Health and Safety Planning Guide

For Planners, Safety Officers, and Supervisors For Protecting Responders Following a Nuclear Detonation

December 2016

FOREWORD TO THIS DOCUMENT

As the Interagency Policy Coordination Subcommittee for Preparedness and Response to Radiological and Nuclear Threats was completing the "Planning Guidance for Response to a Nuclear Detonation" (Second Edition, June 2010), it became evident that additional guidance for protecting responders following a nuclear detonation was necessary. Guidance is needed to provide information for the needs of the responders themselves, as well as emergency planners. Both approaches are integral to the safety of responders who will put their lives and health in jeopardy for the public good.

This guidance is a supplement to the "Planning Guidance for Response to a Nuclear Detonation". It is intended for planners, safety officers and supervisors of responders to assist in the preparation for health and safety management in the event of a successful improvised nuclear device (IND) event. This guidance defines "responders" as a diverse set of individuals who are critical to mitigating the potential catastrophic effects of an IND. This broad definition includes professional and traditional first responders (e.g., emergency medical services practitioners, firefighters, law enforcement, and hazardous material (HAZMAT) personnel); the emergency management community; public health and medical professionals; skilled support personnel; and emergency service and critical infrastructure personnel. Responders may be from government, volunteer, or private sector organizations. It is important to note that these responders may face a variety of hazards in addition to radiation, so health and safety planning and preparedness efforts need to protect all responders from all hazards. Appendix A of this document includes a "Quick Reference Guide" that can be used as part of a training program for responders as part of an overall preparedness program, as well as a reference at the scene of an event. The "Quick Reference Guide" is focused on the hazards and precautions associated with radiation.

This document was approved for publication by the National Security Council led Domestic Readiness Group on 17 November 2016.

Health and Safety Planning Guide for Protecting First Responders Following a Nuclear Detonation

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Figures and Tables

ACRONYMS

ALARA	As Low As Reasonably Achievable
APR	Air-Purifying Respirator
ARS	Acute Radiation Syndrome, a.k.a. Radiation Sickness
Bq	Becquerel
Ci	Curie
CBRNE	Chemical, Biological, Radiological, Nuclear, or Explosive
DF	Dangerous Fallout (zone)
DPM	Disintegrations per Minute
DPS	Disintegrations per Second
DHS	Department of Homeland Security
EMP	Electromagnetic Pulse
EMS	Emergency Medical Services
EMT	Emergency Medical Technician
ERHMS	Emergency Responder Health Monitoring and Surveillance
Gy	Gray
HAZMAT	Hazardous Material
HAZWOPER	Hazardous Waste Operations
HEPA	High Efficiency Particulate Air
IC	Incident Commander
ICS	Incident Command System
IND	Improvised Nuclear Device
KI	Potassium Iodine
KT	Kiloton
LD	Light Damage (zone)
LEL	Lower Explosive Limit
MD	Moderate Damage (zone)
NCRP	National Council on Radiation Protection & Measurements
NFPA	National Fire Protection Association
NIMS	National Incident Management System
NIOSH	National Institute for Occupational Safety and Health
OSHA	Occupational Safety and Health Administration

PAPR	Powered Air-Purifying Respirator
PPE	Personal Protective Equipment
PPM	Parts per Million
R	Roentgen
RAD	Radiation Absorbed Dose
RDD	Radiological Dispersal Device
REM	Roentgen Equivalent (in) Man
SAR	Supplied-Air Respirator
SCBA	Self-Contained Breathing Apparatus
SD	Severe Damage (zone)
SI	International System of Units
SOFR	Safety Officer
Sv	Sievert
TECP	Totally Encapsulating Chemical-Protective
TEDE	Total Effective Dose Equivalent
TLD	Thermoluminescent Dosimeter
UC	Unified Command
WMD	Weapons of Mass Destruction

1. INTRODUCTION

In June 2010, The National Security Council Staff Interagency Policy Coordination Subcommittee for Preparedness and Response to Radiological and Nuclear Threats published the "Planning Guidance for Response to a Nuclear Detonation" (Second Edition).[1] This document is a supplement to the Planning Guidance to provide additional guidance for protection of response workers.

The purpose of this guide is to provide response planners, safety officers, and supervisors with specific guidance and recommendations to protect responders from the effects and impacts of a 10 kiloton (KT) improvised nuclear device (IND) within the first 72 hours of a detonation. An IND is an illicit nuclear weapon bought, stolen, or otherwise originating from a nuclear State, or a weapon fabricated by a terrorist group from illegally obtained fissile nuclear weapons material that produces a nuclear explosion.

While there are similarities to the detonation of a Radiological Dispersal Device (RDD or "dirty bomb"), this Guide is specifically designed to protect responders in an IND scenario.[2] There are likely to be tens or hundreds of thousands of casualties with serious traumatic injuries including severe burns, blindness, deafness, amputations, other blast injuries, radiation sickness, etc. Responders will face the prospect of being overwhelmed by the public need and its concerns.

Responders to an IND event need to be prepared to face a scene that is unlike any other they may have encountered, and some of this guidance will be counter-intuitive to those trained in emergency response. However, it is critical that responders utilize the principles in this Guide to remain as safe and healthy as possible, not only for their own safety, but also to remain available for the ongoing mission of saving lives.

> In the event of the detonation of an IND, first responders should assess the surroundings to estimate if a high-dose-rate radiation potential exists and determine if rescue measures are necessary until radiation levels can be accurately determined and the responders are assigned through the Incident Command System. This will allow proper assessment and management of the risks. Responders should not rush into the most damaged areas (i.e., areas around the center of the explosion). By following the recommendations presented in this Guide, responders should be able to identify how to prioritize their efforts in order to maximize rescue potential while minimizing the risks to themselves, thus remaining available for ongoing rescue missions.

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[1] National Security Staff Interagency Policy Coordination Subcommittee for Preparedness and Response to Radiological and Nuclear Threats, *Planning Guidance for Response to a Nuclear Detonation*, Second Edition, June 2010.

[2] In contrast, a radiological dispersal device (RDD) is a relatively small-scale incident causing some direct damage and resulting in low-level radiological contamination.

This Guide is organized to answer, as quickly as possible, the following questions that should be asked before proceeding with the mission:

1. What are the likely impacts of the incident?
2. What is the extent of the damage?
3. What will responders find as they move towards ground zero (i.e., location of the detonation)?
4. What physical hazards should be anticipated?
5. What are the radiation considerations?
6. Where can the most victims who will benefit from responder action be found?
7. What are the activities or tasks to be performed?
8. What level of training should responders have to perform each task?
9. What is the recommended Personal Protective Equipment (PPE) for each type of hazard?
10. What are the health risks of radiation exposure?
11. What additional equipment should be employed to protect against radiation exposure?
12. What are “dose/turnback limits” or “stay times” and how are they calculated?
13. What are the recommended personnel decontamination procedures?
14. How should responder exposure be monitored in the short and long-term?

This guide does not address the management or safety issues inherent with the large, anticipated fleeing population that is expected from people in the area of an IND explosion, which was considered beyond the scope of this publication.

Target Audience

The target audiences for this Guide are the planners, safety officers, and supervisors responsible for worker health and safety programs. For an incident such as this the response will not only include emergency search and rescue operations, but infrastructure support, communications, crowd control, and debris/road clearing. Preparation for this type of event will involve a wide variety of responders including, but not limited to, the following at the city, county, state, tribal, territorial and federal levels:

- Incident Command (IC)/Unified Command (UC) system leadership teams
- pre-event trainers
- federal, state and local, tribal and territorial response support
- local health commissioners and/or staff

- firefighters
- emergency medical services
- urban search and rescue teams
- hazardous material (HAZMAT) teams
- police/law enforcement
- military (Active, Reserve, and National Guard)
- field medical services
- health physicists
- Coast Guard and water rescue units
- victim extraction and airlift
- aerial damage survey/mapping
- communications (aerial, truck)
- engineering response teams
- utility and public works crews
- transportation workers and drivers
- vehicle towing operators
- heavy equipment operators
- debris removal and road clearing
- other skilled support personnel (construction, trade services, etc.)
- volunteers (organized and independent)

Responders

This guidance defines “responders” as a diverse set of individuals who are critical to mitigating the potential catastrophic effects of an improvised nuclear detonation. This broad definition includes professional and traditional first responders (e.g., emergency medical services practitioners, firefighters, law enforcement, and HAZMAT personnel); the emergency management community; public health and medical professionals; skilled support personnel; and emergency service and critical infrastructure personnel. Responders may be from government, volunteer, or private sector organizations. Responders who are not adequately trained in advance of an emergency may need additional training in order to understand potential risks and hazards in the environment and how to safely carry out any actions to be taken.

Additional Response Hazards

Many of the hazards of an IND are typical of other emergency response incidents, and the response to an IND must consider not just the radiological hazards, but the full range of incident hazards. The National Preparedness Goal contains the core capabilities that responders (depending on roles, responsibilities, and authorities during an incident) should factor into response and recovery actions.[3] Core capabilities pertinent to the response community in an IND response include but are not limited to: environmental response/health and safety, mass search and rescue, on scene security, and fatality management. The appendices in this document provide example health and safety hazards along with relevant precautions and OSHA references that may assist in the planning to deliver capabilities following an IND incident.

Priorities

This guide has been developed with comprehensive safety considerations to support operations in what is anticipated to be an incredibly complex and dynamic response environment. It is important to consider that very specific safety considerations (some of which are not unique to the IND environment) are outlined in sections such as "emergency planning," "site control," and the appendices. Given the anticipated resource constrained environment of the post-IND environment, it may be helpful for planners to consider prioritizing safety issues in the initial response phases. Example priorities may include:

- Accountability of responders
- Site(s) characterization
- Establishment of safe evacuation routes/shelter positions
- Briefing of responders on radiation threat
- Exposure monitoring (and associated just in time training/re-training)

Phases of Response

The response to an IND incident can be divided into three time phases – the Early (emergency) Phase, the Intermediate (stabilization) Phase, and the Late (recovery) Phase – that are generally accepted as being common to all nuclear/radiological incidents. The phases represent time periods in which the Incident Command or Unified Command[4] officials would be making decisions regarding protective actions for first responders, and quite possibly early public health

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[3] National Preparedness Goal, September, 2015 http://www.fema.gov/national-preparedness-goal

[4] Department of Homeland Security's *National Incident Management System*, December 2008 (www.fema.gov/national-incident-management-system) for more information on NIMS and the ICS.

protective actions. Although these phases cannot be represented by precise time periods and may overlap, they provide a useful framework for the considerations involved in emergency response planning. As this document is intended to protect emergency responders during the first 72 hours of an event of this magnitude, only the early phase of response is described in this document.

Scenario Basis

In the development of this Guide for protecting responders, a number of critical assumptions were necessary, including:

- A nominal 10 KT yield, ground-detonated IND is assumed for purposes of estimating impacts in high-density urban areas.
- There will only be limited operational federal response at the scene for the first 72 hours. The full extent of federal assets may not be available for several days.
- The blast and heat from the detonation will compromise much of the local municipal response capability, and responders will be coming in from surrounding communities.
- Responders will arrive on the scene trained to perform their tasks, and equipped with immediately available PPE, monitoring, and dosimetry equipment. These will not be optimal for an IND event, and additional PPE and dosimetry equipment will need to be distributed at the scene.
- Numerous, well-meaning, but untrained volunteers will enter the scene to offer assistance.

2. INCIDENT COMMAND SYSTEM

Homeland Security Presidential Directive/HSPD5 states its purpose as:

To enhance the ability of the United States to manage domestic incidents by establishing a single, comprehensive national incident management system.

HSPD5 instructs the Secretary of Homeland Security to develop and administer a National Incident Management System (NIMS) to provide a consistent nationwide approach for Federal, State, local, tribal and territorial governments to work effectively and efficiently together to prepare for, respond to, and recover from domestic incidents, regardless of cause, size, or complexity. NIMS represents a core set of doctrines, concepts, principles, terminology, and organizational processes that enables effective, efficient, and collaborative incident management. As an element of NIMS, the Incident Command System (ICS), describes a widely applicable management system that integrates a combination of facilities, equipment, personnel, procedures, and communications into a common operational structure. For additional information on NIMS or ICS, see Department of Homeland Security's National Incident Management System.[5]

While ICS uses a standardized all-hazards incident management approach, here are a few key points about ICS in a post IND environment:

- No single agency, jurisdiction, region or even state will have all of the capabilities needed to mount the comprehensive response needed for IND event. A Unified Command (UC) structure will be required.
- ICS Structures should be flexible and scalable depending on the needs of the incident and of the local jurisdiction(s).
- The coordinating commands in the neighboring jurisdictions will face many obstacles when establishing command and control. These obstacles include:
    - Lack of communications
    - Lack of staff; some concerned for personal safety
    - Lack of situational awareness
- The IC/UC has ultimate responsibility for safe conduct at the incident.
- Decisions and actions taken in the initial hours after detonation could have the greatest impact on the population.
- Planners should assume the worst case situations and assess what alternative resources could be used, i.e. non-uniformed personnel or non-governmental organizations.

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[5] Department of Homeland Security's *National Incident Management System*, December 2008 (www.fema.gov/national-incident-management-system) for more information on NIMS and the ICS.

The Federal Radiological Monitoring and Assessment Center (FRMAC)[6], upon request, will integrate into the UC with the coordinating agency, state, and local responders and establish priorities to develop a monitoring and assessment plan for response.

Response capabilities and resources may be mostly provided by neighboring boroughs, suburbs, cities, counties, and states through mutual aid agreements or other planning mechanisms. Some neighboring response capabilities, however, will be directly affected by fallout and advised to shelter in place until radiation dose rates have fallen. Regional response planning for the safety of responders in advance of a nuclear explosion is imperative.

[6] National Nuclear Security Administration's Federal Radiological Monitoring and Assessment Center, http://www.nnsa.energy.gov/aboutus/ourprograms/emergencyoperationscounterterrorism/respondingtoemergencies-0-1

3. OVERVIEW OF A NUCLEAR EXPLOSION

Overview

A nuclear detonation produces several important effects impacting the urban environment and people. In this Guide, the term "nuclear effects" means those outputs from the nuclear explosion, namely primary effects including blast, thermal (heat) and initial radiation, and secondary effects including electromagnetic pulse (EMP) and fallout. All of these effects impact people, infrastructure, and the environment, and they significantly affect the ability to respond to the incident. The term "nuclear impacts" will be used to describe the consequences to materials, people, or the environment as a result of nuclear effects, such as structural damage, fire, radioactivity, and human health consequences.[7]

Effects and Impacts of a Nuclear Explosion

Thermal radiation or **"**Nuclear Flash" in the form of extreme heat, light, and radiation, causing widespread burn injuries and igniting fires both from the initial thermal effects, and by igniting gas from broken gas lines and fuel tanks. Thermal injuries include flash burns, flame burns, flash blindness, and retinal burns[8]. Observing the thermal flash may result in temporary or permanent eye injury or blindness. The flash will also draw people's attention while the accompanying blast sends high-velocity shrapnel in the form of flying debris and glass outwards causing countless eye-trauma injuries.

Prompt radiation a component of the nuclear flash, is an intense pulse of radiations originating from the fission of nuclear material and early radioactive decay. Prompt radiation lasts up to one minute and can be a significant contributor to an individual's total radiation dose.

The **Nuclear blast** is the explosion caused by a nuclear detonation and includes the initial fireball, the overpressure wave, and extremely high winds, causing casualties and structural damage and collapse. Blast wave injuries include fractures, lacerations, projectile injuries from glass and debris, rupture of internal organs, and pulmonary hemorrhage and edema. The number of eye injuries caused by a nuclear blast is likely to be extensive. The intense noise of a nuclear blast will result in ruptured ear drums and damaged inner ear structures. Individuals subjected to the blast noise may be rendered temporarily or permanently deaf. This loss of hearing will contribute to overall confusion and may hinder communication with survivors.

Fallout is the process or phenomenon of the descent to the earth's surface of particles contaminated with radioactive material from the radioactive cloud. The term is also applied in a collective sense to the contaminated particulate matter itself. Fallout is formed in and around the fireball, is carried upwards into wind patterns and deposited gravitationally over a significant

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[7] For more information on nuclear effects and impacts, see *Planning Guidance for Response to a Nuclear Detonation*, National Security Staff, 2010 (2nd Edition).

[8] *Medical Management of the Acute Radiation Syndrome: Recommendations of the Strategic National Stockpile Radiation Working Group*, Annals of Internal Medicine, Vol. 140 Number 12, June 15, 2004

distance downwind. Radiation from fallout can be lethal, especially closer into ground zero where deposition patterns may be dense. Residual radiation includes radiation emitted from deposited fallout particles, and radiation emanating from local materials activated by neutrons during the initial radiation burst. Some material may be re-suspended by crumbling buildings, demolition/excavation, fire, or vehicles and other human activities and locally dispersed. Radiation injury and illness are discussed later in this document.

Combined injuries will be common among victims of the immediate effects of a nuclear detonation who are likely to suffer from burns and/or physical trauma, in addition to radiation exposure. High radiation dose combined with other injury substantially reduces survival.

The **electromagnetic pulse (EMP)** is a complex phenomenon generated by the detonation that produces a high-voltage surge. It poses no direct health threat, but may damage electronic equipment miles from ground zero, including communications equipment and infrastructure.

Many of the injuries from a nuclear detonation can be prevented or reduced if individuals, including emergency responders, know to take shelter[9] at the first sign of an unexpected intense flash of light, and remain sheltered as the particles and debris/projectiles from the initial blast settle to the ground. Note that some local emergency responders sheltering in place may need to shelter for up to 24 hours and may not be available for response operations during this initial timeframe.

All of these effects may be extensive, making local response to the incident particularly difficult. Responder units within one to three miles of ground zero at the time of a nuclear explosion may be depleted or completely non-functional. Response capabilities outside of the blast zone are likely to be only nominally affected, and should be able to mobilize and respond, provided they are not within the path of dangerously high levels of fallout. For further information see Planning Guidance for Response to a Nuclear Detonation.

[9] To take "shelter" as used in this document means going in or staying in any enclosed structure to escape direct exposure to fallout. Shelter may include the use of pre-designated facilities or locations. See *Planning Guidance for Response to a Nuclear Detonation,* June 2010, pages 66-79.

4. THE EARLY PHASE OF RESPONSE

The early phase (or emergency phase) is the period at the beginning of the incident when immediate decisions for effective protective actions are required, and when field measurement data generally are not available. Exposure to the radioactive plume, short-term exposure to deposited radioactive material, and inhalation of radioactive material are generally taken into account when considering protective actions for the early-phase responders. The response during the early phase includes initial emergency actions to save lives and protect public health and welfare in the short term, considering that the effective time period for these protective actions will likely span the first few hours to a few days. Response priority should be given to evacuation, shelter-in-place and first-aid actions, with rescue activities taking place only after more accurate readings are available.[10]

In an IND detonation, the areas close to the explosion will be devastated, and access and communications will be extremely limited. Response units may need to remain sheltered until radiation levels decay to a lower exposure level. The first responders on the scene will likely include senior fire department officials — these individuals will begin organizing according to ICS until relieved of command by more appropriate officials. The initial response will be organized by an Incident Commander (IC), typically a senior officer from the local fire department. The IC initiates response actions by coordinating rescue assets and resources mostly from the local and surrounding jurisdictions. As the incident progresses, command may need to be transferred to a more qualified individual, or to a Unified Command structure.

Radiological monitoring capabilities vary among local emergency medical services. In most urban jurisdictions, the initial level of radiation monitoring may only include basic measurements of ambient exposure rate and surface contamination from available instruments. Assistance from more sophisticated state and federal assets are not expected to be forthcoming, or even possible, for hours or days. As a result, reliable radiation measurements and data will not be available for the IC to use in making early decisions.

Initially, these basic monitoring readings will be the primary source of information the IC will use to direct initial rescue operations. As more advanced measurement capabilities arrive and report to the IC, a more complete and accurate characterization of hazards will begin to develop. The IC will then be able to use the advanced monitoring data to better direct rescue actions. This graduated escalation of response action levels will likely continue as more monitoring and rescue assets arrive and report to the IC for assignment. At some point, the role of IC will transition from the local on-scene jurisdictional commander to the senior IC or Unified Command (UC) governmental officials.

Additionally, effective public messaging will be difficult during the early response; a tool to support this is FEMA's "Improvised Nuclear Device Response and Recovery Communications in the Immediate Aftermath", June 2013. http://www.fema.gov/media-library-data/20130726-1919-25045-0892/communicating_in_the_immediate_aftermath__final_june_2013_508_ok.pdf

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[10] National Security Staff Interagency Policy Coordination Subcommittee, *Planning Guidance for Response to a Nuclear Detonation*, Second Edition, June 2010.

5. THE ZONED APPROACH TO NUCLEAR DETONATION RESPONSE

Overview

The Planning Guidance for Response to a Nuclear Detonation base document provides a thorough description of damage zones and the zoned approach to response. The goal of a zoned approach to nuclear detonation response is to save lives while also managing risks to emergency responders. The guiding principle when performing a response is to ensure that the overall benefits (primarily lives saved, but also key infrastructure protection) outweigh the risks (primarily the risks to response worker life and health). For example, close to ground zero the likelihood of survivable victims is very low and the total risk (radiation and physical hazards) to responders is very high. Other zones will have varying proportions of injured people, and varying degrees of injury, thus providing rough indicators of where limited resources may be best deployed. Finally, high radiation from fallout may overlay zones with heavy physical impacts as well as outlying areas with no physical impact at all. Before work is performed in any fallout-impacted area, the radiation levels must be carefully assessed.

