expressed usually as the equivalent mass of trinitrotoluene (TNT) [*e.g.*, in kilotons (thousands of tons of TNT)].

personal dose equivalent (at 10 mm): An operational quantity used in personal monitoring. In this case, measured at a depth of 10 mm.

personal protection equipment (PPE**):** (see *bunker gear*).

personal radiation detector: A device worn by an individual to monitor the radiation dose received by the individual.

photons: (see *radiation types*).

prodromal: Relating to prodrome (an early or premonitory symptom of a disease).

rad: (see *radiation units and names*).

radiation control zones: In this Report, radiation control zones are categorized by exposure rate. Three zones are defined:

- cold [outdoor exposure rate ≤10 mR h^{-1} (~0.1 mGy h^{-1} air-kerma rate)];
- hot [>10 mR h^{-1} (~0.1 mGy h^{-1})]; or
- or dangerous-radiation zones [≥10 R h^{-1} (~0.1 Gy h^{-1})].

radiation types (ionizing):

alpha particles: Energetic nuclei of helium atoms, consisting of two protons and two neutrons emitted spontaneously from nuclei in the decay of some radionuclides (*e.g.*, ^{226}Ra). Alpha particles have very low penetrating power (*e.g.*, typically stopped by a few centimeters of air or the outer dead layer of skin). Alpha particles are generally not a health problem unless the source is taken into the body *via* inhalation, ingestion or absorption, or through wounds.

beta particles: Energetic electrons or positrons (*i.e.*, positively charged electrons) emitted spontaneously from nuclei in the decay of some radionuclides (*e.g.*, ^{90}Sr). Beta particles are not highly penetrating (*e.g.*, the lower-energy beta particles are typically stopped by a few millimeters of tissue; the higher-energy beta particles can be stopped by a few centimeters of tissue). However, beta particles on the skin can cause significant injury if not removed by timely decontamination.

gamma rays: High-energy electromagnetic radiation (photons) emitted in nuclear transitions (*e.g.*, radioactive decay of ^{137}Cs) with energies particular to the transition. Gamma rays have moderate-to-high penetrating power, are often able to penetrate deep into the body, and require thick shielding, such as up to ~3 feet (1 m) of concrete.

neutrons: Uncharged particles found in the nucleus of every atom except ^{1}H. Energetic neutrons are produced in spontaneous fission of nuclei (*e.g.*, ^{252}Cf), fission induced by absorption of neutrons by nuclei (*e.g.*, ^{239}Pu), and by absorption of other particles by nuclei (*e.g.*, absorption of alpha particles by ^{9}Be). Neutrons have no electric charge, are usually highly penetrating, have an enhanced ability to cause biological damage, and require thick shielding.

photons: Quanta of electromagnetic radiation, having no charge or mass, but having momentum (see *gamma rays* and *x rays*).

x rays: Electromagnetic radiation (photons) emitted in transitions of atomic orbital electrons after ionization or excitation of atoms (yielding characteristic x rays), or in the deceleration of energetic charged particles (*e.g.*, electrons) in passing through matter (bremsstrahlung). X rays are typically of lower energy than gamma rays, but some orbital electron transitions are of higher energy than some nuclear transitions, so there can be an overlap between the low-energy gamma rays and high-energy x rays. X rays have moderate-to-high penetrating power, are able to penetrate deep into the body, and may require shielding of up to a few tens of centimeters of concrete.

radiation units and names:

becquerel (Bq**):** The SI special name for the unit [disintegration per second (s^{-1})] of activity. 1 Bq = 1 disintegration per second (see *activity* and *curie*).

curie (Ci**):** The previous special unit for activity. 1 curie = 3.7×10^{10} disintegrations per second = 3.7×10^{10} Bq (see *activity* and *becquerel*).

gray (Gy**):** The SI special name for the unit (J kg^{-1}) of absorbed dose. 1 Gy = 1 J kg^{-1} (see *absorbed dose* and *rad*).

rad: The previous special unit for absorbed dose. 1 rad = 0.01 J kg^{-1}; 100 rad = 1 Gy (see *absorbed dose* and *gray*).

rem: The previous special unit for equivalent dose and effective dose. 1 rem = 0.01 J kg^{-1}; 100 rem = 1 Sv (see *equivalent dose*, *effective dose*, and *sievert*).

roentgen (R**):** The previous special unit for exposure. 1 R = 2.58×10^{-4} coulombs per kilogram (C kg^{-1}) (see *exposure*).

sievert (Sv**):** The SI special name for the unit (J kg^{-1}) of equivalent dose and effective dose. 1 Sv = 1 J kg^{-1} (see *equivalent dose*, *effective dose*, and *rem*).

radioactivity: The property of some atomic nuclei of spontaneously emitting gamma rays or subatomic particles (*e.g.*, alpha and beta particles).

radiological: A general term pertaining to radiation and radioactive material.

radionuclide: A radioactive element, man-made or from natural sources, with a specific atomic weight.

rem: (see *radiation units and names*).

roentgen (R**):** (see *radiation units and names*).

sensitivity: A measure of the ability of a radiation measuring device to detect small doses or low levels of contamination.

sievert (Sv**):** (see *radiation units and names*).

stochastic effects: Health effects, the probability of which, rather than their severity, is assumed to be a function of radiation dose without a threshold.

terrorism: The unlawful use of force against individuals or property to intimidate a government, the civilian population, or any segment thereof, in the furtherance of political objectives.

therapy: The practical treatment for remediation of diseases or disorders.

threshold: The point at which a stimulus first produces an effect (response).

time-to-vomiting: A symptom of acute radiation syndrome; the time lapse from radiation exposure to when vomiting initially occurs.

triage: Medical screening of patients prior to treatment to determine their relative priority for treatment, with separation into one of three groups: (1) those who cannot be expected to survive even with treatment; (2) those who will recover without treatment; and (3) the highest priority, those who will or may survive with treatment. Triage is also used as a tool to sort individuals who may have been exposed to large doses of radiation. The triage for persons exposed to radiation is to sort them into categories of high, intermediate and low, and is associated with acute radiation syndrome.

urban canyon: An artifact of an urban environment similar to a natural canyon. It is caused by streets cutting through dense blocks of structures, especially skyscrapers, which cause a canyon effect that channels the wind.

x rays: (see *radiation types*).

Abbreviations and Acronyms

ALARA	as low as is reasonably achievable
AMTS	alternative medical treatment site
ARS	acute radiation syndrome (sickness)
CAC	Codex Alimentarius Commission (FAO/WHO)
CCFAC	Codex Committee on Food Additives and Contaminants
CDG	Clinical Decision Guide
CMHT	Consequence Management Home Team
CMRT	Consequence Management Response Team
CRC	community reception center
DMORT	Disaster Mortuary Operational Response Team (DHHS)
ED	emergency department (of a hospital or medical center)
EOC	emergency operations center
EMP	electromagnetic pulse
FAO	Food and Agriculture Organization (UN)
FEMA	Federal Emergency Management Agency (DNS)
FRMAC	Federal Radiological Monitoring and Assessment Center (DOE)
EMS	emergency medical services
HAZMAT	hazardous material
HRDC	hospital reception and decontamination center
IMAAC	Interagency Modeling and Atmospheric Assessment Center (DHS)
IND	improvised nuclear device
JIC	joint information center
KI	potassium iodide
LD_{50}	lethal dose for causing death in 50 % of exposed persons (can also be defined for any other percentage of the population)
MRC	Medical Reserve Corps
NARAC	National Atmospheric Release Advisory Center
NIMS	National Incident Management System (FEMA)
NRF	National Response Framework (FEMA)
NRIA	Nuclear/Radiological Incident Annex (FEMA)
PAG	Protective Action Guide
PF	protection factor
PPE	personal protection equipment
RAP	Radiological Assistance Program (DOE)
RDD	radiological dispersal device
REAC/TS	Radiation Emergency Assistance Center/Training Site

RED	radiation exposure device
SI	Systeme Internationale (International System) of Units
TDC	temporary decontamination center
SNS	Strategic National Stockpile (CDC)
VMI	Vendor Managed Inventory (CDC)

References

AFRRI (2003). Armed Forces Radiobiology Research Institute. *Medical Management of Radiological Casualties,* 2nd ed., http://www.afrri.usuhs.mil (accessed September 28, 2010) (Armed Forces Radiobiology Research Institute, Bethesda, Maryland).

AFRRI (2007). Armed Forces Radiobiology Research Institute. *Biodosimetry Worksheet*, http://www.afrri.usuhs.mil/outreach/pdf/afriiform331.pdf (accessed September 28, 2010) (Armed Forces Radiobiology Research Institute, Bethesda, Maryland).

