Planning Guidance for Response to a Nuclear Detonation

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U.S. Department of Homeland Security
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This guidance was developed by a Federal interagency committee with representation from the Executive Office of the President (Homeland Security Council and Office of Science and Technology Policy), the Departments of Defense, Energy, Health and Human Services, Homeland Security, Transportation, Veteran's Affairs, the Environmental Protection Agency, the National Aeronautics and Space Administration, and the Nuclear Regulatory Commission.

Please refer comments and questions to the Office of Science and Technology Policy, Executive Office of the President (www.ostp.gov).

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Acronym List

AC	Assembly Center
AFRRI	Armed Forces Radiobiology Research Institute
ALARA	As Low as Reasonably Achievable
ARS	Acute Radiation Syndrome
ASPR	Assistant Secretary for Preparedness & Response
ATSDR	Agency for Toxic Substances and Disease Registry
CBC	Complete Blood Count
CDC	Centers for Disease Control and Prevention
CONOPS	Concept of Operations
CRCPD	Conference of Radiation Control Program Directors
DF	Dangerous Fallout
DHHS	Department of Health and Human Services
DHS	Department of Homeland Security
DIME	Delayed, Immediate, Minimal or Expectant
DOD	Department of Defense
DOE	Department of Energy
DOT	Department of Transportation
EMAC	Emergency Management Assistance Compact
EMP	Electromagnetic Pulse
EPA	Environmental Protection Agency
ESAR-VHP	Emergency System for Advanced Registration of Volunteer Health Professionals
FEMA	Federal Emergency Management Agency
FHA	Federal Highway Administration
FRMAC	Federal Radiological Monitoring and Assessment Center
Haz Mat	Hazardous Materials (designating specialty emergency response team)
HSC	Homeland Security Council
IAEA	International Atomic Energy Agency
IC	Incident Command
ICRP	International Council on Radiation Protection
IMAAC	Interagency Modeling and Atmospheric Assessment Center
IND	Improvised Nuclear Device
KT	Kiloton
LD	Light Damage
LD50	Median Lethal Dose 50
LSI	Life-saving Intervention
MC	Medical Care Sites
MD	Moderate Damage
mph	miles per hour

MT	Millions of Tons
NCRP	National Council on Radiation Protection and Measurements
NG	No-go
NIOSH	National Institute of Occupational Safety and Health
NPS	National Planning Scenario
NRC	Nuclear Regulatory Commission
NRF	National Response Framework
OEG	Operational Exposure Guidance
OSHA	Occupational Safety and Health Administration
OSTP	Office of Science and Technology Policy
PAG	Protective Action Guide
PCC	Policy Coordination Committee
PPE	Personal Protective Equipment
psi	pounds per square inch
R&D	Research and Development
RDD	Radiological Dispersal Device
REAC/TS	Radiation Emergency Assistance Center/Training Site
REMM	Radiation Event Medical Management
REP	Radiological Emergency Preparedness
RITN	Radiation Injury Treatment Network
RN	Radiological/Nuclear or Radiological and Nuclear
RTR	Radiation TRiage, TReatment, and TRansport system
SALT	Sort, Assess, Life-saving intervention, Treatment/Transport
TEDE	Total Effective Dose Equivalent
TNT	Trinitrotoluene
US	United States
USG	United States Government

Definitions[1]

Adequate shelter – shelter that protects against acute radiation effects, and significantly reduces radiation dose to occupants during an extended period

ALARA – (Acronym for "As Low As Reasonably Achievable") –A process to control or manage radiation exposure to individuals and releases of radioactive material to the environment so that doses are as low as social, technical, economic, practical, and public welfare considerations permit.

Beta burn – beta radiation induced skin damage

Blast effects – The impacts caused by the shock wave of energy through air that is created by detonation of a nuclear device. The blast wave is a pulse of air in which the pressure increases sharply at the front, accompanied by winds.

Combined injury – Victims of the immediate effects of a nuclear detonation are likely to suffer from burns and physical trauma, in addition to radiation exposure.

Electromagnetic Pulse (EMP) – A sharp pulse of radiofrequency (long wavelength) electromagnetic radiation produced when an explosion occurs near the earth's surface or at high altitudes. The intense electric and magnetic fields can damage unprotected electronics and electronic equipment over a large area.

Emergency Management Assistance Compact (EMAC) – A Congressionally ratified organization that provides form and structure to interstate mutual aid. Through EMAC, a disaster-affected State can request and receive assistance from other member States quickly and efficiently, resolving two key issues up front: liability and reimbursement.

Fallout – 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.

LD_{50} – The amount of a radiation (or a chemical) that kills 50% of a sample population.

Operational Exposure Guidance (OEG) – Department of Defense dose limits to US troops.

Personal Protective Equipment (PPE) – Includes all clothing and other work accessories designed to create a barrier against hazards. Examples include safety goggles, blast shields, hard hats, hearing protectors, gloves, respirator, aprons, and work boots.

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[1] Where available, definitions have been adapted from Glasstone and Dolan (Glasstone and Dolan 1977) or the DHS Planning Guidance (DHS 2008).

Radiation effects – Impacts associated with the ionizing radiation (alpha, beta, gamma, neutron, etc.) produced by or from a nuclear detonation.

rad – A unit expressing the absorbed dose of ionizing radiation. Absorbed dose is the energy deposited per unit mass of matter. The units of rad and gray are the units in two different systems for expressing absorbed dose.
1 rad = 0.01 gray (Gy); 1 Gy = 100 rad;

rem – A unit of absorbed dose that accounts for the relative biological effectiveness of ionizing radiations in tissue (also called equivalent dose). 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 two different systems for expressing equivalent dose. 1 rem = 0.01 Sieverts (Sv); 1 Sv = 100 rem

Roentgen (R) – A unit of gamma or x-ray exposure in air. It is the primary standard of measurement used in the emergency responder community in the United States. For the purpose of this guidance, one R of exposure is approximately equal to one rem of whole-body external dose.

- 1,000 micro-roentgen (microR) = 1 milli-roentgen (mR)
- 1,000 milli-roentgen (mR) = 1 Roentgen (R), thus
- 1,000,000 microR = 1 Roentgen (R)

Roentgen per hour (R/hour) – A unit used to express gamma or x-ray exposure in air per unit of time (exposure rate).

Shelter – 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. It also includes locations readily available at the time of need, including staying inside where you are, or going immediately indoors in any readily available structure.

Shelter-in-place – staying inside, or going immediately indoors in any readily available structure.

Thermal effects – Impacts associated with the electromagnetic radiation emitted from the fireball as a consequence of its very high temperature.

References for Definitions:

Glasstone, Samuel and Philip J. Dolan. 1977. *The Effects of Nuclear Weapons*. Washington, DC: US Government Printing Office.

US Department of Homeland Security. Federal Emergency Management Agency. 2008. *Planning Guidance for Protection and Recovery Following Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND) Incidents*, Federal Register, Vol. 73, No. 149. http://www.fema.gov/good_guidance/download/10260.

Units

For the case of a nuclear detonation, persistent beta-gamma radiation levels will affect some response decisions. For the purpose of this planning guidance, the following simplifying assumptions about units used in measuring this radiation applies: 1 R (exposure in air) $\cong$ 1 rad (adsorbed dose) $\cong$ 1 rem (whole-body dose) (NCRP 2005).

For the purpose of this planning guidance, the rem unit is assumed to be equivalent to the sievert unit and 1 rem = 10 mSv will be applied as the basis for comparison of traditional and SI units. Exposure rate (R/hour) can be expressed in terms of Sv/hour. Therefore: 1 R/hour $\cong$ 0.01 Sv/hour

Radiation Measurement Units:

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

Conventional/SI Unit Conversions:

1 Curie = 3.7 x 10^{10} disintegrations/second	1 Becquerel = 1 disintegration/second
1 rad	0.01 Gray (Gy) or 1 centiGray (cGy)
1 rem	0.01 Sieverts (Sv)
1 Roentgen (R)	0.000258 Coulomb/kilogram (C/kg)
1 Gray (Gy)	100 rad
1 Sievert (Sv)	100 rem
1 Coulomb/kilogram (C/kg)	3,876 Roentgens

References for Units

National Council on Radiation Protection and Measurements (NCRP). 2005. *Key Elements of Preparing Emergency Responders for Nuclear and Radiological Terrorism,* Commentary No. 19 (Bethesda).

Structure of this Document

The planning guidance is organized in a stepwise manner using terminology and concepts of the National Planning Scenario #1, the National Response Framework, and other technical and policy documents. The planning guidance presents general background information that builds a foundation for specific planning recommendations. This is the bulk of the material presented in the document. **Bold text is used throughout the document to emphasize important material or concepts.** Text boxes that run the length of the page have been generated to summarize key information following the presentation of information in the context of the guidance.

Text boxes that run the length of the page have been generated following the delivery of key information.

This key information has been pulled to the beginning of each chapter as a summary of **KEY POINTS.**

KEY POINTS

1. Key points summarize important information captured throughout each chapter.
2. The key points are presented at the beginning of each chapter.

Relevant supporting information that may be useful, but is not essential for planners, is included throughout the planning guidance. This additional informational is useful for subject matter experts and for educational purposes. The information is captured in grey text boxes.

Background Points are in Grey Boxes

In each chapter appropriate background or additional information of a technical nature has been included in grey boxes to enable those who seek supporting information to have access, while those who wish to bypass may do so. This is non-essential information and can be bypassed when using the planning guidance.

INTRODUCTION

One of the most catastrophic incidents that could befall the United States (US), causing enormous loss of life and property and severely damaging economic viability, is a **nuclear detonation in a US city**. It is incumbent upon all levels of government, as well as public and private parties within the US, to prepare for this incident through focused nuclear attack response planning. Nuclear explosions present substantial and immediate radiological threats to life. Local and State community preparedness to respond to a nuclear detonation could result in life-saving on the order of tens of thousands of lives.

The purpose of this guidance is to provide emergency planners with nuclear detonation-specific response recommendations to maximize the preservation of life in the event of an urban nuclear detonation. This guidance addresses the unique effects and impacts of a nuclear detonation such as scale of destruction, shelter and evacuation strategies, unparalleled medical demands, management of nuclear casualties, and radiation dose management concepts. The guidance is aimed at response activities in an environment with a severely compromised infrastructure for the **first few days** (e.g., 24 – 72 hours) when it is likely that many Federal resources will still be en route to the incident.

The target audiences for the guidance are response planners and their leadership. Emergency responders should also benefit in understanding and applying this guidance. The target audiences include, but are not limited to, the following at the city, county, and State levels:

- Elected officials in government jurisdictions
- Emergency managers
- Law enforcement authority planners
- Fire response planners
- Emergency medical service planners
- Hazardous material (Haz Mat) planners
- Utility services and public works emergency planners
- Transportation planners
- Medical receiver planners (e.g., hospitals)
- Other metropolitan emergency planners, planning organizations, and professional organizations that represent the multiple disciplines that conduct emergency response activities

The planning guidance recommendations are focused on providing express consideration of the following topics relevant to emergency planners within the first few days of a nuclear detonation: 1) shelter and evacuation, 2) medical care, and 3) population monitoring and decontamination. Worker safety and health are briefly discussed in Chapter 2; however, more extensive guidance is not presently available and is expected to be the focus of future Federal endeavors. Additional work is also needed to support the following relevant topics: pre-event public education (including public alert and warning systems), establishing and maintaining infrastructure for electromagnetic pulse (EMP) proof responder communications, psychological impacts to the population, fatality management, and nuclear detonation response training. As recommendations become available on these issues, which are minor considerations within this planning guidance or wholly unaddressed, they will be incorporated into future editions of this planning guidance.

The planning guidance summarizes recommendations based on what is currently known about the consequences of a nuclear detonation in an urban environment. It provides recommendations based on existing knowledge and existing techniques. The Federal government is supporting continuing studies that will inevitably provide more robust and comprehensive recommendations.

Since the events of September 11, 2001, the nation has taken a series of historic steps to address threats against our safety and security. This guidance represents an additional step in this continuing effort to increase the nation's preparedness for potential attacks against our nation. It was developed in response to gaps noted in the previously published Department of Homeland Security (DHS) "Planning Guidance for Protection and Recovery Following Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND) Incidents" (**Federal Register** , Vol. 73, No. 149, Friday, August 1, 2008;[2] http://www.fema.gov/good_guidance/download/10260) and hereafter referred to as DHS Planning Guidance (DHS 2008). While the publication provides substantial guidance to Federal, State, and local planners for responding to such incidents, it concedes that it does not sufficiently prepare local and State emergency response authorities for managing the catastrophic consequences of a nuclear detonation as follows:

> "In addition to the issuance of this Guidance, in response to interagency working group discussions and public comments, further guidance will be provided for the consequences that would be unique to an IND attack. This Guidance was not written to provide specific recommendations for a nuclear detonation (IND), but to consider the applicability of existing PAGs[3] to RDDs and INDs. In particular, it does not consider very high doses or dose rate zones expected following a nuclear weapon detonation and other complicating impacts that can significantly affect life-saving outcomes, such as severely damaged infrastructure, loss of communications, water pressure, and electricity, and the prevalence of secondary hazards. Scientifically sound recommendations for responders are a critical component of post-incident life-saving activities, including implementing protective orders, evacuation implementation, safe responder entry and operations, and urban search and rescue and victim extraction."

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[2] By agreement with the Environmental Protection Agency (EPA), the DHS Planning Guidance (DHS 2008) published is final and its substance will be incorporated without change into the revision of the 1992 EPA Manual of Protective Actions Guides and Protective Actions for Nuclear Incidents - the PAG Manual (EPA 1992). This notice of final guidance will therefore sunset upon publication of the new EPA PAG Manual (see, http://www.epa.gov/radiation/rert/pags.html)

[3] PAGs stands for Protective Action Guidelines

This guidance does not replace the DHS Planning Guidance (DHS 2008); however, it does provide specific guidance for response in the damaged region surrounding a nuclear detonation (i.e., within approximately three miles of a 10 kiloton (KT) device) and the life threatening fallout region (i.e., where fallout is deposited within 10 – 20 miles of the detonation site). The DHS Planning Guidance (DHS 2008) will continue to serve planners who are preparing for the protection of populations beyond these immediately life-threatening areas. The existing DHS Planning Guidance (DHS 2008), combined with this planning guidance, provide more comprehensive guidance for emergency response planners to prepare for responding to consequences of a nuclear detonation.

This guidance was developed by a Federal interagency committee (see Appendix A for membership). The planning guidance was subject to two extensive reviews, a technical review (e.g., Federal interagency and national laboratory subject matter experts) and a stakeholder review (e.g., emergency response community representatives from police, fire, emergency medical services, medical receivers, and professional organizations such as the Health Physics Society, the American Public Works Association, and the International Association of Fire Chiefs) resulting in 1650 comments from over 70 individual reviewers representing nine Federal departments and national laboratories and 30 communities and professional organizations.