There are two types of zones referenced in this document. They are described below in the order in which they will be encountered by responders arriving from outside of the affected area.

Damage Zones	a.	Light Damage (LD) zone
	b.	Moderate Damage (MD) zone
	c.	Severe Damage (SD) zone
Fallout Zone	a.	Dangerous Fallout (DF) zone
	b.	Radiation Control (Fallout) Area

These zones are further defined later in this document. The zones will overlap, especially within the fallout plume, creating a variety of radiological conditions across damage zones. While the approximate boundaries of the damage zones will remain stable after the initial explosion, the boundaries of the radiation areas will vary, depending on wind conditions, and decrease over time due to radioactive decay.

Damage Zones

The blast following an urban nuclear explosion is the primary output and cause of physical destruction of structures. Visual indicators and damage to structures can be used to determine zones, which will each have health and survival implications. The purpose of establishing zones is to help plan response operations and prioritize actions; however, responders need to be aware that there are no clear boundaries between the representative damage zones.

The following damage zone definitions will be used in responding to a 10 KT, ground-burst nuclear explosion in an urban environment. They are presented in the order in which they will be encountered by responders, starting three miles out from the point of detonation (ground zero). There are approximately 10-12 city blocks per mile. Figure 5-1 displays the projected damage zones for a 10 KT IND. Note: Distances are approximate and will depend on many factors.

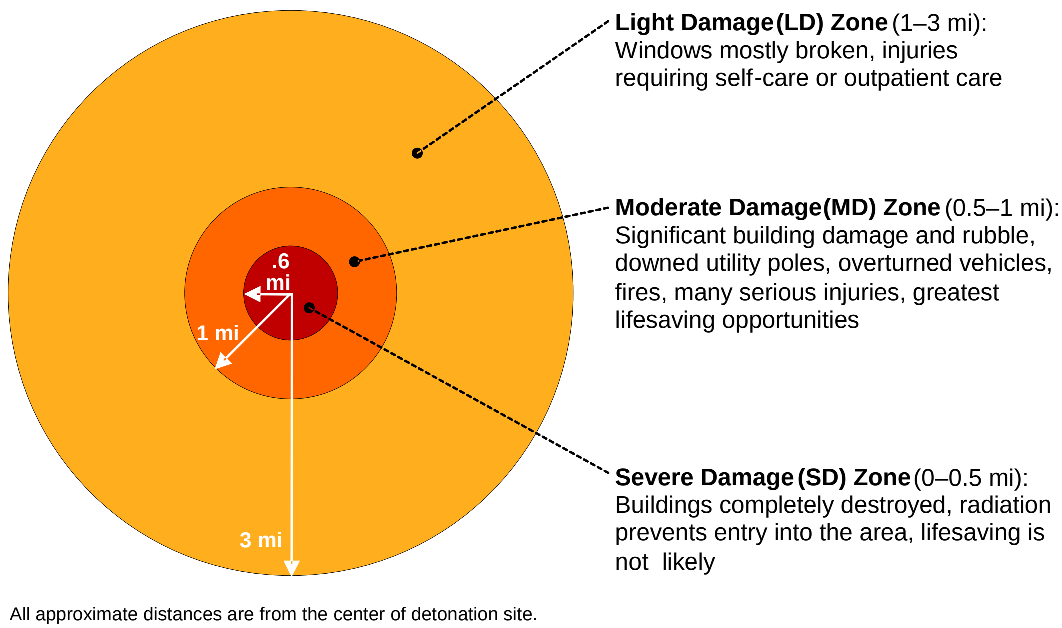

Figure 5-1: Damage Zones[11]

- **Light Damage (LD) Zone**: (1 – 3 miles from ground zero)
  - Most of the injuries incurred within the LD zone are not expected to be life threatening.
  - Most of the injuries would be associated with flying glass and debris from the blast wave and traffic accidents.
  - Some windows may be broken at the outer limits, and flying-glass-related injuries begin to occur.
  - Moving inward, windows and doors will be blown-in and gutters, shutters, roofs, and lightly constructed buildings will have increasing damage.
  - Litter and rubble will increase and there will be increasing numbers of stalled and crashed vehicles making emergency vehicle passage difficult.
  - More significant structural damage to buildings indicates entry into the MD zone.

[11] Graphic from *Planning Guidance for Response to a Nuclear Detonation*, First Edition, National Security Staff, 2009

- **Moderate Damage (MD) Zone**: (0.5 – 1 mile from ground zero)
  - Many casualties in the MD zone will survive; these survivors will benefit most from urgent medical care. There will be many victims with severe trauma injuries and radiation exposure.
  - Hazards include elevated radiation levels, downed power lines, ruptured gas, electrical, communications, and water lines; fires, unstable structures, sharp metal objects, broken glass, ruptured vehicle fuel tanks, etc.
  - Visibility in much of the MD zone may be limited for an hour or more after the explosion due to dust raised by the shock wave and subsequent collapsing buildings. Smoke from fires will also obscure visibility.
  - Significant structural damage will be evident, including fires, blown-out building interiors, blown-down utility lines, overturned automobiles, caved-in roofs; some collapsed buildings, and blown-over telephone and street light poles.
  - Sturdier buildings (e.g., reinforced concrete) will remain standing; lighter commercial and multi-unit residential buildings may have fallen or be structurally unstable; and many wood frame houses will be destroyed.
  - Substantial rubble and crashed/overturned vehicles in streets are expected to make evacuation and passage of rescue vehicles difficult or impossible without street clearing. Moving towards ground zero in the MD zone, rubble will completely block streets and require heavy equipment to clear.

- **Severe Damage (SD) Zone**: (0 – 0.5 miles from ground zero)
  - Finding most buildings severely damaged or collapsed indicates that responders have reached the SD zone. Few, if any, buildings will be structurally sound or even standing in the SD zone, and very few people will have survived.
  - Response within the SD zone should not be attempted until radiation dose rates have dropped substantially, and the MD zone response is significantly advanced.
  - All response missions must be justified to minimize responder risks based on risk/benefit considerations. **First responders should not enter the SD zone during the first 72 hours and the MD zone response is significantly advanced.**
  - Some people protected within stable structures (e.g., subterranean parking garages or subway tunnels) at the time of the explosion may survive the initial blast, may have been subjected to high radiation exposure.
  - Very high radiation levels and other hazards are expected in the SD zone, significantly increasing risks to survivors and responders.
  - Increased building damage and debris will clutter streets, eventually making streets impassable and timely response impracticable. Approaching ground zero, all buildings will

be destroyed creating very deep rubble.

Radiation Dispersal

Besides the immediate blast and heat damage, the other primary output from a nuclear explosion is radiation that can be categorized in two ways:

1. **Initial nuclear radiation** occurs nearly instantaneously with the flash. Initial radiation can be an important contributor to casualties, particularly in the SD zone. The intensity of initial nuclear radiation, however, decreases with distance from ground zero.

2. **Residual radiation (fallout)** occurs after the initial explosion and is largely associated with radioactive fallout. A smaller contributor to residual radiation is induced radioactivity (by neutron activation) of materials in the ground and structures in close proximity to ground zero.

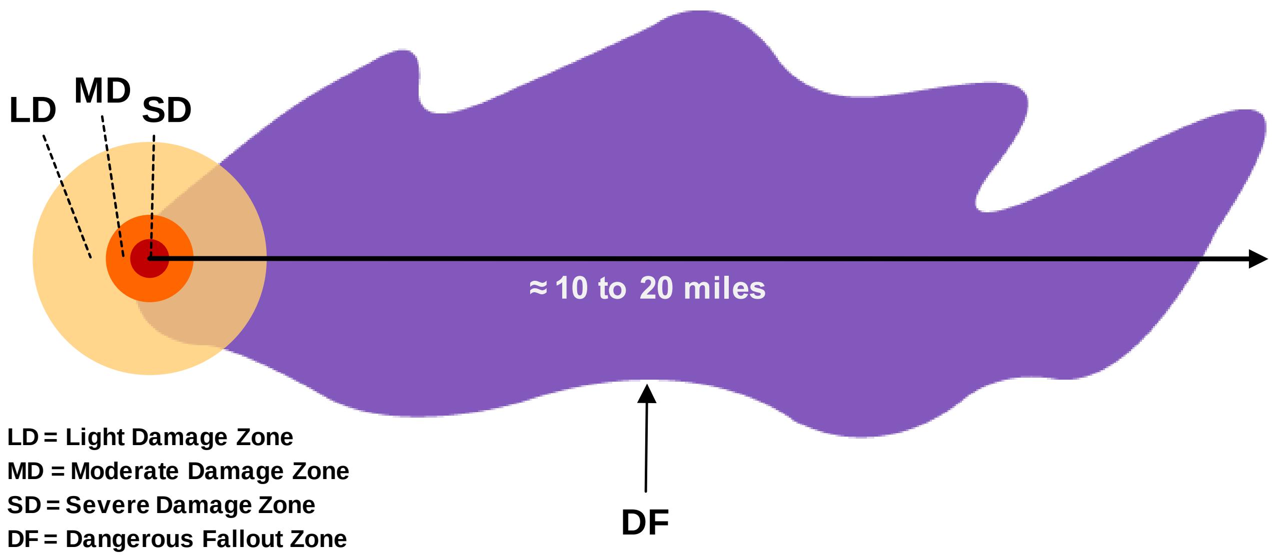

Figure 5-2: The Overlapping Nature of the Damage Zones with the Fallout Pattern[12]

Fallout commonly refers to the radioactive dust created when a nuclear weapon explodes. During the fission process, radionuclides that emit gamma and beta radiation are created. After the explosion, these radionuclides attach to airborne particles of varying sizes to form fallout. If the detonation occurs near the ground level, fallout can be especially heavy as the shock wave crushes and loosens thousands of tons of earth and urban infrastructure (e.g., dust from buildings, roads, concrete, etc.) that can become caught in the fireball.

[12] Graphic from *Planning Guidance for Response to a Nuclear Detonation*, Edition 1, 2009

As the fallout cloud rises, upper-level winds transport the radioactive particles over significant distances downwind. The fallout pattern will be irregular and difficult to predict, due to shifting wind and weather patterns. Geological and structural features such as hills and tall buildings may also affect the deposition of fallout. However, the fallout will be subject to rapid radioactive decay and the boundaries of the fallout zones will immediately begin to shrink in size. Because of this rapid decay, the boundaries of the fallout zones will change rapidly in the first few days.

As a rule, the most hazardous fallout particles are readily visible as fine, sand-sized grains closer to ground zero. Visible fallout may be seen on clean surfaces and provides strong evidence of dangerous levels of radioactivity. The lack of visible fallout, however, should not suggest the lack of radiation. Therefore, appropriate radiation monitoring should always be performed to determine the safety of an area.

Fallout that is immediately hazardous to the public and emergency responders will have descended to the ground within about 24 hours. The most significant fallout hazard area will extend as much as 10 to 20 miles downwind from ground zero for a 10 KT explosion.

Radiation Control (Fallout) Areas

Identifying and establishing fallout areas is recommended for planning emergency response to a nuclear detonation.[13] The area bounded by 0.01 R/h (0.0001 Gy/h)[14] may be depicted as an area where radioactivity is found, and the radiation hazard is lower closest to the 0.01 R/h (0.0001 Gy/h) boundary while the radiation hazard increases approaching the 10 R/h (0.1 Gy/h) boundary. Fallout areas above the dose rate of 10 R/h (0.1 Gy/h) are designated the Dangerous Fallout (DF) zone, while areas with lower level contamination constitute general radiation control areas. Where practical, perimeters should be established to match physical boundaries (e.g., streets and fences) that are close to the radiation levels that define the fallout areas, including the DF zone.

High radiation from fallout will overlay inner damage zones as well as outlying areas with little or no physical damage, especially within the fallout plume, creating a variety of radiological conditions. While the approximate boundaries of the damage zones will remain stable after the initial explosion, the boundaries of the radiation zones will vary, depending on deposition patterns, and decrease over time due to radioactive decay.

Figures 5-3 through 5-4 display the relationship between the damage zones and the fallout areas. In routine radiation emergency response, entering the zone bounded by 0.01 R/h (0.0001 Gy/h) entails donning appropriate ***personal protective equipment (PPE)*** and being properly monitored for radiation. Provided responders take appropriate planning measures for dose monitoring and keeping exposures as low as reasonably achievable (ALARA), emergency operations can be safely performed within the area bounded by 0.01 R/h (0.0001 Gy/h). The area bounded by 0.01 R/h (0.0001 Gy/h) should raise awareness of all responders operating in the area and result in establishing staging, triage, and reception centers outside of this area whenever possible.

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[13] *Planning Guidance for Response to a Nuclear Detonation*, 1st Ed, 2009

[14] See Acronyms on page 6 and further explanations of units and conversions on pages 31 & 32

The Dangerous Fallout zone is described below. Descriptions of radiation measurement terms may be found in the Health Effects of Radiation section of this Guide.

- **Dangerous Fallout (DF) Zone**: (irregular, up to 10 – 20 miles from ground zero)
  - The DF zone is a hazardous area and any response operations within it must be justified, optimized, and planned.
  - Unlike the damage zones, the DF zone is distinguished by radiation levels, not by structural damage.
  - Radiation levels in the DF zone exceed 10 R/h (0.1Gy/h). (R = Roentgen and Gy = Gray, described in the Health Effects of Radiation section of this Guide and see pages 31 & 32 for conversions)
  - Exposure to radioactivity levels within the DF zone has the potential to produce Acute Radiation Syndrome (ARS).
  - In area where the DF zone overlaps the LD or MD zones, response activities should be guided by the potentially lethal radiation hazard of the DF zone.
  - It is important that responders refrain from undertaking missions in areas where radioactivity may be present until radiation levels can be accurately determined and readily monitored.
  - When planning entry into the DF zone, return transportation out of the zone should be provided.
  - Actions taken within the DF zone must be justified, optimized and planned; and should be restricted to time-sensitive, mission-critical activities such as rescuing identified victims and critical infrastructure missions.

Responders must remain aware of changes in **upper-level** wind direction and weather conditions at all times. Surface wind direction is not reliable for predicting fallout direction.

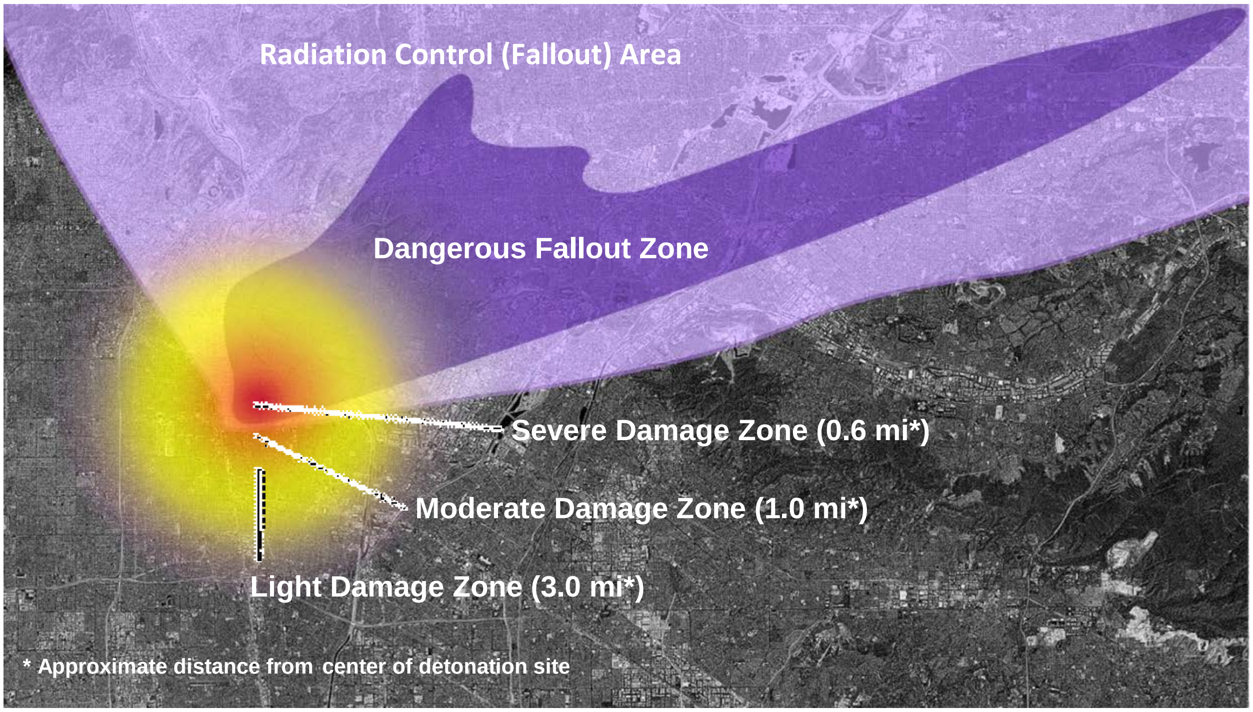


Figure 5-3: Understanding the Relationship between the Zones [15]

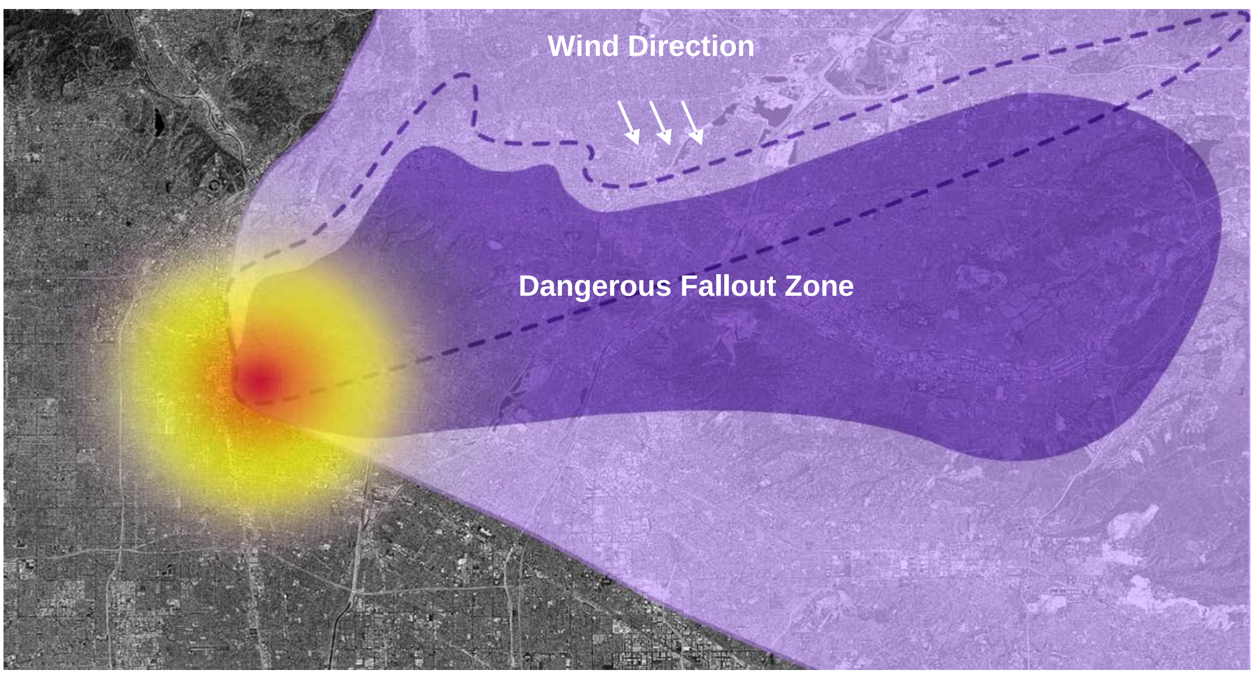


Figure 5-4: The Effect of Changing Winds and Radioactive Decay on the Fallout Zones after Several Hours [15]

[15] Figures 5-3 and 5-4, Lawrence Livermore National Laboratory

Approaching the Scene

The damage zones provide rough guidelines for where the most people can be rescued, and the radiation (fallout) zones provide direction as to where it is, or is not, safe to operate. By understanding the relationship between the zones, emergency responders will be able to fully maximize rescue operations while keeping themselves as safe as possible.

To identify the area of maximum rescue potential, certain generalizations must be accepted:

- Responders should approach the area from upwind, outside of the fallout areas.
- Many people in the LD zone will survive on their own.
- Many people in the MD zone will survive only if they are rescued and treated.
- Most people in the SD zone will not survive, even if they are rescued.
- The DF zone is extremely hazardous to emergency responders and should not be entered without mission-specific justification, optimization and planning.
- The areas with the most survivable victims and therefore the maximum rescue potential are in the LD and MD zones where they fall outside of the DF zone. Rescue efforts should be concentrated in areas.

Changing Fallout Zone Boundaries and Radioactive Decay

The fallout boundaries will depend on many factors, and will change as the incident evolves. At least during the early portion of the response effort, the demarcation of fallout areas boundaries will be incomplete due to limited personnel, resources, and monitoring equipment. Perimeters will be established based upon available monitoring data and predictive modeling. It will be vital to establish reliable communications between field response teams and their command center to quickly exchange information on radiation levels. The command center will maintain the most complete data and must know the location of each response team at all times in order to monitor their estimated radiation doses, and control personnel movement.

Contamination from fallout will hinder response operations in the radiation control areas and may preclude some actions until sufficient radioactive decay, or decontamination has occurred. However, the fallout will be subject to rapid radioactive decay and once deposition is ended, the fallout areas will immediately begin to shrink in size in the first few days. The DF zone reaches its maximum extent after the first few hours and then shrinks in size. For example, the DF zone may initially grow to 10-20 miles within the first few hours and then begin to recede. The boundaries of the larger radiation control area will also recede due to radioactive decay.