AHRQ (2005). Agency for Healthcare Research and Quality. *Altered Standards of Care in Mass Casualty Events: Bioterrorism and Other Public Health Emergencies*, AHRQ Publication No. 05-0043, http://www.ahrq.gov/research/altstand/altstand.pdf (accessed September 28, 2010) (Health Systems Research, Rockville, Maryland).

ALEXANDER, G.A., SWARTZ, H.M., AMUNDSON, S.A., BLAKELY, W.F., BUDDEMEIER, B., GALLEZ, B., DAINIAK, N., GOANS, R.E., HAYES, R.B., LOWRY, P.C., NOSKA, M.A., OKUNIEFF, P., SALNER, A.L., SCHAUER, D.A., TROMPIER, F., TURTELTAUB, K.W., VOISIN, P., WILEY, A.L., JR. and WILKINS, R. (2007). "BiodosEPR-2006 meeting: Acute dosimetry consensus committee recommendations on biodosimetry applications in events involving uses of radiation by terrorists and radiation accidents," Radiat. Meas. **42**(6–7), 972–996.

ANNO, G.H., YOUNG, R.W., BLOOM, R.M. and MERCIER, J.R. (2003). "Dose response relationships for acute ionizing-radiation lethality," Health Phys. **84**(5), 565–575.

ANSARI, A. (2009). *Radiation Threats and Your Safety: A Guide to Preparation and Response for Professionals and Community* (CRC Press, Boca Raton, Florida).

ANSI (2006a). American National Standards Institute. *Criteria for Alarming Personal Radiation Detectors for Homeland Security*, ANSI N42.32-2006 (American National Standards Institute, Washington).

ANSI (2006b). American National Standards Institute. *American National Standard for Portable Radiation Detection Instrumentation for Homeland Security*, ANSI N42.33-2006 (American National Standards Institute, Washington).

ASTM (2008). American Standard Test Method. *Standard Practice for Radiological Emergency Response*, ASTM E2601-08 (American Standard Test Method International, West Conshohocken, Pennsylvania).

BASLER, B. (2006). "No friend left behind: The public demands evacuation plans for people and pets," AARP Bull. (May).

BECKER, S.M. (2001). "Psychological effects of radiation accidents," pages 515 to 523 in *Medical Management of Radiation Accidents*, 2nd ed., Gusev, I.A., Guskova, A.K. and Mettler, F.A., Jr., Eds. (CRC Press, Boca Raton, Florida).

BECKER, S.M. (2004). "Emergency communication and information issues in terrorism events involving radioactive materials," Biosecur. Bioterror. **2**(3), 195–207.

BECKER, S.M. (2005). "Addressing the psychosocial and communication challenges posed by radiological/nuclear terrorism: Key developments since NCRP Report No. 138," Health Phys. **89**(5), 521–530.

BERGER, M.E., LEONARD, R.B., RICKS, R.C., WILEY, A.L., LOWRY, P.C. and FLYNN, D.F. (2009). *Hospital Triage in the First 24 Hours after a Nuclear or Radiological Disaster*, http://orise.orau.gov/reacts/files/triage.pdf (accessed September 28, 2010) (Oak Ridge Institute for Science and Education, Oak Ridge, Tennessee).

BLAKELY, W.F., CARR, Z., CHU, M.C., DAYAL-DRAGER, R., FUJIMOTO, K., HOPMEIR, M., KULKA, U., LILLIS-HEARNE, P., LIVINGSTON, G.K., LLOYD, D.C., MAZNYK, N., PEREZ MDEL, R., ROMM, H., TAKASHIMA, Y., VOISIN, P., WILKINS, R.C. and YOSHIDA, M.A. (2009). "WHO 1st consultation on the development of a global biodosimetry laboratories network for radiation emergencies (BioDoseNet)," Radiat. Res. **171**(1), 127–139.

BMA (1983). British Medical Association. *The Medical Effects of Nuclear War: The Report of the British Medical Association's Board of Science and Education* (John Wiley, New York).

BRODSKY, A., JOHNSON, R. and GOANS, R. (2004). *Public Protection from Nuclear, Chemical, and Biological Terrorism* (Medical Physics Publishing, Madison, Wisconsin).

BUDDEMEIER, B.R. and DILLON, M.B. (2009). *Key Response Planning Factors for the Aftermath of Nuclear Terrorism*, LLNL-TR-410067 (Lawrence Livermore National Laboratory, Livermore, California).

BUSHBERG, J.T., KROGER, L.A., HARTMAN, M.B., LEIDHOLDT, E.M., JR., MILLER, K.L., DERLET, R. and WRAA, C. (2007). "Nuclear/radiological terrorism: Emergency department management of radiation casualties," J. Emerg. Med. **32**(1), 71–85.

CAC (2004). Codex Alimentarius Commission. *Proposed Draft Revised Guideline Levels for Radionuclides in Foods Following Accidental Nuclear Contamination for Use in International Trade,* CAC/GL 51989 (World Health Organization, Geneva).

CAC (2006). Codex Alimentarius Commission. *Codex General Standard for Contaminants and Toxins in Foods*, CODEX STAN 193-1995 (adopted 1995, revised 1997), http://www.codexalimentarius.net/download/standards/17/CXS_193e.pdf (accessed September 28, 2010) (World Health Organization, Geneva).

CDC (2003). Centers for Disease Control and Prevention. *Interim Guidelines for Hospital Response to Mass Casualties from a Radiological Incident*, Smith, J.M. and Spano, M.A., Eds. (Centers for Disease Control and Prevention, Atlanta, Georgia).

CDC (2007a). Centers for Disease Control and Prevention. *International Health Regulations*, http://www.cdc.gov/cogh/ihregulations.htm (accessed

September 28, 2010) (Centers for Disease Control and Prevention, Atlanta, Georgia).

CDC (2007b). Centers for Disease Control and Prevention. *Radiological Terrorism: Just in Time Training for Hospital Clinicians*, http://www.bt.cdc.gov/radiation/justintime.asp (accessed September 28, 2010) (Centers for Disease Control and Prevention, Atlanta, Georgia).

CDC (2007c). Centers for Disease Control and Prevention. *Population Monitoring in Radiation Emergencies: A Guide for State and Local Public Health Planners*, http://www.emergency.cdc.gov/radiation/pdf/population-monitoring-guide.pdf (accessed September 28, 2010) (Centers for Disease Control and Prevention, Atlanta, Georgia).

CDC (2008a). Centers for Disease Control and Prevention. *Population Monitoring after a Release of Radioactive Materials*, http://www.emergency.cdc.gov/radiation/populationmonitoring.asp (accessed September 28, 2010) (Centers for Disease Control and Prevention, Atlanta, Georgia).

CDC (2008b). Centers for Disease Control and Prevention. *Strategic National Stockpile (SNS)*, http://www.bt.cdc.gov/Stockpile (accessed September 28, 2010) (Centers for Disease Control and Prevention, Atlanta, Georgia).

COCDM (1996). The City of Oklahoma City Document Management. *Alfred P. Murrah, Federal Building Bombing, April 19, 1995: Final Report* (Fire Protection Publications, Stillwater, Oklahoma).

CRCPD (2006). Conference of Radiation Control Program Directors, Inc. *Handbook for Responding to a Radiological Dispersal Device, First Responder's Guide—The First 12 Hours*, CRCPD Publication 06-6 (Conference of Radiation Control Program Directors, Inc., Frankfort, Kentucky).

CROCKER, G.R., O'CONNOR, J.D. and FREILING, E.C. (1966), "Physical and radiochemical properties of fallout particles," Health Phys. **12**(8), 1099–1104.

DHHS (2008). U.S. Department of Health and Human Services. *Disaster Mortuary Operational Response Teams (DMORTs)*, http://www.hhs.gov/aspr/opeo/ndms/teams/dmort.html (accessed September 28, 2010) (U.S. Department of Health and Human Services, Washington).

DHHS (2010). U.S. Department of Health and Human Services. *Radiation Event Medical Management: Guidance on Diagnosis and Treaatment for Health Care Providers*, http://www.remm.nlm.gov (accessed September 28, 2010) (U.S. Department of Health and Human Services, Washington).

DHS (2008). U.S. Department of Homeland Security. *Planning Guidance for Protection and Recovery Following Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND) Incidents*, 73 FR 149, http://www.fema.gov/good_guidance/download/10260 (accessed September 28, 2010) (U.S. Department of Homeland Security, Washington).

DOD (2001). U.S. Department of Defense. *Treatment of Nuclear and Radiological Casualties* (Army FM 4-02.283), *Fallout Protection for Homes with Basements* (Navy NTRP 4-02.21): Series H-12 (revised May 1967), http://www.army.mil/usapa/doctrine/active_fm.html (accessed September 28, 2010) (U.S. Department of Defense, Washington).