The guidance is based upon the IND scenario, National Planning Scenario (NPS) #1, provided by the Homeland Security Council in partnership with DHS and the interagency Federal community, for use in national, Federal, State, and local homeland security preparedness activities. Scenario-based planning is a useful tool for Federal, State, and local planners, and, increasingly, departments and agencies are using the DHS NPSs to develop strategic, concept, and operational plans for designing response exercises and for other planning purposes. However, the NPSs have sometimes been applied as rigidly prescriptive scenarios against which planning should occur, not with the flexibility originally intended. This application has often been the case with NPS #1, which describes a nuclear detonation in Washington, DC and provides specific modeled outcomes of impacts and consequences. While it is impossible to predict the precise magnitude and impact of a nuclear detonation this scenario provides a foundation for preparedness and planning efforts, as well as for initial response actions in the absence of specific measurements.

It is expected that planners and exercise designers will use this guidance, and the scenario on which it is based, and tailor them to their specific circumstances or to compare differing inputs and assumptions. Factors that planners and exercise designers may consider changing from parameters in NPS #1 may include target city, specific location of detonation, size and type of weapon, date and time of day, population features, meteorological conditions, and assumptions about local, regional, or national response to the incident.

Target audiences should use this planning guidance in their preparedness efforts. They are encouraged to meet and work with their Federal, State, and local counterparts and partners, as each bring important knowledge to the design of implementation plans. Of special note are those planners with existing relationships with the Federal Emergency Management Agency (FEMA) Radiological Emergency Preparedness (REP) Program associated with communities in the vicinity of commercial nuclear power plants. Appropriate processes and procedures from the REP Program are expected to be an important tool in developing local response plans for nuclear detonations.

Finally, critical assumptions in the development of this guidance for a nuclear detonation include:

- **There will be no significant Federal response at the scene for 24 hours and the full extent of Federal assets will not be available for up to 72 hours.** Emergency response is principally a local function. Federal assistance will be mobilized as rapidly as possible; however, for purposes of this document, no significant Federal response is assumed for 24 – 72 hours.

- **A nominal 10 KT yield nuclear device is assumed for purposes of estimating impacts in high-density urban areas**. Variation in the size and type of the nuclear device has a significant effect on the estimation of impacts, however, most homeland security experts agree on 10 KT as a useful assumption for planning.

- **The lessons from multi-hazard planning and response will be applicable to the response to a nuclear detonation.** While fallout and the scale of the damage presented by a nuclear detonation present significantly complicating hazards, most aspects of multi-hazard planning and many of the response capabilities are still useful. Planners and responders bring a wealth of experience and expertise to nuclear detonation response. This guidance provides nuclear-detonation specific information and context to allow planners, responders, and their leaders to bring their existing capabilities to bear in a worst-case scenario.

- Although based on technical analyses and modeling of the consequences of nuclear explosions, the **recommendations are intentionally simplified to maximize their utility in uncertain situations where technical information is limited**. Recommendations are intended to be practical in nature and appropriate for use by planners in addressing actions for the general public and emergency responders.

- While it is recognized that the fallout from a nuclear detonation will reach across many jurisdictions, potentially involving multiple States, this **guidance is intended primarily for the target audience specified above with respect to the first few days in the physically damaged areas and life-threatening fallout zone.**

References for Introduction

US Department of Homeland Security. 2008. *Planning Guidance for Protection and Recovery Following Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND) Incidents*, Federal Register, Vol. 73, No. 149. http://www.fema.gov/good_guidance/download/10260.

US Environmental Protection Agency. Office of Radiation Programs. 1992. *Manual of Protective Actions Guides and Protective Actions for Nuclear Incidents.* http://www.epa.gov/radiation/docs/er/400-r-92-001.pdf.

Chapter 1 - Nuclear Detonation Effects and Impacts in an Urban Environment

KEY POINTS

1. There are no clear boundaries between damage zones resulting from a nuclear detonation, but generally, the light damage (LD) zone is characterized by broken windows and easily managed injuries; the moderate (MD) zone by significant building damage, rubble, downed utility poles, overturned automobiles, fires, and serious injuries; and the no-go (NG) zone by completely destroyed infrastructure and radiation levels resulting in unlikely survival of victims.
2. It is anticipated that some injuries (e.g., eye injuries, blast injuries — particularly from flying debris and glass) can be prevented or reduced in severity if individuals that perceive an intense and unexpected flash of light seek immediate cover. The speed of light, perceived as the flash, will travel faster than the blast overpressure allowing a few seconds for some people to take limited protective measures.
3. Blast, thermal, and radiation injuries in combination will result in prognoses for patients worse than those for the individual injury mechanisms.
4. EMP effects could result in extensive electronics disruptions complicating the function of communications, computers, and other essential electronic equipment.
5. The most hazardous fallout particles are readily visible as fine, sand-sized grains, but the lack of apparent fallout should not be misrepresented to mean radiation isn’t present; therefore appropriate radiation monitoring should always be performed. Fallout that is immediately hazardous to the public and emergency responders will descend to the ground within about 24 hours.
6. The most effective life-saving opportunities for response officials in the first 60 minutes following a nuclear explosion will be the decision to safely shelter or evacuate people in expected fallout areas.

Overview

A nuclear detonation would produce several important effects that impact the urban environment and people. In this discussion, the term “nuclear effects” will mean those primary outputs from the nuclear explosion, namely blast, thermal, and prompt radiation. Important secondary effects covered here include electromagnetic pulse (EMP) and fallout. All of these effects have impacts on 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.

Generally, when considering nuclear explosion scenarios perpetrated by a terrorist, experts assume a low-yield nuclear device detonated at ground level.[4] Low yield in this context ranges from fractions of a kiloton (KT) to 10 KT. The descriptions and planning factors provided in this document are based on the Department of Homeland Security (DHS) National Planning Scenario (NPS) #1, which describes a nuclear device yield of 10 KT detonated at ground level in an urban environment. The effects of a nuclear explosion less than 10 KT would be less; however, there is no easy or direct correlation factor to use for scaling of effects.

A nuclear detonation produces an explosion far surpassing that of any conventional explosive. An explosion occurs when an exothermic reaction creates a rapidly expanding fireball of hot gas or plasma. The expanding fireball produces a destructive shock wave. In a chemical-based explosion (such as dynamite or trinitrotoluene (TNT), a common explosive), the heat produced reaches several thousand degrees and creates a gaseous fireball on the order of a few meters in diameter. While energy in a chemical explosion derives from reactions between molecules, the energy released in a nuclear explosion derives from the splitting (or fission) of atomic nuclei of uranium or plutonium (i.e., fissile material). Pound-for-pound, a nuclear explosion releases ~10 million times more energy than a chemical explosive. The heat in a nuclear explosion reaches millions of degrees where matter becomes plasma. The nuclear fireball for a 10 KT nuclear device can achieve a diameter of approximately 650 ft (200 meters), and the shock wave and degree of destruction is correspondingly large.

Blast

The primary effect of a nuclear explosion is the blast that it generates. Blast generation is the same in any kind of explosion. The blast originates from the rapidly expanding fireball of the explosion, which generates a pressure wave front moving rapidly away from the point of detonation. Blast is measured by the overpressure[5] and dynamic pressure[6] that it produces. Initially, near the point of detonation for a surface nuclear burst (also referred to as ground zero), the overpressure is extremely high (thousands of pounds per square inch (psi) expanding out in all directions from the detonation at hundreds of miles per hour). With increasing distance from ground zero, the overpressure and speed of the blast wave dissipate to where they cease to be destructive (see Table 1.1).

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[4] It should be noted that if a state-built weapon were available to terrorists, the presumption of low yield may no longer hold.

[5] Pressure over and above atmospheric pressure, and measured in pounds per square inch (psi).

[6] Manifested as wind, dynamic pressure is a term associated with the velocity of flow and is measured in miles per hour (mph).

Accompanying the overpressure wave is dynamic pressure that is wind generated by the passing pressure wave. A very high wind velocity is associated with a seemingly small amount of overpressure, as shown in Table 1.1. The combination of overpressure and wind is extremely destructive to structures. For example, at 5 psi, the wind velocity may reach over 160 miles per hour. The full impact of overpressure and dynamic pressure on structures common in a modern city is not currently known; however, past tests and computer models aid in impacts estimation.

The magnitude of a nuclear explosion is quantified in terms of the amount of conventional explosive it would take to create the same blast effect. The amount of explosive power from a nuclear explosion, or the "yield," is measured relative to TNT, and is usually in the thousands of tons (kilotons, or KT) of TNT. A small nuclear device, for example, would be a 1 KT device, meaning it would produce an explosive yield equivalent to one thousand tons of TNT. Most nuclear weapons in the world today were designed to deliver less than 200 KT; but, some can deliver millions of tons (MT) of yield. For comparison the size of the Murrah Federal Building bombing in Oklahoma City, OK (1995) was 2.5 tons of TNT equivalents.

Table 1.1: Relation of wind speed to peak overpressure and distance for a 10 KT explosion; adapted from Glasstone and Dolan (Glasstone and Dolan 1977)

Peak Overpressure (psi)	Approximate Distance from Ground Zero (miles)	Maximum Wind Speed (mph)
50	0.18	934
30	0.24	669
20	0.30	502
10	0.44	294
5	0.6	163
2	1.1	70

Physical destruction of structures following an urban nuclear explosion at different overpressures is described as follows:

1. Buildings sustain minor damage — damage corresponds to overpressures in the range of approximately 0.15 to about 2 psi
2. Most buildings are moderately damaged — damage corresponds to overpressures between 2 and 5 psi
3. Buildings are badly damaged or destroyed — damage corresponds to overpressures around 5 to 8 psi
4. Only heavily reinforced buildings remain standing, but are significantly damaged and all other buildings are completely destroyed — damage corresponds to 10 psi or greater

The amount of damage to structures can be used to describe zones for use in response planning. Each zone will have health and survival implications, although not as neatly as arbitrary zone delineations would indicate. The purpose of establishing zones is to help plan response operations and prioritize actions. The following zones are proposed for planning response to a 10 KT surface burst nuclear explosion in an urban environment and are summarized in Figure 1.1:[7]

Light Damage (LD) Zone:

- ❒ The outer boundary of the LD zone may be defined by the prevalence of broken windows, with approximately 25% broken. This corresponds to approximately 0.5 psi. Shattering of windows and associated injury from flying glass will occur to about three miles (4.8 km) from ground zero making this distance a reasonable estimate of the outer boundary of the LD zone. However, window breakage may occur to a lesser degree out to five miles (8 km) or more from ground zero.
- ❒ Doors and window frames may be blown in at overpressures of about two psi. Essentially all windows will be shattered out to one psi and perhaps 25% at 0.5 psi.
- ❒ As a responder moves inward, windows and doors will be blown in and gutters, window shutters, roofs, and light construction will have increasing damage. Litter and rubble will increase moving towards ground zero and there will be increasing numbers of stalled and crashed automobiles, making emergency vehicle passage difficult.
- ❒ Blast overpressures that characterize the LD zone are calculated to be about 0.5 psi at the outer boundary and 2–3 psi at the inner boundary. More significant structural damage to buildings will indicate entry into the moderate damage zone.

Moderate Damage (MD) Zone:

- ❒ Responders may expect they are transitioning into the MD zone when building damage becomes substantial. This damage may correspond to a distance of about one mile (1.6 km) from ground zero for a 10 KT nuclear explosion.
- ❒ Observations in the MD zone include significant structural damage, blown out building interiors, blown down utility poles, overturned automobiles, some collapsed buildings, and fires. In the MD zone sturdier buildings (e.g., reinforced concrete) will remain standing, lighter commercial and multi-unit residential

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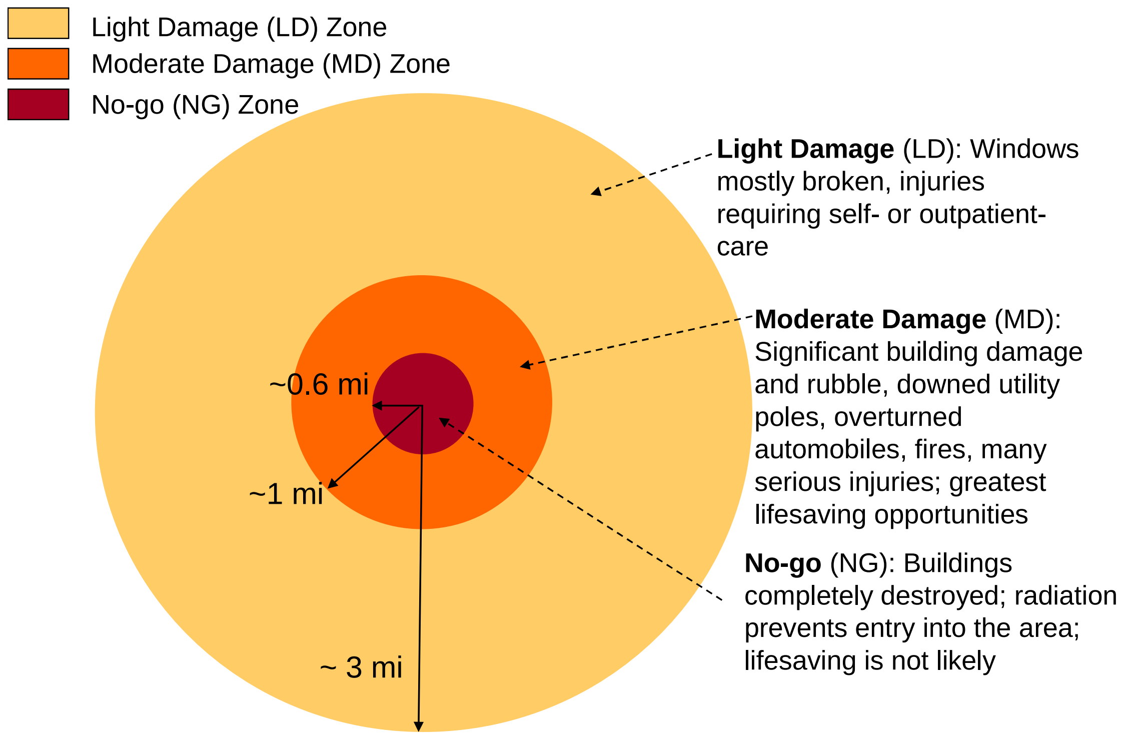
[7] In order to provide some basic parameters to describe the generic urban environment this document assumes a nominal 10 KT detonation in a modern city with a population of several million. While distances would vary the zone descriptions apply to any size nuclear explosion. Building types will include a mix of high rise commercial structures of varying ages and design, with some residential high rises, and high daytime population density at the ground zero location. Building heights and population density are assumed to drop off with distance from the ground zero location in favor of low, lighter constructed buildings, and increased residential structures.

buildings may be fallen or structurally unstable, and most single-family houses would be destroyed.