Responders and the public should be aware that while substantial radioactive decay occurs early on, the original radioactivity may have been so high that the residual radioactivity may still be elevated to hazardous levels, even after several days.

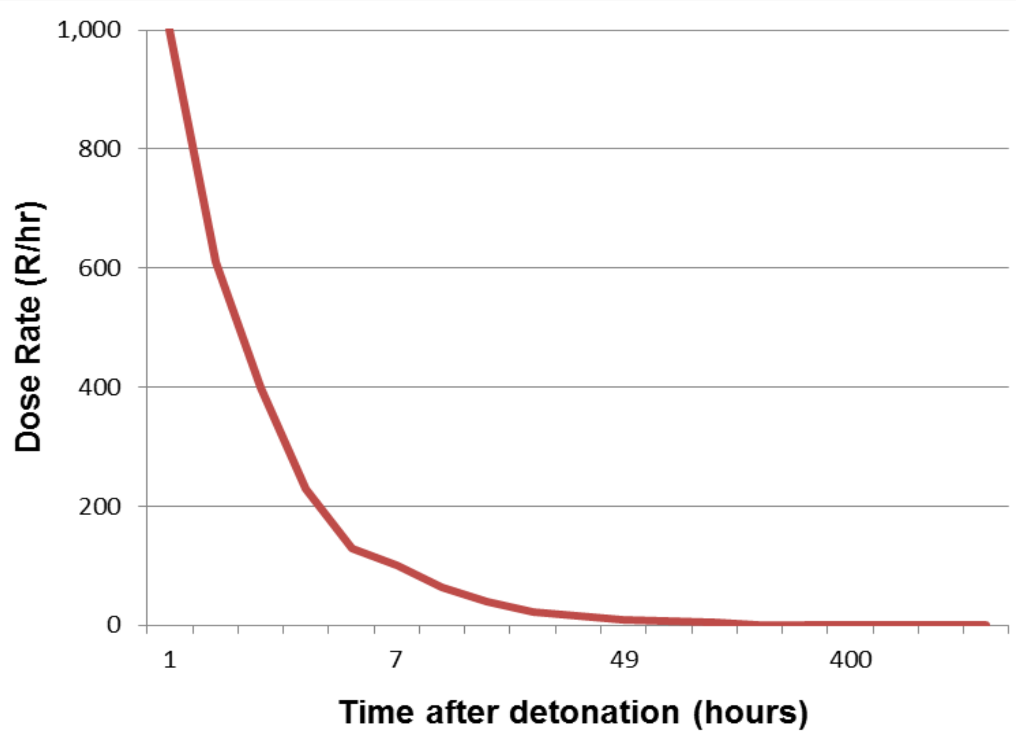
The 7-10 Rule of Radioactive Decay

A basic rule for easily predicting approximate future exposure rates is called the “7-10 Rule of Thumb”. This rule, based on exposure rates determined by survey instruments, states that for every 7-fold increase in time after detonation, there is a 10-fold decrease in the radiation exposure rate. For example, if the radiation dose rate at 1 hour after the explosion is taken as a reference point, then at 7 hours after the explosion the dose rate will have decreased to one-tenth; at 7x7 = 49 hours (roughly 2 days) it will be one-hundredth; and at 7x7x7 = 343 hours (roughly 2 weeks) the dose rate will be one-thousandth of that at 1 hour after the burst. Another aspect of the rule is that at the end of 1 week (7 days), the radiation dose rate will be about one tenth of the value after 1 day.

Of course, for accuracy and reliability, nothing can replace direct instrument readings.

Table 5-1: Examples of Dose Rate Decay over Time Following a Nuclear Explosion[16]

Time (hours)	Dose Rate (R/h) (*Gy/h*)	Time (hours)	Dose Rate (R/h) (*Gy/h*)
1	1,000 (*10*)	36	15 (*0.15*)
1.5	610 (*6.1*)	49 (~2 days)	10 (*0.1*)
2	400 (*4*)	72 (3 days)	6.2 (*0.062*)
3	230 (*2.3*)	100 (~ 4days)	4.0 (*0.04*)
5	130 (*1.3*)	200 (~ 8 days)	1.7 (*0.017*)
7	100 (*1*)	400 (~ 17 days)	0.69 (*0.0069*)
10	63 (*0.63*)	600 (~ 25 days)	0.40 (*0.004*)
15	40 (*0.4*)	800 (~ 33 days)	0.31 (*0.0031*)
24	23 (*0.23*)	1,000 (~ 42 days)	0.24 (*0.0024*)



[16] *The Effects of Nuclear Weapons,* Glasstone and Dolan, 1997

6. HEALTH EFFECTS OF IONIZING RADIATION

People who survive the physical shockwave and heat may still suffer severe health effects from radiation. Exposure to high doses of radiation can be life-threatening, and can cause severe short and/or long-term acute and chronic illness, especially cancer. Additionally, the prognosis for patients suffering from combined traumatic (blast and thermal) injuries and radiation exposure will be worse than for patients suffering the same magnitude of either trauma or radiation alone.

The likelihood and, in some cases, the severity of the health effects that can result from exposure to ionizing radiation depend on several variables, including:[17]

- Type of radiation (alpha, beta, gamma, neutron)
- Amount of radiation absorbed by the body (dose measured in units of rad)
- Route of exposure
  - External exposure: tissues in the body are damaged by penetrating radiation energy from outside the body. This type of exposure ends when the source is removed.
  - Internal exposure: radionuclides are inhaled, ingested or absorbed through open wounds and expose tissues from inside the body. Exposure from internal sources only stops when the radionuclide is eliminated from the body. This is a lesser concern compared to external exposure, after a nuclear detonation.
- Target organ (e.g., iodine is taken up by the thyroid; strontium is taken up by bone)
- Portion of the body exposed
- Dose rate of exposure and length of time exposed
- Age at the time of exposure (youngest victims are most radiosensitive)
- Chemical form and particle size of the radionuclide(s).

[17] National Academies and the U.S. Department of Homeland Security, *Nuclear Attack Fact Sheet*, 2009

Types of Ionizing Radiation[18]

The term *radiation* refers to the process by which energy is emitted as particles or waves through a wide range of the electromagnetic spectrum.

Higher frequency radiation with enough energy to remove electrons from atoms, thus creating ions, is called ionizing radiation. Examples of this type of radiation are x-ray and gamma radiation. Ionizing radiation can damage human DNA, and therefore exposure to it, especially in higher energies, must be limited.

There are four types of ionizing radiation associated with a nuclear detonation: alpha particles, beta particles, gamma and x-ray radiation, and energetic neutrons. These types of radiation are considered ionizing radiation because they are capable of depositing sufficient energy in tissue to ionize the atoms that make up the tissue.

Alpha particles are charged particles that have low penetrating power and a short range (1 to 2 inches) in air. Alpha particles are not an external hazard since the most energetic alpha particles generally fail to penetrate the outer dead layer of skin and can be easily stopped (shielded) by a sheet of paper. However, when taken into the body alpha emitting particles, such as some radioactive dust, can cause significant damage and are a potential hazard if inhaled, ingested, injected, or absorbed through open wounds.

Beta particles are smaller and more penetrating than alpha particles, but produce less damage in the tissues they pass through. The range in air of beta particles varies depending upon their energy and may range from less than an inch to 20 or more feet. Some beta particles are energetic enough to penetrate skin (about ½ inch) and are therefore more hazardous externally than alpha particles. Exposure to large amounts of beta radiation from external sources may cause skin burns. Beta emitters can also be harmful if they enter the body through inhalation, ingestion, injection, or absorption through open wounds. Beta particles are typically stopped by a thick layer of clothing or by sheets of plastic or Plexiglas.

Gamma rays and X-rays are high-energy, low-wavelength electromagnetic rays with no mass, no charge, and travel at the speed of light. They frequently accompany the emission of alpha and beta particles, and always accompany fission in great quantities. Gamma and X-rays are very penetrating and can travel tens or hundreds of feet in air and up to 12 miles depending upon their initial energy. Gamma and X-rays are a radiation hazard for the entire body. They can be absorbed by tissue, or pass completely through the human body. Gamma and X-ray radiation is best stopped or shielded by very dense materials such as lead or several feet of concrete. X-rays are generally lower in energy and less penetrating than gamma rays.

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[18] **Non-ionizing radiation**: Lower frequency radiation with enough energy to move atoms around in a molecule or cause them to vibrate, but not enough to remove electrons, is called non-ionizing radiation. Examples of this type of radiation are radio waves, microwaves, infrared, and visible light. Some radiation waves induce heat or current through interaction with matter, but do not cause ionizations.

Neutrons are uncharged particles that are found in the nuclei of atoms. Neutrons are released energetically during the fission reaction of a nuclear explosion. It is very difficult to shield against energetic neutrons. Because they are uncharged, neutrons are quite penetrating but can be stopped by materials with high hydrogen content such as water, concrete, and many plastics.

As mentioned in Section 3, the detonation of a nuclear weapon produces an intense pulse of ionizing radiation called “initial radiation” or “prompt radiation”. This radiation is made up primarily of gamma and neutron radiation. The radiation emitted after the initial radiation is termed “residual radiation” or “fallout” and is the result of radioactive debris near the blast site, fallout from the pulverized and vaporized building materials and soil that was aerosolized, and radiation from soil and building materials activated by the intense neutron radiation from the initial blast. The highest contribution to human dose from residual radiation is from beta, X-ray, and gamma radiation.

Radiation Quantities and Units

The primary radiation quantities and units used in this document are those commonly used in emergency response:

- **Radioactivity** is a measured quantity of any radioisotope based on the radioactive decay over time; it is used to measure contamination levels. Becquerel is the SI unit for curie. 1 Bq – 1 disintegration per second. 1 Curie (Ci) = 3.7×10^{10} Becquerel (Bq)
    - Disintegrations per minute (dpm) /or per second (dps)
        - 1 dps = 1 Becquerel (Bq)
        - 60 dpm = 1dps = 1 Bq
        - 1 Curie (Ci) = 3.7×10^{10} Becquerel (Bq)
- **Exposure** is the amount of X-ray or gamma radiation that will produce a specific amount of ionization in air. The unit of exposure is the roentgen (R), which measures the energy produced by X-ray or gamma radiation in a cubic centimeter of air, which is equal to 2.58×10^{-4} coulombs (C) per kg. One roentgen of X-ray or gamma radiation exposure is roughly equivalent to one *rad* of absorbed dose. A milliroentgen, or “mR”, is equal to one one-thousandth of a roentgen, or 0.001 R.
- **Exposure Rate**: Roentgens per hour (R/hr) or milliroentgens per hour (mR/hr)
- **Absorbed Dose** is the amount of radiation energy deposited per unit mass of matter.
- **Rad**, or *Radiation Absorbed Dose,* is the traditional unit of absorbed dose, recognizing that different materials that receive the same exposure may not absorb the same amount of energy. Gray (Gy) is the International System of Units (SI) unit of rad.
- **Gray** (Gy): 1 Gy = 100 rad, 1 rad = 0.01 Gy or 1 centi-Gray (cGy)
- **Absorbed Dose Rate**: Rad per hour (rad/hr) or Gray per hour (Gy/hr)

- **Rem** or *Roentgen Equivalent (in) Man*, is the unit of absorbed dose that accounts for the relative biological effectiveness in tissue (also called equivalent dose). The rem relates the absorbed dose in human tissue to the biological effect of the radiation. For X and gamma rays and beta particles, 1 rad of absorbed dose results in approximately 1 rem of equivalent dose.

- **Sievert** (Sv): 1 Sv = 100 rem, 1 rem = 0.01 Sv or 10 milli-Sievert (mSv)

- **Equivalent Dose** is the absorbed dose of radiation in a human that will produce a specific biological effect. Not all radiation produces the same biological effect, even for the same amount of absorbed dose; rem relates the absorbed dose in human tissue to the effective biological damage of the radiation. The units of rem and Sievert are the units in the traditional and SI systems for expressing equivalent dose. 1 rem = 0.01 Sieverts (Sv); 1 Sv = 100 rem

- **Total Effective Dose Equivalent (TEDE)** The projected sum of the effective dose equivalent from external radiation exposure and time-committed effective dose equivalent from internal radiation exposure.

When measuring the high gamma radiation levels in nuclear fallout, the units of roentgen, rad, and rem are taken to be equal for photon (gamma and X-ray) radiation: 1R = 1 rad = 1 rem

External, Internal, and Absorbed Doses

A person receives an external dose by exposure to X-ray, gamma, high-energy beta, or neutron radiation sources. A person receives an internal dose by ingesting or inhaling radioactive material or by absorption through a wound. The external exposure stops when the person leaves the area of the source, is decontaminated (if needed), or the source is removed. Radioactive particles settled on skin, hair, clothing, and other surfaces continue to emit ionizing radiation that may cause external doses until removed; and if inhaled, ingested or absorbed, will cause internal doses which are difficult to measure and quantify. The internal exposure continues for days, months or years until the radioactive material decays or is flushed from the body by natural or medical processes. Respiratory protection is an important component of PPE for responders operating within Radiation Control (Fallout) Areas.

A person who has ingested/inhaled radioactive material receives an internal dose to several different organs depending on the radionuclide. The radiation will deliver a dose over a period of time. The absorbed dose to each organ is dependent on the chemical element and its uptake within the organ. The sensitivity of an organ to radiation also varies. A person can also receive both an internal dose and an external dose. But, by far the greatest hazard to both responders and victims after a nuclear detonation is posed by external exposure.

Short-Term Symptoms and Effects

Acute Radiation Syndrome (ARS), also known as Radiation Sickness, may develop in individuals who absorb radiation levels of 100 rad (1 Gy) or above, depending on the type of radiation and the individual. Symptoms of ARS include nausea, vomiting, diarrhea, and reduced blood cell counts. Minor symptoms and/or blood changes may be seen in the 50 to 100 rad (0.5 to 1 Gy) range. Absorbed doses above 100 rad (1 Gy) can result in increasingly severe bone marrow damage. Gastrointestinal damage occurs at greater than 350 rad (3.5 Gy); and pancytopenia (predisposition to infection, bleeding, and poor wound healing) at greater than 550 rad (5.5 Gy), all of which can contribute to death. At extreme doses greater than 1000 rad (10 Gy) cognitive function is impaired and at greater than 2000 rad (20 Gy) cerebrovascular collapse occurs, leading to certain death.[19] Radiation, especially beta radiation, can also cause skin burns and localized injury. A small percentage of fatalities may begin to appear at doses of around 125 rad (1.25 Gy) and at doses between 300 and 400 rad (3 and 4 Gy) about half of those exposed will die without supportive treatment (see Table 6-1). At very high doses, greater than 1,000 rad, people can die within hours or days; most will not survive even with full medical care. Fetuses are especially sensitive to radiation; effects may include growth retardation, malformations, or impaired brain function. The greatest risk to fetuses is for miscarriage during the first trimester. Pregnant responders must be restricted from any activities that may expose them to radiation hazards.

Long-Term Effects

Radiation exposure increases the risk of developing cancer, including leukemia, later in life and may increase the potential for genetic effects. The risk of life-shortening effects from radiation is proportional to the dose. A small absorbed dose equates to a small increase in risk. A large absorbed dose equates to a greater increase in risk. A long-term medical surveillance program should be established to monitor potential health effects of responders to a nuclear detonation.

Incidents involving radiation or radioactive material usually will require emergency responders to be aware of the potential for health effects associated with various levels of radiation exposure. Any whole-body absorbed dose is presumed to increase a person's lifetime risk of fatal cancer, although by a small percentage. As the absorbed dose increases, the risk increases. Although the risk of acute death from radiation can be somewhat mitigated through prompt medical treatment, the long term risk of cancer will still exist.

Tables 6-1, 6-2, and 6-3 display the likelihood of health effects following radiation exposure. For example, in Table 6-1, each short-term whole body dose of 1 rad increases the lifetime risk of fatal cancer by approximately 0.06 percent. Currently in the US, approximately 40% of the population will experience cancer and 23% of the population will experience a fatal cancer.[20] A radiation

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[19] *Medical Management of the Acute Radiation Syndrome: Recommendations of the Strategic National Stockpile Radiation Working Group*, Annals of Internal Medicine, Vol. 140 Number 12, June 15, 2004

[20] Lifetime Risk (Percent) of Being Diagnosed with Cancer by Site and Race/Ethnicity: Males, 18 SEER Areas, 2009-2011 (Table 1.16) and Females, 18 SEER Areas, 2009-2011 (Table 1.17). 2014.

dose of 25 rad (0.25 Gy) would increase the average individual lifetime risk of fatal cancer from 23% to 24.8%, or by 1.8%. Similarly, a dose of 100 rad (1 Gy) would increase the average individual lifetime risk of fatal cancer by 8%.

Lifetime Risk (Percent) of Dying from Cancer by Site and Race/Ethnicity: Males, Total US, 2009-2011 (Table 1.19) and Females, Total US, 2009-2011 (Table 1.20). 2014.

Table 6-1: Approximate Health Effects after Radiation Exposure[21]

Short-Term[a] Whole Body Dose (rad)/(*Gy*)	Acute Death[b] From Radiation Without Medical Treatment (%)	Acute Death From Radiation With Medical Treatment (%)	Acute Symptoms (Nausea and Vomiting Within Four Hours) (%)	Excess Lifetime Risk of Fatal Cancer Due to Short-Term Radiation Exposure[c] (%)
1 (*0.01*)	0	0	0	0.06
10 (*0.1*)	0	0	0	0.6
25 (*0.25*)	0	0	0	1.8
50[d] (*0.5*)	0	0	0	3
100 (*1*)	<5	0	5-30	8
150 (*1.5*)	<5	<5	40	9
200 (*2*)	5	<5	60	16
300 (*3*)	30-50	15-30	75	24[e]
600 (*6*)	95-100	50	100	>40[e]
1,000 (*10*)	100	>90	100	>50[e]

a. "Short-term" refers to the radiation exposure during the initial response to the incident. The acute effects listed are likely to be reduced by about one-half if radiation exposure occurs over weeks.

b. Acute deaths are likely to occur from 30 to 180 days after exposure, with few if any after that time. Estimates are for healthy adults. Individuals with other injuries, and children, will be at greater risk.

c. Most cancers are not likely to occur until decades after exposure, although leukemia has a shorter latency period (less than five years). Projections for this column derived from EPA Radiogenic Cancer Risk Models and Projections for the U.S. Population (April 2011) below 25 rad (where a dose and dose rate effectiveness factor apply) and from Key Elements of Preparing Emergency Responders for Nuclear and Radiological Terrorism, NCRP Commentary 19, above 25 rad.

d. Radiogenic cancer risk estimates are based on prolonged exposures to ionizing radiation at low doses and dose rates. At high acute doses (~50 rad (0.5 Gy) and higher), the projected excess cancer risk estimates may underestimate the actual additional cancer risk, in part because the DNA repair mechanism becomes less efficient

e. Applies to those individuals that survive acute radiation syndrome.

Notes a, b, c and e from Table 6-1 source material: *Approximate acute death, acute symptoms, and lifetime fatal cancer risk estimates as a function of whole-body absorbed doses (for adults), for use in decision making after short-term radiation exposure (adapted from AFRRI, 2003; Goans and Wasalenko, 2005; IAEA, 1998; ICRP, 1991; Mettler and Upton, 1995)* Table 6-2 displays the likelihood of ARS and the associated short-term health effects.[22]

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[21] Adapted from NCRP Commentary No. 19: *Key Elements of Preparing Emergency Responders for Nuclear and Radiological Terrorism* (National Council on Radiation Protection and Measurements)

[22] Adapted from *EPA Protective Action Guide and Planning Guidance For Radiological Incidents,* March 2013

Table 6-2: Probability of Acute Radiation Syndrome*

Feature or Illness	Effects of Whole Body Absorbed Dose from external radiation or internal absorption, by dose range in rad (*Gy*)[23]				
	0-100 (*0-1*)	100-200 (*1-2*)	200-600 (*2-6*)	600-800 (*6-8*)	>800 (*>8*)
Nausea/Vomiting	None[a]	5-50%	50-100%	75-100%	90-100%
Time of Onset		3-6 h	2-4 h	1-2 h	<1 h to minutes
Duration		<24 h	<24 h	<48 h	<48 h
Lymphocyte Count	Unaffected	Minimally Decreased	<1,000 at 24 h	<500 at 24 h	Decreases within hours
Central Nervous System Function	No Impairment	No Impairment	Cognitive impairment for 6-20 h	Cognitive impairment for > 20 h	Rapid incapacitation
Mortality	None	Minimal	Low with aggressive therapy <5 to 50%[b]	High	Very High: Significant neurological symptoms indicate lethal dose

*Prompt health effects with whole-body absorbed doses received within a few hours.

a. A small number of exposed individuals may experience symptoms such as nausea and vomiting at doses between 50 and 100 rad (0.5 and 1 Gy).

b. The LD 50/60 or the lethal dose with NO medical intervention to 50% of the population after 60 days is between 320 and 450 rad or 3.2 - 4.5 Gy.