DOE (2000). U.S. Department of Energy. *Model Procedure for a Medical Examiner/Coroner on the Handling of a Body/Human Remains that are Potentially Radiologically Contaminated* (Rev. 4, 2005) (U.S. Department of Energy, Washington).

DOE (2010). U.S. Department of Energy. *Federal Radiological Monitoring and Assessment Center Response Phases, Consequence Management Home Team (CMHT),* http://www.nv.doe.gov/nationalsecurity/homelandsecurity/frmac/phases.aspx#CMHT (accessed September 28, 2010) (U.S. Department of Energy, National Nuclear Security Administration, Las Vegas, Nevada).

DOT (1977). U.S. Department of Transportation. *Hazardous Material Table, Special Provisions, Hazardous Communications, Emergency Response Information, Training Requirements and Security Plans*, Subpart Labeling, 49 CFR 172.403, Class 7 radioactive material (U.S. Department of Transportation, Washington).

EMSA (2009). Emergency Medical Services Authority. *Disaster Medical Services—Hospital Incident Command System (HICS)*, http://www.emsa.ca.gov/hics (accessed September 28, 2010) (Emergency Medical Services Authority, Sacramento, California).

EOP (2010). Executive Office of the President. *Planning Guidance for Response to a Nuclear Detonation*, 1st ed., http://hps.org/hsc/documents/Planning_Guidance_for_Response_to_a_Nuclear_Detonation-2nd_Edition_FINAL.pdf (accessed September 28, 2010) (Executive Office of the President, Office of Science and Technology Policy, Washington).

EPA (1974). U.S. Environmental Protection Agency. *Safe Drinking Water Act of 1974* (amended) (U.S. Environmental Protection Agency, Washington).

EPA (1992). U.S. Environmental Protection Agency. *Manual of Protective Action Guides and Protective Actions for Nuclear Incidents*, EPA 400-R-92-001(1992), http://www.epa.gov/radiationdocs/er/400-r-92-001.pdf (accessed September 28, 2010) (U.S. Environmental Protection Agency, Washington).

EPA (2007). U.S. Environmental Protection Agency. *Communicating Radiation Risks: Crisis Communications for Emergency Responders*, EPA 402-F-07-008 (U.S. Environmental Protection Agency, Washington).

EPA (2008a). U.S. Environmental Protection Agency. *Radioactive Waste Disposal: An Environmental Perspective*, EPA 402-K-94-001, http://www.epa.gov/radiation/docs/radwaste (accessed September 28, 2010) (U.S. Environmental Protection Agency, Washington).

EPA (2008b). U.S. Environmental Protection Agency. *Homeland Security*, http://www.epa.gov/radiation/rert/homelandsecurity.html#federalresponse (accessed September 28, 2010) (U.S. Environmental Protection Agency, Washington).

FBI/CDC (2009). Federal Bureau of Investigation/Centers for Disease Control and Prevention and Prevention. *Radiological/Nuclear Law*

Enforcement and Public Health Investigation Handbook (U.S. Department of Health and Human Services, Washington).

FDA (1998). U.S. Food and Drug Administration. *Accidental Radioactive Contamination of Human Food and Animal Feeds: Recommendations for State and Local Agencies,* http://www.fda.gov/downloads/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/UCM094513.pdf (accessed September 28, 2010) (U.S. Food and Drug Administration, Rockville, Maryland).

FEMA (2002). Federal Emergency Management Agency. *Background Information on FEMA-REP-22: Contamination Monitoring Guidance for Portable Instruments Used for Radiological Emergency Response to Nuclear Power Plant Accidents* (Federal Emergency Management Agency, Washington).

FEMA (2005). Federal Emergency Management Agency. *Compendium of Federal Terrorism Training for State and Local Audiences*, http://www.fema.gov/compendium/indes.jsp (accessed September 28, 2010) (Federal Emergency Management Agency, Washington).

FEMA (2008a). Federal Emergency Management Agency. *National Response Framework*, http://www.fema.gov/pdf/emergency/nrf/nrf-core.pdf (accessed September 28, 2010) (Federal Emergency Management Agency, Washington).

FEMA (2008b). Federal Emergency Management Agency. *Nuclear/Radiological Incident Annex to the National Response Framework*, http://www.fema.gov/pdf/emergency/nrf/nrf_nuclearradiologicalindidentannex.pdf (accessed September 28, 2010) (Federal Emergency Management Agency, Washington).

FEMA (2008c). Federal Emergency Management Agency. *National Incident Management System* (December 2008), http://www.fema.gov/pdf/emergency/nims/NIMS_core.pdf (accessed September 28, 2010) (Federal Emergency Management Agency, Washington).

FMS (2008). Federal Medical Stations. *Federal Medical Station Profile*, http://www.texasjrac.org/documents/FMSfactsheetv3-1.pdf (accessed September 28, 2010) (Centers for Disease Control and Prevention, Atlanta, Georgia).

GARTY, G., CHEN, Y., SALERNO, A., TURNER, H., ZHANG, J., LYULKO, O., BERTUCCI, A., XU, Y., WANG, H., SIMAAN, N., RANDERS-PEHRSON, G., YAO, Y.L., AMUNDSON, S.A. and BRENNER, D.J. (2010). "The Rabit: A rapid automated biodosimetry tool for radiological triage," Health Phys. **98**(2), 209–217.

GLASSTONE, S. and DOLAN, P.J., Eds. (1977). *The Effects of Nuclear Weapons*, 3rd ed., http://handle.dtic.mil/100.2/ADA087568 (accessed September 28, 2010) (U.S. Department of Defense, Washington).

GOANS, R.E. and WASELENKO, J.K. (2005). "Medical management of radiological casualties," Health Phys. **89**(5), 505–512.

HANZLICK, R., NOLTE, K. and DEJONG, J. (2007). *The Medical Examiner/Coroner's Guide for Contaminated Deceased Body Management* (National Association of Medical Examiners, Atlanta, Georgia).

HARPER, F.T., MUSOLINO, S.V. and WENTE, W.B. (2007). "Realistic radiological dispersal device hazard boundaries and ramifications for early consequence management decisions," Health Phys. **93**(1), 116.

HPS (2008). Health Physics Society. *Emergency Department Management of Radiation Casualties*, www.hps.org/hsc/documents/emergency.ppt (accessed September 28, 2010) (Health Physics Society, McLean, Virginia).

HRDINA, C.M., COLEMAN, C.N., BOGUCKI, S., BADER, J.L., HAYHURST, R.E., FORSHA, J.D., MARCOZZI, D., YESKEY, K. and KNEBEL, A.R. (2009). "The "RTR" medical response system for nuclear and radiological mass-casualty incidents: A functional TRiage-TReatment-TRansport medical response model," Prehosp. Disaster Med. **24**(3), 167–178.

IAEA (1990). International Atomic Energy Agency. *Extension of the Principles of Radiation Protection to Sources of Potential Exposure*, Safety Series No. 104 (International Atomic Energy Agency, Vienna).

IAEA (1996). International Atomic Energy Agency. *International Basic Safety Standards for Protection Against Ionizing Radiation and for the Safety of Radiation Sources*, Safety Series No. 115 (International Atomic Energy Agency, Vienna).

IAEA (1997). International Atomic Energy Agency. *Method for the Development of Emergency Response Preparedness for Nuclear or Radiological Accidents*, IAEA-TECDOC Series No. 953 (International Atomic Energy Agency, Vienna).

IAEA (1998). International Atomic Energy Agency. *Diagnosis and Treatment of Radiation Injuries*, Safety Report Series No. 2 (International Atomic Energy Agency, Vienna).

IAEA (2001). International Atomic Energy Agency. *Cytogenetic Analysis for Radiation Dose Assessment: A Manual*, Technical Reports Series No. 405 (International Atomic Energy Agency, Vienna).

IAEA (2004a). International Atomic Energy Agency. *Application of the Concepts of Exclusion, Exemption and Clearance*, Safety Guide No. RS-G-1.7, http://www-ns.iaea.org/downloads/drafts/ds161.pdf (accessed September 28, 2010) (International Atomic Energy Agency, Vienna).

IAEA (2004b). International Atomic Energy Agency. *Code of Conduct on the Safety and Security of Radioactive Sources*, IAEA/CODECO/2004 (International Atomic Energy Agency, Vienna).

IAEA (2004c). International Atomic Energy Agency. *Measures to Strengthen International Cooperation in Nuclear, Radiation and Transport Safety and Waste Management: Radiological Criteria for Radionuclides in Commodities*, GC(48)/RES/10 under 805 A, 4, pt. 23 (International Atomic Energy Agency, Vienna).