- ☐ Substantial rubble and crashed and overturned vehicles in streets are expected, making 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.
- ☐ Within the MD zone, broken water and utility lines are expected and fires will be encountered.
- ☐ Many casualties in the MD zone will survive and these survivors, in comparison to survivors in other zones, will benefit most from urgent medical care.
- ☐ A number of hazards should be expected in the MD zone, including elevated radiation levels, potentially live, downed power lines, ruptured gas lines, sharp metal objects and broken glass, ruptured vehicle fuel tanks, and other hazards.
- ☐ Visibility in much of the MD zone may be limited for an hour or more after the explosion because of dust raised by the shock wave and from collapsed buildings. Smoke from fires will also obscure visibility.
- ☐ Blast overpressures that characterize the MD zone are: outer boundary, about 2–3 psi, and inner boundary, about 5–8 psi. When most buildings are severely damaged or collapsed, responders have encountered the no-go zone.

No-go (NG) Zone:

- ☐ Few, if any, buildings are expected to be structurally sound or even standing in the NG zone, and very few people would survive; however, 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.
- ☐ Very high radiation levels and other hazards are expected in the NG zone making this zone gravely dangerous to survivors and responders; therefore, the NG zone should be considered a no-go zone during the early days following the explosion.
- ☐ Rubble in streets is estimated to be impassable in the NG zone making timely response impossible. Approaching ground zero, all buildings will be rubble and rubble may be 30 feet deep or more.
- ☐ The NG zone may have a radius on the order of 0.6 miles (1.0 km). Blast overpressure that characterizes the NG zone is 5–8 psi and greater.



All approximated distances from center of detonation site

Figure 1.1: Representative damage zones for 10 KT nuclear explosion (not to scale; circles are idealized here for planning purposes)

These zone delineations are rough approximations that can assist response planners. They will be referred to during the remainder of Chapter 1 discussions and will be further developed for response planning in Chapter 2. There are no clear boundaries between the damage zones. Initial response units may make observations and estimates, based on information contained in this document, for purposes of making zone delineations at the scene. Some of the visual markers provided above will help to distinguish the zones.

There are no clear boundaries between the representative damage zones resulting from a nuclear detonation, but generally, the light damage (LD) zone is characterized by broken windows and easily managed injuries; the moderate (MD) zone by significant building damage, rubble, downed utility poles, overturned automobiles, fires, and serious injuries; and the no-go (NG) zone by completely destroyed infrastructure and high radiation levels resulting in unlikely survival of victims.

It is important to recognize that the zones depicted as circles in Figure 1.1 should be defined not by precise distances, but by the degree of observable physical damage for purposes of response planning. Nuclear weapon experts believe damage will be highly unpredictable; for example, some lighter buildings may survive closer to ground zero while robust structures may be destroyed under relatively low overpressure resulting from complex wave reflection and diffraction in the urban cityscape. Glass breakage is an important factor in assessing blast damage, but different kinds of glasses break at widely varying overpressures. Some modern windows may survive two psi, whereas others will shatter at 0.15 psi. The glass dimensions, hardening, thickness, and numerous other factors influence glass breakage. Zoned planning, however, will help officials estimate overall response needs and preplan the logistical support necessary for a response.

Blast Injuries

The most critical, direct overpressure blast injuries will include lung damage, eardrum rupture, and damage to the hollow viscera (e.g., esophagus, stomach, small and large intestine, rectum). When the blast wave hits the human body, rapid compression and decompression result in transmission of pressure waves through the tissues, resulting in damage primarily at junctions between different tissues (e.g., bone and muscle, at the interface between tissue and air spaces). Lung tissue and the gastrointestinal system, both of which contain air, are particularly susceptible to injury. The resulting tissue damage can lead to severe hemorrhage or to air emboli (i.e., incorporation of air into the bloodstream that can result in blockage of major arteries or the heart), either of which can be rapidly fatal. Perforation of the eardrums would be a common but minor blast injury. Table 1.2 provides an overview of impacts relative to the peak overpressure of the blast wave.

Table 1.2: Impacts of peak overpressure of blast; adapted from Glasstone and Department of Defense (DOD) (Glasstone and Dolan 1977; DOD 2001)

Peak Overpressure (psi)	Type of Structure	Degree of Damage
0.15-1	Windows	Moderate (broken)
3-5	Apartments	Moderate
3-5	Houses	Severe
6-8	Reinforced concrete building	Severe
6-8	Massive concrete building	Moderate
100	Personnel shelters	Severe (collapse)
	Type of Injury to People	
5	Threshold for eardrum rupture	
15	Threshold for serious lung damage	
50	50% incidence of fatal lung damage	

As shown in Table 1.2, the human body is remarkably resistant to overpressure, particularly when compared with rigid structures such as buildings. Although many would survive the blast overpressure itself, they will not easily survive the crushing injuries incurred during the collapse of buildings (see Figure 1.2) from the blast overpressure or the impact of shrapnel (e.g., flying debris and glass).

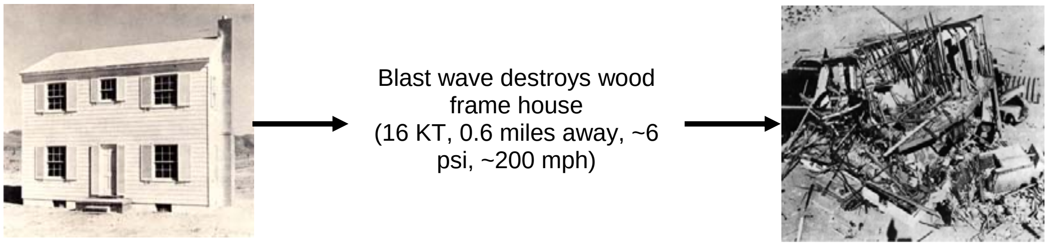


Figure 1.2: Blast wave effects on a house, indicating low survivability

The majority of casualties from blast effects will result from wind generated from the blast overpressure. The velocity of the wind will lift and throw people causing serious injuries for a 10 KT yield within a mile of ground zero. It will also turn lighter objects into flying shrapnel resulting in impalement injuries. Heavier objects may present crushing hazards. Head injuries, damage to body extremities, and internal organ damage will result.

The probability of penetrating injuries from flying debris increases with increasing velocity, particularly for small, sharp debris such as glass fragments. Single projectile injuries will be rare; however, multiple, varied projectile injuries will be common. Blast wave pressures above three to five psi can produce flying debris and glass fragments with sufficient velocity to cause blunt trauma or deep lacerations resulting in injuries that require professional medical attention. For a 10 KT detonation, the range for these effects is about 0.6 – 1 mile (1–1.6 km). However, broken and shattered windows will be observed at much greater distances. Large windows can break at blast wave pressures down to 0.15 psi and people will be subject to injury from the falling glass of tall buildings. For 10 KT, these lower pressure window breakages could range out several miles from ground zero. Although, not directly relevant to expectations in a modern urban environment, at Nagasaki (21 KT) and Hiroshima (16 KT) minor injuries from flying glass extended to two miles, serious injuries were prevalent out to one mile, and falling glass was not an issue for lack of tall buildings beyond the MD zone.

Thermal Radiation (or Heat)

An important effect of a nuclear detonation is the generation of an intense thermal pulse of energy (i.e., the nuclear flash). The potential for fire ignition in modern cities from thermal effects is poorly understood but remains a major concern. Fires may be started by the initial thermal burst igniting flammable materials in buildings, or by the ignition of gas from broken gas lines and ruptured fuel tanks.

Fires destroy infrastructure, pose a direct threat to survivors and responders, and may threaten people taking shelter or attempting to evacuate. If fires are able to grow and coalesce, a firestorm[8] could develop that would be beyond the abilities of firefighters to control.

The NG zone might be depicted as a large concrete rubble area (with a very large hole in the middle) and is not expected to be conducive for fueling fires. The MD zone is the more likely the area where fires will erupt and threaten survivors and responders because of the intense thermal pulse and the severe damage to infrastructure (such as gas lines and fuel tanks). Depending on the flammability of various materials, blast winds can either extinguish or fan the burning materials. The LD zone with minor infrastructure damage may also have fires but these should be more easily contained and mitigated.

> The thermal pulse of energy from a nuclear detonation originates from two sources. First, a short intense pulse of heat (the flash) occurs from the fission event itself, then the expanding fireball continues to radiate for several seconds as it rockets upward. The thermal pulse generates instantaneous direct energy in the infrared, visible, and ultraviolet wave bands, but most of the thermal radiation comes from the fireball itself. The thermal radiation intensity at any given point will depend on distance from the detonation and the location of the burst (e.g., detonation high above the ground, or detonation at the surface of the earth). In general, the thermal hazard is greatest in the case of a low-altitude air burst. General thermal effects will be less for surface bursts resulting from less direct line-of-sight contact with the energy radiating from the detonation. Surface bursts result in a large part of the thermal energy being absorbed by the ground and any buildings around ground zero. Partial and sometimes complete shadowing from the thermal pulse and fireball may be provided to people inside or behind buildings and other structures. Terrain irregularities, moisture, and various gases in the air near the surface of the earth will tend to reduce the amount of thermal energy that is transported at distance.

Thermal Injuries

Close to the fireball, the thermal energy is so intense that infrastructure and humans are incinerated. Immediate lethality would be 100% in close proximity. The distance of lethality will vary with nuclear yield, position of the burst relative to the earth's surface, weather, environment, and how soon victims can receive medical care.

Thermal radiation emitted by a nuclear detonation causes burns in two ways; direct absorption of thermal energy through exposed surfaces (flash burns) or indirectly from fires ignited by the burst (see Figure 1.3). Thermal energy from the burst is delivered to bare skin or through clothing to the skin so quickly that burn patterns will be evident. The victim will be burned on the side facing the fireball. If people were out in the open and not protected by terrain, buildings, or other shadowing structures, flash burns would be the most common injuries among survivors. Tall city buildings between people and the burst provide substantial shadowing from the burst and reduce the overall flash burn impact. People within line of sight of the burst may be subject to burn injuries up to two miles away for a 10 KT

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

device. The farther away from ground zero a person is, the less severe the burn injury will be. Early treatment can reduce mortality rates among the severely burned victims.

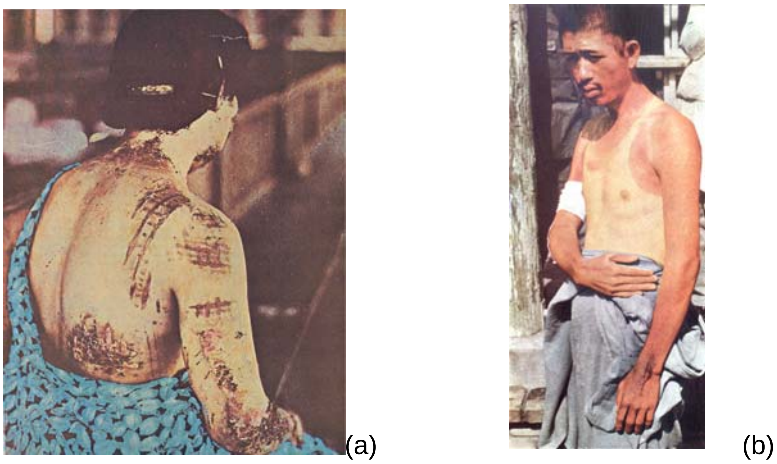

Figure 1.3: Flash burn victims from (a) Hiroshima showing pattern burns (i.e., the dark colored material pattern on the victims clothing absorbed the thermal energy and burned the skin), and (b) Nagasaki showing profile burns (i.e., burns around the light colored clothing that reflected the thermal energy).

Secondary fires are expected to be prevalent in the MD zone. Secondary fires will result in medically routine burns, but the health threat will be compounded by other injury mechanisms associated with a nuclear explosion.

Observation of the thermal flash can result in temporary or permanent eye injuries. Temporary flash blindness may occur in people who observed the flash of intense light energy with their peripheral vision. This blindness is a temporary condition that results from a depletion of photopigment from the retinal receptors. The duration of flash blindness can last several seconds when the exposure occurs during daylight. The blindness may then be followed by a darkened after-image that lasts for several minutes. At night, when one's pupils are fully dilated, flash blindness may last for up to 30 minutes and may occur up to 15 miles away from the detonation resulting in traffic accidents far removed from the damage zones.

Sudden exposures to high-intensity sources of light can cause eye injury, specifically to the retina. Factors that determine the extent of eye injury include pupil dilation, spectral transmission through the ocular media, spectral absorption by the retina and choroids, length of time of exposure, and the size and quality of the image. Eye injury is a result of not only thermal energy but also photochemical reactions that occur within the retina with light wavelengths in the range of 400 to 500 nanometers.

Direct observation of the brilliant flash of light from a nuclear detonation can also cause macular-retinal burns. Burns of the macula will result in permanent scarring with resultant loss in visual acuity, or blindness. Burns of the peripheral regions of the retina will produce scotomas (blind spots), but overall visual acuity will be less impaired. These burns can occur at distances of several miles under optimal conditions and roughly double in range at night.

A nuclear explosion involves the splitting, or fission, of the nuclei of uranium or plutonium. During and following a nuclear explosion, radiation is released. This radiation includes both electromagnetic (e.g., ultraviolet, infrared, visible, gamma and x-ray) and particulate radiation (e.g., alpha and beta particles, and neutrons). The intense visible light that occurs is one of the hallmarks of a nuclear explosion; it can be seen from many kilometers away and can be blinding. The health threat from these types of radiation varies; however gamma radiation contributes the greatest early threat from the initial radiation and from radiation associated with fallout.

It is anticipated that some injuries (e.g., eye injuries, blast injuries, particularly from flying debris and glass) can be prevented or reduced in severity if individuals that perceive an intense and unexpected flash of light as described here seek immediate cover. The speed of light, perceived as the flash, will travel faster than the blast overpressure allowing a few seconds for some people to take limited protective measures.

Radiation and Fallout

One of the primary outputs from a nuclear explosion is radiation. Intense radiation is generated by the nuclear fission process that creates the explosion, and it is generated from the decay of radioactive fission products (radionuclides) resulting from nuclear fission. During a nuclear explosion, fission products are created that attach to particles and debris to form fallout; these particles are the main source of contamination associated with a nuclear explosion. Fission products emit primarily gamma and beta radiation. The various fission products have widely differing radioactive half-lives.[9] Some have very short half-lives (e.g., fractions of a second), while others can continue to emit radiation for months or years. To help in making radiation dose assessments, radiation from a nuclear explosion is categorized as prompt radiation, which occurs within the first minute, and latent radiation, which occurs after the first minute and is largely associated with radioactive fallout. Both can deliver lethal radiation doses. Moderate to large radiation doses are known to increase long-term cancer risk as well.

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[9] The radioactive half-life for a given radionuclide is the time for half the radioactive nuclei in a given sample to undergo radioactive decay. After two half-lives, there will be one-fourth of the original sample, after three half-lives one-eight of the original sample, and so forth.