Table 6-3: Fatal Cancer Risk

	Effects of Whole Body Absorbed Dose from external radiation or internal absorption, by dose range in rad (*Gy*)		
	0-100 (*0-1*)	100-200 (*1-2*)	200-600 (*2-6*)
Percentage of Increased * Lifetime Risk[24]	1 rad = 0.06% 10 rad = 0.6% 50 rad = 3% 100 rad = 8%	100 rad = 8% 150 rad = 9% 200 rad = 16%	200 rad = 16% 300 rad = 24% 600 rad = >40%

* Above normal cancer risk

[23] *Medical Management of Radiological Casualties*, 2nd Ed, Armed Forces Radiobiology Research Institute, April 2003

[24] Adapted from *EPA Radiogenic Cancer Risk Models and Projections for the U.S. Population*, April 2011 and NCRP Commentary 19

7. RESPONDER HEALTH AND SAFETY

Efficient, safe deployment of response workers is essential to minimizing loss of life after a nuclear explosion. Responders will be an indispensable resource, and responder safety and health is a key consideration in all response planning. For a nuclear detonation, response workers will include not only urban search and rescue, fire and police, and emergency medical technicians (EMTs), but also utility workers, engineers, and other skilled support personnel (such as truck drivers, equipment operators, and debris contractors) that provide immediate support services during critical response operations.

Response within the SD zone should not be attempted until radiation dose rates have dropped substantially in the days following the incident, and the MD zone response is significantly advanced. The 10 R/h point of the DF zone is used to indicate that workers should return to a safe area unless they are undertaking a sufficiently justified mission; that is, a mission with a benefit that justifies the anticipated radiation dose (other potential responder hazards would be additive).

Responders who enter fallout areas should be equipped with radiation monitoring equipment that provides unambiguous alarms, based on predefined levels, to facilitate decision making.

> Radioactivity cannot be seen or felt; it must be measured. Therefore, contrary to the natural impulse and training of responders, teams should not enter affected areas without first confirming the level of radioactivity in the area they are entering. (Dangerous fallout may be visible as fine sand, dust, or haze on clean surfaces. It is an indicator of radioactivity because fallout particles carry radioactivity. However, the absence of visible fallout should not be mistaken as an indicator that it is safe, nor should all dust or haze clouds be considered to have fallout within them.)
>
> Following a nuclear detonation, it must be assumed that chemical, biological and radiological releases have occurred. All rescue and response operations should be performed in teams, ideally with a health physicist or radiation protection specialist performing radiation detection and monitoring. A safety officer performing oxygen deficiency and toxic chemical monitoring may be necessary.
>
> Since it is unrealistic to expect that this will be possible in all circumstances, particularly in the early response phase, ICs should strive to adhere as closely as possible to these recommendations.

It is assumed that responders will arrive on the scene already trained to perform their task assignments and bring with them the necessary PPE to perform their tasks in non-radiological circumstances. Abbreviated job hazard analyses, including PPE requirements, are detailed in the Appendices to this document. This section will therefore focus on the radiologic component and the additional risks involved and precautionary steps that must be taken to protect first responders.

Because of the serious short- and long-term risks of responding to this kind of incident, the following radiation protection principles should apply:

- **Justification**: The principle that an action should only be taken if the benefits of the action outweigh the total (radiation and non-radiation) risks. For the initial response to a nuclear explosion, the primary mission is rescuing survivable victims. This means that the benefit of the operation is the number of survivable victims rescued, and the risk of the operation is the total risk to the responders conducting rescue operations.

- **Optimization**: The principle that ensures that the magnitude of the individual impact (radiation dose, or chemical or physical injury), the number of people impacted, and the likelihood of incurring such impacts where these are not certain to be received, are kept as low as reasonably achievable (ALARA).

- **Limitation**: The principle that radiation doses to individuals from planned exposure situations, other than medical exposure of patients, should not exceed the appropriate limits recommended by the relevant authorities (i.e., Incident Commander). Once operations no longer involve emergency operations (e.g., lifesaving or infrastructure/population protection), limits should follow OSHA regulations for radiation exposure.[25]

In an IND response, responders may experience extreme temperatures or noise levels, chemical and biological exposures, smoke/dust inhalation, widespread fires, collapsing structures and numerous other physical hazards. In areas on the periphery of the detonation, the ambient risk will include hazards that may far outweigh the radiation hazard. If the risks (physical or radiological) in the worker's environment are high, justification becomes the operative principle – the particular task must have significant health benefit potential (lifesaving), or a critical action to save or restore key infrastructure – and the principle of limitation may be replaced by risk management. Risk management is a comprehensive approach to worker protection that accounts for all potential hazards, and assists in determining whether the overall benefits of the contemplated action outweigh the associated risks.

In addition to justification, every effort must be made to keep worker exposures ALARA in responding to a nuclear detonation. In lower-risk environments and low priority missions, ALARA means making every reasonable effort to maintain exposures as far below protective criteria (dose limits) as practical (see Table 7-1), taking into consideration the state of technology, economics, and social factors. In a high-risk environment, ALARA means making every reasonable effort to minimize the total risk (radiological and non-radiological) to the responder while making every appropriate effort to maximize the health benefit of the actions being taken.

ALARA is achieved through the use of the following administrative and engineering controls:

- Minimizing the **time** spent in radiation areas (e.g., by working quickly and efficiently).

[25] During the initial emergency response following a nuclear detonation, OSHA will likely operate in a technical assistance and support mode, pursuant to the National Response Framework, rather than issuing citations for workplace violations. However, OSHA retains its enforcement authority under the Occupational Safety and Health (OSH) Act of 1970. Guidance in this document does not necessarily reflect the requirements of the OSH Act, which federal OSHA or state occupational safety and health plans will continue to enforce in non-emergency situations.

- Maintaining the maximum **distance** from sources of radiation. (Perform most rescue operations outside of the SD and DF zones.)

- **Shielding** radiation sources, personnel, or both to reduce exposures. Shielding is any material or obstruction that absorbs radiation and protects personnel or material from the effects of ionizing radiation; very dense materials such as lead provide shielding from gamma radiation, as do concrete, brick, and stone.

- PPE does not provide protection from all exposures, but wearing properly selected PPE can prevent contamination of skin and clothing and the possible inhalation, ingestion or puncture intake of radioactive materials (note that PPE will not protect against gamma radiation).

- Effective decontamination of responders and equipment when they exit the fallout zones and prompt medical care as needed.

- Planning dangerous missions carefully to minimize physical hazard risk and optimize mission efficiency.

The early phase of the response is likely to involve critical missions in high-risk environments where actions (such as lifesaving) can have major health benefits. In this environment, radiation control options to limit occupational exposure may be limited, or due to the magnitude of the incident, might generate greater overall health risk to both responders and victims. All emergency activities must be carried out taking into consideration both the benefits to be achieved by the emergency response operation, and the potential for additional adverse health impacts to those conducting the operation.

Responders may need to shelter in place for a period of time following a detonation. The NCRP recommends that emergency service facilities (e.g., police stations, fire stations, emergency operations centers, etc.) 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.

It should be noted that consistent with the “National Response Framework Worker Safety and Health Support Annex”, this document does not replace the responsibilities of private sector and local, state, territorial, tribal, insular area, and Federal government employers; rather, it ensures that assistance is available to meet those responsibilities in incidents requiring a coordinated Federal response.

Dose Guidelines for Responders

Employers must comply with all applicable OSHA requirements, including worker dose limits for ionizing radiation, during emergency response and recovery operations. Under the OSHA Ionizing Radiation standard (29 CFR 1910.1096), responders generally must not exceed a 5-rem

(0.05 Sv) annual whole-body dose of ionizing radiation. [26] However, this Health and Safety Planning Guide does not provide a maximum exposure dose (i.e., turnback level). It is not possible to predict for such an extreme event all of the factors that would be necessary to establish a single maximum dose that could apply to all responders for all missions. The 5, 10, and 25 rem (0.05, 0.1, and 0.25 Sv) guidelines described in Table 7-1 should be viewed as flexible limits applicable to the range of early phase emergency response actions. They should serve as decision points for planning for the protection of responders during response to a nuclear detonation. Incident Commanders need to understand and consider the risks associated with various doses of ionizing radiation, and establish protocols as part of the planning process for determining when to stop, or not initiate, actions.

In any situation where responders may be exposed to ionizing radiation, take all reasonable actions to minimize dose and provide appropriate protection to responders. The Incident Commander or employer must ensure that responders are adequately informed of and have an adequate understanding of the risks associated with the actions to be taken and are appropriately trained, to the extent feasible, on those actions. “NCRP Commentary 19”, Appendix A, provides guidance on essential training competencies for varying levels of emergency responders responding to nuclear emergencies.

Since there is assumed to be no threshold below which there is not an associated risk from radiation dose, responders who are reasonably expected to receive more than 25% of the occupational dose limit, should be appropriately trained and monitored.[27]

Even during emergency response and recovery operations, OSHA standards always apply. OSHA protections cover most private sector and civilian federal employees in all U.S. states and territories. Public-sector employees, including police officers and other emergency responders, in states that operate their own OSHA-approved occupational safety and health programs (state plans) are also covered by state OSHA requirements.

[26] The OSHA Ionizing Radiation standard (29 CFR 1910.1096) permits whole-body exposure up to 1.25 rem (0.0125 Sv) per calendar quarter, which is typically interpreted as 5 rem (0.05 Sv) per year. In circumstances where exposure above this level would not cause a worker’s accumulated occupational dose to the whole body to exceed 5(*n*-18) rems (((5(*n*-18))/100) Sv), where *n* equals the individual's age in years at his/her last birthday, employers may permit workers to receive a 3-rem dose in a single quarter. Allowing workers to receive doses above the 1.25-rem (0.0125 Sv) quarterly limit is also contingent upon compliance with certain recordkeeping and other requirements of the Ionizing Radiation standard.

[27] See 29 CFR 1910.1096, Ionizing radiation

Table 7-1: Responder Dose Guidelines in the Early Phase

For all exposures, responders must be fully informed of the risks of exposure they may experience and are trained, to the extent feasible, on actions to be taken. Each responder should make an informed decision as to how much radiation risk they are willing to accept to save lives.		
Activity	**Total Effective Dose Equivalent (TEDE)[a] Guideline**	**Conditions**
Annual limit for all occupational exposures, including for radiation workers[b]	5 rem (*0.05 Sv*)	All reasonably achievable actions must be taken to minimize dose.
Infrastructure protection and restoration necessary for public welfare (e.g., a power plant), in lower-hazard areas such as the Light Damage zone and fallout areas excluding the Dangerous Fallout zone and elevated radiation areas	10 rem (*0.1 Sv*)	• All appropriate actions and controls must be implemented; however, exceeding 5 rem (0.05 Sv) is unavoidable. • Appropriate respiratory protection and other personal protection is provided and used. • Monitoring available to project or measure dose.
Life-saving, medical response, infrastructure restoration, or protection of populations in medium-hazard areas, such as the Moderate Damage zone, and fallout areas excluding the Dangerous Fallout zone	25 rem (*0.25 Sv*)	• All appropriate actions and controls must be implemented; however, exceeding 5 rem (0.05 Sv) is unavoidable. • Appropriate respiratory protection and other personal protection is provided and used. • Monitoring available to project or measure dose.
Life-saving and critical infrastructure missions (i.e., missions that directly protect significant populations from substantial risks of injury, illness, or death) in high-hazard zones, including the Dangerous Fallout zone, to include missions that critically enable the larger response effort, such as fire suppression and critical infrastructure engineering missions	Greater than 25 rem[c] (*> 0.25 Sv*)	• All appropriate actions and controls must be implemented; however, exceeding 5 rem (0.05 Sv) is unavoidable. • If lifesaving emergency responder doses approach or exceed 50 rem (0.5 Sv) emergency responders must be made fully aware of both the acute and the chronic (cancer) risks of such exposure. • Appropriate respiratory protection and other personal protection is provided and used. • Monitoring available to project or measure dose. • Life-saving and critical infrastructure engineering missions are least likely to be successful in the Severe Damage zone; and may subject responders to lethal doses of radiation. • All missions are evaluated and justified by the Incident Commander, including assessment of hazards, value of the mission, and likelihood of success.

a. The sum of the effective dose equivalent from external radiation exposure and committed effective dose equivalent from internal radiation exposure.

b. Includes workers in Department of Energy and Nuclear Regulatory Commission-licensed facilities.

c. The 2008 DHS Guidance and 2013 PAG Manual provide radiation emergency worker guidance, stating "The emergency intervention needed to prevent further destruction and loss of life may result in increased exposure. Exceeding the Response Worker Guidelines … may be unavoidable in responding to such events." Additionally the 2013 PAG Manual states, "The 25 rem (0.25 Sv) lifesaving response worker guidelines provide assurance that exposures will not result in detrimental deterministic health effects (i.e., prompt or acute effects). However, it could increase the risk of stochastic (chronic) effects, such as the risk of cancer." Clinically significant exposures are covered in tables 6.2 and 6.3.

Life-Saving Decision Making

For lifesaving and other critical operations, the Incident Commander should minimize the total radiation dose to the responders in order to make the maximum use of scarce worker resources in a prolonged high demand incident. . High risk operations require risk management decision making, often with incomplete information. All responder missions in high risk environments must be optimized and justified.

In justifying high-risk missions, the Incident Commander should ask the following questions:

1. Are there victims to be rescued; what level of confidence do you have that there are survivable victims?

2. How many survivable victims are there?

3. What is the likelihood of a successful mission (victims are saved, water pressure is restored)?

4. How many response workers are needed to execute the mission?

5. What are the hazards response workers will encounter?

6. Will response workers would be placed in a potentially lethal situation?

7. Does the benefit (potential lives saved, critical infrastructure mission) merit the health risk to response workers?

8. What can be done to minimize or avoid this risk to response workers?

9. What are the physical resource implications of the mission; are the appropriate resources available, and is the quantity adequate to sustain further response efforts?

10. Are there more critical missions evident that would take precedence? Or other rescue missions where there is a greater likelihood of survivable victims and less risk to workers?

11. Would the health impacts of the mission on responders (injury, high radiation dose, or death) compromise the extended incident response?

Any responder anticipated to receive exposure to radiation should be adequately informed of and have an adequate understanding of the risks they may experience during missions, and are trained, to the extent feasible, on actions to be taken. This information and understanding should include the short-term (acute) health effects and long-term (chronic; i.e., cancer) risks of radiation exposure. Since there is assumed to be no threshold below which there is not an associated risk from radiation dose, responders who are reasonably expected to receive more than 25% of the occupational dose limit, should be appropriately trained and monitored.

Responders undertaking emergency activities where incident doses may exceed the annual occupational dose limit of 5 rem (0.05 Sv) should meet the following criteria:

- Responders should be adequately informed of and have an adequate understanding of the potential health effects of their exposures and the numerical estimates of the increase in their lifetime risk of cancer. Advance understanding of the risks associated with an IND attack may expedite informed consent during the actual incident. Responders should be experienced in performing the required tasks (so that they will likely be able to accomplish the tasks more quickly, which will decrease their exposure).
- Responders should be trained to work in hazardous environments, including radiation environments.
- Declared pregnant responders should not exceed 500 mrem (0.005 Sv), the occupational radiation declared pregnant worker recommended limit.
- Responders should be over the age of 18.
- Responders should be in an established radiation dose monitoring program.
- The total number of responders involved with these tasks should be kept as low as necessary for the tasks to be completed as efficiently as possible.
- Dosimetry or alternative method of monitoring responders for radiation exposure should be used.

Response worker dose guidelines are based on cumulative dose. It is assumed that doses received in response to a radiological incident would be “once in a lifetime” doses, and that future radiological exposures would be substantially lower.

Examples of dose estimate and stay time calculations are below (1 roentgen = 1 rad)

1. **Cumulative Dose Calculation**

Cumulative Dose = Cumulative Exposure = Exposure Rate x Time

For example, at the outer edge of the DF zone (10R/hr) for 2.5 hours:

Cumulative Exposure = 10R/hr x 2.5 hours

Cumulative Dose = 25 rad

2. **Stay Time Calculation**

$$\text{Stay Time} = \frac{\text{Decision Dose (limit)}}{\text{Dose Rate}}$$

For example at the outer edge of the DF zone (10R/hr):

$$\text{Stay Time} = \frac{\text{25 rad limit}}{\text{10 R/hour average dose rate}}$$

Stay Time = 2.5 hours

Because of the potential for excessive responder cumulative doses, time spent in the DF zone should be minimized.

Note that decision dose and stay times do not include internal dose (e.g., from inhalation, ingestion) as it is assumed that the responder is wearing effective respiratory protection. For this example, the decision dose and stay time is based on external exposures.

Background Radiation

Background radiation is constantly present in the environment. It is emitted from a variety of natural (e.g., radon, cosmic rays) and artificial (e.g., power plants, imaging equipment, tobacco, etc.) sources. The average annual radiation dose to individuals in the United States is approximately 620 mrem/yr (0.620 rem or 0.062 Sv), about half of which comes from medical imaging (e.g., x-rays and CT scans).

Table 7-2: "RULES OF THUMB" FOR RESPONDERS

At first sign of a nuclear explosion	Shelter-in-place at the first sign of an intense flash of light and stay sheltered for at least one hour to let the initial dust settle. Cover ears against sound that will follow the visual blast.
Don't rush in	Determine radiation levels first, wear appropriate PPE, define the mission
Stay aware of wind and weather	Always approach potential fallout zones from upwind direction
Radiation Dose	❖ The annual occupational dose limit for ionizing radiation is 5 rem (rad, *0.05 Sv*) *This limit would likely be exceeded in an IND emergency* ❖ **Keep exposures to a minimum, for the health and safety of responders** ❖ Normal guideline for lifesaving or protection of large populations, 25 rem (rad,*0.25 Sv*) ❖ Catastrophic event, such as an IND incident, may warrant > 25 rem (rad, *0.25 Sv*) for lifesaving.
Exposure	❖ Responders who are reasonably expected to receive more than 25% of the occupational dose limit, should be appropriately monitored. ❖ Ensure responders have been adequately informed of and have an adequate understanding of the risks, including of short- and long-term effects, they may experience during missions, and are trained, to the extent feasible, on actions to be taken. ❖ Each responder should make an informed decision as to how much radiation risk they are willing to accept to save lives.
Area for maximizing rescue potential	The portion of the MD zone falling outside of the DF zone offers the best potential for rescuing the most survivable victims.
Recognizing Fallout Particles	Fine, sand-sized grains. However, lack of apparent fallout does not suggest lack of radiation. Continued radiation monitoring is required.
Fallout decays rapidly	7-10 Rule: For every sevenfold increase in time after detonation, there is a tenfold decrease in the radiation rate. So, after seven hours the radiation rate is only 10% of the original and after 49 hours (7 x 7 = 49) it is 1%.
Decision Dose or Turn-back Dose	When approaching or surveying the scene, the 10 R/h (*0.1 Gy/h*) point normally indicates that workers should return to a safe area, unless they are undertaking a sufficiently justified mission to validate the exposure.
Acute Radiation Syndrome (ARS)	Nausea, vomiting or diarrhea indicates exposure of 100 rad (*1 Gy*) or more. Exit radiation area immediately and seek medical care.
Decontamination*	Remove all outer clothing and footwear. Shower if possible, or wipe skin and hair with moist towelettes.

***** For Medical Responders: Provide life-saving medical care before decontamination.

Do not forget -- all of the other hazards that go with a catastrophic event will still exist.

8. MEDICAL SURVEILLANCE REQUIREMENTS

The OSHA Hazardous Waste Operations and Emergency Response Standard (29 CFR 1910.120) requires employers to provide medical surveillance for first responders who are expected to be part of an organized HAZMAT team or hazardous material specialists to control or stabilize emergency or potential emergency releases of hazardous substances. These requirements specify a baseline medical examination and ongoing monitoring. The medical exam must include a determination of fitness for duty, including the ability to wear any required PPE under conditions that may be expected for an incident. The employer must obtain from the examining physician a written opinion that includes any recommended limitations, such as respirator use, upon the employee's assigned work and that the worker is able to wear a respirator and/or participate as a HAZMAT team member. Employers have a duty to know and follow laws applicable in their jurisdictions (note that in some cases, state, local, tribal and territorial responders are not covered by OSHA standards), which may include state or local requirements and HAZWOPER protection extended by EPA regulations to certain public sector workers. Responders should also follow applicable state or local guidance documents, provided by the employer or incident command.

Ideally, a pre-established respiratory protection program should be in place with a fit test and physical conducted by a physician or licensed health care provider. In the immediate aftermath of a nuclear detonation, this may not be possible.

During the early phase, the availability of medical care will necessarily be limited as hospitals and medical offices will be overwhelmed with injured victims. Furthermore, nearby medical facilities will be in the process of evacuation to safe areas, free from radiation hazards. Accordingly, each response team should be prepared to perform basic first aid and CPR for its own members and to implement team rescue activities to minimize risk of injury. Entry into the affected area should include a plan for the transport of sick or injured responders to medical facilities that may be miles away. Having team members who are qualified first aid and CPR providers is essential, particularly since personnel who are EMTs will likely be called away to treat detonation victims. ICs should activate their contacts with area hospitals to identify those that would be able to accept responders as patients during the initial response. Since response teams may be from non-local areas, they should be provided with the names and addresses of available hospitals and directions.

If a responder is seriously injured, treatment of those injuries always takes priority over decontamination and management of radiation injury. Ideally, special procedures and considerations should be provided for injured responders who are also contaminated with radioactive material. Medical triage should be conducted based on traditional surgical and medical considerations (serious trauma first) with the understanding that triage may need to be adjusted for combined injury (radiation and trauma) because normally sub-lethal or minimally lethal trauma can act together with radiation injury to increase the likelihood of mortality. This depends on the radiation dose and the severity of the injury (or burn). An interactive triage tool is available online from the U.S. Department of Health and Human Services Radiation Emergency Medical Management website at http://www.remm.nlm.gov/triagetool_intro.htm.