IAEA (2005). International Atomic Energy Agency. *Generic Procedures for Medical Response During a Nuclear or Radiological Emergency*, http://www-pub.iaea.org/MTCD/publications/PDF/EPR-MEDICAL-2005_web.pdf (accessed September 28, 2010) (International Atomic Energy Agency, Vienna).

IAEA (2006). International Atomic Energy Agency. *Manual for Emergency Responders to a Radiological Emergency*, http://www-pub.iaea.org/MTCD/publications/PDF/EPR_FirstResponder_web.pdf (accessed September 28, 2010) (International Atomic Energy Agency, Vienna).

ICRP (1993). International Commission on Radiation Protection. *Protection From Potential Exposure: A Conceptual Framework*, ICRP Publication 64, Ann. ICRP **23**(1) (Elsevier, New York).

ICRP (1996). International Commission on Radiological Protection. *Radiological Protection and Safety in Medicine*, ICRP Publication 73, Ann. ICRP **26**(2) (Elsevier, New York).

ICRP (1997). International Commission on Radiological Protection. *Protection for Potential Exposures: Application to Selected Radiation Sources*, ICRP Publication 76, Ann. ICRP **27**(2) (Elsevier, New York).

ICRP (1999). International Commission on Radiological Protection. *Protection of the Public in Situations of Prolonged Radiation Exposure: The Application of the Commission's System of Radiological Protection to Controllable Radiation Exposure Due to Natural Sources and Long-lived Radioactive Residues*, ICRP Publication 82, Ann. ICRP **29**(12) (Elsevier, New York).

ICRP (2005). International Commission on Radiological Protection. *Protecting People Against Radiation Exposure in the Event of a Radiological Attack*, ICRP Publication 96, Ann. ICRP **35**(1) (Elsevier, New York).

ICRP (2007). International Commission on Radiological Protection. *The 2007 Recommendations of the International Commission on Radiological Protection*, ICRP Publication 103, Ann. ICRP **37**(2–4) (Elsevier, New York).

ICRP (2008). International Commission on Radiological Protection. *Scope of Radiological Protection Control Measures,* ICRP Publication 104, Ann. ICRP **37**(5) (Elsevier, New York).

ICRU (2002). International Commission on Radiation Units and Measurements. *Retrospective Assessment of Exposures to Ionising Radiation*, ICRU Report 68, J. ICRU **2**(2).

IOM (2009). Institute of Medicine. *Assessing Medical Preparedness to Respond to a Terrorist Nuclear Event: Workshop Report* (National Academies Press, Washington).

JCS (1997). Joint Chiefs of Staff. *Joint Tactics, Techniques, and Procedures for Morgue Affairs in Joint Operations*, Joint Pub 4-0.7 (Joint Chiefs of Staff, Washington).

KOENIG, K.L. (2003). "Strip and shower: The duck and cover for the 21st century," Ann. Emerg. Med. **42**(3), 391–394.

LA COUNTY (2009). Los Angeles County. *Multi-Agency Radiological Response Plan, Volume II, Attachment 5* (February 2009) (Los Angeles County, Los Angeles, California).

LEVANON, I. and PERNICK, A. (1988). "The inhalation hazard of radioactive fallout," Health Phys. **54**(6), 645–657.

LOMBARDO, J.S., BURKOM, H. and PAVLIN, J. (2004). "ESSENCE II and the framework for evaluating syndromic surveillance systems," MMWR **53**(Suppl), 159–165.

MAIELLO, M.L. and GROVES, K.L. (2006). "Resources for nuclear and radiation disaster response," Nucl. News **49**(10), 29–34.

METTLER, F.A., JR. and VOELZ, G.L. (2002). "Major radiation exposures: What to expect and how to respond," N. Engl. J. Med. **346**(20), 1554–1561.

MRC (2008). Medical Reserve Corps. *Volunteers Building Strong, Healthy, and Prepared Communities*, http://www.medicalreservecorps.gov/HomePage (accessed September 28, 2010) (Office of the Civilian Volunteer Medical Reserve Corps, Rockville, Maryland).

MUSOLINO, S.V. and HARPER, F.T. (2006). "Emergency response guidance for the first 48 hours after the outdoor detonation of an explosive radiological dispersal device," Health Phys. **90**(4), 377–385.

MUSOLINO, S.V., DEFRANCO, J. and SCHLUECK, R. (2008). "The ALARA principle in the context of a radiological or nuclear emergency," Health Phys. **94**(2), 109–111.

NAME (2006). National Association of Medical Examiners. *The Medical Examiner / Coroner's Guide for Contaminated Deceased Body Management* (National Association of Medical Examiners, Atlanta, Georgia).

NATO (1996). North American Treaty Organization. "Chapter 3: Effects of nuclear explosions," in *NATO Handbook on the Medical Aspects of NBC Defensive Operations (Part I - Nuclear)* (U.S. Departments of the Army, Navy, and Air Force, Washington.

NCRP (1985). National Council on Radiation Protection and Measurements. *SI Units in Radiation Protection and Measurements*, NCRP Report No. 82 (National Council on Radiation Protection and Measurements, Bethesda, Maryland).

NCRP (1993). National Council on Radiation Protection and Measurements. *Limitation of Exposure to Ionizing Radiation*, NCRP Report No. 116 (National Council on Radiation Protection and Measurements, Bethesda, Maryland).

NCRP (2001). National Council on Radiation Protection and Measurements. *Management of Terrorist Events Involving Radioactive Material*, NCRP Report No. 138 (National Council on Radiation Protection and Measurements, Bethesda, Maryland).

NCRP (2005). National Council on Radiation Protection and Measurements. *Key Elements of Preparing Emergency Responders for Nuclear and Radiological Terrorism*, NCRP Commentary No. 19 (National Council on Radiation Protection and Measurements, Bethesda, Maryland).

NCRP (2008). National Council on Radiation Protection and Measurements. *Management of Persons Contaminated with Radionuclides*, NCRP Report No. 161 (National Council on Radiation Protection and Measurements, Bethesda, Maryland).

NCRP (2009). National Council on Radiation Protection and Measurements. *Self Assessment or Radiation-Safety Programs,* NCRP Report No. 162 (National Council on Radiation Protection and Measurements, Bethesda, Maryland).

NCRP (in press). National Council on Radiation Protection and Measurements. *Population Monitoring and Decontamination Following a Radiological or Nuclear Incident*, NCRP Report No. 166 (National Council on Radiation Protection and Measurements, Bethesda, Maryland).

NEMA (2009). National Emergency Management Association. *Emergency Management Assistance Compact*, http://www.emacweb.org (accessed September 28, 2010) (National Emergency Management Association, Lexington, Kentucky).

NFPA (2005). National Fire Protection Association. *Professional Competence of Responders to Hazardous Materials Incidents*, NFPA Standard 472 (National Fire Protection Association, Quincy, Massachusetts).

NMDP (2010). National Marrow Donor Program. *RITN: Radiation Injury Treatment Network*, http://www.ritn.net (accessed September 28, 2010) (National Marrow Donor Program, Minneapolis, Minnesota).

NRC (1992). U.S. Nuclear Regulatory Commission. *Planned Special Exposures*, Regulatory Guide 8.35, http://www.nrc.gov/reading-rm/doc-collections/reg-guides/occupational-health/rg/8-35 (accessed September 28, 2010) (U.S. Nuclear Regulatory Commission, Washington).

NRC (1993). U.S. Nuclear Regulatory Commission. *Standards for Protection Against Radiation,* 10 CFR Part 20, http://www.nrc.gov/reading-rm/doc-collections/cfr/part020 (accessed September 28, 2010) (U.S. Nuclear Regulatory Commission, Washington).

NRC (2006). U.S. Nuclear Regulatory Commission. *Medical Use of Byproduct Material: Final Rule*, 10 CFR Part 35, http://www.nrc.gov/reading-rm/doc-collections/cfr/part035 (accessed September 28, 2010) (U.S. Nuclear Regulatory Commission, Washington).

ORISE (2010). Oak Ridge Institute for Science and Education. *Radiation Emergency Assistance Center/Training Site (REAC/TS)*, http://orise.orau.gov/reacts (accessed September 28, 2010) (Oak Ridge Institute for Science and Education, Oak Ridge, Tennessee).

OSHA (2005). Occupational Safety and Health Administration. *Best Practices for Hospital-Based First Receivers of Victims from Mass Casualty Incidents Involving the Release of Hazardous Substances*, http://www.osha.gov/dts/osta/bestpractices/firstreceivers_hospital.pdf (accessed September 28, 2010) (Occupational Safety and Health Administration, Washington).