For low-yield detonations (e.g., 10 KT and less) prompt radiation can be an important contributor to casualties. The intensity of prompt radiation, however, is of short duration and decreases with increasing distance from ground zero. This decrease is a result of the radial distribution of radiation as it travels away from the point of detonation, and the absorption, scattering, and capture of radiation by the atmosphere and buildings. Buildings help to block the direct path of prompt radiation, however, even if an individual is shielded behind buildings, backscattered radiation from the atmosphere can still deliver a dose that could make people sick or even prove fatal.

Even if a person is at a safe distance with respect to prompt radiation, radioactive fallout can deliver a lethal radiation dose. The intensity of latent radiation from fallout diminishes generally with distance from the point of detonation (depending on meteorological factors), and with time as the radionuclides decay away. Sheltering in a heavily constructed building away from windows or in a basement provides good protection (see Chapter 3).

Although the latent radiation hazard from a nuclear explosion arises mainly from fission products, another source can arise when neutrons impact materials such as metal, soil, rock, and buildings that are in close proximity to ground zero. The absorption of neutrons in materials can make them radioactive, emitting beta and gamma radiation. These radioactive materials decay in the same manner as fission products. In addition to local radioactive fallout, the immediate area around ground zero, mostly within the NG zone, may be radioactive for several weeks or months as a result of this neutron-induced radioactivity in buildings, soil, metals, and other materials.

The decay of nuclear weapons fission products follows the relationship, $R_t = R_1 t^{-1.2}$, where R_t is the gamma radiation dose rate at time t after the explosion and R_1 is the dose rate at unit time, for example one hour. However, a standard rule of thumb for the decay, called the 7–10 rule, makes for easy approximations. This rule states that for every sevenfold increase in time after detonation, there is a tenfold decrease in the radiation rate. Table 1.3 summarizes relative dose rates at various times after a nuclear explosion. The following explanation and accompanying Table 1.3 are from *The Effects of Nuclear Weapons*, by Glasstone and Dolan 1977 (Glasstone and Dolan 1977):

> “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 (or roughly 2 days) it will be one-hundredth; and at 7x7x7 = 343 hours (or 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. This rule is accurate to within about 25 percent up to 2 weeks or so and is applicable to within a factor of two up to roughly 6 months after the nuclear detonation.”

Table 1.3: Example dose rate decay from early fallout tracked as a function of time after a nuclear explosion; adapted from Glasstone and Dolan (Glasstone and Dolan 1977).

Time (hours)	Dose Rate (R/hour)	Time (hours)	Dose Rate (R/hour)
1	1,000	36	15
1.5	610	48	10
2	400	72	6.2
3	230	100	4.0
5	130	200	1.7
6	100	400	0.69
70	63	600	0.40
15	40	800	0.31
24	23	1,000 (~ 42 days)	0.24

Fallout is particulate material (and larger debris) that is engulfed by or drawn up into the fireball. Smaller particles, below 1 mm, generally have fission products fused into or condensed onto them, creating radioactive fallout that could be carried a significant distance. As the fireball cools, the particulates are drawn back to earth by gravity. If the detonation occurs near the earth's surface, the shock wave will crush and loosen thousands of tons of earth and urban infrastructure (e.g., buildings, roads, concrete) that can become entrained in the fireball. Some of this material will be vaporized by the intense heat of the fireball, some will be partially melted, and some will remain essentially unchanged.

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

Fallout particles studied during historical weapons testing ranged in size from submicron up to centimeters, and they behave according to standard aerodynamic principles. As the fireball rises, winds shift its particle-laden column resulting in fluctuation of the fallout pattern of deposition as upper level winds finally convey the cooling fireball. Winds at ground level typically do not reflect wind speeds and directions at higher levels, and the fallout path may veer in unexpected ways, and carry fallout a significant distance.

As a rule, fallout particles that are most hazardous are readily visible as fine sand-sized grains, but the lack of apparent fallout should not be misrepresented to mean radiation isn't present; therefore appropriate radiation monitoring should always be performed. Fallout that is immediately hazardous to the public and emergency responders will descend to the ground within about 24 hours. The most significant hazard area will extend 10 to 20 miles from ground zero. Within a few miles of ground zero exposure rates in excess of 100 R/hour during the first four to six hours post-detonation may be observed. The area covered by fallout that impacts responder life-saving operations and/or has acute radiation injury potential to the population is known as the dangerous fallout (DF) zone. To the three zones already described (LD, MD, and NG), a fourth is added, the dangerous fallout (DF) zone.

While fallout may trigger consideration of PAGs hundreds of miles away (DHS 2008), this DF zone pertains to near-in areas to focus on activities that maximize population survival and limit acute radiation injuries. Figure 1.4 illustrates the relation of the DF zone to zones LD, MD and NG.

> The most hazardous fallout particles are readily visible as fine, sand-sized grains, but the lack of apparent fallout should not be misrepresented to mean radiation isn't present; therefore appropriate radiation monitoring should always be performed. Fallout that is immediately hazardous to the public and emergency responders will descend to the ground within about 24 hours.

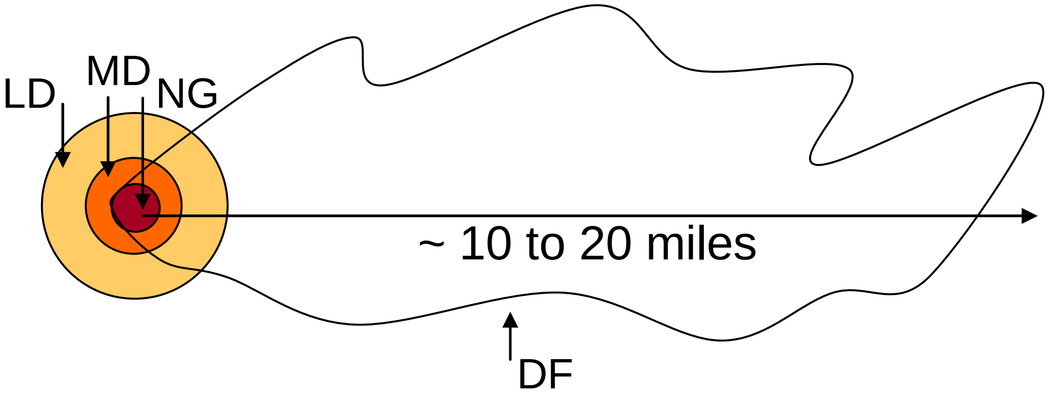

Figure 1.4: Representative dangerous fallout (DF) zone in which an early and direct threat from fallout radioactivity exists. A radiation exposure rate of 10 R/hour is used to delimit this zone.

The DF zone is distinguished not by structural damage, but by fallout radiation levels. A radiation exposure rate of 10 R/hour is used to delimit this zone. This zone is a hazardous area and any response operations within the DF zone must be justified, optimized, and planned. 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. Responder planning recommendations for the DF zone are provided in Chapter 2.

Rarely does fallout form easily predictable deposition patterns. Winds of varying speed and direction at different levels of lower and upper atmosphere push the fireball and the descending fallout material in directions that may not be evident from ground-level observation. Therefore, ground-level winds should never be used to predict the path of fallout deposition. Dangerous fallout may land on people who think the fallout is being blown a different direction, because of upper-level winds; or early evacuation could prove ineffective, even fatal, if planning assumes a straight line deposition pattern based on ground-level winds. To add to the complication of the fallout zone, there will be small areas that are significantly more radioactive and others that are less radioactive within the overall fallout field because of micro-level wind variation.

Beyond 20 miles, the extended fallout area will still require shelter and/or evacuation orders to minimize radiation exposure to the population. As a general rule, the population in the local fallout area should immediately shelter to avoid exposure to fallout prior to any consideration for evacuation (see Chapter 3).

Contamination from fallout will hinder response operations in the local fallout areas and may preclude some actions before sufficient radioactive decay has occurred. However, the fallout will be subject to rapid radioactive decay and the DF zone will immediately begin to shrink in size with time. The radiation exposure rate at a given location, whether in the center of the DF zone or at the perimeter (10 R/hour), will diminish with time resulting in a gradually smaller DF zone. Monitoring ground radiation levels is imperative for the response community. Combining the measured radiation levels with predictive plume models and/or aerial measurement systems can prove invaluable in determining response courses of action and developing protective action decisions.

Finally, fallout travels substantial distances beyond the DF zone boundary, though levels beyond the DF boundary would not be lethal. However, fallout in areas 100 or more miles away may warrant protective actions (e.g., sheltering and/or evacuation, food collection prohibitions, water advisories). Fallout deposition at great distances (e.g., 100 miles) is dictated by the parameters of jet stream winds. Fallout of fine particle size will continue to move on the jet streams and have a low-level global impact.

Radiation Injuries and Fallout Health Impacts

A nuclear explosion will produce dangerous levels of prompt radiation, and radiation from fallout. Elevated radiation doses will produce clinical injuries and death. Prompt radiation from a 10 KT nuclear detonation can deliver a radiation dose of approximately 400 rads (4 Gy or 400 cGy) at a distance of just over half a mile (~0.9 km) whereby ~50% of the population who are out in the open (unshielded) will not survive. This level of dose is called the LD_{50} dose for untreated patients. Medical care increases one's chances of survival up to a dose of ~600 rads (600 cGy). Even with medical care, many victims that receive radiation doses over ~600 rads would not be expected to survive. The time to death for these victims ranges from several weeks to a few months.

Nuclear fallout can cause acute health effects (short-term effects), including death, and long-term health risks, especially cancer. Close in to the explosion out to about 10 to 20 miles from ground zero, unsheltered people could receive acute and even lethal radiation doses. A simplified acute radiation dose chart is shown below (Table 1.4). From this chart, responders will note that if they are subjected to acute doses above ~200 rem (200 cGy), they will likely be unable to perform their jobs adequately and be at risk of becoming a casualty themselves. Below the range of acute effects, the risk of cancer is increased over a person's lifetime.

Table 1.4: Approximate acute death and acute symptoms estimates as a function of whole-body absorbed doses (for adults), for use in decision making after short-term[a] radiation exposure adapted from NCRP, AFRRI, Goans, IAEA, ICRP and Mettler (NCRP 2005; DOD, 2003; Goans and Wasalenko, 2005; IAEA, 1998; ICRP, 1991; Mettler and Upton, 1995).

Short-Term 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 4 h) (%)
1 (0.01)	0	0	0
10 (0.1)	0	0	0
50 (0.5)	0	0	0
100 (1)	<5	0	5 – 30
150 (1.5)	<5	<5	40
200 (2)	5	<5	60
300 (3)	30 – 50	15 – 30	75
600 (6)	95 – 100	50	100
1,000 (10)	100	>90	100

[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 d after exposure and few if any after that time. Estimates are for healthy adults. Individuals with other injuries, and children, will be at greater risk.

In zones where acute or lethal doses may occur, attention should be directed towards minimizing doses to levels as low as can be achieved to maximize survival under the circumstances. In zones further away and where relatively low radiation doses are observed (i.e., from fallout), attention should be given to managing radiation exposures with the goal of minimizing cancer risk and other long-term effects. Chapter 3 provides more information on radiation dose management and protective actions.

Perhaps the most effective life-saving opportunity for response officials in the first 60 minutes following a nuclear explosion will be the decision to shelter or evacuate populations in the expected fallout areas. When individuals remain in a nuclear fallout area, the fallout deposited on the ground and roofs will lead to an immediate external radiation exposure from gamma radiation. The radiation dose from fallout is often referred to as the ground shine dose and it is orders of magnitude greater than internal hazards resulting from inhalation or ingestion of radioactive material in the DF zone. However, respiratory protection for the public, even ad hoc protection (e.g., holding a cloth over one’s mouth and nose), is better than no protection at all. Emergency responder respiratory protection recommendations are provided in Chapter 2, “Response Worker Safety.”

> The most effective life-saving opportunities for response officials in the first 60 minutes following a nuclear explosion will be the decision to safely shelter or evacuate people in expected fallout areas.

Fallout exposure can be effectively minimized by taking shelter in a sufficiently protective structure. It is critical that pre-event public education address this protective action measure directly with the public. Emergency responders should attempt to transmit shelter or evacuate decisions to the public. Individuals need to understand the shelter adequacy of the shelter in which they are located to be able to make their own decisions. Sheltering and evacuation is the subject of Chapter 3.

Many people sheltering or being evacuated will need at least rudimentary decontamination. Effective decontamination of people from fallout is straightforward (i.e., remove clothes and shower). If contamination is not brushed or washed off, it can cause beta burns to the skin. If responders find themselves caught in an area during active fallout from the plume, they should brush each other off every few minutes until they can find suitable shelter or evacuate from the fallout area. Decontamination will place additional constraints on responder resources. Mass decontamination of populations can involve sending people home or to an alternate location to change clothes and shower. This subject is extensively addressed in Chapter 5.

Combined Injuries

Nuclear explosions produce thermal, blast, and radiation injuries that will often occur in combination. Research has led to the conclusion that the prognosis of patients suffering from both radiation and traumatic injuries (including burns) will be worse than the prognosis of patients suffering the same magnitude of either trauma or radiation exposure alone. For example, the LD_{50} for untreated, combined-injury casualties may be reduced from ~400 rad (400 cGy) to as low as 250 rad (250 cGy). Combined-injury patients who have received significant, but less than lethal, radiation doses (100 to 200 rads, or equivalently, 100 to 200 cGy) will also require more support than those who have traumatic injuries alone.

> Blast, thermal, and radiation injuries in combination will result in prognoses for patients worse than those for the individual injury mechanisms.

EMP

A phenomenon associated with a nuclear detonation called electromagnetic pulse (EMP) poses no direct health threat, but can be very damaging to electronic equipment. EMP is an electromagnetic field generated from the detonation that produces a high-voltage surge. This voltage surge can impact electronic components that it reaches. The EMP phenomenon is a major effect for bursts at very high altitude, but it is not well understood how it radiates outward from a surface level detonation and to what degree it will damage the electronic systems that permeate modern society.[10] Although experts have not achieved consensus agreement on expected effects, generally they believe that the most severe consequence of the pulse would not travel beyond about two miles (three km) to five miles (eight km) from a surface level 10 KT detonation. Stalling of vehicles and disruptions in communications,

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[10] NPS #1 is a surface burst scenario. If the detonation were to occur at altitude, for example, if the device were carried up a thousand feet or more in a small plane, EMP would have a significantly larger impact on electronics and could seriously hamper communications and other systems locally.

computer equipment, control systems, and other electronic devices could result. Another EMP phenomenon called source-region EMP may lead to conductance of electricity through conducting materials (e.g., pipes and wires) and could cause damage much further away, but this subject requires further research and analysis. Because the extent of the EMP effect is expected to occur relatively close to ground zero, other effects of the explosion (such as blast destruction) are expected to dominate over the EMP effect. Equipment brought in from unaffected areas should function normally if communications towers and repeaters remain functioning.

EMP effects could result in extensive electronics disruptions complicating the function of communications, computers, and other essential electronic equipment.