If possible, responders with minor injuries should be decontaminated (except for the wounds) before transport to a medical facility. Decontamination should not be conducted if the procedures might aggravate an injury or cause more serious health effects. In the event of serious injury, the employer should inform the receiving medical facility of the status of the responder's radiological contamination before removal from the incident site. If possible, steps should be taken to limit or prevent the spread of contamination during transfer of the responder as well as at the medical facility. This can be accomplished by removing contaminated clothing or covering contamination with a clean sheet or blanket. Removal of outer clothing and shoes can reduce contamination by as much as 90 percent.

Team members should be alert to the symptoms of ARS in themselves and others, and report the first signs to their team leader. Nausea and vomiting are early signs of ARS. Onset of these symptoms should trigger a removal from the fallout zone to a medical treatment facility, and the time of initial vomiting should be noted to assist with future medical treatment. First responders showing signs of ARS will require prompt diagnosis and treatment of conditions related to possible radiation exposure.

One method for assessing the amount of radiation exposure of an individual is biodosimetry. This useful tool can estimate radiation dose in the early phase after a nuclear detonation. Various methods of biodosimetry include assessing the responders' signs and symptoms (e.g., time from exposure to the onset of vomiting), performing serial lymphocyte counts and other monitoring alterations in blood counts (can be done by most clinical laboratories and are generally available after several hours), and performing cytogenetic analysis (takes several days and must be done by specialty laboratories). Newer point-of-care biodosimetry assays are being developed. The capacity for biodosimetry will be limited and surge capacity networking will be needed. For the data to be useful for medical management, biodosimetry samples should be analyzed at laboratories experienced and accredited for this type of analysis.

When internal contamination of radioactive material is suspected an *in vivo* bioassay (i.e., whole-body counting, lung counting, etc.) or *in vitro* bioassay (i.e., collection and analysis of biological samples) can be used to accurately determine a responder's cumulative total effective dose (from both internal and external exposure). However, the internal dose from inhalation during the early phase after a nuclear detonation is dwarfed by the high external radiation rates. Additionally, an *in vitro* bioassay performed in the first few days after intake results in high levels of uncertainty in the estimated dose. Therefore, bioassay analyses performed in the early phase after the incident are not considered useful.

PPE may produce excessive heat stress in responders. While this is particularly dangerous when ambient temperatures are hot, PPE may exacerbate heat stress even when ambient conditions are considered cool. Water-vapor-impermeable, air-impermeable, thermally insulating clothing, encapsulating suits, and multiple layers of clothing all severely restrict heat removal. Furthermore, PPE use may restrict ability to perform regular tasks (e.g. US&R and shoring). Therefore, PPE use may significantly limit activities responders are usually able to accomplish (a significant planning factor).

Responders should be provided with shaded rest areas and potable water. Additional information on heat stress is available on OSHA's website at: https://www.osha.gov/SLTC/heatstress/index.html.[28]

If possible, medical stations specifically for responders should be established to triage injuries, measure vital signs, perform skin evaluations and assess the mental status of responders who appear to be suffering from heat stress or other stress disorders. The results of onsite medical monitoring must be documented and maintained.

Follow-up medical care of all responders who have been exposed to high levels of radioactivity should include long-term monitoring (i.e., over decades) and focus on delayed effects, most significantly the detection of blood disorders and cancer. For patients with relatively low-dose exposures, the long-term psychological needs may be more medically significant than radiation-induced injuries.

A plan for monitoring responder health and safety is an important part of protecting them. Recognizing this, the National Institute for Occupational Safety and Health (NIOSH) worked with the U.S. National Response Team (NRT) and a number of federal agencies, state health departments, labor unions, and volunteer responder groups to develop the Emergency Responder Health Monitoring and Surveillance (ERHMS) system. The ERHMS consists of an "NRT Technical Assistance Document" and "A Guide for Key Decision Makers". The ERHMS provides guidelines for protecting responders over a full range of emergency types and settings. It is for use by all who are involved in the deployment and protection of responders. This includes incident management and response organization leadership, health, safety and medical personnel, and responders themselves. State and local response organizations should review http://www.cdc.gov/niosh/topics/erhms/ for more information.

Potassium Iodide (KI)

Response organizations may be considering stockpiling and distributing potassium iodide (KI) tablets to responders. KI blocks the uptake of a particular radionuclide (radioactive iodine) common to nuclear reactors. KI can decrease thyroid cancer incidence in exposed children and young adults following a nuclear reactor accident. However, IND events will have other isotopes, and KI will not protect against these other high-risk isotopes. Respiratory protection is the preferred method to avoid inhalation of a broad range of radionuclides including radioactive iodine. In addition, KI must be taken within a few hours of exposure to be useful. Therefore, the response organization should consider this short timeframe of effectiveness in the planning process. Organizations should consider consulting with their occupational physician for advice on this measure.

KI was not recommended for early medical response in the "Planning Guidance for Response to a Nuclear Detonation". According to the International Commission on Radiological Protection (ICRP), "In most cases, the value of KI administration is expected to be low. Even when there is

[28] Specific guidance regarding determination of heat loading can be found in ACGIH, 2011, Heat Stress and Strain, in TLVs and BEIs, American Conference of Industrial Hygienists, Cincinnati, OH

a significant release of radioactive iodine (e.g., following a nuclear yield from a weapon), the value of administration of KI to adults is small. Recent analysis of epidemiological studies following external radiation exposure of the thyroid, have shown little if any risk to persons exposed over the age of 20 (Ron et. al., 1995). For a number of reasons, the carcinogenic effect of radioiodine is felt to be even less than from external radiation. As a result, there is little reason to consider large programs to distribute KI to adults in the event of terrorist incidents."

9. DECONTAMINATION

In the initial response phase of an IND, there will be migration of radiological and chemical substance contamination from the impacted areas into the non-contaminated areas as a result of population and animal migration, as well as air and water transport. Decontamination, for the purpose of this Guide, is focused on protecting responders and prevention of gross contamination migration incidental to the response actions. Wastes from decontamination should be safely stored so as not to unduly expose personnel to radiation hazards and to avoid theft that could expose others to radiation hazards.

Decontamination of response team members and their clothing and protective equipment is essential to limit exposures to radiation that could be caused by settled dust particles (fallout). Ideally, team members emerging from contaminated areas should undergo full decontamination consisting of removal and disposal or laundering of outer clothing, boots, boot covers, and gloves; removal and laundering or disposal of inner clothing; full shower with hair shampooed; removal of respirator in the shower; and donning clean contaminant-free clothing upon completion of showering. At a minimum, they should be monitored for contamination and if contaminated and no shower is available, clothing should be removed in a manner that minimizes spread of any contamination and a shower should be sought as soon feasible. Worn clothing and equipment should be sealed in double plastic bags, and stored in a secured (from theft) and isolated area at least 20 feet away from personnel, other people, or animals, where the radioactive contamination will decay. At some future time, when monitoring equipment and decontamination stations are available, the used clothing and equipment may be evaluated and cleaned for re-use.

Personnel who assist in performing decontamination should wear protective clothing such as disposable coveralls or plastic rain suits; nitrile gloves; neoprene boots or latex disposable booties over footwear; chemical splash goggles; and a half-face N-100 respirator (disposable face mask or cartridge-style). Responders should be frequently monitored for significant contamination, and should be cognizant of their own contamination levels. At the conclusion of their work shift, responders should decontaminate protective (outer) clothing first, remove protective clothing and equipment, then remove their clothing, shower and shampoo, and don clean clothing.

In the absence of power and water supplies, decontamination methods may need to be modified, even to the point of requiring the removal and disposal or storage of all worn clothing and PPE, including respirators. Stockpiling a few days' supplies for each responder will facilitate replacement of clothing and PPE used during the first few days of the response. If clothing has radioactive contamination or if this cannot be determined because of a lack of appropriate instrumentation, the only safe course of action is total replacement of clothing and PPE after each exit from the contaminated zone. Several pre-moistened towelettes can be used to wipe small areas of skin and hair, for example exposed hands and hair. Responders should use each towelette only on a small area of the body, focusing on the hands and face first, to prevent spreading radioactive contamination. Masking tape can also be used to remove contamination from the skin. Contaminated waste from the decontamination should be placed in double plastic bags and stored in an isolated area at least 20 feet away from personnel, other people, or animals, until it can be appropriately disposed.

As it is essential to remove all external radioactive contamination as soon as possible, responders should be transported to shower facilities as soon as it is feasible upon exit from contaminated areas. They should thoroughly shower and shampoo and change all clothing worn. Under no circumstances should clothing or equipment be shaken or cleaned with compressed air because this will disperse the contamination to cause further exposure.

Similar to the decontamination of personnel, vehicles and other equipment used by the recovery team must be decontaminated upon exit from contaminated areas. Ideally, this would be accomplished by HEPA vacuum cleaning, followed by the application of detergent using long-handled brushes, rinsing with water. In the early phases of a post nuclear detonation, all reasonable efforts to contain contaminated water during decontamination should be employed.

Decontamination will usually be necessary, however in some cases it may not be required based on readings from hand-held instrumentation.

10. EMERGENCY PLAN FOR RESPONSE PERSONNEL

To the greatest extent practicable, the following preparations should be made to handle responder nuclear emergencies:

- Evacuation routes should be identified and communicated to each team member prior to entry.
- Current information regarding radiation levels in their planned work areas should be communicated prior to entry and updated throughout the entry as new information becomes available.
- Emergency alerting equipment should be carried to alert and/or summon team members.
- At least two members of each entry team should be certified in first aid and CPR and should carry first aid supplies.
- At least two emergency rooms within reasonable proximity should be identified, with directions to them available. Ideally, they should be located in opposite directions from the planned response area so that the team can choose the path with the least fallout and road rubble.
- A vehicle should be positioned as close as possible to each team for emergency use, but team members may need to be prepared to travel considerable distances by foot to reach this vehicle.
- Transportation should be available to quickly and safely insert or remove responders from the radiation zones in order to maximize their productivity by minimizing the time spent getting to and from their task area.
- Team members should remain alert to upper-level wind direction, radiation readings, and threats from civilian violence. Team members should be prepared to self-evacuate if conditions become unsafe for them.

ICS 206 form should be used to prepare a Medical Plan specifically for responders. Forms can be found at (https://training.fema.gov/emiweb/is/icsresource/icsforms.htm).

11. SITE CONTROL

The perimeters of the fallout zones will be continuously changing, making it difficult to erect visible barriers or warning signs. As the IC receives updated radiation monitoring data, the maps will be re-drawn. Planners should work to ensure response teams have access to the most current maps. These will be used in conjunction with the response team's radiation measurements and fed back to the IC's staff. The IC's instructions to each response unit should clearly authorize each entry into the radiation (fallout) zones and record the duration of each entry. This will be essential to control the radiation doses received by response personnel. No entry into the DF zone should be made without justification, optimization and planning, and response team members must sign in and out for each entry and exit to the DF zone. A radiological exposure log must be maintained for each responder, calculating their cumulative dose. Once a responder's decision dose has been reached, further explicit authorization must be made by the IC prior to re-entry into a radiation zone.[29]

Control points should be established just outside the elevated radiation area to support the entry response teams. These control points should maintain communications with the entry teams and be ready to re-supply them and to provide decontamination services.

Essential supplies should include multiple complete sets of clothing and PPE for each team member, extra supplies of respirator cartridges and air tanks, toilet facilities, washing facilities (showers, soap, shampoo and clean towels), potable (drinking) water, electrolyte replacement beverages, first aid supplies, plastic garbage bags to contain contaminated clothing and supplies, trailer or shed for storage of contaminated supplies, radiation monitoring equipment, and mobile communications equipment with backup. If the weather is cold or rainy, warm-up shelters will be needed, and if the weather is warm, shaded rest areas should be provided. Ideally, office trailers with generators, portable toilets and refreshments could be in place. Although, this may not be feasible until after the initial 72 hours.

Personnel entering the controlled area must follow established safety guidelines, including the following restrictions:

- Personnel entering or departing any radiation zone shall report to a monitoring manager or designated representative.
- The buddy system should be employed by all field-monitoring teams.
- Personnel should be adequately trained to perform their assigned tasks safely.
- All personnel entering the impacted area should be fully informed about potential hazards and applicable procedures at the site.

[29] DOE, *NNSA Radiological Emergency Response Health and Safety Manual*, 2001

- Appropriate PPE must be worn at all times.
- Personal dosimetry and other monitoring equipment should be required for entry into impacted areas, including:
- Dosimetry:
  - Personal Dosimeter (Thermoluminescent Dosimeter or Optically Stimulated Luminescence dosimeter)
  - Self-Reading Dosimeter (Electronic Personal Dosimeter or Personal Pocket Dosimeter)
- Other monitoring
  - Personal Air Sampling
  - Bioassay type, frequency, etc.
- Decontamination procedures should be performed upon exiting any fallout zone.

12. PERSONAL PROTECTIVE EQUIPMENT

PPE is worn to protect responders from hazards that cannot be adequately controlled through other methods, such as elimination, substitution, engineering controls, safer work practices, or administrative controls. The selection of PPE is based initially on anticipation of hazards and hazard levels and is modified as monitoring is performed to identify actual conditions. Normally, PPE is selected to protect workers from the worst levels of hazard anticipated. In a nuclear detonation scenario, we must necessarily balance maximum responder protection with real-world limitations of the availability of PPE during the initial response period where life-saving missions are paramount. It must be further noted that PPE provides protection against some, but not all, forms of radiation. This limitation should guide all decisions to authorize entry into radiation exposure areas.

Employers must also provide respirators, which are applicable to and suitable for the purpose intended to meet OSHA requirements for respiratory protection under 29 CFR 1910.134. Respiratory protection reduces the inhalation of radioactive particles (including radioactive dusts) created by the detonation and the numerous resulting fires. Respiratory protection, depending upon the type selected, may also reduce exposure to oxygen-deficient atmospheres and hazardous chemicals. Assignment of respiratory protection should be limited to responders who have been trained to use the assigned respirators and who have been fit-tested to be sure that the respirator performs properly. Respirator users should also be medically certified as being healthy enough to wear a respirator (see also Section 8 – Medical Surveillance). Respiratory protection will be essential wherever there is radioactive contamination or dust.
Dermal protection reduces exposure to dusts, chemical substances, and biological contaminants. Covering skin, face and hair not only reduces skin absorption, but also prevents transfer of contamination to the mouth or nose. Careful decontamination and removal of all coverings is essential to prevent the spread of contamination outside the impacted area. Selection of dermal protection depends on anticipated hazards and tasks assigned.

Other PPE may be needed for specific situations or tasks. These may include hearing protection, fall protection, visibility vests, hard hats, steel toe footwear, flotation devices, lineman gloves for electrical workers, flame resistant (FR) clothing, welding helmets, thermal gloves, etc.

A note about heat stress: PPE requirements may increase the risk of heat-related injury in responders even when ambient conditions are considered cool. Responders should remain vigilant to the signs of heat stress in themselves and others. If possible, heat stress monitoring programs should be implemented, including measurement of vital signs (e.g., blood pressure, heart rate/pulse, and core temperature), skin evaluation, and assessment of mental status.[30]

[30] Additional information on heat stress is available at: https://www.osha.gov/SLTC/heatstress/index.html. Specific guidance regarding determination of heat loading can be found in ACGIH, 2011, Heat Stress and Strain, in TLVs and BEIs, American Conference of Industrial Hygienists, Cincinnati, OH

Appendix P lists the PPE for various hazards. When multiple hazards are anticipated, the PPE should be the most protective PPE type specified for each body part.

PPE Worksheet for Multiple Hazards

Each responder or response team should complete Table 12-1 by listing the anticipated hazards, then identifying the prescribed PPE from Appendices A through O for each hazard. Where PPE requirements conflict or when multiple hazards are anticipated, the PPE should be the most protective type specified for each body part. Radiation detection equipment is discussed in the Radiation Detection and Air Monitoring Equipment, Section13.

Table 12-1: Example of Selection of PPE for Responders Exposed to Multiple Hazards

Name of Task:	
List of Hazards:	
Radiation Monitoring	
Headgear	
Eyewear	
Hearing Protection	
Respirator	
Torso	
Gloves	
Footwear	

13. RADIATION DETECTION AND AIR MONITORING EQUIPMENT

In general, very few responders have experience working in major disasters that include highly radioactive areas. Effective emergency response actions within the damage zones can only be accomplished with appropriate planning, responder training, provision and use of appropriate PPE, and other mission-critical capabilities, including alarming and passive radiation dosimetry, air monitors, and substance-specific monitors. Responders with dosimetry should be trained in setting and responding to appropriate turn-back doses. ICS Form 215, Operational Planning Worksheet and ICS Form 215A, Incident Action Plan Safety Analysis are examples of the types of forms that should be developed and used to plan and document required PPE for emergency response and rescue activities. Examples of these forms may be found online (https://training.fema.gov/emiweb/is/icsresource/icsforms.htm). The IC should assign a Safety Officer to each entry team who will perform monitoring and communicate findings back to the IC for go/no-go decisions.

For the purposes of this document, instruments can be divided into the following categories:

1. **Alarming Personal Radiation Dosimeters** (i.e., active devices) for use by responders working in fallout zones. These devices actively monitor radiation levels and are set to notify workers (by alarm) of elevated radiation conditions, or when they are approaching dose limits. Ideally, alarming personal radiation dosimeters should be capable of identifying radiation exposure rates in the range of 1 mR/hr (~0.01 mGy/hr) to 500 R/hr (~5 Gy/hr), and be able to integrate exposure up to 500 R (~5 Gy) with a visual status indicator (not necessarily a numerical readout). According to the NCRP, instruments should be set to alert responders when the exposure rate reaches 10 mR/hr (0.0001Gy/hr). Whenever possible, such a dosimeter should be assigned to each responder who enters a fallout zone.
2. **Passive Dosimeters** to monitor accumulated radiation exposure or dose. These passive dosimeters reliably measure the wearer's total external radiation dose, but do not generally display the dose level in real time. Many current dosimeters such as film dosimeters (badges), thermoluminescent dosimeters (TLDs), and optically stimulated luminescent dosimeters, are passive devices that require a processing system to determine the wearer's dose. As a result, passive dosimeters are not appropriate for managing radiation doses at the scene because the results cannot be determined until well after the dose is received. These dosimeters are valuable to measure an individual's total external radiation dose following the incident, but are not appropriate for managing dose at the scene.
3. **Survey Instruments** to detect the presence of an external radiation field and surface contamination are generally available to meet the needs of the response community. A thin-window Geiger-Mueller (GM) (either "pancake" or end-window) hand-held survey meter would be acceptable to monitor either surface or personnel contamination. Radiation survey instruments are well suited to scanning for contamination and should have detection capabilities of at least 6,000 dpm/cm^2 (100 Bq/cm^2) for beta or gamma surface contamination, and 600 dpm/cm^2 (10 Bq/cm^2) for alpha surface contamination. These values are one-tenth of the respective values for surface contamination at the outer edge of the fallout zones [i.e., 60,000 dpm/cm^2 (1,000 Bq/cm^2) for beta or gamma; 6,000 dpm/cm^2 (100 Bq/cm) for alpha]. The maximum activity likely to be encountered in an IND incident is

difficult to specify, but the upper range of detection for instruments used for contamination monitoring should be between a factor of 100 and 1,000 above the minimum capabilities given above.

4. **Radionuclide Identifiers** to determine the type of radioactive material. While much of the initial response to a nuclear or radiological incident can be managed without knowing the specific radioactive material(s) present, identification of the radioactive materials will allow better management of contaminated individuals and improve protective measures for the responders. Commercially available radioactive material identifiers (generally referred to as radionuclide identifiers) have been available for many years to identify gamma-ray emitting radioactive materials. These instruments usually require considerably more knowledge and skill to operate than a survey meter. Improved units are now available that are small, relatively lightweight, and provide information in a manner that can be interpreted by individuals trained at the technician level.

5. **Oxygen Meters and Explosimeters** to measure oxygen levels and the potential for explosion are essential for entry into buildings, below-surface excavation, and near potential chemical spill sources such as tanks and flammable gas containers. Many oxygen and explosimeter instruments also measure specific gases such as carbon monoxide, carbon dioxide, hydrogen sulfide, or other toxic gases. Fire departments use these routinely, but response teams that are less familiar with their use should have established maintenance programs and qualified personnel should perform calibration checks immediately before using the instrument in the field. Oxygen levels below 19.5 % can cause effects ranging from mental inattention to loss of consciousness and death, and are therefore unsafe unless an air-supplying respirator is worn. Explosimeters only work when oxygen levels are adequate, i.e., >19.5%. If explosimeter levels exceed 10%, the area is potentially explosive and no entry should be made until levels fall below 10%. If the meter detects carbon monoxide, levels should be below 50 ppm for safe entry. Carbon dioxide levels should be below 5000 ppm for safe entry. Both CO and CO_2 are byproducts of combustion and can be expected to be elevated at fire scenes. Air-purifying respirators do not provide protection from oxygen deficiency, explosivity, or excessive CO or CO_2, and for this reason monitoring and retreat are vital precautions for recovery teams. Firefighters, on the other hand, are equipped with self-contained breathing apparatuses (SCBA) and may enter areas with unsafe levels of these gases, according to their established procedures. The instruments should be “on” continuously during initial entry and during entry into any structure or excavation. It is important to take measurements at various heights within structures, as some gases are heavier or lighter than air. Operators/technicians trained in the instruments should check the readouts frequently. These instruments must be maintained and calibrated prior to use. The detectors have a limited shelf life and must be replaced per manufacturer’s instructions.

6. **Multiple Gas Detectors** to detect the presence of explosive or toxic gases, including oxygen deficiency, carbon monoxide, hydrogen sulfide, ammonia, chlorine, hydrogen, cyanide, phosphine, sulfur dioxide, methane, natural gas, or propane. There are many multi-gas instruments available with alarming sensors and bright graphic displays that can detect gases in PPM (parts per million), LEL (lower explosive limit), and/or percent volume.