OSHA (2006). Occupational Safety and Health Administration. *Hazardous Waste Operations and Emergency Response*, OSHA Regulations 29 CFR 1910.120[q] (Occupational Safety and Health Administration, Washington).

PARKER, D.D. and PARKER, J.C. (2007). "Estimating radiation dose from time to emesis and lymphocyte depletion," Health Phys. **93**(6), 701–704.

PELLMAR, T.C. and ROCKWELL, S. (2005). "Priority list of research areas for radiological nuclear threat countermeasures," Radiat. Res. **163**(1), 115–123.

SCHENK, T.L. (2006). *Alternative Medical Treatment Site Plan (AMTS), Pre-Hospital Planning Emergency Medical Response* (Florida Department of Health, Tallahassee, Florida).

SCHENK, T.L. (2008). *Triage Report: A Brief Assessment of Florida's Pre-Hospital Triage Strategy* (final draft, September 2008) (Florida Department of Health, Tallahassee, Florida).

SMITH, J.M., ANSARI, A. and HARPER, F.T. (2005). "Hospital management of mass radiological casualties: Reassessing exposures from contaminated victims of an exploded radiological dispersal device," Health Phys. **89**(5), 513–520.

TJC (2005). The Joint Commission. *Standing Together: An Emergency Planning Guide for America's Communities* (The Joint Commission, Oakbrook Terrace, Illinois).

UEVHPA (2007). Uniform Emergency Volunteer Health Practitioners Act. National Conference of Commissioners on Uniform State Laws, http://www.uevhpa.org/DesktopDefault.aspx?tabindex=1&tabid=69 (accessed September 28, 2010) (National Conference of Commissioners on Uniform State Laws, Chicago, Illinois).

U.S. ARMY (2008). *U.S. Army Board Study Guide: Version 5.3*, http://www.armystudyguide.com/content/powerpoint/First_Aid_Presentations/triage-2.shtml (accessed September 28, 2010) (U.S. Army, Washington).

WASELENKO, J.K., MACVITTIE, T.J., BLAKELY, W.F., PESIK, N., WILEY, A.L., DICKERSON, W.E., TSU, H., CONFER, D.L., COLEMAN, C.N., SEED, T., LOWRY, P., ARMITAGE, J.O. and DAINIAK, N. (2004). "Medical management of the acute radiation syndrome: Recommendations of the Strategic National Stockpile Radiation Working Group," Ann. Intern. Med. **140**(12), 1037–1051.

WEISDORF, D., APPERLEY, J., COURMELON, P., GORIN, N.C., WINGARD, J. and CHAO, N. (2007). "Radiation emergencies: Evaluation, management, and transplantation," Biol. Blood Marrow Transplant. **13**(Suppl. 1), 103–106.

WHO (2004). World Health Organization. *Guidelines for Drinking-Water Quality, Third Edition, Volume 1 Recommendations,* http://www.who.int/water_sanitation_health/dwq/gdwq3_9.pdf (accessed September 28, 2010) (World Health Organization, Geneva).

WOOD, C.M., DEPAOLO, F. and WHITAKER, R.D. (2007). *Guidelines for Handling Decedents Contaminated with Radioactive Materials* (Centers for Disease Control and Prevention, Atlanta, Georgia).

YOSHIMURA, A.S. and BRANDT, L.D. (2009). *Analysis of Sheltering and Evacuation Strategies for an Urban Nuclear Detonation Scenario*, SAND2009-3299 (Sandia National Laboratories, Albuquerque, New Mexico).

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The National Council on Radiation Protection and Measurements is a non-profit corporation chartered by Congress in 1964 to:

1. Collect, analyze, develop and disseminate in the public interest information and recommendations about (a) protection against radiation and (b) radiation measurements, quantities and units, particularly those concerned with radiation protection.
2. Provide a means by which organizations concerned with the scientific and related aspects of radiation protection and of radiation quantities, units and measurements may cooperate for effective utilization of their combined resources, and to stimulate the work of such organizations.
3. Develop basic concepts about radiation quantities, units and measurements, about the application of these concepts, and about radiation protection.
4. Cooperate with the International Commission on Radiological Protection, the International Commission on Radiation Units and Measurements, and other national and international organizations, governmental and private, concerned with radiation quantities, units and measurements and with radiation protection.

The Council is the successor to the unincorporated association of scientists known as the National Committee on Radiation Protection and Measurements and was formed to carry on the work begun by the Committee in 1929.

The participants in the Council's work are the Council members and members of scientific and administrative committees. Council members are selected solely on the basis of their scientific expertise and serve as individuals, not as representatives of any particular organization. The scientific committees, composed of experts having detailed knowledge and competence in the particular area of the committee's interest, draft proposed recommendations. These are then submitted to the full membership of the Council for careful review and approval before being published.

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SC 1-15 Radiation Safety in NASA Lunar Missions'
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SC 1-18 Use of Ionizing Radiation Screen Systems for Detection of Radioactive Materials that Could Represent a Threat to Homeland Security
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SC 1-20 Biological Effectiveness of Photons as a Function of Energy

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SC 2-3 Radiation Safety Issues for Image-Guided Interventional Medical Procedures
SC 2-5 Investigation of Radiological Incidents

Program Area Committee 3: Nuclear and Radiological Security and Safety

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SC 5-1 Approach to Optimizing Decision Making for Late-Phase Recovery from Nuclear or Radiological Terrorism Incidents
SC 64-22 Design of Effective Effluent and Environmental Monitoring Programs

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In recognition of its responsibility to facilitate and stimulate cooperation among organizations concerned with the scientific and related aspects of radiation protection and measurement, the Council has created a category of NCRP Collaborating Organizations. Organizations or groups of organizations that are national or international in scope and are concerned with scientific problems involving radiation quantities, units, measurements and effects, or radiation protection may be admitted to collaborating status by the Council. Collaborating Organizations provide a means by which NCRP can gain input into its activities from a wider segment of society. At the same time, the relationships with the Collaborating Organizations facilitate wider dissemination of information about the Council's activities, interests and concerns. Collaborating Organizations have the opportunity to comment on draft reports (at the time that these are submitted to the members of the Council). This is intended to capitalize on the fact that Collaborating Organizations are in an excellent position to both contribute to the identification of what needs to be treated in NCRP reports and to identify problems that might result from proposed recommendations. The present Collaborating Organizations with which NCRP maintains liaison are as follows:

American Academy of Dermatology
American Academy of Environmental Engineers
American Academy of Health Physics
American Academy of Orthopaedic Surgeons
American Association of Physicists in Medicine
American Bracytherapy Society
American College of Cardiology
American College of Medical Physics
American College of Nuclear Physicians
American College of Occupational and Environmental Medicine
American College of Radiology
American Conference of Governmental Industrial Hygienists
American Dental Association
American Industrial Hygiene Association
American Institute of Ultrasound in Medicine
American Medical Association
American Nuclear Society
American Pharmaceutical Association
American Podiatric Medical Association
American Public Health Association
American Radium Society
American Roentgen Ray Society
American Society for Radiation Oncology
American Society of Emergency Radiology
American Society of Health-System Pharmacists
American Society of Nuclear Cardiology
American Society of Radiologic Technologists
Association of Educators in Imaging and Radiological Sciences
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Defense Threat Reduction Agency
Electric Power Research Institute
Federal Aviation Administration
Federal Communications Commission
Federal Emergency Management Agency
Genetics Society of America

Health Physics Society
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Institute of Nuclear Power Operations
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Society of Nuclear Medicine
Society of Radiologists in Ultrasound
Society of Skeletal Radiology
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U.S. Army
U.S. Coast Guard
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U.S. Department of Housing and Urban Development
U.S. Department of Labor
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U.S. Environmental Protection Agency
U.S. Navy
U.S. Nuclear Regulatory Commission
U.S. Public Health Service
Utility Workers Union of America

NCRP has found its relationships with these organizations to be extremely valuable to continued progress in its program.

Another aspect of the cooperative efforts of NCRP relates to the Special Liaison relationships established with various governmental organizations that have an interest in radiation protection and measurements. This liaison relationship provides: (1) an opportunity for participating organizations to designate an individual to provide liaison between the organization and NCRP; (2) that the individual designated will receive copies of draft NCRP reports (at the time that these are submitted to the members of the Council) with an invitation to comment, but not vote; and (3) that new NCRP efforts might be discussed with liaison individuals as appropriate, so that they might have an opportunity to make suggestions on new studies and related matters. The following organizations participate in the Special Liaison Program:

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Canadian Association of Medical Radiation Technologists
Canadian Nuclear Safety Commission
Central Laboratory for Radiological Protection (Poland)
China Institute for Radiation Protection
Commissariat a l'Energie Atomique (France)
Commonwealth Scientific Instrumentation Research Organization (Australia)
European Commission
Health Council of the Netherlands
Health Protection Agency
International Commission on Non-ionizing Radiation Protection
International Commission on Radiation Units and Measurements
International Commission on Radiological Protection
International Radiation Protection Association
Japanese Nuclear Safety Commission
Japan Radiation Council
Korea Institute of Nuclear Safety
Russian Scientific Commission on Radiation Protection
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World Association of Nuclear Operators
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NCRP values highly the participation of these organizations in the Special Liaison Program.