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Chapter 2 - A Zoned Approach to Nuclear Detonation Response

KEY POINTS

1. The goal of a zoned approach to nuclear detonation response is to save lives, while managing risks to emergency response worker life and health.
2. Response to a nuclear detonation will be provided from neighboring response units; therefore advance planning is required to establish mutual aid agreements and response protocols.
3. Radiation detection equipment should be capable of reading dose rates up to 1,000 R/hour.
4. Radiation safety and measurement training should be required of any workers that would be deployed to a radiation area.
5. 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.
6. Responders should focus medical attention in the LD zone only on severe injuries and should encourage individuals to shelter in safe locations to expedite access to severely injured individuals.
7. Response within the MD zone requires planners to prepare for elevated radiation levels, unstable buildings and other structures, downed power lines, ruptured gas lines, hazardous chemicals, sharp metal objects, broken glass, and fires.
8. The MD zone should be the focus of early life-saving operations. Early response activities should focus on medical triage with constant consideration of radiation dose minimization.
9. Response within the NG zone should not be attempted until radiation dose rates have dropped substantially in the days following a nuclear detonation, and the MD zone response is significantly advanced.
10. The highest hazard from fallout occurs within the first four hours and continues to drop as the radioactive fission products decay.
11. The most important mission in the DF zone is communicating protective action orders to the public. Effective preparedness requires public education, effective communication plans, messages, and means of delivery in the DF zone.

Overview

As stated in Chapter 1, defining zones can be a useful approach to planning and executing a response, including predicting casualties and medical needs, determining where to locate staging areas, determining incident management requirements, assessing potential worker hazards, determining how to access affected areas, and determining how to prioritize mission objectives especially for medical triage. While presented generically here, response planning must be done on a city-specific basis. The priority of saving lives is emphasized along with protecting emergency response workers. The zones in this recommended approach to nuclear explosion emergency response are based on visual indicators of physical damage and on radiation levels that will need to be measured in the field. The basic zones were described in Chapter 1 and their use is expanded here.

The goal of a zoned approach to nuclear detonation response is to save lives, while managing risks to emergency response worker life and health.

Zoned Approach to Response

The physical and radiological (fallout) impacts of nuclear explosion may be extensive making local response to the incident difficult. Responder units within one or two miles from ground zero of a surface, 10 KT nuclear explosion may be compromised or completely nonfunctional. However, response capabilities more than five miles away from ground zero are likely to be minimally affected by blast and electromagnetic pulse (EMP) and should be able to mobilize and respond, provided they are not impacted by dangerous levels of fallout. Therefore, response to a nuclear explosion may largely be provided by neighboring boroughs, suburbs, cities, townships, and counties through mutual aid agreements or other planning mechanisms. Some neighboring response capabilities, however, will be directly affected by fallout and advised to shelter until dose rates have fallen.[11] Regional response planning in advance of a nuclear explosion is imperative to maximize response efficacy.

Response to a nuclear detonation will largely be provided from neighboring response units; therefore advance planning is required to establish mutual aid agreements and response protocols.

The hazard from high radioactivity is an ever-present threat for responders and survivors in the early postdetonation time period. Radioactivity cannot be seen or felt; it must be detected and measured with specialized equipment capable of measuring high levels of radioactivity consistent with a nuclear detonation. Equipment should be capable of reading dose rates up to 1,000 R/hour. Radiation safety and measurement training should be required of any workers deployed to radiation areas. Response teams should not enter affected areas without first confirming the level of radioactivity in the area they are entering.

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[11] In the scenario being considered here, a surface level nuclear explosion will generate a large amount of dangerous fallout.

Planners and responders should remember that dose rates will be decreasing significantly in the first 48 hours. The level of radioactivity will need to be monitored periodically to properly characterize the changing hazard. Federal assets to support radiation monitoring will become available in the early days following a nuclear detonation, but local responders will be operating without substantial Federal support on the ground for approximately 24 to 72 hours. Beginning about 30 minutes to 1 hour after a nuclear detonation, the Federal Interagency Modeling and Atmospheric Assessment Center (IMAAC) will be able to provide plume and fallout projections to State and local authorities through the Department of Homeland Security (DHS). The projections will be continuously updated as additional information becomes available from the incident location.

Radiation detection equipment should be capable of reading dose rates up to 1,000 R/hour.

Radiation safety and measurement training should be required of any workers that could potentially be deployed to a radiation area.

Response Functions and Priorities

Response teams that may use a zoned response approach to nuclear detonation response include radiation assessment support teams, police and fire fighters, emergency medical personnel, search and rescue teams, Haz Mat teams, engineering response teams,[12] medical triage units, and response support functions. The main objective of early response is the preservation of life. While the life-saving objective is aimed at the general public, the safety and health of response workers is also critical. Emergency response planners and incident commanders must carefully weigh the decision to send response workers into situations where they may receive very high-radiation doses and/or physical injuries, both to protect the responder and to maximize responder resources. During the first hours and days after a nuclear attack, as many as one hundred thousand[13] individuals may live or die depending on the ability of responders to treat injuries and protect people from lethal exposures to radiation.

A number of nuclear explosion impacts (described in Chapter 1) severely hinder the life-saving mission. Successful execution of life-saving and supporting response activities, such as search and rescue and fire fighting, is determined in part by the incident area conditions. Area access for such missions may be severely hindered by deep rubble, smoke and dust, stalled and crashed automobiles, and downed power lines. Fire fighting may be hampered or prevented by low water pressure. Worker safety concerns may affect response planning and

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[12] The term engineering response teams is used here to include teams of workers tasked with clearing rubble and debris from transportation routes, repairing critical transportation infrastructure, stabilizing damaged utilities (e.g., gas, electric, and water), assessing structural damages to buildings, bridges, and other structures, and other critical engineering-related tasks.

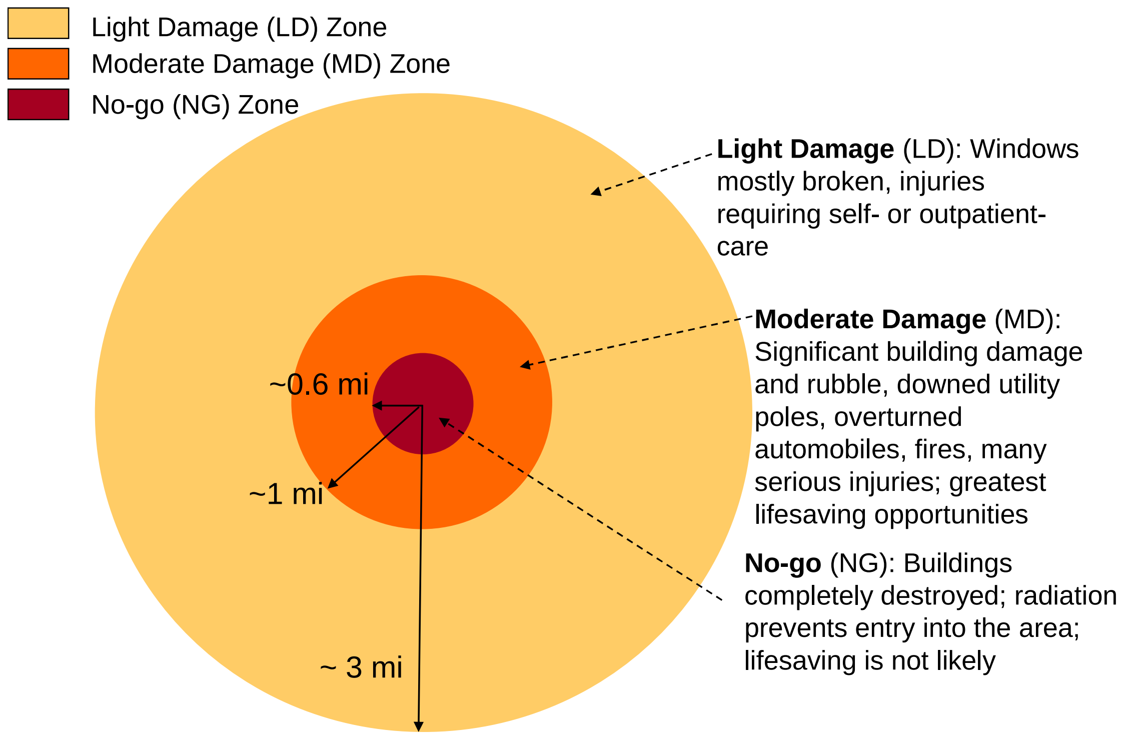
[13] In some computer simulated high-density urban scenarios, several hundred thousand people may be at risk of death following a 10 KT nuclear explosion where effective planning and response actions could save many of them.

mission execution. Planning for response in impacted areas according to zones (by type and magnitude of physical impact and level of radiation) will help planners optimize response asset allocation and deployment of resources to most effectively support the life-saving activities. For example, areas where significant street rubble is expected warrant rapid deployment of street clearing equipment to allow access to areas where medical triage is a priority, or to open critical access routes for other key missions. Likewise, engineering teams may be needed to stabilize structures and utilities, such as water, gas, and power lines before fire, search and rescue, or medical teams can enter.

The nature and magnitude of impacts provides indicators for prioritizing search and rescue and medical triage missions. For example, close to ground zero the likelihood of survivors is very low. Other zones will have varying proportions of injured people, and varying degrees of injury, thus providing rough indicators where scarce resources may be best deployed. Planning response activities by zones based on the magnitude and type of impact and expected casualties will help planners set priorities to realize the greatest number of lives saved.

Finally, high radiation from fallout may overlay zones with heavy physical impacts as well as outlying areas with no physical impact at all. Therefore, planning in these zones must account for heavy damage, moderate or light damage, and no damage at all, depending on the distance from ground zero along the path of fallout deposition. Areas of combined physical (trauma and burn) and radiation impacts also generate casualties with combined physical and radiation health impacts. These combined injuries significantly reduce survival. The ability to plan response around combined impact zones will help officials plan for and focus efforts where life-saving activities will realize the most lives saved.

In Chapter 1, four zones were described based on the magnitude of physical damage and radiation levels associated with fallout. Emergency response operations can be planned using these four zones. They are provided again for convenience as Figure 2.1: the light damage (LD) zone; the moderate damage (MD) zone; and, the “no-go” (NG) zone; and, Figure 2.2: the dangerous fallout (DF) zone.



Light Damage (LD): Windows mostly broken, injuries requiring self- or outpatient-care

Moderate Damage (MD): Significant building damage and rubble, downed utility poles, overturned automobiles, fires, many serious injuries; greatest lifesaving opportunities

No-go (NG): Buildings completely destroyed; radiation prevents entry into the area; lifesaving is not likely

All approximated distances from center of detonation site

Figure 2.1: Representative damage zones for 10 KT nuclear explosion (not to scale; circles are idealized here for planning purposes) (Identical to Figure 1.1)

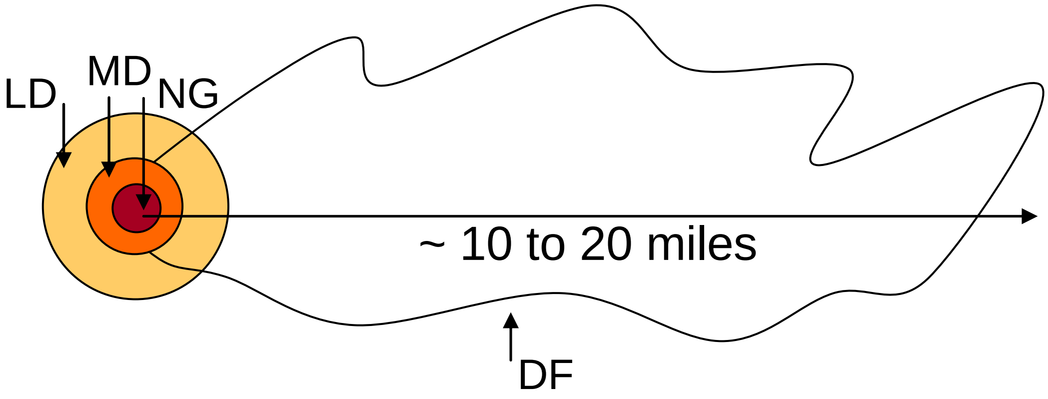


Figure 2.2: Representative dangerous fallout (DF) zone for a 10 KT nuclear explosion in which an early and direct threat from fallout radioactivity exists. A radiation exposure rate of 10 R/hour is used to delimit this zone. (Identical to Figure 1.4)

LD Zone Response

The outer perimeter of the LD zone will become recognizable when responders consistently see broken windows. The outer perimeter of the LD zone is arbitrarily set at approximately 25% observable broken windows. The LD zone will require some street clearing of small rubble and debris and stalled or crashed vehicles. Passage into this zone will become increasingly difficult and require heavy equipment and debris removal capabilities. Responders may encounter elevated radiation in the LD zone; however; elevated radiation doses would be associated predominantly with the major path of fallout deposition where the DF zone is overlaying.

The severity of injuries responders will encounter in the LD zone should be relatively light, consisting mostly of superficial wounds. Elevated radiation doses from prompt radiation and burns from the detonation itself (see Chapter 1) are not expected in the LD zone because of the distance from ground zero and the shielding provided by buildings. Injuries are anticipated to result primarily from flying glass and debris, falls, and traffic accidents. Glass and other projectile penetrations are expected to be superficial (e.g., 1 centimeter depth) in the torso, limbs, and face. Eyes are particularly vulnerable. As responders proceed inward they will begin to observe an increasing frequency and severity of injuries from flying glass and debris, and crush, translation and tumbling injuries.[14] Glass shards will become prominent in injured individuals. Glass alone, depending on where it has entered the body, may present a direct threat to life. In summary, the most injuries incurred within the LD zone are not expected to be life threatening. Injuries resulting from traffic accidents are likely to be the most serious injuries in the LD zone. As responders penetrate further in towards the MD zone, the number and severity of physical injuries will increase.

Most 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, falls, and traffic accidents.

Responders should expect LD zone survivors to be panicked and confused, and to request medical assistance. A small percentage of injured in the LD zone may require emergency care, for example, for severe blood loss or head injury from a traffic accident. But, the population as a whole in the LD zone is anticipated to have a good chance for survival without immediate medical attention. Responders should resist spending time and resources on minor injuries in order to maximize the use of medical resources on more critical needs closer in to ground zero. Response actions in this zone should be focused on encouraging individuals to stay safely sheltered so that responders can expedite access to MD zone casualties.

Responders should focus medical attention in the LD zone only on severe injuries and should encourage individuals to shelter in safe locations to expedite access to severely injured individuals.

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[14] Translation and tumbling injuries are those incurred when people are thrown about and into solid objects by the blast wave.

As responders continue to advance into and through the LD zone, the occurrence of shattered windows continues to increase until all glass is shattered in buildings, and damage to roofs and building facades is observed. Some lighter buildings are collapsed. Injury from flying glass and debris will be more severe and serious injuries associated with building structural damage will increase. At this point, responders are entering the MD zone.