7. **Organic Vapor Detectors** to detect many carbon-containing chemical vapors such as solvents and gasoline. In general, they cannot distinguish among harmful vapors but are used

as an indicator of the presence of organic air contaminants. It is essential to perform a calibration check when instruments are turned on, following manufacturer instructions, to be sure that the instrument will respond properly. The presence of elevated readings could indicate a health hazard and air-purifying respirators with P-100 and organic vapor cartridges are not adequate protection against all chemical contaminants. Until the chemical contamination is identified, the prudent course is avoidance. Outdoor readings are not expected to exceed 10 ppm and if readings at or above this level are encountered, it may indicate a dangerous chemical release. The detectors should be “on” continuously and the operators should check the readouts frequently.

7. **Substance-Specific Detectors and Instrumentation** to measure the presence of large sources of specific chemicals in the air. For example, water treatment plants may have large stocks of chlorine gas that could be released during a nuclear detonation. Advance planning should identify any chemicals of concern and plan for appropriate assessment equipment.

14. TRAINING

Hazardous Waste Operations (HAZWOPER) Training – Specialist Employee

All responders who enter a hazardous area should be trained in HAZWOPER at a level consistent with their assigned duties (number 1 or number 2 below). State and local employees are covered either by OSHA-approved state plans, which are required to be at least as effective as the federal standards, or by the EPA's HAZWOPER standard 40 CFR 311, which applies the HAZWOPER standard in states without OSHA-approved state plans.

1. HAZWOPER-Trained Persons receive a certificate of training and must renew their training in an 8-hour refresher course annually. (OSHA 29 CFR 1910.120(e)).
   - **General site workers:** 40-hour initial HAZWOPER training (e.g., heavy equipment operators, fire fighters, search and rescue personnel, laborers, technicians) and a minimum of three days actual field experience under the direct supervision of a trained, experienced supervisor.
   - Occasional onsite with limited scope work involving minimal exposure: 24-hour HAZWOPER training and a minimum of one day actual field experience under the direct supervision of a trained, experienced supervisor.
   - **Supervisor:** Initial 24- or 40-hour HAZWOPER training, depending on their supervisory responsibilities (see 29 CFR 1910.120(e)(3)), plus 8 hours supervisor HAZWOPER training
2. Responders receive performance-based training that must be refreshed annually. (OSHA 29 CFR 1910.120(q)(6))
   - **First Responder:** Strictly limited to recognizing situations, understanding hazards, identifying the presence of hazardous substances in an emergency, and making the appropriate notifications
   - **First Responder Operations Level:** At least 8 hours training to be able to protect nearby persons, property, or the environment from the effects of the release; trained to respond in a defensive fashion without actually trying to stop the release (e.g., medical personnel, evacuation drivers, communications personnel)
   - **HAZMAT Technician:** At least 24 hours training to respond to releases or potential releases for the purpose of stopping the release; they assume a more aggressive role than a first responder (e.g., structural engineers, road crews, police engaged in traffic/crowd control)
   - **HAZMAT Specialist:** At least 24 hours of training equal to the technician level, additional competency in selecting PPE; perform specialized control, containment, and/or confinement operations; determine and implement decontamination procedures; develop a site safety and control plan; and understand chemical, radiological and toxicological terminology and behavior (e.g., health physicists, linemen, utility or chemical plant operators)

- **On-Scene Incident Commander:** At least 24 hours of training equal to the first responder operations level; additional competency to assume control of the incident scene to implement the ICS. Additionally, ICs should possess certification as a NIMS type Incident Commander, per NIMS guidelines[31].
- **Other Training**
    - **Skilled Support Personnel:** Workers who are skilled in the operation of certain equipment such as mechanized earth moving or digging equipment or crane and hoisting equipment, and who are needed temporarily to perform immediate emergency support work, and who will be or may be exposed to the hazards at an emergency response scene shall be given an initial briefing at the site prior to their participation in any emergency response. The initial briefing shall include instruction in the wearing of appropriate PPE, what chemical, biological, radiological, and nuclear hazards are involved, and what duties are to be performed. All other appropriate safety and health precautions shall be used to assure the safety and health of these personnel. (OSHA 29 CFR 1910.120(q)(4))[32]
- **Initial Safety Briefing:** All responding personnel must be provided an initial briefing that reviews the work plan, radiation hazards, anticipated chemical/biological hazards, ergonomic hazards, heat stress, work procedures, chain of command, use of PPE, decontamination procedures, monitoring, medical surveillance, emergency procedures, and site controls.

National Fire Protection Association (NFPA) Training

The DHS has adopted NFPA Standard 472, "Standard of Competence for Responders to Hazardous Materials/Weapons of Mass Destruction Incidents", 2013 Edition.

Scope

- 1.1.1 This standard shall identify the minimum levels of competence required by responders to emergencies involving hazardous materials/weapons of mass destruction.
- 1.1.2 This standard shall apply to any individual or member of any organization who responds to hazardous materials/WMD incidents.
- 1.1.3 This standard shall cover the competencies for awareness level personnel, operations level responders, hazardous materials technicians, incident commanders, hazardous materials officers, hazardous materials safety officers, and other specialist

[31] For more information on NIMS resource management, visit: https://www.fema.gov/resource-management-mutual-aid

[32] OSHA 29 CFR 1910.120(q)(4), *Occupational Safety and Health Standards, Hazardous Waste Operations and Emergency Response; Emergency Response Program to Hazardous Substance Releases; Skilled Support Personnel*

employees.

The table of contents for the NFPA 472 Standard can be found in Appendix S. The full document may be obtained from the NFPA website at:
http://www.nfpa.org/aboutthecodes/AboutTheCodes.asp?DocNum=472

Additional Training

Daily Safety Briefing: All responder personnel must be briefed daily on the tasks to be performed, changing site conditions, precautions to be taken, lessons learned from previous work, and reminders on work practices as needed. Ensure responders know that slips, trips, and falls can cause serious injuries, and they should be on the lookout for these hazards during response activities.

Personal Protective Equipment Training: All personnel using PPE must be trained in the uses and limitations of each piece of PPE worn. (OSHA 29 CFR 1910.132-138)[33]

Specialized Training: All response personnel must be appropriately trained and qualified to perform assigned tasks and to decline tasks for which they are not qualified. Examples of specialized tasks requiring training are heavy equipment operation, electrical work, lockout/tagout, firefighting, and vehicle operation.

Hospital/Field/Triage Medical Personnel Recommended Training: (adapted from OSHA *Best Practices for Hospital-Based First Receivers of Victims from Mass Casualty Incidents Involving the Release of Hazardous Substances*, 2005 and REAC/TS guidance *The Medical Aspects of Radiation Incidents*, September 2013.)

- Medical personnel include pre-clinical, clinical, and support staff involved with patient triage, field treatment, transport, and definitive care. Although some patients may require decontamination at a healthcare facility, most should be decontaminated prior to transport and non-critically injured persons should be decontaminated by other than medical personnel. There is limited risk of radiation exposure from contaminated patients; therefore, radiation decontamination should **NEVER** cause a delay lifesaving patient care.

- As appropriate to their respective roles and responsibilities, medical personnel should be able to:
    - conduct situation/scene size-up, hazard assessment (e.g. chemical, radiation), and patient triage and initial care;
    - select and use personal protection and other hazard mitigation methods (e.g. isolation and decontamination);

33 OSHA 29 CFR 1910.132-138, Occupational Safety and Health Standards, *Personal Protective Equipment*

  - employ the hospital incident command system (ICS) and facility mass casualty surge methodologies for patient flow, patient assessment, and medical management of trauma and radiation injury;
  - understand that lifesaving medical or surgical care must **NEVER** be delayed because of possible radiation contamination.

- Training should include a combination of lecture, small-group activity, exercises and hands-on instruction in hazard assessment, use of PPE, proper patient triage, and safe practice of medical procedures (including radiation screening and, if necessary, decontamination). Written and practical examinations, exercises, and refresher training are recommended to evaluate and maintain competency.

15. COMMUNICATIONS

In 2011, DHS determined that 90 percent of all high-risk urban areas designated within the Urban Area Security Initiative (UASI) were able to demonstrate response-level emergency communications (the capacity of individuals with primary operational leadership responsibility to manage resources and make timely decisions during a multi-agency incident without technical or procedural communications impediments) within one hour for routine events involving multiple jurisdictions and agencies.[34]

Following a nuclear detonation, the EMP may disable electronics, including communications in the immediate vicinity. The NCRP recommends that emergency services facilities prepare for backup communication that will survive the loss of communication repeaters and electrical power.

Even after a period of time, cellular telephone systems may not be functional and nearby emergency response radio systems may be compromised. Establishing communications between response units is likely to present unique challenges. Therefore, response units may need to self-mobilize until communications have been restored. They should follow the recommendations presented in this Guide to operate as safely as possible.

Responders may need to attempt a variety of methods to establish and maintain communications. Once communications have been established, the Incident Communications Plan should be employed.

The IC or their incident communications personnel should maintain, at a minimum, the following incident communications plan forms:

- ICS 205 to provide, in one location, information on all radio frequency assignments down to the Division/Group level for each operational period
- ICS 205a to list methods of contact for personnel assigned to the incident (radio frequencies, phone numbers, pager numbers, etc.)

As each responder joins the incident they should check-in with the Communications Unit Leader and receive radio frequency information and/or provide cell phone information.

Communications equipment should be carried by each entry team that will enable communication back to the command post, with other teams from their organization, and with other local organizations. Communications equipment should be compatible with other organizations, and each team member must know how to operate the communications equipment.

[34] *DHS National Emergency Communications Plan: Urban Area Communications Key Findings and Recommendations,* 2011.

16. RECORDKEEPING

Employers already have established recordkeeping systems for their employees that address training, respirator fit tests, monitoring and exposures, medical records, and occupational injury/illness cases. Having immediately available summaries of these records will enable ICs to assign personnel to responder activities, based on their status. The major modification that will be needed is the ability to record and monitor each responder's radiation exposure level upon exit from DF and/or elevated radiation area so that an up-to-date record of each responder's radiation exposure is available at all times. This record will be used to make deployment decisions and must be as complete and accurate as possible.

As discussed in the section on Site Control, all responders arriving at the scene should be required to check-in and check-out of the fallout zones. Their time in each zone should be logged and their cumulative radiation doses should be recorded in a radiation exposure log. In areas where other hazardous materials are present, exposures must also be measured and recorded.

In the early response phases, prior to the arrival of more sophisticated measuring equipment it is anticipated that exposures will need to be estimated based on the best information available. Cumulative exposures and doses must be calculated using the most cautious estimates possible.

As more advanced equipment becomes available, cumulative doses of radiological and other hazardous substances will be determined by using several methods:

1. Personal dosimetry
2. Personal dosimetry of others in the task group
3. Surveillance instruments coupled with time-in-zone logs
4. Bioassay
5. Medical tests

Dose and exposure records should be maintained for each responder and updated with each entry into the response area. Once a responder reaches the decision dose, the IC must determine whether the benefits of additional efforts outweigh the much higher risk to the responder.

As of January 1, 2015, all employers must report all work-related fatalities within 8 hours and all work-related inpatient hospitalizations, all amputations and all losses of an eye within 24 hours.

Any injuries incurred during the response must be recorded. When exposure and injury have both been experienced, there is far greater risk to responder health. Therefore, additional considerations must be made with regard to the responder's ability to continue emergency operations.

The results of onsite medical treatment or monitoring, including heat stress monitoring, must be documented and maintained with each responder's record.

Employers are always required to comply with all applicable recordkeeping requirements in OSHA standards, including HAZWOPER and substance/hazard-specific standards.

FOREWORD TO THE APPENDICES

These appendices are meant to provide examples of hazards, control measures, and other information applicable to response to an IND detonation. However, they do not cover every scenario that every worker may encounter during a response mission. The appendices are designed to help employers identify health and safety hazards and protect workers appropriately, but should not be considered as definitive guidelines for compliance with OSHA standards. In many cases, employers will need to combine the recommendations from multiple appendices—particularly with regard to PPE and other precautions described in appendices A through O—to ensure workers are adequately protected. A number of OSHA standards may apply to workers involved in IND response and recovery, depending on what type of operations are being conducted, what hazards (e.g., air contaminants, physical hazards, etc.) are present, or other factors. Under the Occupational Safety and Health (OSH) Act of 1970, employers have a responsibility to:

- provide a workplace free from serious recognized hazards and comply with all applicable standards, rules and regulations issued under the OSH Act;
- ensure employees have and use safe tools and equipment and properly maintain this equipment;
- establish and update operating procedures and communicate them so that employees follow safety and health requirements;
- provide safety training in a language and vocabulary workers can understand;
- where hazardous chemicals are present in the workplace, develop and implement a written hazard communication program and train employees on the hazards they are exposed to and proper precautions (and a copy of safety data sheets must be readily available); and
- provide medical examinations and training when required by OSHA standards.

- **Appendices A – O** represent the hazards that may be involved in a post IND environment.
  - **Hazard:** A description of the types of hazards that may be encountered when performing a task.
  - **Training:** The training required to perform tasks associated with the hazard.
  - **PPE:** Equipment that must be worn or utilized when performing a task associated with the hazard.
  - **Precautions:** Other precautions that should be considered before performing tasks associated with the hazard.
  - **References:** OSHA Standards that apply to the hazard.

  - **Guidance:** Existing guidance from governmental or non-profit organizations that guide the performance of tasks associated with the hazard. It is expected that the Guidance portion of these appendices should be developed by the stakeholders as pertinent documents are identified.

- **Appendix P** provides details of the different types of PPE that may be worn or utilized in the performance of tasks described in this document.

- **Appendix Q** is the Table of Contents from the 2008 Edition of NFPA 472: Standard for Competence of Responders to Hazardous Materials/Weapons of Mass Destruction Incidents and link to obtain the full document.

Appendix A: Radiation

HAZARDS OF RADIATION

High doses of radiation pose immediate and long-term health impacts. PPE can only provide partial protection.

TRAINING FOR RADIATION

Radiation awareness

PERSONAL PROTECTIVE EQUIPMENT FOR RADIATION

Headgear	Coated hood or a helmet. Hard hat recommended due to falling debris.
Eyewear	Full-face respirator provides eye protection. Wear chemical goggles while wearing a half face respirator.
Hearing protection	Hood or helmet should cover ears to prevent entry of dusts into ear canal. Hearing protection (earmuffs/inserts) provides protection against noise and would also protect against dust entry in to the ear canal.
Respirator	SCBA when dust levels are extremely heavy (i.e., obscure vision at 200 feet). Full-face air-purifying respirator (APR) with P-100 filter at a minimum. If available, use a pre-filter that is attached over the outer face of the cartridge and change these whenever breathing becomes more difficult and every time the elevated radiation area is exited. The pre-filter must be manufacturer-approved for use with the specific respirator and cartridge assembly worn.
Torso	Firefighters: Turnout gear All others: Coated coveralls for entry into contamination zones and coveralls for work in zones with <1 R/hr.
Gloves	Nitrile disposable over neoprene, cotton liner optional
Footwear	Firefighters: Firefighter footwear All others: Latex booties over sturdy footwear or neoprene boots

PRECAUTIONS

- Dust build-up on protective clothing will contribute to total radiation exposure. It will be important to replace outer clothing with uncontaminated clothing at least every 4 hours if working in zones with >1 R/hr. Until monitoring establishes exposure levels, respirator cartridges should be changed out at least every 4 hours. Remove all clothing and take a shower to remove radioactive dust at least every 8 hours.
- All PPE must be appropriately discarded or decontaminated upon exit from a contaminated area.
- Heat stress is a potential risk when wearing protective clothing; therefore, breaks should be taken and monitored.

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- After hazards have been determined, PPE requirements may be relaxed upon approval of the IC or SOFR.

REFERENCES

- OSHA 29 CFR 1910.120 Hazardous waste operations and emergency response
- OSHA 29 CFR 1910.132 PPE, General requirements
- OSHA 29 CFR 1910.133 Eye and face protection
- OSHA 29 CFR 1910.134 Respiratory protection
- OSHA 29 CFR 1910.135 Head protection
- OSHA 29 CFR 1910.136 Foot protection
- OSHA 29 CFR 1910.137 Electrical protective equipment
- OSHA 29 CFR 1910.138 Hand protection
- OSHA 29 CFR 1910.1096 Ionizing radiation

Quick Reference Guide:
Radiation Risk Information for Responders Following a Nuclear Detonation

This document supports the "Planning Guidance for Response to a Nuclear Detonation" and was designed to provide responders with specific guidance and recommendations about the radiation risk associated with responding to an improvised nuclear device (IND) event, in order for them to protect themselves from the IND effects. It is intended to be part of preparation training with the "Health and Safety Planning Guide For Planners and Supervisors For Protecting First Responders Following A Nuclear Detonation", but can be used as a stand-alone document.

This provides basic information responders will need for the first 24 -72 hours after an extreme event -- a nuclear detonation. These guidelines are not designed to apply to other, less extreme, radiological events. Specific information/training should be sought for those.

Some of this guidance will be counterintuitive to those trained in emergency response; however, it is critical that responders remain as safe and healthy as possible, not only for their own safety, but also to remain available for the ongoing mission of saving lives. Responders involved in an IND event need to be prepared to see numerous victims with serious traumatic injuries and illness including: severe burns, blindness, deafness, amputations, radiation sickness, etc.

What would a nuclear detonation be like and what can you expect?

- The **Nuclear Flash** would come in the form of an intense burst of light and extreme heat potentially creating a firestorm. Injuries: flash burns, flame burns, flash blindness, and retina burns.
- **Prompt Radiation** would be delivered, resulting in high radiation doses close to the detonation. Injuries: possibility of immediate or delayed (weeks or months) illness or death.
- The **Nuclear Blast** would include an initial fireball, overpressure wave, and extreme high winds. Injuries: crushing, fractures, lacerations, rupture of the viscera, and pulmonary hemorrhage and edema. All of this would take place in mere moments.
- The **Mushroom Cloud/Fallout** radioactive material mixed with debris is carried up and spread by winds for miles. Delayed Injuries: radiation exposures, potentially lethal exposures closer to the detonation.
- The **Electromagnetic Pulse (EMP)** produces a high-voltage surge that poses no direct health threat, but may damage electronic equipment two to five miles from ground zero and disrupt communications.

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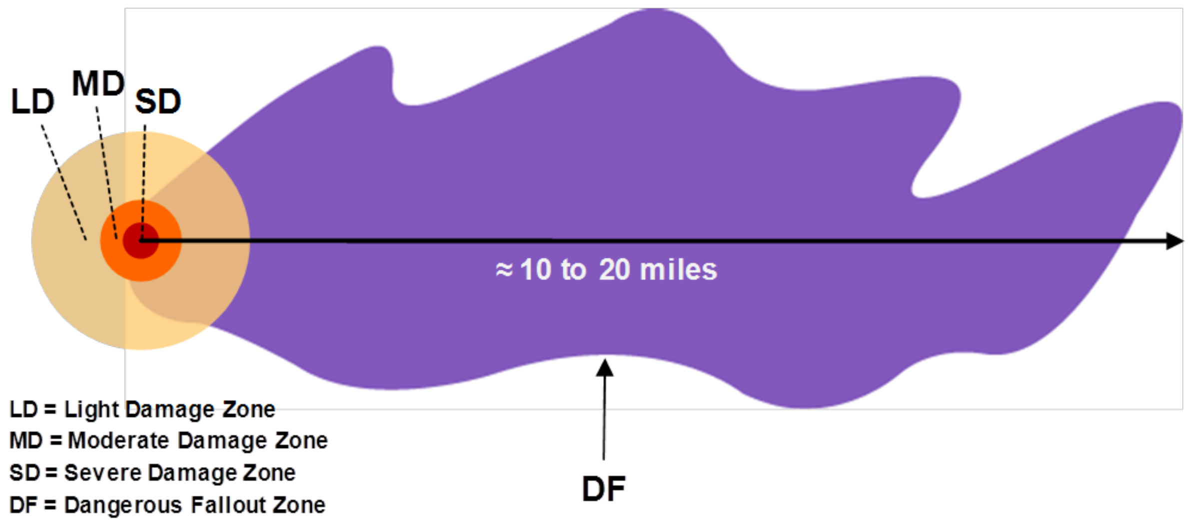
Zoned Response

There will be two different kinds of zones: Damage & Fallout zones
Response organizations will use these terms to establish official zones
*(These distance **estimates** are for a 10 KT IND, ground burst)*

Severe Damage – **0 to 0.5 mi**: Buildings completely destroyed, **radiation is too high to enter** for 72 hours, survivors unlikely

Moderate Damage – **0.5 to 1 mi**: Significant building damage, rubble, downed power lines, overturned vehicles, limited visibility for the first hour or more due to dust and smoke, serious injuries, **best lifesaving opportunities**.

Light Damage – **1 to 3 mi**: Windows mostly broken, injuries not expected to be life-threatening



Fallout zones change with time. As the fallout is spread by wind the area expands. After the initial distribution, the zones shrink as the radioactivity decays.

Dangerous Fallout zone – **up to 20 mi** from ground zero: Radioactive dust from the explosion create radiation levels exceeding **10 R/hr** (see table)(*0.1 Gy/h*), not limited to damage zones, **actions taken** here must be **justified**, planned and always kept As Low As Reasonably Achievable (ALARA); **time-sensitive**, mission-critical activities such as rescuing identified injured survivors. Advise other survivors to shelter in place.