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8	*Control and Removal of Radioactive Contamination in Laboratories* (1951)
22	*Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure* (1959) [includes Addendum 1 issued in August 1963]
25	*Measurement of Absorbed Dose of Neutrons, and of Mixtures of Neutrons and Gamma Rays* (1961)
27	*Stopping Powers for Use with Cavity Chambers* (1961)
30	*Safe Handling of Radioactive Materials* (1964)
32	*Radiation Protection in Educational Institutions* (1966)
35	*Dental X-Ray Protection* (1970)
36	*Radiation Protection in Veterinary Medicine* (1970)
37	*Precautions in the Management of Patients Who Have Received Therapeutic Amounts of Radionuclides* (1970)
38	*Protection Against Neutron Radiation* (1971)
40	*Protection Against Radiation from Brachytherapy Sources* (1972)
41	*Specification of Gamma-Ray Brachytherapy Sources* (1974)
42	*Radiological Factors Affecting Decision-Making in a Nuclear Attack* (1974)
44	*Krypton-85 in the Atmosphere—Accumulation, Biological Significance, and Control Technology* (1975)
46	*Alpha-Emitting Particles in Lungs* (1975)

47 *Tritium Measurement Techniques* (1976)
49 *Structural Shielding Design and Evaluation for Medical Use of X Rays and Gamma Rays of Energies Up to 10 MeV* (1976)
50 *Environmental Radiation Measurements* (1976)
52 *Cesium-137 from the Environment to Man: Metabolism and Dose* (1977)
54 *Medical Radiation Exposure of Pregnant and Potentially Pregnant Women* (1977)
55 *Protection of the Thyroid Gland in the Event of Releases of Radioiodine* (1977)
57 *Instrumentation and Monitoring Methods for Radiation Protection* (1978)
58 *A Handbook of Radioactivity Measurements Procedures*, 2nd ed. (1985)
60 *Physical, Chemical, and Biological Properties of Radiocerium Relevant to Radiation Protection Guidelines* (1978)
61 *Radiation Safety Training Criteria for Industrial Radiography* (1978)
62 *Tritium in the Environment* (1979)
63 *Tritium and Other Radionuclide Labeled Organic Compounds Incorporated in Genetic Material* (1979)
64 *Influence of Dose and Its Distribution in Time on Dose-Response Relationships for Low-LET Radiations* (1980)
65 *Management of Persons Accidentally Contaminated with Radionuclides* (1980)
67 *Radiofrequency Electromagnetic Fields—Properties, Quantities and Units, Biophysical Interaction, and Measurements* (1981)
68 *Radiation Protection in Pediatric Radiology* (1981)
69 *Dosimetry of X-Ray and Gamma-Ray Beams for Radiation Therapy in the Energy Range 10 keV to 50 MeV* (1981)
70 *Nuclear Medicine—Factors Influencing the Choice and Use of Radionuclides in Diagnosis and Therapy* (1982)
72 *Radiation Protection and Measurement for Low-Voltage Neutron Generators* (1983)
73 *Protection in Nuclear Medicine and Ultrasound Diagnostic Procedures in Children* (1983)
74 *Biological Effects of Ultrasound: Mechanisms and Clinical Implications* (1983)
75 *Iodine-129: Evaluation of Releases from Nuclear Power Generation* (1983)
76 *Radiological Assessment: Predicting the Transport, Bioaccumulation, and Uptake by Man of Radionuclides Released to the Environment* (1984)
77 *Exposures from the Uranium Series with Emphasis on Radon and Its Daughters* (1984)
78 *Evaluation of Occupational and Environmental Exposures to Radon and Radon Daughters in the United States* (1984)
79 *Neutron Contamination from Medical Electron Accelerators* (1984)
80 *Induction of Thyroid Cancer by Ionizing Radiation* (1985)
81 *Carbon-14 in the Environment* (1985)
82 *SI Units in Radiation Protection and Measurements* (1985)

83 *The Experimental Basis for Absorbed-Dose Calculations in Medical Uses of Radionuclides* (1985)
84 *General Concepts for the Dosimetry of Internally Deposited Radionuclides* (1985)
86 *Biological Effects and Exposure Criteria for Radiofrequency Electromagnetic Fields* (1986)
87 *Use of Bioassay Procedures for Assessment of Internal Radionuclide Deposition* (1987)
88 *Radiation Alarms and Access Control Systems* (1986)
89 *Genetic Effects from Internally Deposited Radionuclides* (1987)
90 *Neptunium: Radiation Protection Guidelines* (1988)
92 *Public Radiation Exposure from Nuclear Power Generation in the United States* (1987)
93 *Ionizing Radiation Exposure of the Population of the United States* (1987)
94 *Exposure of the Population in the United States and Canada from Natural Background Radiation* (1987)
95 *Radiation Exposure of the U.S. Population from Consumer Products and Miscellaneous Sources* (1987)
96 *Comparative Carcinogenicity of Ionizing Radiation and Chemicals* (1989)
97 *Measurement of Radon and Radon Daughters in Air* (1988)
99 *Quality Assurance for Diagnostic Imaging* (1988)
100 *Exposure of the U.S. Population from Diagnostic Medical Radiation* (1989)
101 *Exposure of the U.S. Population from Occupational Radiation* (1989)
102 *Medical X-Ray, Electron Beam and Gamma-Ray Protection for Energies Up to 50 MeV (Equipment Design, Performance and Use)* (1989)
103 *Control of Radon in Houses* (1989)
104 *The Relative Biological Effectiveness of Radiations of Different Quality* (1990)
105 *Radiation Protection for Medical and Allied Health Personnel* (1989)
106 *Limit for Exposure to "Hot Particles" on the Skin* (1989)
107 *Implementation of the Principle of As Low As Reasonably Achievable (ALARA) for Medical and Dental Personnel* (1990)
108 *Conceptual Basis for Calculations of Absorbed-Dose Distributions* (1991)
109 *Effects of Ionizing Radiation on Aquatic Organisms* (1991)
110 *Some Aspects of Strontium Radiobiology* (1991)
111 *Developing Radiation Emergency Plans for Academic, Medical or Industrial Facilities* (1991)
112 *Calibration of Survey Instruments Used in Radiation Protection for the Assessment of Ionizing Radiation Fields and Radioactive Surface Contamination* (1991)
113 *Exposure Criteria for Medical Diagnostic Ultrasound: I. Criteria Based on Thermal Mechanisms* (1992)
114 *Maintaining Radiation Protection Records* (1992)
115 *Risk Estimates for Radiation Protection* (1993)
116 *Limitation of Exposure to Ionizing Radiation* (1993)