MD Zone Response

While no clear demarcation exists, responders may recognize the transition to the MD zone by the prevalence of significant building structural damage. Observations in the MD zone include significant structural damage, overturned vehicles, and fires. In the MD zone sturdier buildings (e.g., reinforced concrete) will remain standing, lighter commercial and multi-unit residential buildings may be structurally unstable or collapsed, and many wood framed and brick residential structures will have collapsed. Telephone poles and street light poles may be blown over. Substantial rubble in streets from damaged buildings and crashed and overturned vehicles should be expected, making evacuation and passage of rescue vehicles very difficult or impossible without street clearing. Within the MD zone, broken water and utility lines and numerous fires should be expected.

A major threat to survivors may be fire. Fire was a major cause of death in the nuclear attack on Hiroshima; however, experts suggest that differences in modern US city design and construction make a raging firestorm unlikely. Fires in tall office buildings can lead to high concentrations of fatalities. Water pressure for firefighting is a major concern because of damage to the utility systems, and trained engineering teams will be required to stabilize them. This challenge may take many hours as deep rubble in the streets will make access by response vehicles very difficult or impossible without concerted street clearing and debris hauling efforts.

The MD zone is expected to have a high proportion of survivors, many of whom will have life-threatening injuries. The greatest opportunity to effect life-saving in the MD zone is in areas not affected by fallout (i.e., where the DF zone is overlapping the MD zone). All early response activities in this zone should facilitate delivery of medical care to survivors. Prompt access, search and rescue, and delivery of medical attention is essential to maximizing lives saved, but this zone poses great challenges in access, search and rescue, fire, and hazards to response workers.

Response planning must be city-specific. Targeted search and rescue missions may be sensible in the MD zone, such as locations with special populations (e.g., schools or hospitals), or in discrete locations such as tunnels and subways. As a result of the extent of impacts and hazards, an effective response will require well-planned, expeditious actions to maximize saving lives. Therefore, early response planning should focus on facilitating MD zone medical triage. However, responders should enter the MD zone and focus response efforts in areas outside the dangerous fallout (DF) zone, except to implement shelter or evacuation orders as appropriate. This approach will help maximize life-saving while preserving the viability of the responder workforce.

The MD zone presents significant hazards to response workers that must be considered and planned for, including elevated radiation levels, unstable buildings and other structures, downed power lines, ruptured gas lines, hazardous chemicals, and sharp metal objects and broken glass. Fires fed by broken gas lines, ruptured vehicle fuel tanks, and other sources will be prevalent and may pose a significant danger to survivors and responders. Visibility in much of the MD zone may be low for an hour or more after the explosion resulting from dust raised by the shock wave and from collapsed buildings. Low visibility may be exacerbated and extended in duration because of smoke from fires.

Radiation levels in the MD zone may be very high, especially in the first hours after the incident. High radiation may be a result of local deposition of fallout debris and/or from neutron activation of local materials. Where the primary path of fallout deposition (the DF zone) crosses the MD zone, radiation levels are expected to be elevated and pose an imminent danger for 12 hours or more. Responders advancing into a zone should always be led by radiation assessment teams or adequately equipped and trained Haz Mat teams to characterize the radiation threat. A mission into a radioactive zone should always have a benefit that justifies the anticipated radiation dose to response workers.

Response within the MD zone requires planners to prepare for elevated radiation levels, unstable buildings and other structures, downed power lines, ruptured gas lines, hazardous chemicals, sharp metal objects, broken glass, and fires.

The MD zone should be the focus of early life-saving operations. Early response activities should focus on facilitating medical triage with constant consideration of radiation dose minimization.

In summary, the MD zone should be the heart of a nuclear explosion response, with the goal of managing the impacted scene through aggressive rubble removal and site access, fire suppression, and structural and utility stabilization, in order to facilitate expeditious search and rescue and medical triage. Response planners should develop plans for MD zone response that includes:

- Establishing nuclear emergency response protocols that maximize life-saving potential
- Organizing neighboring response units
- Establishing Incident Command (IC)
- Deploying radiation assessment teams, engineering response teams (e.g., road clearing, debris hauling capabilities), Haz Mat and search and rescue teams, and medical response teams

NG Zone Response

Once the responder recognizes severe damage to infrastructure such as complete building destruction and high rubble piles completely preventing access, the chance of encountering survivors is minimal, and prohibitive risks to response workers should be assumed. However, as the overall response progresses, the Incident Commander may consider strategic rescues within the NG zone. Response within the NG zone should not be attempted until radiation dose rates have dropped substantially in the days following a nuclear detonation, and the MD zone response is significantly advanced. At that point, search and rescue efforts may focus on underground structures that could have maintained their integrity.

Response within the NG zone should not be attempted until radiation dose rates have dropped substantially in the days following a nuclear detonation, and the MD zone response is significantly advanced.

DF Zone Response

Fallout will likely be widespread longitudinally along the path of upper level winds, and locally fallout may also exhibit significant spread as a result of lower level winds. In the DF zone, fallout particles may be visible as fine sandy material, either actively falling out as the plume passes, or visible on clean surfaces. Visible fallout provides strong evidence of dangerous levels of radioactivity. But, fallout may not be noticeable on rough or dirty surfaces, and there is no method to reliably estimate radiation dose rates based on the quantity of visible fallout. Therefore, visible fallout may possibly be used as an indicator of a direct radiation hazard, but the lack of apparent fallout should not replace appropriate radiation measurements.

High levels of radiation from fallout pose a direct threat to survivors and response workers.[15] The National Council on Radiation Protection and Measurements (NCRP) has recommended 10 R/hour (R/hour) as a nuclear-explosion fallout zone delimiter, stating responders should, *"Establish an inner perimeter at 10 R hour^{-1} exposure rate (~0.1 Gy hour^{-1} air-kerma rate). Exposure and radioactivity levels within the inner perimeter have the potential to produce acute radiation injury and thus actions taken within this area should be restricted to time-sensitive, mission-critical activities such as life-saving."*(NCRP, 2005). Thus, the perimeter of the DF zone is defined by an exposure rate of 10 R/hour. The 10 R/hour point would normally indicate that workers should return to a safe area, unless they are undertaking a sufficiently important mission; a mission with a benefit that justifies the anticipated radiation dose. This exposure rate also indicates that much higher rates may be nearby and is useful for making shelter/evacuation decisions (see Chapter 3).

Fallout will also traverse the physical damage zones. Dangerous levels of fallout are expected in the MD and LD zones as well as areas that are otherwise unaffected, for example 10 to 20 miles from ground zero. Lower level fallout will continue for a hundred miles or more (see Chapter 3 for shelter and evacuation planning recommendations). As stated in Chapter 1, the highest hazard from fallout occurs within the first four hours and continues to drop as the fission products decay. As radioactivity levels drop, the DF zone will steadily shrink.

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[15] The other source of residual radioactivity after a nuclear explosion is induced radioactivity in materials (e.g., construction materials, rock, and soil) resulting from neutron absorption. Generally, in the scenario being considered here, significant neutron activation will not occur beyond the NG zone. Activation radioactivity decays rapidly similar to the decay rate for fallout.

The highest hazard from fallout occurs within the first four hours and continues to drop as the fission radionuclides decay.

The most important mission in the DF zone is communicating protective action orders to the public. Generally, the order would be to seek and remain in a robust shelter until advised otherwise to avoid exposure to fallout. This communication is a temporary action until the affected population can be evacuated in a safe and orderly fashion. Preparedness planning and effective communication plans, messages, and means of delivery will be the key to survival for many in the DF zone.

The most important mission in the DF zone is communicating protective action orders to the public. Effective preparedness requires public education, effective communication plans, messages, and means of delivery in the DF zone.

Radiation exposure rates in high-fallout areas can reach thousands of R/hour, delivering doses that are fatal. Allowing time for radioactive decay of fallout significantly improves the ability to respond safely. When planning response in highly radioactive zones, the time for decay must be weighed against the urgency of saving lives. In the most critical time period, the first hours after the explosion, radiation is also highest. Waiting could cost survivor’s lives; advancing could cost responder’s lives. The 7–10 rule, described in Chapter 1, is a useful rule-of-thumb for estimating radiation dose rates after a nuclear explosion. Officials and responders should not rely on the 7–10 rule in lieu of actual measurements when sending responders into radioactive areas. A healthy, viable responder workforce is critical to saving lives after a nuclear explosion. Incident Commanders should use great discretion in sending workers into highly radioactive areas, and planning and training are critical to successful post-nuclear response.

Response Worker Safety

Emergency response worker safety and health is an essential consideration in response planning. Emergency response workers will be the primary resource for the response. For a nuclear attack, emergency response workers will not only include fire and police, but will likely include emergency medical technicians, utility workers, and other skilled support personnel (such as truck drivers, equipment operators and debris contractors) that provide immediate support services during response operations. Besides the radiation hazards, these responders will face widespread fires, collapsing structures, chemical exposures, smoke/dust inhalation, and numerous other physical and health hazards. In general, emergency response workers do not have substantial experience working in radioactive environments. Safe emergency response actions within the LD, MD, and DF zones can only be accomplished with appropriate planning, responder training, provision and use of personal protective equipment (PPE), and other mission critical equipment, including dosimetry.

Most organizations have a safety and health management program, but no single organization will be able to manage the vast array of significant hazards that must be conducted in order to sustain resources for all of the response operations. An emergency response worker safety management program for this scenario will need to be integrated into overall operations, reviewing the tasks and occupations involved in the operations, analyzing the hazards posed to the workers, and establishing the necessary protection for the workers.

An emergency responder safety management program will need to be established as early on in the response as possible. Local responders would need to establish a base-level program that would expand as more response organizations arrive. As more organizations are brought into the response safety representatives of these organizations will need to be integrated. The safety management program will also need subject matter experts on the safety precautions necessary for the vast array of hazards. The challenge of the safety management program will be the need to track and analyze dosimetry for those responders who have entered the impacted area and provide this information back to the Incident Commander in a timely manner for making future operational decisions.

Monitoring exposures of workers is significantly different from the atmospheric and environmental monitoring performed by the Federal Radiological Monitoring and Assessment Center (FRMAC). Atmospheric and environmental monitoring supports general mapping and plume modeling, but worker monitoring will need to address the specific dose received by each individual responder. Rather than general monitoring devices, each individual responder will likely need a dosimeter. Preparedness activities need to address how response organizations will obtain the vast quantity of dosimeters that will be needed.

Components of the emergency responder safety management program would need to include the following:

- Hazard risk assessments for each operation to minimize exposure during the response
- Worker safety and health needs assessment
- PPE including respirators for every responder
- Dosimetry including electronic alarming dosimeters
- Data management to track responders and their accumulated dose should be performed
- Training and communication will need to be performed
- Preparations for a medical surveillance program will need to be performed

The DHS Planning Guidance (DHS 2008) provided a summary of radiation emergency worker guidelines, similar to the EPA 1992 PAG Manual (EPA 1992). The summary table provided the following dose guidelines in alignment with emergency worker activities: 5 rem for all response actions, 10 rem for protecting valuable property necessary for public welfare (e.g., power plants), and 25 rem for lifesaving activities. The 25rem dose recommendation was footnoted as follows:

> “EPA’s 1992 PAG Manual states that “Situations may also rarely occur in which a dose in excess of 25 rem for emergency exposure would be

> unavoidable in order to carry out a lifesaving operation or avoid extensive exposure of large populations." Similarly, the NCRP and ICRP raise the possibility that emergency responders might receive an equivalent dose that approaches or exceeds 50 rem (0.5 Sv) to a large portion of the body in a short time (NCRP 1993; ICRP 1996). If lifesaving emergency responder doses approach or exceed 50 rem (0.5 Sv), emergency responders must be made aware of both the acute and the chronic (cancer) risks of such exposure."

The DHS guidance document and the emergency worker guidelines were developed for a wide range of possible radiological scenarios, from a small radiological dispersal device (RDD) that may impact a single building to an improvised nuclear device (IND) that could potentially impact a large geographic region. The guidance does not represent strict dose or dose rate limits. The 5, 10, and 25 rem guidelines should not be viewed as inflexible limits applicable to the range of early phase emergency response actions covered by this guidance. The guidelines should serve as decision points for planning for the protection of emergency response workers as well as for making worker protection decisions during emergency response to a nuclear detonation. Because of the range of impacts and case-specific information needed, it is impossible to develop a single turn-back dose level for all emergency responders to use in all situations, especially those that involve life-saving operations. However, the guidance does provide recommendations and decision points at which emergency responders must have the training necessary to understand and consent to progressively higher radiation doses.

Decisions regarding emergency response actions in incidents involving high-radiation exposures require careful consideration of the benefits to be achieved by the "rescue" or emergency response action (e.g., the significance of the outcome to individuals, large populations, general welfare, or valuable property necessary for public welfare), and the potential health impacts (i.e., acute and chronic) to emergency workers. The planning for a potential high-radiation exposure incident should provide how to weigh the potential for and significance of the success of the emergency response or rescue operation against the potential for and significance of the health and safety risks to the emergency workers participating in the response action.

State and local emergency response officials should use these guidelines to develop specific operational plans and response protocols for protection of emergency response workers. It is essential to ensure that emergency workers are trained so they have full knowledge of the associated risks prior to initiating emergency action. Having adequate training is also necessary for emergency response workers to give informed consent. Indeed above 5 rem (the normal occupational dose limit), worker participation should proceed only on a voluntary basis. It is also essential that emergency responders have adequate PPE and other equipment for responding to the incident and are provided a medical evaluation after exposure.

Incident Commanders should make every effort to employ the "as low as reasonably achievable" (ALARA) principle when responding to an incident. Protocols for maintaining ALARA doses should include the following health physics and industrial hygiene practices:

- Maintain distance from sources of radiation
- Shield the radiation source
- Minimize the time spent in the contaminated area (e.g., rotation of emergency responders)
- Use personal dosimeters (radiation badges) and alarming dosimeters to determine dose
- Properly select and use respirators and other personal protective equipment (PPE), appropriate for minimizing dose to internally deposited radioactive materials (e.g., alpha and beta emitters)
- Use prophylactic medications, when appropriate, that block the uptake or reduce the retention time of radioactive material in the body

Responding to a nuclear detonation in communities will be extremely difficult and hazardous. Therefore, it is absolutely essential that there be detailed advance planning and preparation, including purchasing and prepositioning the necessary equipment for responders. Planning should include evaluating data (radiation survey and personal monitoring) and information on possible or anticipated radiation exposures from a nuclear explosion, developing procedures for reducing and controlling exposures of all workers involved in the emergency response action, and developing appropriate decision-making criteria for responding to the nuclear detonation. Planning should also address how to obtain and preposition essential equipment that includes appropriate personal protective equipment (e.g., respirators, clothing) for protecting emergency responders who enter contaminated areas, radiation detection meters or other measurement equipment, and personal dosimeters.