Elevated radiation area – **up to several hundreds of miles**: from **0.01 R/hr to 10 R/hr (***0.0001 to 0.1Gy/h***)**, potentially hazardous, and cumulative radiation exposure should be monitored.

Key Points for Zoned Response

Most people in the LD zone will survive on their own, but critical injuries may still exist.

MD zone outside of the DF zone - Area with the **most survivable victims** and therefore the maximum rescue potential. Rescue efforts should be concentrated in this area.

Many people in the MD zone will survive only if they are rescued and treated.

Most people in the SD zone will not survive, even if they can be rescued.

The **DF zone** is extremely hazardous and **should not be entered without justification**.

Responders should approach the area from upwind, outside of the fallout zones.

Responders should assess the surroundings to determine if rescue measures are immediately needed or can wait until radiation levels can be accurately determined and the responders are formally dispatched through the Incident Command System.

Responders should not rush into the most damaged areas without a thorough hazard and mission assessment.

What happens to the body when exposed to radiation?

There are two ways to be affected by radiation, **exposure** and **contamination** (see protective gear). There are two types of **effects** on the body, acute and long-term.

1. **Acute**: This is when the body gets a large dose of radiation quickly; symptoms can manifest quickly, in minutes to hours. See the table below for the onset times for initial affects.

Acute Radiation Syndrome (Radiation Sickness) *

<table>
<tr><th rowspan="2">Feature or Illness</th><th colspan="5">Effects of Whole Body Absorbed Dose from external radiation or internal absorption, by dose range in rad/Gy</th></tr>
<tr><th>0-100 (0-1)</th><th>100-200 (1-2)</th><th>200-600 (2-6)</th><th>600-800 (6-8)</th><th>>800 (>8)</th></tr>
<tr><td>Nausea/Vomiting</td><td rowspan="3">None[a]
(see note)</td><td>5-50%</td><td>50-100%</td><td>75-100%</td><td>90-100%</td></tr>
<tr><td>Time of Onset after Exposure</td><td>3-6 hr</td><td>2-4 hr</td><td>1-2 hr</td><td><1 hr to minutes</td></tr>
<tr><td>Duration</td><td><24 hr</td><td><24 hr</td><td><48 hr</td><td><48 hr</td></tr>
<tr><td>Lymphocyte Count (blood)</td><td>Unaffected</td><td>Minimally Decreased</td><td><1,000 at 24 hr</td><td><500 at 24 hr</td><td>Decreases within hours</td></tr>
<tr><td>Central Nervous System Function (brain & nerves)</td><td>No Impairment</td><td>No Impairment</td><td>Cognitive impairment for 6-20 hr</td><td>Cognitive impairment for > 20 hr</td><td>Rapid incapacitation</td></tr>
<tr><td>Death</td><td>None</td><td>Minimal</td><td>Low with aggressive therapy
<5 to 50%[b]</td><td>High</td><td>Very High</td></tr>
</table>

*Prompt health effects from whole-body absorbed doses received within a few hours.

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a. A small number of exposed individuals may experience symptoms such as nausea and vomiting at doses between 50 and 100 rad (0.5 and 1 Gy).

b. The LD 50/60 or the lethal dose with NO medical intervention to 50% of the population after 60 days is between 320 and 450 rad (3.2 - 4.5 Gy).

2. **Long-term**: There is an increased risk of getting cancer later in life after a radiation exposure. Any risk of life-shortening effects from radiation is proportional to the dose. Most cancers are not likely to occur until several decades after exposure; although leukemia has a shorter latency period (<5 yr), NCRP Commentary No.19 Key Elements of Preparing for Nuclear and Radiological Terrorism (2005).

Fatal Cancer

	Effects of Whole Body Absorbed Dose from external radiation or internal absorption, by dose range in rad (*Gy*)		
	0-100 (*0-1*)	100-200 (*1-2*)	200-600 (*2-6*)
Percentage of Increased Lifetime Risk[1]	1 rad = 0.06% 10 rad = 0.6% 50 rad = 3% 100 rad = 8%	100 rad = 8% 150 rad = 9% 200 rad = 16%	200 rad = 16% 300 rad = 24% 600 rad = >40%

[1] Derived from EPA Radiogenic Cancer Risk Models and Projections for the U.S. Population, April 2011 and from NCRP Commentary 19.

Incidents involving radiation or radioactive material usually will require responders to be aware of the potential for health effects associated with various levels of radiation exposure. Any whole-body radiation dose can increase a person's lifetime risk of fatal cancer. As the dose increases, the risks also increase. High radiation doses (i.e., >100 rad (1Gy)) can be potentially life-threatening, although the risk of acute death from radiation can be mitigated through prompt medical treatment. Without proper medical assistance 50% of people with radiation doses of ~400 rem (rad or 4 Gy) or higher will most likely die in 60 days.

State and local jurisdictions may have their own guidance regarding decision dose limits. Responders should abide by jurisdictional limits until the IC system is in place and new limits have been established.

"RULES OF THUMB" FOR RESPONDERS

At first sign of a nuclear explosion	Shelter-in-place at the first sign of an intense flash of light and stay sheltered for at least one hour to let the initial dust settle. Cover ears against sound that will follow the visual blast.
Don't rush in	Determine radiation levels first, wear appropriate PPE, define the mission
Stay aware of wind and weather	Always approach potential fallout zones from upwind direction
Radiation Dose	❖ The annual occupational dose limit for ionizing radiation is 5 rem (rad or *0.05 Sv*) *This limit would likely be exceeded in an IND emergency* ❖ **Keep exposures to a minimum, for the health and safety of responders** ❖ Normal guideline for lifesaving or protection of large populations, 25 rem (rad or *0.25 Sv*) ❖ Catastrophic event, such as an IND incident, may warrant > 25 rem (rad or 0.*25 Sv*) for lifesaving.
Exposure	❖ Responders who are reasonably expected to exceed more than 25% of the occupational dose limit, should be appropriately monitored. ❖ Ensure responders have been adequately informed of and have an adequate understanding of the risks, including of short- and long-term effects, they may experience during missions, and are trained, to the extent feasible, on actions to be taken. ❖ Each responder must make an informed decision as to how much radiation risk they are willing to accept to save lives.
Area for maximizing rescue potential	The portion of the MD zone falling outside of the DF zone offers the best potential for rescuing the most survivable victims.
Recognizing Fallout Particles	Fine, sand-sized grains. However, lack of apparent fallout does not suggest lack of radiation. Continued radiation monitoring is required.
Fallout decays rapidly	7-10 Rule: For every sevenfold increase in time after detonation, there is a tenfold decrease in the radiation rate. So, after seven hours the radiation rate is only 10% of the original and after 49 hours (7 x 7 = 49) it is 1%.
Decision Dose or Turn-back Dose	When approaching or surveying the scene, the 10 R/h (*0.1 Gy/h*) point normally indicates that workers should return to a safe area, unless they are undertaking a sufficiently justified mission to validate the exposure.
Acute Radiation Syndrome (ARS)	Nausea, vomiting or diarrhea indicates exposure of 100 rad (*1 Gy*) or more. Exit radiation area immediately and seek medical care.
Decontamination*	Remove all outer clothing and footwear. Shower if possible, or wipe skin and hair with moist towelettes.

***** For Medical Responders: Provide life-saving medical care before decontamination.

Do not forget -- all of the other hazards that go with a catastrophic event will still exist.

Use or disclosure of the information contained in this document is subject to the restriction on the title sheet of this document.

CONSIDERATIONS FOR SELF-PROTECTION AGAINST RADIOACTIVE CONTAMINATION

Reminders: ***These items will not protect you from radiation exposure, only contamination.*** *Radiation exposure does not necessarily mean someone is contaminated with radioactive particles.*

Wear Personal Protective Gear appropriate to your role and hazards you may encounter.

Headgear	Coated hood, or a helmet. Hard hat recommended due to falling debris.
Eyewear	Full-face respirator protects eyes or chemical goggles with a half-face respirator.
Ear protection	Hood or helmet to cover ear canal and prevent entry of dusts. Alternative: Hearing protection.
Respirator	Self-contained breathing apparatus (SCBA) when dust levels are extremely heavy (i.e., obscure vision at 200 feet), if available, use NIOSH-certified. Full-face air-purifying respirator (APR) with P-100 filter at a minimum. If available, use a pre-filter that is attached over the outer face of the cartridge and change these whenever breathing becomes more difficult and every time the elevated radiation zone is exited. The pre-filter must be manufacturer-approved for use with the specific respirator and cartridge assembly worn. CAUTION: If not experienced in changing filter/cartridges in a contaminated environment, users should not attempt to change it in the clean zone.
Torso	Firefighters: Turnout gear All others: Coated coveralls for entry into contamination zones and coveralls for work in zones with <1 R/hr (*0.01 Gy/h*).
Gloves	Nitrile disposable or neoprene, cotton liner optional
Footwear	Firefighters: Firefighter footwear All others: Latex booties over sturdy footwear or neoprene boots
Radiation Dosimeter	If available, radiation dosimeters can help you determine how much you have been exposed to and when you need to leave the radiation area. Remember to return them for reading and use by other responders. When available, it is recommendable that electronic personal dosimeters are used with alarm dose and alarm dose rate capabilities.

After hazards have been determined, PPE requirements may be increased or relaxed, upon approval of the Incident Commander or Site Safety Officer.

Appendix B: Hazardous Substances

HAZARDS OF HAZARDOUS SUBSTANCES

Chemical and biological releases resulting from the initial explosion, and subsequent structural damage/collapse/fires, may include asbestos, silica, heavy metals, and organic substances. The experience of first responders from catastrophic events indicates that heavy dust levels will overwhelm the body's ability to protect itself, and can lead to permanent lung damage and shortened life expectancy, therefore proper PPE must be worn.

TRAINING FOR HAZARDOUS SUBSTANCES

- 24-hour or 40-hour initial HAZWOPER training with annual refresher training (see section 14 for more information on training for hazardous substances)
- Current respirator fit test

PERSONAL PROTECTIVE EQUIPMENT FOR HAZARDOUS SUBSTANCES

Headgear	Coated hood or helmet
Eyewear	Full-face respirator
Hearing protection	--
Respirator	SCBA when dust levels are extremely heavy (i.e., obscure vision at 200 feet). Full-face air-purifying respirator (APR) with P-100 filter and organic vapor cartridge, at a minimum. If available, use a pre-filter that is attached over the outer face of the cartridge and change these whenever breathing becomes more difficult <u>and</u> every time the elevated radiation area is exited. The pre-filter must be manufacturer-approved for use with the specific respirator and cartridge assembly worn.
Torso	Firefighters: Turnout gear All others: Coated coveralls
Gloves	Nitrile disposable over neoprene, cotton liner optional
Footwear	Firefighters: Firefighter footwear All others: Latex booties over sturdy footwear or neoprene boots

PRECAUTIONS

- All PPE will lose its protective value quickly when exposed to the levels of contamination expected as the result of an IND and therefore needs to be changed out frequently. Until monitoring establishes exposure levels, respirator cartridges should be changed out at least every 4 hours, and whenever breathing becomes difficult due to dust in the filter.

- All PPE must be discarded or decontaminated upon exit from a contaminated area.
- Heat stress is a potential risk when wearing protective clothing; therefore breaks should be taken and monitored.
- After hazards have been determined, PPE requirements may be modified upon approval of the IC or SOFR.

REFERENCES

- OSHA 29 CFR 1910.120 Hazardous waste operations and emergency response
- OSHA 29 CFR 1910.132 PPE, General requirements
- OSHA 29 CFR 1910.133 Eye and face protection
- OSHA 29 CFR 1910.134 Respiratory protection
- OSHA 29 CFR 1910.135 Head protection
- OSHA 29 CFR 1910.136 Foot protection
- OSHA 29 CFR 1910.137 Electrical protective equipment
- OSHA 29 CFR 1910.138 Hand protection

Appendix C: Confined Spaces

HAZARDS OF CONFINED SPACES

Confined Spaces are enclosures large enough for human entry, but having limited means of egress and not designed for human occupancy. If hazards are present or could become present, then a permit system is required to ensure the safety of entrants. Unknown chemical, radiological or biological contaminants may pose hazards, as well as lack of lighting, tight spaces and obstructions, engulfment or drowning hazards, smoke and fire, steam, live electrical components, unstable structures, presence of animals, etc.

TRAINING FOR CONFINED SPACES

- Confined space training and rescue; respirator training.

PERSONAL PROTECTIVE EQUIPMENT FOR CONFINED SPACES

Headgear	Hard hat covered with a coated hood
Eyewear	Full-face respirator provides eye protection
Hearing protection	Hearing protection (inserts or muffs) required at sustained noises >85 dBA
Respirator	SCBA respirator
Torso	All entrants to wear a harness assembly attached to a retrieval line. Firefighters: Turnout gear All others: Coated coveralls over sturdy long pants and long sleeve shirt
Gloves	Nitrile disposable over neoprene (or over leather if sharp edges are anticipated), cotton liner optional
Footwear	Firefighters: Firefighter footwear All others: Steel toe footwear

PRECAUTIONS

- Assess space and retrieval capabilities. Perform air monitoring before and during entry within the space and identify any hazards.
- Test the retrieval system prior to entry and practice communication signals with all entry team members
- Inform the Command Post of planned entry prior to entry.
- Heat stress is a potential risk when wearing protective clothing; therefore breaks should be taken and monitored.
- Confined spaces with hazards present or potentially present require a written entry permit specific to each entry. Entrants and attendants must be specifically trained in confined

space hazards and procedures. Tragically, many would-be rescuers are killed while trying to rescue without following established procedures.

REFERENCES

- OSHA 29 CFR 1910.120 Hazardous waste operations and emergency response
- OSHA 29 CFR 1910.132 PPE, General requirements
- OSHA 29 CFR 1910.133 Eye and face protection
- OSHA 29 CFR 1910.134 Respiratory protection
- OSHA 29 CFR 1910.135 Head protection
- OSHA 29 CFR 1910.136 Foot protection
- OSHA 29 CFR 1910.137 Electrical protective equipment
- OSHA 29 CFR 1910.138 Hand protection
- OSHA 29 CFR 1910.146 Permit-required confined spaces

Appendix D: Heavy Equipment

HAZARDS OF HEAVY EQUIPMENT OPERATION

Heavy Equipment (operation & awareness) including trucks, bulldozers, cranes, fork trucks, and other heavy equipment will be needed to clear roads and move rubble to enable rescue operations and to control fires. Equipment operators are trained and experienced, but ground personnel may not be accustomed to working around heavy equipment.

TRAINING FOR HEAVY EQUIPMENT OPERATION

- Heavy equipment operators must be trained and authorized to operate assigned equipment.
- Flaggers must be trained.
- All other personnel must be briefed and reminded to keep clear and stay outside operator blind spots.

PERSONAL PROTECTIVE EQUIPMENT FOR HEAVY EQUIPMENT OPERATION

Headgear	Hard hat if within the work zone of heavy equipment
Eyewear	Safety glasses
Hearing protection	Hearing protection (inserts or muffs) required at sustained noises >85 dBA
Respirator	When heavy equipment is operated in an environment where air contaminants, such as particulates or chemical vapors, pose a respiratory hazard, respiratory protection (i.e., respirators) may be required. In some cases, the use of heavy equipment itself may generate dust that contains silica (e.g., from jackhammering or cutting concrete, block, or brick) or other contaminants that pose respiratory hazardous to equipment operators and other responders.
Torso	Ground personnel to wear high visibility vests (Class 1, 2, or 3)
Gloves	Leather work gloves optional for operators and laborers
Footwear	Steel toe shoes or boots if within the work area of heavy equipment

PRECAUTIONS

- Ground personnel must maintain a safe distance from heavy equipment and keep in mind that the operator may not be able to see them.
- Operation of heavy equipment in enclosed areas may lead to a buildup of dangerous levels of carbon monoxide and carbon dioxide, as well as hazardous diesel exhaust.

- Maintain situational awareness, particularly for downed electrical lines and uneven working surfaces, as well as overhead hazards.

REFERENCES

- OSHA 29 CFR 1910.132 PPE, General requirements
- OSHA 29 CFR 1910.133 Eye and face protection
- OSHA 29 CFR 1910.134 Respiratory protection
- OSHA 29 CFR 1910.135 Head protection
- OSHA 29 CFR 1910.136 Foot protection
- OSHA 29 CFR 1910.137 Electrical protective equipment
- OSHA 29 CFR 1910.138 Hand protection
- OSHA 29 CFR 1910.178 Powered industrial trucks

Appendix E: Hazardous Energy Control

HAZARD OF HAZARDOUS ENERGY

Hazardous Energy Control including electrical, mechanical, hydraulic, pneumatic, chemical, thermal, or other energy may be hazardous if it is unexpectedly released or if personal contact occurs. Downed electrical lines, pressurized containers, live steam lines and other energy sources may be encountered by recovery teams; and equipment may have energized parts that could be hazardous to the touch or while performing repairs.

TRAINING FOR HAZARDOUS ENERGY

- Work on or contact with energized electric lines is limited to qualified electricians.
- Lockout/tagout training

PERSONAL PROTECTIVE EQUIPMENT FOR HAZARDOUS ENERGY

Headgear	Hard Hat. Wear a Class "E" rated hard hat if working near energized circuits.
Eyewear	Safety glasses; add a face shield if working on energized circuits.
Hearing protection	Single hearing protection if noise >85 dBA
Respirator	--
Torso	Firefighters: Turnout gear All others: sturdy long pants and long sleeve shirt. Wear fire resistant (FR) shirt and pants if working on energized circuits.
Gloves	Leather work gloves. Wear lineman gloves if working on energized circuits.
Footwear	Firefighters: Firefighter footwear All others: Sturdy steel toe footwear (leather or neoprene)

PRECAUTIONS

- Test unknown electric lines and equipment with a remotely handled circuit tester before approaching, or else steer clear (at least 10 feet from electrical lines if the ground is dry and much further if the ground is damp).

REFERENCES

- OSHA 29 CFR 1910.147 The control of hazardous energy (lockout/tagout)
- OSHA 29 CFR 1910.301-399 Electrical

Appendix F: Falls (Surface)

HAZARD OF FALLS

Falls (surface): Walking surfaces may be uneven and fractured. Ground holes and fissures may be present. Walking surfaces on or in buildings and bridges may be weakened, broken, fractured, unsteady, etc. Rain, water spills, or ice can create slippery conditions.

TRAINING FOR FALLS

- Team members should be reminded of the need to watch their step. Ankle, knee and back injuries from falls will limit the effectiveness of the recovery team.

PERSONAL PROTECTIVE EQUIPMENT FOR FALLS

Headgear	--
Eyewear	--
Hearing protection	--
Respirator	--
Torso	Sturdy long pants and long sleeve shirt. Wear high visibility vest if near traffic or heavy equipment
Gloves	--
Footwear	Firefighters: Firefighter footwear All others: Steel toe footwear

PRECAUTIONS

- Slips, trips and falls can cause serious injury and these injuries will severely limit the effectiveness of the recovery team.

REFERENCES

- OSHA 29 CFR 1910.136 Foot protection

Appendix G: Fires

HAZARDS OF FIRES

Fires will be encountered throughout the SD and MD zones and into the LD zone. Leaking fuels will contribute.

TRAINING FOR FIRES

- Firefighting is limited to members of the firefighter units.

PERSONAL PROTECTIVE EQUIPMENT FOR FIRES

Headgear	Firefighters helmet
Eyewear	Full-face respirator (SCBA)
Hearing protection	--
Respirator	Full-face SCBA respirator
Torso	Firefighters: Turnout gear
Gloves	Firefighter gloves
Footwear	Firefighter footwear

PRECAUTIONS

- Non-firefighters should call in fires to the command post.
- Firefighters must remain in protective gear until they exit the contaminated area. This will necessitate carrying extra air bottles. Firefighters must remember that they are still in a hazard zone after they extinguish a fire.

REFERENCES

- OSHA 29 CFR 1910.132 PPE, General requirements
- OSHA 29 CFR 1910.133 Eye and face protection
- OSHA 29 CFR 1910.134 Respiratory protection
- OSHA 29 CFR 1910.135 Head protection
- OSHA 29 CFR 1910.136 Foot protection
- OSHA 29 CFR 1910.137 Electrical protective equipment
- OSHA 29 CFR 1910.138 Hand protection
- OSHA 29 CFR 1910 Subpart L Fire Protection

Appendix H: Explosions

HAZARDS OF EXPLOSIONS

Explosions can be expected in the aftermath of an IND. Heat may cause closed vessels to explode and if their contents are flammable, a flaming explosion may ensue. Buildings where fuel vapors accumulate may explode upon contact with a spark or ignition source.

TRAINING FOR EXPLOSIVE HAZARDS

- Any team that plans to enter buildings or investigate chemical containers must have a person trained to operate an explosimeter.

PERSONAL PROTECTIVE EQUIPMENT FOR EXPLOSIVE HAZARDS

Headgear	Firefighters helmet
Eyewear	Full-face respirator (SCBA) and face shield
Hearing protection	Double hearing protection (inserts and muffs) if explosion is anticipated
Respirator	Full-face SCBA respirator
Torso	Firefighters: Turnout gear
Gloves	Firefighter gloves
Footwear	Firefighter footwear

PRECAUTIONS

- Do not enter any area where the explosimeter reading is at or greater than 10%. If entry appears safe, continue explosimeter monitoring and test all areas of the enclosure, including high and low as some vapors are heavier or lighter than air.
- After hazards have been determined, PPE requirements may be modified upon approval of the IC or SOFR.