117 *Research Needs for Radiation Protection* (1993)
118 *Radiation Protection in the Mineral Extraction Industry* (1993)
119 *A Practical Guide to the Determination of Human Exposure to Radiofrequency Fields* (1993)
120 *Dose Control at Nuclear Power Plants* (1994)
121 *Principles and Application of Collective Dose in Radiation Protection* (1995)
122 *Use of Personal Monitors to Estimate Effective Dose Equivalent and Effective Dose to Workers for External Exposure to Low-LET Radiation* (1995)
123 *Screening Models for Releases of Radionuclides to Atmosphere, Surface Water, and Ground* (1996)
124 *Sources and Magnitude of Occupational and Public Exposures from Nuclear Medicine Procedures* (1996)
125 *Deposition, Retention and Dosimetry of Inhaled Radioactive Substances* (1997)
126 *Uncertainties in Fatal Cancer Risk Estimates Used in Radiation Protection* (1997)
127 *Operational Radiation Safety Program* (1998)
128 *Radionuclide Exposure of the Embryo/Fetus* (1998)
129 *Recommended Screening Limits for Contaminated Surface Soil and Review of Factors Relevant to Site-Specific Studies* (1999)
130 *Biological Effects and Exposure Limits for "Hot Particles"* (1999)
131 *Scientific Basis for Evaluating the Risks to Populations from Space Applications of Plutonium* (2001)
132 *Radiation Protection Guidance for Activities in Low-Earth Orbit* (2000)
133 *Radiation Protection for Procedures Performed Outside the Radiology Department* (2000)
134 *Operational Radiation Safety Training* (2000)
135 *Liver Cancer Risk from Internally-Deposited Radionuclides* (2001)
136 *Evaluation of the Linear-Nonthreshold Dose-Response Model for Ionizing Radiation* (2001)
137 *Fluence-Based and Microdosimetric Event-Based Methods for Radiation Protection in Space* (2001)
138 *Management of Terrorist Events Involving Radioactive Material* (2001)
139 *Risk-Based Classification of Radioactive and Hazardous Chemical Wastes* (2002)
140 *Exposure Criteria for Medical Diagnostic Ultrasound: II. Criteria Based on all Known Mechanisms* (2002)
141 *Managing Potentially Radioactive Scrap Metal* (2002)
142 *Operational Radiation Safety Program for Astronauts in Low-Earth Orbit: A Basic Framework* (2002)
143 *Management Techniques for Laboratories and Other Small Institutional Generators to Minimize Off-Site Disposal of Low-Level Radioactive Waste* (2003)
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146 *Approaches to Risk Management in Remediation of Radioactively Contaminated Sites* (2004)
147 *Structural Shielding Design for Medical X-Ray Imaging Facilities* (2004)
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149 *A Guide to Mammography and Other Breast Imaging Procedures* (2004)
150 *Extrapolation of Radiation-Induced Cancer Risks from Nonhuman Experimental Systems to Humans* (2005)
151 *Structural Shielding Design and Evaluation for Megavoltage X- and Gamma-Ray Radiotherapy Facilities* (2005)
152 *Performance Assessment of Near-Surface Facilities for Disposal of Low-Level Radioactive Waste* (2005)
153 *Information Needed to Make Radiation Protection Recommendations for Space Missions Beyond Low-Earth Orbit* (2006)
154 *Cesium-137 in the Environment: Radioecology and Approaches to Assessment and Management* (2006)
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158 *Uncertainties in the Measurement and Dosimetry of External Radiation* (2007)
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NCRP Commentaries

No.	Title
1	*Krypton-85 in the Atmosphere—With Specific Reference to the Public Health Significance of the Proposed Controlled Release at Three Mile Island* (1980)
4	*Guidelines for the Release of Waste Water from Nuclear Facilities with Special Reference to the Public Health Significance of the Proposed Release of Treated Waste Waters at Three Mile Island* (1987)
5	*Review of the Publication, Living Without Landfills* (1989)
6	*Radon Exposure of the U.S. Population—Status of the Problem (1991)*

7 *Misadministration of Radioactive Material in Medicine—Scientific Background* (1991)
8 *Uncertainty in NCRP Screening Models Relating to Atmospheric Transport, Deposition and Uptake by Humans* (1993)
9 *Considerations Regarding the Unintended Radiation Exposure of the Embryo, Fetus or Nursing Child* (1994)
10 *Advising the Public about Radiation Emergencies: A Document for Public Comment* (1994)
11 *Dose Limits for Individuals Who Receive Exposure from Radionuclide Therapy Patients* (1995)
12 *Radiation Exposure and High-Altitude Flight* (1995)
13 *An Introduction to Efficacy in Diagnostic Radiology and Nuclear Medicine (Justification of Medical Radiation Exposure)* (1995)
14 *A Guide for Uncertainty Analysis in Dose and Risk Assessments Related to Environmental Contamination* (1996)
15 *Evaluating the Reliability of Biokinetic and Dosimetric Models and Parameters Used to Assess Individual Doses for Risk Assessment Purposes* (1998)
16 *Screening of Humans for Security Purposes Using Ionizing Radiation Scanning Systems* (2003)
17 *Pulsed Fast Neutron Analysis System Used in Security Surveillance* (2003)
18 *Biological Effects of Modulated Radiofrequency Fields* (2003)
19 *Key Elements of Preparing Emergency Responders for Nuclear and Radiological Terrorism* (2005)
20 *Radiation Protection and Measurement Issues Related to Cargo Scanning with Accelerator-Produced High-Energy X Rays* (2007)

Proceedings of the Annual Meeting

No. Title

1 *Perceptions of Risk,* Proceedings of the Fifteenth Annual Meeting held on March 14-15, 1979 (including Taylor Lecture No. 3) (1980)
3 *Critical Issues in Setting Radiation Dose Limits*, Proceedings of the Seventeenth Annual Meeting held on April 8-9, 1981 (including Taylor Lecture No. 5) (1982)
4 *Radiation Protection and New Medical Diagnostic Approaches,* Proceedings of the Eighteenth Annual Meeting held on April 6-7, 1982 (including Taylor Lecture No. 6) (1983)
5 *Environmental Radioactivity,* Proceedings of the Nineteenth Annual Meeting held on April 6-7, 1983 (including Taylor Lecture No. 7) (1983)
6 *Some Issues Important in Developing Basic Radiation Protection Recommendations*, Proceedings of the Twentieth Annual Meeting held on April 4-5, 1984 (including Taylor Lecture No. 8) (1985)
7 *Radioactive Waste*, Proceedings of the Twenty-First Annual Meeting held on April 3-4, 1985 (including Taylor Lecture No. 9)(1986)
8 *Nonionizing Electromagnetic Radiations and Ultrasound,* Proceedings of the Twenty-Second Annual Meeting held on April 2-3, 1986 (including Taylor Lecture No. 10) (1988)

9 *New Dosimetry at Hiroshima and Nagasaki and Its Implications for Risk Estimates*, Proceedings of the Twenty-Third Annual Meeting held on April 8-9, 1987 (including Taylor Lecture No. 11) (1988)

10 *Radon*, Proceedings of the Twenty-Fourth Annual Meeting held on March 30-31, 1988 (including Taylor Lecture No. 12) (1989)

11 *Radiation Protection Today—The NCRP at Sixty Years*, Proceedings of the Twenty-Fifth Annual Meeting held on April 5-6, 1989 (including Taylor Lecture No. 13) (1990)

12 *Health and Ecological Implications of Radioactively Contaminated Environments*, Proceedings of the Twenty-Sixth Annual Meeting held on April 4-5, 1990 (including Taylor Lecture No. 14) (1991)

13 *Genes, Cancer and Radiation Protection,* Proceedings of the Twenty-Seventh Annual Meeting held on April 3-4, 1991 (including Taylor Lecture No. 15) (1992)

14 *Radiation Protection in Medicine,* Proceedings of the Twenty-Eighth Annual Meeting held on April 1-2, 1992 (including Taylor Lecture No. 16) (1993)

15 *Radiation Science and Societal Decision Making,* Proceedings of the Twenty-Ninth Annual Meeting held on April 7-8, 1993 (including Taylor Lecture No. 17) (1994)

16 *Extremely-Low-Frequency Electromagnetic Fields: Issues in Biological Effects and Public Health*, Proceedings of the Thirtieth Annual Meeting held on April 6-7, 1994 (not published).

17 *Environmental Dose Reconstruction and Risk Implications,* Proceedings of the Thirty-First Annual Meeting held on April 12-13, 1995 (including Taylor Lecture No. 19) (1996)

18 *Implications of New Data on Radiation Cancer Risk*, Proceedings of the Thirty-Second Annual Meeting held on April 3-4, 1996 (including Taylor Lecture No. 20) (1997)

19 *The Effects of Pre- and Postconception Exposure to Radiation*, Proceedings of the Thirty-Third Annual Meeting held on April 2-3, 1997, Teratology **59**, 181–317 (1999)

20 *Cosmic Radiation Exposure of Airline Crews, Passengers and Astronauts*, Proceedings of the Thirty-Fourth Annual Meeting held on April 1-2, 1998, Health Phys. **79**, 466–613 (2000)

21 *Radiation Protection in Medicine: Contemporary Issues*, Proceedings of the Thirty-Fifth Annual Meeting held on April 7-8, 1999 (including Taylor Lecture No. 23) (1999)

22 *Ionizing Radiation Science and Protection in the 21st Century,* Proceedings of the Thirty-Sixth Annual Meeting held on April 5-6, 2000, Health Phys. **80**, 317–402 (2001)

23 *Fallout from Atmospheric Nuclear Tests—Impact on Science and Society,* Proceedings of the Thirty-Seventh Annual Meeting held on April 4-5, 2001, Health Phys. **82**, 573–748 (2002)

24 *Where the New Biology Meets Epidemiology: Impact on Radiation Risk Estimates*, Proceedings of the Thirty-Eighth Annual Meeting held on April 10-11, 2002, Health Phys. **85**, 1–108 (2003)

25 *Radiation Protection at the Beginning of the 21st Century–A Look Forward*, Proceedings of the Thirty-Ninth Annual Meeting held on April 9–10, 2003, Health Phys. **87**, 237–319 (2004)