Respiratory protection of emergency responders is an essential issue that will need to be addressed during the planning phase and also during the emergency. Initially, emergency responders will need respiratory protection as exposure levels are being characterized. The National Institute of Occupational Safety and Health (NIOSH) has prepared guidance on selecting appropriate PPE for response to terrorism incidents involving chemical, biological, and radiological events (DHHS, 2008). OSHA's web site is a resource for emergency response planning and action as it provides guidance on the proper use of respiratory protection equipment (http://www.osha.gov/). Effective advance planning will help to ensure that the emergency worker guidelines are correctly applied and that emergency workers are not exposed to radiation levels that are higher than necessary in the specific emergency action.

Additional Guidance for State and Local Planners

Additional guidance for state and local emergency response planners is available from several sources. There are a number of resources available that can be used to establish recommendations regarding emergency responder dose limits. The EPA’s guidance provides for greater than 25 rem (0.25 Sv) for lifesaving activities or protection of large populations (EPA, 1992). There is no upper limit provided by the EPA guidance. The newly published DHS Planning Guidance (DHS, 2008) modifies the EPA guidance (EPA 1992) slightly as described in Table 2.3 in the grey box that follows. The National Council on Radiation Protection and Measurement (NCRP) (NCRP 2001b), International Commission on Radiological Protection (ICRP) (ICRP 1996), and the Conference of Radiation Control Program Directors (CRCPD 2006) all provide 50 rem (0.5 Sv) for life-saving. Finally, the International Atomic Energy Agency (IAEA) (IAEA 2006) provides a recommendation of 100 rem (1 Sv) for life-saving.

NCRP's Commentary 19 (NCRP 2005) provides additional responder guidelines that are applicable for consideration in planning for nuclear detonation response. These guidelines only address short-term (acute or deterministic) effects. Exposure at these levels can also result in long-term (lifetime cancer or stochastic) health effects. The NCRP guidelines are summarized in Table 2.3.

Table 2.3: NCRP Emergency Responder Guidelines (Adapted from NCRP Commentary 19 (NCRP 2005))

CONCEPT	VALUE	EXPLANATION
Inner Perimeter	10 R/hour	Responders should establish an inner perimeter (e.g., an operational boundary) at an exposure rate of 10 R/hour. Exposure and radioactivity levels within the inner perimeter have the potential to produce acute radiation injury and thus actions taken within this area should be restricted to time-sensitive, mission-critical activities such as life-saving.
Decision Dose	50 rad	The cumulative absorbed dose that triggers a decision on whether to withdraw an emergency responder from within or near (but outside) the inner perimeter is 50 rad (50 cGy).
Responder Acute Radiation Sickness	>100 rad	Nausea and vomiting are among the earliest clinical signs of acute radiation sickness. Nausea and vomiting are symptoms that occur as whole-body absorbed doses become high [i.e., >100 rad (>1 Gy)]. If these symptoms occur during the conduct of activities within a radiation area, the affected individual(s) should be removed from the area, and provided appropriate medical care.
ALARA for Terrorism Incidents	n/a	In a nuclear terrorism emergency, it may be neither practical nor appropriate for radiation protection considerations to automatically be governed by guidelines applied in more routine scenarios. While the fundamental concept of keeping all radiation exposures as low as reasonably achievable (ALARA) should still apply, it may not be realistic to apply other traditional radiation protection guidelines for limitation of radiation dose. The traditional guidelines are based on an assumption of low-level exposure over long periods, and govern activities and situations that are more controllable and are not as critical as those associated with responding to a nuclear terrorism incident.
Radiation Control for Terrorism Incidents	n/a	The approach to worker radiation protection in a terrorism incident is based on two considerations: (1) the identification of radiation control zones, and (2) the control of the absorbed dose to individual emergency responders. The radiation control zones segment the site into areas of differing levels of radiation risk by using observed exposure rates. The absorbed dose to an individual emergency responder governs decisions regarding duration (stay time) for various emergency response activities.

US Military Planning

The US Military has established a system for mission-specific risk-based dose limits that includes life-saving activities. In current doctrine, US military personnel become restricted from ever again engaging in operational radiological/nuclear missions once they have exceeded 125 rad (125 cGy) dose accumulation. Whereas military commanders set their Operational Exposure Guidance (OEG) (i.e., dose limits to US troops) at any level in nuclear war, the risk analysis for extremely high-priority missions, to include life-saving, yields a maximum OEG of 125 rad (125 cGy). For operations other than war and also based on mission priorities and risk analysis, military commanders limit OEG levels to 75 rad (75 cGy) and below. (DOD 2008; DOD 2001)

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Chapter 3 - Shelter / Evacuation Recommendations

KEY POINTS

1. There are two principal actions that may be taken to protect the public from fallout: taking shelter and evacuation.
2. The best initial action immediately following a nuclear explosion is to take shelter in the nearest building or structure and listen for instructions from authorities.
3. Shelters such as houses with basements, large multi-story structures, and underground spaces (e.g., parking garages and tunnels), can generally reduce doses from fallout by a factor of 10, or more. These structures would generally provide shelter defined as “adequate.”
4. Single-story wood frame houses without basements provide only minimal shelter. These structures may not provide adequate shelter for extended periods in the DF zone.
5. Evacuations should be prioritized based on the fallout pattern and radiation intensity, adequacy of shelter, impending hazards (e.g., fire and structural collapse), fallout pattern and density, medical and special population needs, sustenance resources (e.g. food and water), and response operational and logistical considerations.
6. When evacuations are executed, travel should be at right angles to the fallout path (to the extent possible) and away from the plume centerline, sometimes referred to as “lateral evacuation.”
7. No evacuation should be attempted until basic information is available regarding fallout distribution and radiation dose rates.
8. Decontamination of persons is generally not a lifesaving issue. Simply brushing off outer garments will be useful until more thorough decontamination can be accomplished.

Overview

One of the greatest threats to the life and health of people in the vicinity of a nuclear explosion is exposure to radioactive fallout. People may be exposed to dangerous levels of fallout in the moderate damage (MD) and light damage (LD) zones, and further out to 10 or 20 miles in the dangerous fallout (DF) zone. There are two principal actions that may be taken to protect the public from fallout: taking shelter and evacuation. These protective actions may be self-executed by informed members of the public, or they may be communicated and orchestrated by response officials during the incident. Timely decisions about shelter and evacuation are critical to saving lives and reducing radiation injuries. The effective implementation of protective actions during an incident is largely dependent on pre-event preparedness and dissemination of guidance to the public. This section provides an overview of sheltering and evacuation and describes the protective actions and planning considerations for the decision-maker.

Given the large uncertainties involved, recommendations presented here are necessarily general in nature and should be used to inform city-specific response planning and preparedness. In addition, both responders and the public will need to consider their own specific circumstances (physical condition, ease of egress, access to evacuation routes, and access to adequate shelter) in deciding the best course of action.

There are two principal actions that may be taken to protect the public from fallout: taking shelter and evacuation.

The standard ways to reduce radiation exposure are as follows: reduce time in the zone, increase distance from the source of radiation (the fallout), and/or use of dense materials (like concrete, brick, or earth) as shielding against the radiation. In the case of widespread fallout, the primary protective actions are to take shelter and to evacuate. Evacuation reduces time spent exposed to radiation; the goal, of course, is to avoid exposure. Sheltering protects people by (a) providing shielding, and (b) increasing distance from fallout, especially in the center of a large building. 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. It also includes locations readily available at the time of need, including staying inside where you are, or going immediately indoors in any readily available structure. “Adequate” shelter is shelter that protects against acute radiation effects, and significantly reduces radiation dose to occupants during an extended period.

The objectives of guidance in this chapter are as follows:

- Protect the public from the acute effects of high radiation exposure associated with fallout in the initial 72 hours after a nuclear explosion. Generally, symptoms will occur with radiation doses approaching 100 rad. The potential for acute radiation effects increases with higher radiation doses, and above 200 rad medical treatment will likely be needed.
- Reduce long-term risks from radiation exposure associated with fallout from a nuclear explosion.
- Ensure that actions taken result in more benefit than harm to both individuals and the public.

Protective Actions

Protective Action Recommendations

The Environmental Protection Agency (EPA) publishes protective actions guides (PAGs)[16] for nuclear incidents. *The Department of Homeland Security "Planning Guidance for Protection and Recovery Following Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND) Incidents*" (DHS 2008) affirms the applicability of existing EPA guidance for radiological dispersal device (RDD) and improvised nuclear device (IND) incidents in areas beyond those subject to the elevated radiation dose rates and other impacts associated with a nuclear explosion. The radiation protection principles, however, are the same regardless of the potential dose or circumstances. The difference in the case of a nuclear explosion is that priority must be given to the radiation protection principle that acute-level radiation exposures should be prevented. Existing PAGs could be applied in areas outside the DF zone, which could be below the radiation level of acute health effects. They should also be applied during the intermediate phase of the incident, when relocation would be considered as a protective action.

As stated earlier, the primary means of protecting the public from radiation associated with fallout following a nuclear explosion is to shelter and/or to evacuate. Secondary protective actions include removal of fallout particles from one's clothing and body (decontamination), and avoiding inhaling and ingesting fallout particles. Planners should consider what actions are to be recommended to the public, where those actions would apply, how they would be communicated, how they would be supported and implemented by responders, and what resources are needed for successful implementation.

Nuclear explosion impacts are complex and extensive (see Chapter 1). No single protective action will be adequate for all locations and times; therefore planners should consider the following three tiers of protective action recommendations:

1. Generic recommendations issued in advance of an incident that are coupled with public education and outreach. Pre-designated public shelters may be part of this strategy for communities that do not have abundant, adequate shelter options.
2. Initial recommendations issued as soon as possible after an incident, which are based on little or no incident data. Generally, the recommendation would be for the public to take shelter immediately in the most adequate, readily available shelter.
3. Follow-up recommendations issued once additional data and information become available. These recommendations may include continued shelter for a set period of time followed by evacuation, and specific evacuation instructions for selected areas or populations, such as heavily impacted areas or for vulnerable populations. The most important information influencing these recommendations will be the local distribution and extent of the fallout, the intensity of fallout radiation, and the available shelter and evacuation options.

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[16] A protective action guide (PAG) is the projected dose to a reference individual, from an accidental or deliberate release of radioactive material, at which a specific protective action to reduce or avoid that dose is recommended.

Shelter Recommendations

Sheltering in the most accessible building or structure is the best initial action immediately following a nuclear explosion. This includes **"Shelter-in-place", which means staying inside, or going immediately indoors in any readily available structure**. People should remain sheltered and listen for instructions from authorities. Even in areas where fallout has not yet arrived, sheltering is advised until it is clear where the fallout areas are. Otherwise, evacuees could be caught outside when the fallout arrives or flee unaffected areas and unknowingly enter into a fallout area.

> The best initial action immediately following a nuclear explosion is to take shelter in the nearest building or structure and listen for instructions from authorities.

"Adequate shelter" is defined as shelter that protects against acute radiation effects, and significantly reduces radiation dose to occupants during an extended period. The adequacy of shelter is a function of initial radiation dose rates when fallout arrives, and the dose rate reduction afforded by the structure. A shelter far from the DF zone may be adequate even if it provides little shielding, whereas the same shelter close into the DF zone may not be adequate. The primary risk from nuclear fallout is penetrating radiation that needs to be reduced as much as possible by shielding using dense building material, and increased distance from deposited fallout, including on roofs, that may be afforded by large buildings. Good shielding materials include concrete, brick, stone and earth, while wood, drywall, and sheet metal provide minimal shielding. Basements and large concrete structures are good examples of adequate shelter. Large buildings often have thick walls of concrete or other refractory material, but also provide the benefit of increased distance from deposited fallout materials when people gather away from exterior walls. This distance from exterior walls and roofs can substantially reduce radiation dose to those sheltering.

Shelters such as houses with basements, large multi-story structures, and underground spaces (e.g., parking garages, and tunnels), can generally reduce doses from fallout by a factor of 10, or more. These structures would generally provide adequate shelter, and individuals with ready access to these structures would protect themselves effectively even where initial unshielded fallout dose rates would result in lethal radiation dose levels.

> Shelters such as houses with basements, large multi-story structures, and underground spaces (e.g., parking garages and tunnels), can generally reduce doses from fallout by a factor of 10, or more. These structures would generally provide shelter defined as "adequate."

Some structures offer limited fallout protection, particularly single-story wood frame structures without basements. These structures may not provide adequate shelter for extended periods in the DF zone. Emergency managers may have to issue supplemental orders to those sheltering in wood frame structures (e.g., stay in the center of the structure at ground level) in order to minimize dose while sheltering. Because shelter in these and similar light structures may not be adequate for extended periods, consideration should be given to expedited evacuation of people sheltered in them, especially in the DF zone. Figure 3.1

provides a summary of the radiation exposure reduction factors as a function of building type and location within the building. Table 3.1 presents a tabular summary of radiation reduction factors for buildings.

Single-story wood frame houses without basements provide only minimal shelter. These structures may not provide adequate shelter for extended periods in the DF zone.

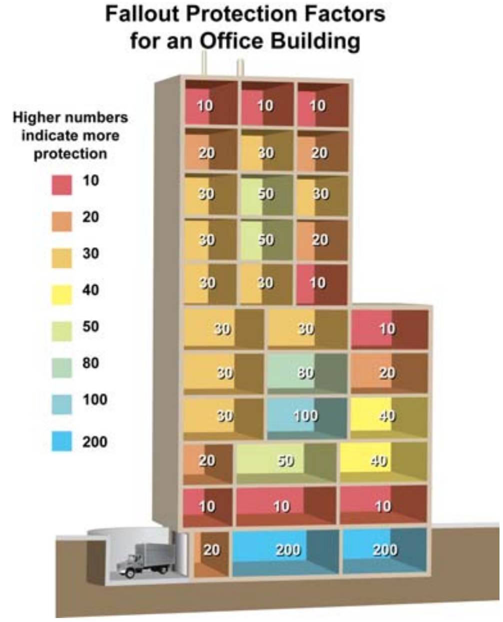

Figure 3.1 a: Building as shielding – numbers represent a dose reduction factor". A dose reduction factor of 10 indicates that a person in that area would receive 1/10th of the dose of a person in the open.

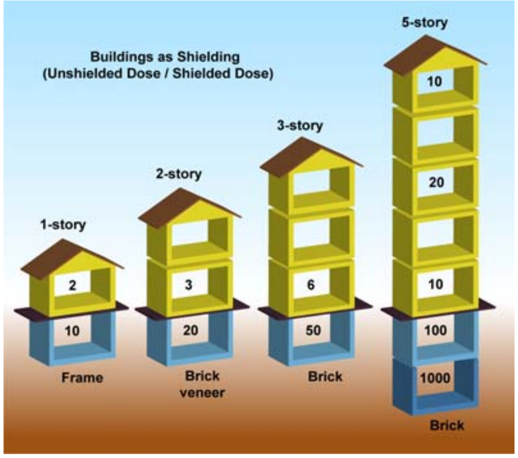

Figure 3.1 b: Building as shielding: numbers represent a dose reduction factor. A dose reduction factor of 200 indicates that a person in that area would receive 1/200th of the dose of a person out in the open.