REFERENCES

- OSHA 29 CFR 1910.120 Hazardous waste operations and emergency response
- OSHA 29 CFR 1910.132 PPE, General requirements
- OSHA 29 CFR 1910.133 Eye and face protection
- OSHA 29 CFR 1910.134 Respiratory protection
- OSHA 29 CFR 1910.135 Head protection

- OSHA 29 CFR 1910.136 Foot protection
- OSHA 29 CFR 1910.137 Electrical protective equipment
- OSHA 29 CFR 1910.138 Hand protection

Appendix I: Working at Height

HAZARDS OF WORKING AT HEIGHTS

Working at height includes ladders, scaffolds, elevating platforms, and unprotected surfaces with elevation changes of 4 or more feet.

TRAINING FOR WORKING AT HEIGHTS

- Scaffolds must be supervised by a trained and authorized scaffold-qualified person.
- Ladder users must be trained.
- Users of personal fall protection systems (harness and lanyard) must be trained. A qualified person must oversee use.

PERSONAL PROTECTIVE EQUIPMENT FOR WORKING AT HEIGHTS

Headgear	Hard hat
Eyewear	Safety glasses
Hearing protection	Single hearing protection if noise >85 dBA
Respirator	--
Torso	Approved harness and lanyard if working at unprotected heights of 4 or more feet
Gloves	Selected on basis of task and hazards.
Footwear	Firefighters: Firefighter footwear All others: sturdy footwear, preferably with ankle support

PRECAUTIONS

- Inspect personal fall protection system if assigned to wear one. Anchorages must be approved.
- Mark unprotected edges to warn others of fall hazard
- Ensure that rescue is possible if someone falls while wearing personal fall protection equipment. Generally, rescue should be accomplished within 15 minutes to prevent bodily harm from developing while in the suspended position.
- If climbing or moving about while using personal fall protection, maintain 100% tie-in by using two lanyards.
- Ensure that ladders are tall enough to reach target height. Do not stand on the top two steps of a stepladder.

REFERENCES

- OSHA 29 CFR 1926.450-454 Scaffolds
- OSHA 29 CFR 1926.500-503 Fall protection
- OSHA 29 CFR 1926.1050-1053 Stairways and ladders

Appendix J: Welding and Cutting

HAZARDS OF WELDING AND CUTTING

Welding & Cutting. Hot work increases fire hazards and can release toxic substances into the air. Hot cutting may be necessary to quickly cut metal debris that entraps victims.

TRAINING FOR WELDING AND CUTTING

- Operators should be experienced with their equipment.

PERSONAL PROTECTIVE EQUIPMENT FOR WELDING AND CUTTING

Headgear	Welder's helmet to protect the head, face, neck and ears from direct radiant energy from the arc.
Eyewear	For cutting, welder's lenses with a shade number of 4 (light to medium cutting) to 5 (medium to heavy cutting). For welding, welders need lenses with shades of 5 to 14, depending on the type of welding performed. Nearby personnel must also wear appropriate shaded goggles.
Hearing protection	Hearing protection (inserts or muffs) required at sustained noises >85 dB
Respirator	SCBA for all cutting in enclosed areas or full-face air-purifying respirator (APR) with P-100 cartridges for cutting in open air.
Torso	Fire resistant (FR) shirt and pants or FR coveralls
Gloves	Welder's gloves
Footwear	Leather steel toe boots

PRECAUTIONS

- A supervisor must authorize all cutting and welding operations, based on assessment of need and absence of fire or other hazards.
- A fire watch must be in place for each weld or hot cut operation. Remove combustible materials from immediate area prior to work.
- Remove surface dust from areas to be cut so as to reduce airborne hazards.
- Noncombustible or flame-proof screens or blankets should be used to protect others from sparks and intense light.
- Air-supplied respirators are ordinarily preferable, but for work in radiologically contaminated areas, air cylinders and hoses will become contaminated and may lead to additional radiation exposures to users.
- The use of air-purifying respirators is justified based on the assumption that hot cutting work will be essential for saving lives, if performed in well-ventilated areas. If the air-

purifying respirator assembly cannot fit under the welder's helmet, a powered air-purifying respirator (PAPR) may be required to provide breathing protection when it is not feasible to use SCBA.

- Metal to be cut may contain or be coated with lead, cadmium, chromium or other toxic substances. These will be released into the air with hot cutting. Cutting without knowledge of these hazards is only justified in order to save lives.
- After hazards have been determined, PPE requirements may be relaxed upon approval of the IC or SOFR.

REFERENCES

- OSHA 29 CFR 1910.251-255 Welding, Cutting and Brazing

Appendix K: Trenching and Excavation

HAZARDS OF TRENCHING AND EXCAVATION

Excavation will be needed to rescue trapped victims and to restore underground utilities. Excavation may also be needed to control surface liquids such as spills and runoff. Trenching and excavation work presents serious hazards to all workers involved. Cave-ins pose the greatest risk and are much more likely than other excavation-related accidents to result in worker fatalities. Other potential hazards include falls, falling loads, hazardous atmospheres, and incidents involving mobile equipment.

TRAINING FOR TRENCHING AND EXCAVATION

- OSHA standards require that trenches be inspected daily by a competent person. Excavator operators and flaggers must be trained on and experienced with their operations and equipment.

PERSONAL PROTECTIVE EQUIPMENT FOR TRENCHING AND EXCAVATION

Headgear	Hard hat
Eyewear	Safety glasses with side shields
Hearing protection	Hearing protection (inserts or muffs) required at sustained noises >85 dB
Respirator	--
Torso	Sturdy long pants and long sleeve shirt. Ground personnel to wear high visibility vests.
Gloves	Leather work gloves optional
Footwear	Steel toe footwear

PRECAUTIONS

- Assess ground stability before starting excavation operations, as rubble may not be stable.
- Keep heavy equipment away from trench edges.
- Keep surcharge loads at least 2 feet (0.6 meters) from trench edges.
- Know where underground utilities are located.
- Test for low oxygen, hazardous fumes and toxic gases.
- Inspect trenches at the start of each shift.
- Inspect trenches following a rainstorm.
- Do not work under raised loads.

- Establish a working perimeter and keep all nonessential personnel out of the area.

REFERENCES

- OSHA 29 CFR 1926 Subpart P Excavations
- OSHA 29 CFR 1910.120 Hazardous waste operations and emergency response
- OSHA 29 CFR 1910.132 PPE, General requirements
- OSHA 29 CFR 1910.133 Eye and face protection
- OSHA 29 CFR 1910.134 Respiratory protection
- OSHA 29 CFR 1910.135 Head protection
- OSHA 29 CFR 1910.136 Foot protection
- OSHA 29 CFR 1910.137 Electrical protective equipment
- OSHA 29 CFR 1910.138 Hand protection

Appendix L: Demolition

HAZARDS OF DEMOLITION

Demolition will be necessary to rescue victims and to prevent loss of life.

TRAINING FOR DEMOLITION

- Workers involved in demolition need the OSHA 40-hour construction safety training.

PERSONAL PROTECTIVE EQUIPMENT FOR DEMOLITION

Headgear	Hard hat
Eyewear	Safety glasses with side shields
Hearing protection	Hearing protection (inserts or muffs) required for noise levels from 85-115 dB, and double protection (inserts and muffs) required when noise will exceed 115 dB
Respirator	Full-face air-purifying respirator (APR) with P-100 cartridges
Torso	Sturdy long pant and shirt or coveralls. Ground personnel need high visibility vests.
Gloves	Work gloves as needed
Footwear	Steel toe boots

PRECAUTIONS

- Every feasible precaution must be employed to limit the release of dust, as settled dust on structures to be demolished will pose an additional radiological hazard.
- There may not be time to evaluate building material and content hazards such as asbestos, lead, PCBs, etc. The worst must be assumed.
- Electrical hazards must be evaluated prior to demolition, regardless of urgency.

REFERENCES

- OSHA 29 CFR 1926.850-860 Demolition

Appendix M: Vehicular

HAZARDS OF VEHICULAR TRAFFIC

Vehicular traffic response teams will be hampered by civilian traffic and ensuing traffic jams and accidents. Throughout the response action phase, motor vehicle hazards will be omnipresent.

TRAINING FOR VEHICULAR TRAFFIC

- No specific, but daily briefs should cover traffic safety.

PERSONAL PROTECTIVE EQUIPMENT FOR VEHICULAR TRAFFIC

Headgear	Hard hat recommended
Eyewear	Safety glasses, at a minimum
Hearing protection	--
Respirator	--
Torso	High visibility vests are recommended for all response personnel
Gloves	--
Footwear	Sturdy footwear

PRECAUTIONS

- Wherever possible, establish vehicle barriers to protect responders.

REFERENCES

- OSHA 29 CFR 1910.132 PPE, General requirements
- OSHA 29 CFR 1910.133 Eye and face protection
- OSHA 29 CFR 1910.134 Respiratory protection
- OSHA 29 CFR 1910.135 Head protection
- OSHA 29 CFR 1910.136 Foot protection
- OSHA 29 CFR 1910.137 Electrical protective equipment
- OSHA 29 CFR 1910.138 Hand protection

Appendix N: Water (High or Deep)

HAZARDS OF WORKING IN WATER

High or deep water including floods, spills, dams, bridges will all expose response teams to water hazards. In addition, water from firefighting and rain will present challenges to personal comfort and health.

TRAINING FOR WORKING IN WATER

- Users must be trained in the use of life vests and operation of boats. Know how to throw a life line and pull in victims.

PERSONAL PROTECTIVE EQUIPMENT FOR WORKING IN WATER

Headgear	Hard hat or coated hood with rain visor
Eyewear	Safety glasses or goggles
Hearing protection	--
Respirator	--
Torso	Water repellent clothing. Wear a life vest if working on or over water that is more than 3 feet deep.
Gloves	Water repellent
Footwear	Neoprene boots or replacement of water-soaked footwear. Some people find comfort in wrapping dry socked feet in plastic bags before putting on leather footwear.

PRECAUTIONS

- Thoroughly dry off water-soaked skin every 4 hours in an established safe break area. Carry extra pairs of socks. Use antifungal over-the-counter medications such as sprays for feet to prevent fungal infection.
- Avoid chills by staying as dry as possible.
- Use the buddy system near bodies of water and perform head counts frequently.
- Bring ring buoys with life lines if working near bodies of water.
- Exercise extreme caution downstream of dams until qualified engineers determine their safety.
- As soon as it is feasible, bring in lifesaving water craft.

REFERENCES

- OSHA 29 CFR 1926.106 Working over or near water
- OSHA 29 CFR 1910.132 PPE, General requirements
- OSHA 29 CFR 1910.133 Eye and face protection
- OSHA 29 CFR 1910.134 Respiratory protection
- OSHA 29 CFR 1910.135 Head protection
- OSHA 29 CFR 1910.136 Foot protection
- OSHA 29 CFR 1910.137 Electrical protective equipment
- OSHA 29 CFR 1910.138 Hand protection

Appendix O: Noise

HAZARDS OF NOISE

The nuclear detonation will create hazardous noise and blast energy that are likely to damage hearing, temporarily or permanently. This will make communication with victims difficult, as they may not respond to auditory signals. Fire, heavy equipment operation, sirens, and alarms will each create noise hazards. As a general rule, noise levels that necessitate raised voices in order to be understood at a distance of 3 feet exceed 85 decibels and should be considered the threshold to apply hearing protectors, either ear inserts or muffs.

TRAINING FOR NOISE

- Hearing conservation training is required if workers are exposed to noise levels greater than 85 decibels, averaged over an 8-hour day.

PERSONAL PROTECTIVE EQUIPMENT FOR NOISE

Headgear	Hard hats with slots for ear muffs provide ease of use and comfort for wearing ear muffs.
Eyewear	--
Hearing protection	Hearing protection (inserts or muffs) required for noise levels from 85-115 dB, and double protection (inserts and muffs) required when noise will exceed 115 dB
Respirator	Wear ear muff headbands over the outside of the respirator head harness so as not to interfere with respirator fit.
Torso	--
Gloves	--
Footwear	--

PRECAUTIONS

- Noise level measurements are unlikely to be available and field decisions will have to be made regarding hearing protection, based on perception of noise.
- Team members must agree on simple hand signals when noise and hearing protectors hamper voice communications.
- If inserts are selected, carry multiple sets so that inserts contaminated by dirty hands can be discarded.
- Decontaminate hearing protection each time you exit the hazard zones.
- Hearing protection is rated by a noise reduction rating (NRR). Good practice is to subtract 7 from this rating to compensate for variables affecting performance. Thus,

protectors with an NRR of 30 can be expected to reduce noise by 23 decibels. Of course, hearing protectors must be used for both ears!

- Hearing loss is a lifetime debilitating condition. If in doubt, wear your hearing protection.

REFERENCES

- OSHA 29 CFR 1910.95 Occupational noise exposure

Appendix P: Personal Protective Equipment Overview

PPE refers to the respiratory equipment, garments, and barrier materials used to protect rescuers and medical personnel from exposure to biological, chemical, radioactive, and physical hazards. External contamination occurs when radioactive material gets on a person's clothing, skin, or hair. Responders can also become contaminated internally if radioactive material enters the body through the GI tract, an open wound, or through inhalation of highly radioactive dust. In any situation, the goal of PPE is to prevent the transfer of radioactive material from the environment to the rescuer. Different levels of PPE may be used depending on the hazard present. Employers must ensure that responders in each group have proper PPE; are trained and competent in how to put on, use, and take off PPE; and that the PPE is used correctly at all times when it is needed.

OSHA and EPA have graded PPE ensembles into 4 levels based on the degree of protection provided. Each level of PPE consists of a combination of protective respiratory equipment and clothing, which protects against varying degrees of respiratory, ocular, or dermal exposure (29 CFR 1910.120 App B). Selection of respiratory protection devices is discussed following the descriptions of the 4 levels of PPE. Levels may be modified by adding eye protection, fall protection, visibility vests, or flotation devices, etc., depending on anticipated hazards.

Level A

Level A PPE consists of a SCBA and a totally encapsulating chemical-protective (TECP) suit. Level A PPE provides the highest level of respiratory, eye, mucous membrane, and skin protection, and is to be selected when the greatest level of skin, respiratory, and eye protection is required. Practical limitations to use of Level A are limited air supply (20 – 50 minutes) and heat stress. Wearers must complete 40-hour HAZWOPER training at a minimum. The following constitute Level A equipment to be used as appropriate;

- Positive pressure, full face-piece SCBA, or positive pressure supplied air respirator (SAR) with escape SCBA, approved by the National Institute for Occupational Safety and Health (NIOSH)
- Totally encapsulating chemical-protective suit
- Gloves, outer, chemical-resistant
- Gloves, inner, chemical-resistant
- Boots, chemical-resistant, steel toe and shank
- Disposable protective suit, gloves and boots (depending on suit construction, may be worn over totally encapsulating suit)

Level B

Level B PPE consists of a positive-pressure respirator (SCBA or SAR) and non-encapsulated chemical-resistant garments, gloves, and boots, which guard against chemical splash exposures as shown below. Level B PPE provides the highest level of respiratory protection with a lower level of dermal protection. The following constitute Level B equipment; it may be used as appropriate:

- Positive pressure, full-facepiece SCBA, or positive pressure APR with escape SCBA (NIOSH-approved).
- Hooded chemical-resistant clothing (overalls and long-sleeved jacket; coveralls; one or two-piece chemical-splash suit; disposable chemical-resistant overalls).
- Gloves, outer, chemical-resistant.
- Gloves, inner, chemical-resistant.
- Boots, outer, chemical-resistant steel toe and shank.
- Boot-covers, outer, chemical-resistant (disposable).

Level C

Level C PPE consists of an air-purifying respirator (APR) and non-encapsulated chemical-resistant clothing, gloves, and boots. Level C PPE provides the same level of skin protection as Level B, with a lower level of respiratory protection. Level C PPE is used when the type of airborne exposure is known to be guarded against adequately by an APR. Because of limitations of an APR, Level C is allowable only when oxygen levels are adequate (i.e., $\geq$19.5%), air contaminants are known, and a cartridge can be selected to provide protection from contaminants. The following constitute Level C equipment:

- Full-face or half-mask, air purifying respirators (NIOSH-approved).
- Hooded chemical-resistant clothing (overalls; two-piece chemical-splash suit; disposable chemical-resistant overalls).
- Coveralls.
- Gloves, outer, chemical-resistant.
- Gloves, inner, chemical-resistant.
- Boots (outer), chemical-resistant steel toe and shank.
- Boot-covers, outer, chemical-resistant (disposable).
- Eye protection is usually added if a half face respirator is worn.

Level D

Level D PPE consists of standard work clothes without a respirator. For example, in hospitals, Level D consists of surgical gown, mask, and latex gloves (universal precautions). Level D PPE provides no respiratory protection and only minimal skin protection. The following constitute Level D equipment; it may be used as appropriate:

- Coveralls.
- Gloves.
- Boots/shoes.
- Eye protection is often added.

The primary consideration in selecting appropriate PPE is whether it will be worn in the DF zone and/or the elevated radiation area, or outside of the fallout zones.

The DF zone is immediately dangerous to life and health. Level B PPE is required for first responders or other personnel working inside the DF zone, where contact with fallout and other HAZMAT (including chemical gas or vapors) is likely.

The elevated radiation area poses the risk of radiation exposure and contaminated environment, victims and equipment. The PPE required depends on surface and airborne contamination levels. Responders working in the fallout zones will likely start in Level B, but may be directed to switch to Level A or C by the IC when radiation and contamination levels are better defined.

The area outside of the elevated radiation area, by definition, should be completely uncontaminated. Nevertheless, low levels of contamination will arise due to movement of responders, equipment between zones, and especially from contaminated victims who will self-evacuate from the fallout zones.

Responders outside of the fallout zones, but coming in contact with contaminated victims, should use Level C or D PPE depending on their proximity to the fallout zone perimeter.

Types of Respiratory Protection

Self-Contained Breathing Apparatus (SCBA)
SCBA consists of a full facepiece connected by a hose to a portable tank of compressed breathing air. The open-circuit, positive-pressure SCBA is the most common type. This SCBA provides clean air under positive pressure from a breathing-air cylinder; the air then is exhaled into the environment. Negative-pressure SCBAs are prohibited by OSHA regulations for HAZMAT incidents. SCBA provides the highest level of respiratory protection, with an assigned protection factor of 10,000 when used in a continuing, effective respirator program as required by the OSHA respiratory protection standard.

Supplied-Air Respirators (SAR)
SAR consists of a facepiece connected to an air source away from the contaminated area via an airline. Because SARs have greater breathing air capacities than SCBAs, they can be used for longer periods. SARs are also easier to use. Although negative-pressure (i.e., demand mode) SARs are available, full facepiece, positive-pressure SARs are recommended for HAZMAT incidents. These have an assigned protection factor of 1000. The major drawbacks of SARs are

the hoses that deliver the breathing air. They must be protected from contamination and physical damage, and are limited to a distance of 300 feet.

Air-Purifying Respirators (APR)
An APR consists of a facepiece worn over the mouth and nose with a cartridge or filter that removes specified contaminants from ambient air before inhalation. APRs do not protect against all air contaminants, and must not be used where oxygen levels are inadequate. Full facepiece APRs offer more protection (factor of 50) than half face facepieces (factor of 10).

Three basic types of APRs are available:

- **Powered Air-Purifying Respirators (PAPRs)** deliver purified air under positive pressure to a facepiece mask, helmet, or hood, which provides respiratory and eye protection. Because PAPRs function under positive pressure, they provide greater respiratory protection than negative-pressure APRs: the full facepiece PAPR has an assigned protection factor of 1,000.

- **Negative Pressure Air-Purifying Respirators (APRs)** use air-purifying filters, cartridges, or canisters to remove specific air contaminants before inhalation. These APRs operate under negative pressure, depending on the inspiratory effort of the wearer to draw air through a filter. APRs may be full face, providing eye protection, or half face.

- **Filtering Facepiece APRs (dust masks)** are half-face masks that do not provide eye protection. This type of APR depends on a filter that traps particulates. These are usually single-use (disposable) respirators.

Various Chemical Cartridges or Canisters
These remove particles and/or various chemicals including organic vapors and acid gases. Many cartridges or canisters options are available, but the one used must be carefully selected based on knowledge of the contaminants.

High-Efficiency Particulate Air (HEPA) Filters
HEPA filters remove particles of 0.3-15 µm diameter with an efficiency of 99.997%. HEPA filters are incorporated into various protective respiratory devices including APRs, PAPRs, and half-face respirators.

- **P-100 Filters** are HEPA filters. Respirator filters designated with a “P” are also strongly resistant to oils.

Note about Surgical Masks
Surgical masks are not designed or approved for protection against particulates or chemical vapors. They are designed to protect patients from contaminants generated by the wearer. Although surgical masks filter out large-size particulates, they offer no respiratory protection against chemical vapors. They are not designed or approved for protection against particulates or chemical vapors.

REFERENCES

- OSHA 29 CFR 1910.120 Hazardous waste operations and emergency response
- OSHA 29 CFR 1910.132 PPE, General requirements
- OSHA 29 CFR 1910.133 Eye and face protection
- OSHA 29 CFR 1910.134 Respiratory protection
- OSHA 29 CFR 1910.135 Head protection
- OSHA 29 CFR 1910.136 Foot protection
- OSHA 29 CFR 1910.137 Electrical protective equipment
- OSHA 29 CFR 1910.138 Hand protection

Appendix Q: NFPA Responder Competence Standard

NFPA 472: Standard for Competence of Responders to Hazardous Materials/Weapons of Mass Destruction Incidents, 2013 Edition

Table of Contents

The full NFPA 472 document may be purchased from the NFPA website at:
http://www.nfpa.org/aboutthecodes/AboutTheCodes.asp?DocNum=472

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