26 *Advances in Consequence Management for Radiological Terrorism Events*, Proceedings of the Fortieth Annual Meeting held on April 14–15, 2004, Health Phys. **89**, 415–588 (2005)
27 *Managing the Disposition of Low-Activity Radioactive Materials*, Proceedings of the Forty-First Annual Meeting held on March 30–31, 2005, Health Phys. **91**, 413–536 (2006)
28 *Chernobyl at Twenty*, Proceedings of the Forty-Second Annual Meeting held on April 3–4, 2006, Health Phys. **93**, 345–595 (2007)
29 *Advances in Radiation Protection in Medicine*, Proceedings of the Forty-Third Annual Meeting held on April 16-17, 2007, Health Phys. **95**, 461–686 (2008)
30 *Low Dose and Low Dose-Rate Radiation Effects and Models*, Proceedings of the Forty-Fourth Annual Meeting held on April 14–15, 2008, Health Phys. **97**, 373–541 (2009)

Lauriston S. Taylor Lectures

No. Title

1 *The Squares of the Natural Numbers in Radiation Protection by* Herbert M. Parker (1977)
2 *Why be Quantitative about Radiation Risk Estimates?* by Sir Edward Pochin (1978)
3 *Radiation Protection—Concepts and Trade Offs* by Hymer L. Friedell (1979) [available also in *Perceptions of Risk*, see above]
4 *From "Quantity of Radiation" and "Dose" to "Exposure" and "Absorbed Dose"—An Historical Review* by Harold O. Wyckoff (1980)
5 *How Well Can We Assess Genetic Risk? Not Very* by James F. Crow (1981) [available also in *Critical Issues in Setting Radiation Dose Limits*, see above]
6 *Ethics, Trade-offs and Medical Radiation* by Eugene L. Saenger (1982) [available also in *Radiation Protection and New Medical Diagnostic Approaches*, see above]
7 *The Human Environment—Past, Present and Future* by Merril Eisenbud (1983) [available also in *Environmental Radioactivity*, see above]
8 *Limitation and Assessment in Radiation Protection* by Harald H. Rossi (1984) [available also in *Some Issues Important in Developing Basic Radiation Protection Recommendations*, see above]
9 *Truth (and Beauty) in Radiation Measurement* by John H. Harley (1985) [available also in *Radioactive Waste*, see above]
10 *Biological Effects of Non-ionizing Radiations: Cellular Properties and Interactions* by Herman P. Schwan (1987) [available also in *Nonionizing Electromagnetic Radiations and Ultrasound*, see above]
11 *How to be Quantitative about Radiation Risk Estimates* by Seymour Jablon (1988) [available also in *New Dosimetry at Hiroshima and Nagasaki and its Implications for Risk Estimates*, see above]
12 *How Safe is Safe Enough?* by Bo Lindell (1988) [available also in *Radon*, see above]

13 *Radiobiology and Radiation Protection: The Past Century and Prospects for the Future* by Arthur C. Upton (1989) [available also in *Radiation Protection Today*, see above]

14 *Radiation Protection and the Internal Emitter Saga* by J. Newell Stannard (1990) [available also in *Health and Ecological Implications of Radioactively Contaminated Environments*, see above]

15 *When is a Dose Not a Dose?* by Victor P. Bond (1992) [available also in *Genes, Cancer and Radiation Protection*, see above]

16 *Dose and Risk in Diagnostic Radiology: How Big? How Little?* by Edward W. Webster (1992) [available also in *Radiation Protection in Medicine*, see above]

17 *Science, Radiation Protection and the NCRP* by Warren K. Sinclair (1993) [available also in *Radiation Science and Societal Decision Making,* see above]

18 *Mice, Myths and Men* by R.J. Michael Fry (1995)

19 *Certainty and Uncertainty in Radiation Research* by Albrecht M. Kellerer. Health Phys. **69**, 446–453 (1995)

20 *70 Years of Radiation Genetics: Fruit Flies, Mice and Humans* by Seymour Abrahamson. Health Phys. **71**, 624–633 (1996)

21 *Radionuclides in the Body: Meeting the Challenge* by William J. Bair. Health Phys. **73**, 423–432 (1997)

22 *From Chimney Sweeps to Astronauts: Cancer Risks in the Work Place* by Eric J. Hall. Health Phys. **75**, 357–366 (1998)

23 *Back to Background: Natural Radiation and Radioactivity Exposed* by Naomi H. Harley. Health Phys. **79**, 121–128 (2000)

24 *Administered Radioactivity: Unde Venimus Quoque Imus* by S. James Adelstein. Health Phys. **80**, 317–324 (2001)

25 *Assuring the Safety of Medical Diagnostic Ultrasound* by Wesley L. Nyborg. Health Phys. **82**, 578–587 (2002)

26 *Developing Mechanistic Data for Incorporation into Cancer and Genetic Risk Assessments: Old Problems and New Approaches* by R. Julian Preston. Health Phys. **85**, 4–12 (2003)

27 *The Evolution of Radiation Protection–From Erythema to Genetic Risks to Risks of Cancer to ?* by Charles B. Meinhold, Health Phys. **87**, 240–248 (2004)

28 *Radiation Protection in the Aftermath of a Terrorist Attack Involving Exposure to Ionizing Radiation* by Abel J. Gonzalez, Health Phys. **89**, 418–446 (2005)

29 *Nontargeted Effects of Radiation: Implications for Low Dose Exposures* by John B. Little, Health Phys. **91**, 416–426 (2006)

30 *Fifty Years of Scientific Research: The Importance of Scholarship and the Influence of Politics and Controversy* by Robert L. Brent, Health Phys. **93**, 348–379 (2007)

31 *The Quest for Therapeutic Actinide Chelators* by Patricia W. Durbin, Health Phys. **95**, 465–492 (2008)

32 *Yucca Mountain Radiation Standards, Dose/Risk Assessments, Thinking Outside the Box, Evaluations, and Recommendations* by Dade W. Moeller, Health Phys. **97**, 376–391 (2009)

Symposium Proceedings

No.	Title
1	*The Control of Exposure of the Public to Ionizing Radiation in the Event of Accident or Attack*, Proceedings of a Symposium held April 27-29, 1981 (1982)
2	*Radioactive and Mixed Waste—Risk as a Basis for Waste Classification,* Proceedings of a Symposium held November 9, 1994 (1995)
3	*Acceptability of Risk from Radiation—Application to Human Space Flight,* Proceedings of a Symposium held May 29, 1996 (1997)
4	*21st Century Biodosimetry: Quantifying the Past and Predicting the Future*, Proceedings of a Symposium held February 22, 2001, Radiat. Prot. Dosim. **97**(1), (2001)
5	*National Conference on Dose Reduction in CT, with an Emphasis on Pediatric Patients*, Summary of a Symposium held November 6-7, 2002, Am. J. Roentgenol. **181**(2), 321–339 (2003)

NCRP Statements

No.	Title
1	"Blood Counts, Statement of the National Committee on Radiation Protection," Radiology **63**, 428 (1954)
2	"Statements on Maximum Permissible Dose from Television Receivers and Maximum Permissible Dose to the Skin of the Whole Body," Am. J. Roentgenol., Radium Ther. and Nucl. Med. **84**, 152 (1960) and Radiology **75**, 122 (1960)
3	*X-Ray Protection Standards for Home Television Receivers, Interim Statement of the National Council on Radiation Protection and Measurements* (1968)
4	*Specification of Units of Natural Uranium and Natural Thorium, Statement of the National Council on Radiation Protection and Measurements* (1973)
5	*NCRP Statement on Dose Limit for Neutrons* (1980)
6	*Control of Air Emissions of Radionuclides* (1984)
7	*The Probability That a Particular Malignancy May Have Been Caused by a Specified Irradiation* (1992)
8	*The Application of ALARA for Occupational Exposures* (1999)
9	*Extension of the Skin Dose Limit for Hot Particles to Other External Sources of Skin Irradiation* (2001)
10	*Recent Applications of the NCRP Public Dose Limit Recommendation for Ionizing Radiation* (2004)

Other Documents

The following documents were published outside of the NCRP report, commentary and statement series:

Somatic Radiation Dose for the General Population, Report of the Ad Hoc Committee of the National Council on Radiation Protection and

Measurements, 6 May 1959, Science **131** (3399), February 19, 482–486 (1960)

Dose Effect Modifying Factors in Radiation Protection, Report of Subcommittee M-4 (Relative Biological Effectiveness) of the National Council on Radiation Protection and Measurements, Report BNL 50073 (T-471) (1967) Brookhaven National Laboratory (National Technical Information Service, Springfield, Virginia)

Residential Radon Exposure and Lung Cancer Risk: Commentary on Cohen's County-Based Study, Health Phys. **87**(6), 656–658 (2004)

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