Radiation Reduction Factors of Buildings and Structures

Structure	Gamma Reduction Factor
3-feet Underground	5000
Frame House	2-3
Basement	10-20
Vehicle	1-2
Multi-story Buildings	
Apartment	
Upper stories	100
Lower stories	10
Concrete Blockhouse Shelter	
9-inch walls	11-140
12-inch walls	30-1000
24-inch walls	500-10,000

Table 3.1: Radiation reduction factors for various structures; adapted from Glasstone and Dolan (Glasstone and Dolan 1977). A reduction factor of 1 indicates no reduction. A factor of 10 is presumed adequate shelter.

Sheltering is implicitly short term; everyone sheltering should be evacuated at some point until the safety of the area can be confirmed by officials. The duration of time spent in shelter may range from short, on the order of hours, to several days, depending on the fallout dose rates, adequacy of shelter, local factors and operational factors, and individual circumstances.

Evacuation

Sheltering should be followed by staged, facilitated evacuation for those in fallout-impacted areas. Evacuations should be prioritized based on the fallout pattern and radiation intensity, adequacy of shelter, impending hazards (e.g., fire and structural collapse), medical and special population needs, sustenance resources (e.g., food and water), and response operational and logistical considerations. Evacuations should be planned so as not to obstruct access to transportation routes that are critical for ongoing life-saving missions.

Evacuations should be prioritized based on the fallout pattern and radiation intensity, adequacy of shelter, impending hazards (e.g., fire and structural collapse), medical and special population needs, sustenance resources (e.g. food and water), and response operational and logistical considerations.

In far downwind areas, officials may be able to implement an orderly evacuation before the arrival of fallout, and should develop plans to communicate and carry out a rapid, orderly evacuation. For areas closer in (including the DF zone), where fallout arrives quickly, evacuations should take place after a period of sheltering.

Staged or Phased Evacuation

Early evacuation may be needed to protect some people shortly following sheltering. The staging of evacuations should be driven by the hazard to members of the public and logistical considerations. Early evacuation should be considered for individuals who (1) are close to the detonation (generally within 10 miles), (2) are in the fallout area, (3) who do not have adequate shelter, and (4) who have special vulnerabilities, such as children or the elderly.

In undamaged areas beyond the LD zone, evacuation should only be critical within the DF zone, but may be considered outside the DF zone as long as it does not hinder DF zone evacuation or other response operations. For some people in the LD, MD, and DF zones that are not adequately sheltered, are critically injured, or threatened by building collapse or fire, early evacuation may be required for their survival. Prioritization of early evacuation of at risk populations should be balanced against responder risk, modes of transport, ease of access and egress, control of fires in the area the ability to communicate with them, etc.

Uninjured individuals with adequate shelter conditions may not be the highest priority for early evacuation. Similarly, priority evacuation should not be considered beyond twenty miles from the detonation as long as people have access to minimally protective shelter, including single-story frame houses without basements.

Rapidly defining populations or areas that need early evacuation is a high priority. But, no evacuation should be attempted until basic information is available regarding fallout distribution and radiation dose rates. Evacuation strategies must take into account the dimensions and distribution of the fallout pattern and radiation dose rates. When evacuations are executed, travel should be at right angles to the fallout path (to the extent possible) and away from the plume centerline, sometimes referred to as “lateral evacuation.” This strategy maximizes dose reduction during the course of the evacuation. The fallout direction and deposition pattern may be difficult to ascertain without substantial field measurement of radioactivity, therefore, determining the deposition pattern is a high priority in the early hours after a nuclear explosion.   Once the hazard area is defined and has been communicated to responders and the public, evacuations may proceed. Many people in the LD zone and beyond may be able to reach safety on their own, if they receive basic instructions.

> When evacuations are executed, travel should be at right angles to the fallout path (to the extent possible) and away from the plume centerline, sometimes referred to as “lateral evacuation.”

> No evacuation should be attempted until basic information is available regarding fallout distribution and radiation dose rates.

In issuing evacuation recommendations responders must consider route conditions such as rubble and debris in streets, traffic gridlock, uncontrolled fires, collapsed bridges, other obstacles to mobility, and natural or manmade barriers (e.g., rivers and fenced areas). Attempting to evacuate everyone in too large an area could divert key resources from the zones of highest dose close to the detonation where radiation exposure control is most essential. Responders should assess the status of the transportation infrastructure as one of the top priorities in the first hours after a nuclear explosion. A poorly planned evacuation could result in unnecessary fatalities from radiation exposure, or other hazards that were not foreseen.

If radiation measurement equipment is not available, and data and modeled projections are not available in a timely fashion, responders may need to rely on visual observations. Fallout particles may be visible as fine sandy material, either actively falling out as the plume passes, or visible on clean surfaces. Visible fallout is strong evidence of dangerous levels of radioactivity. But, fallout may not be noticeable on rough or dirty surfaces, and there is no method to reliably estimate radiation dose rates based on the quantity of visible fallout. Therefore, visible fallout may possibly be used as an indicator of a direct radiation hazard, but the lack of apparent fallout should not replace appropriate radiation measurements.

It is also possible that the direction of the fallout plume may be estimated by some observers several miles away in unaffected areas. Such information would be of great value to the Incident Commander in making early protective action decisions. However, confirming and communicating fallout observation information in a timely fashion poses a significant challenge.

In those areas subject to fallout, internal exposure (inhalation or ingestion) will be a secondary radiation protection concern. For evacuees, use of respiratory protection should not interfere with the primary objective of avoiding excessive external radiation exposure. Using even crude respiratory protection (e.g., breathing through a cloth mask) while in fallout areas can further reduce this concern. Responders, however, should maintain respiratory protection at all times during operations in contaminated areas. Responders should consider other potential critical needs of evacuees, such as critical medical care, and how those needs can be met in a timely manner. Decontamination of persons, however, is generally not a lifesaving issue. Simply brushing off outer garments in the course of evacuation will be useful until more thorough decontamination can be accomplished.

> Decontamination of persons is generally not a lifesaving issue. Simply brushing off outer garments will be useful until more thorough decontamination can be accomplished.

Self Evacuations

Examination of the New York and Washington, D.C. events on 9/11 showed that when numerous people evacuate a downtown business district, they are often on foot and headed toward public transit stations. A large proportion of the evacuees will have their residence as their intended destination, even if it is far beyond the distance they need to travel to be safe.

There may be circumstances where planned evacuation efforts are not practical given circumstances and time constraints. For instance, physical damage, impassible streets, and very high dose rates in the NG and MD zones will limit the ability of responders to access areas in standard ways to support an evacuation. In such cases, consideration should be given to supporting those who are able to self-evacuate. It is recognized that some self-evacuation will spontaneously occur following a nuclear explosion. Planners should anticipate self-evacuations and be prepared to assist those who self-evacuate to the extent possible. Assistance could include providing information to self-evacuees, including instructions about how best to leave the area, what direction to travel, and when to go. Support may also be provided to evacuees as they leave (e.g., public reception centers, medical treatment, transportation, self-decontamination instructions, etc.). Self-evacuation may also present a significant obstacle to emergency responder life-saving operations. Unnecessary evacuations can complicate those that are necessary. Public messaging and communication should clearly instruct self-evacuees what to do for their safety and protection, and to avoid hindering critical operations.

No Evacuation

For people who were initially sheltered but who are in areas where there is no fallout (or negligible fallout), evacuation based on radiation hazard will not be necessary (EPA 1992). It is possible, however, that non-radiological hazards may warrant protective actions. Once an area has been determined to be without significant fallout or other hazards from the incident, protective actions are no longer necessary.

Decontaminating Vehicles

The public may attempt to self-evacuate in either official or personal vehicles that may be contaminated. Although this may result in some spread of contamination, concern over spread of minor contamination should not hinder time-sensitive evacuations. The public should simply be directed to rinse or wash down vehicles as soon as practical once they are out of danger. More detailed instructions should be provided at a later time. When possible, official transit vehicles that are used to evacuate individuals from contaminated areas, should be surveyed and controlled (e.g., simple washing or rinsing in a common area) so as to minimize the potential for spreading contamination; however as in the case of personal vehicles, these actions should be implemented in a manner that does not restrict or inhibit necessary evacuations. If there is potential that these simple protective actions will slow down evacuations then they should be avoided.

Planning Considerations

Planning considerations are key factors to consider in planning for and ultimately implementing public shelter and evacuations. The planning considerations provided below are not in priority order and the list is not exhaustive. Additional factors unique to each community should be considered during the planning process.

Situation Assessment

The path of fallout transport and deposition and the delineation of the DF zone are key pieces of information for early shelter and evacuation decision making. Planners should anticipate the need for this information and consider what resources and means they will use to obtain initial fallout projections. Weather information, computer models, visual observations, and access to early federally developed[17] data and fallout projections will all be useful. Standard emergency response tools, including radiation detection instrumentation, used in other high-hazard emergency situations will also be necessary. Planners should continuously assess information and be looking to fold in new resources as time passes and new information becomes available. It is recommended that state and local response officials immediately request federally produced fallout projections and recommendations on protective actions.

Response officials will also need to quickly assess the status of infrastructure and the general impacted environment. Within a few hours, responders will need a basic assessment of the status of transportation systems (i.e., roads, bridges, rails, subways/tunnels, airports, and harbors); communications infrastructure; the electric power grid; water, sewer, and gas infrastructure; the number, location, and severity of fires; and building structural damages. These factors have a major influence on shelter and evacuation decisions. Prior to an incident, models and simulations can help estimate planning needs and constraints.

Adequacy of Shelter

Because the radiation protection properties of potential shelter structures are of significant importance, planners should evaluate the types of shelter commonly available in their planning area (e.g., basements and other below-ground structures, concrete structures, and multi-story structures) that can generally provide adequate shelter. Planners should specifically evaluate the occurrence and general locations of single-story, wood frame structures without basements. These structures provide limited protection against fallout radiation and may not be adequate for shelter. Planners should consider areas where adequate shelter is not readily available and develop options for protection of the public, including information and awareness messaging, evacuation plans, and self-protection measures the public may take. Planners in communities that generally lack adequate shelters should consider implementing a public shelter program that would meet the needs of the community. For example, cities in regions of the country where residential basements are uncommon should consider pre-designating large buildings as public shelters in which people nearby can quickly find adequate shelter.

People occupying inadequate shelter may need to be selectively evacuated early to avoid acute exposures and minimize overall dose. Other factors that would warrant early selective evacuation include stability of the structure, critical medical needs, lack of basic resources such as water (especially after 24 hours), occurrence of fire, and other hazards that may threaten people's lives.

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[17] The Interagency Modeling and Atmospheric Assessment Center (IMAAC) is the official federal center for making fallout projections.

Time

For all protective actions, but especially for the immediate actions after a nuclear explosion has occurred, the speed with which protective action recommendations are issued and implemented is of primary importance. Delays in issuing and implementing recommendations (or orders) could result in a large number of unnecessary fatalities. Planners can expedite these early messages by preparing messages in advance and by planning how they will be communicated in an emergency.

The following guidelines are designed to help planners. It is recognized that conditions may limit the ability of responders to meet these guidelines. They are provided for planning purposes only and as a basis for identifying planning and resource needs.

- Initial projections of fallout deposition should be communicated to responders as rapidly as possible; at most within the first hour and updated every hour.
- Initial self-protection recommendations should be communicated to the public as rapidly as possible, at most within the first hour.
- Early evacuations, if appropriate, should begin as soon as possible and be completed within four hours.
- Staged or phased evacuations (or relocations following sheltering-in-place) should begin, where appropriate, within 48 hours, depending on estimated radiation exposure of the subject population, and logistical and other factors.

Communications

The effectiveness of protective action recommendations depends on the ability to communicate with responders and the public. Planners should specifically consider communications problems that will be caused by a nuclear detonation (i.e., EMP and infrastructure damage) and recognize in their planning that normal means of communication may not be available. Mass communication methods and public guidance on stocking of battery powered radios may be appropriate.

Transportation Planning

A nuclear explosion will create particularly challenging circumstances for carrying out an evacuation. In a preplanned evacuation, information is available during the readiness phase of the incident and the factors that necessitate an evacuation. When no advance warning is given, incomplete, imperfect, and, at times, contradictory information about the incident is likely, at the same time decisions need to be made. Decision makers have little or no time to wait for additional or better information in a no-notice scenario because any delay will likely have a significant effect on the safety of their citizens; they must make decisions with the information available at the time.

Because of the central role of evacuation in a response, transportation planners should be an integral element of the planning effort. Transportation and other planners should consider the full range of planning elements associated with a nuclear explosion. These may include the following:

- Priority areas for evacuation and how to identify them
- Access to the impacted zones
- Transportation resources (vehicles, public transit, air, rail and water routes of egress)
- Massive infrastructure damage (roads, bridges, tunnels, electricity), and
- Evacuation routes, impediments to evacuation, and evacuation time estimates

Further information may be found in the references listed at the end of this chapter in the Evacuation Bibliography.

Long-Term Planning

It should be anticipated that many people will be relocated for a lengthy period (months to years), even at great distances downwind, to avoid unnecessary exposure to fallout radiation. The EPA PAG for relocation in the intermediate phase is 2 rem in the first year. This should be taken into consideration when planning how far to extend recommendations for shelter during the first 72 hours.

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Chapter 4 – Early Medical Care

KEY POINTS

1. There will be a spectrum of casualties including one or more of blast, radiation, and thermal injury. Initial triage and management will be based in part on victim’s post-detonation location history, physical examination, dosimetry predictions from initial models and real-time physical dosimetry (dose measurements), and from available clinical laboratory studies.
2. To maximize overall preservation of life with insufficient resources to manage mass casualties, severely injured victims may be placed into an “expectant” (expected to die) category early on although the criteria for “expectant” will vary depending on resources available. Although expectant, palliation (treatment of symptoms) should be performed when possible.
3. Because of the damage to the infrastructure, the limited availability of resources, and presence of radiation paramedics and clinicians will have to bypass conventional clinical standards of care, preferably using predetermined criteria, in order to maximize the overall preservation of life. Such conditions are to be expected until medical staffing, logistical support, and infrastructure can be restored.
4. Management of serious injury takes precedent over decontamination. Decontamination of personnel and patients from fallout or visible debris involves brushing off, shaking, washing or wiping off the radioactive dust and dirt and should not be a limiting factor in providing medical care.
5. Initial mass casualty triage, also known as sorting, should not be confused with follow-on clinical triage for more specific medical management.
6. There is no established USG interagency medical triage system specifically validated for an urban nuclear detonation; therefore, existing emergency triage algorithms are used with modification for the impact of radiation.
7. For the time frame covered by this guidance processing of the deceased will likely not be a priority in lieu of saving lives; however, fatality management will be one of the most demanding aspects of the nuclear detonation response and should be planned for as early as possible.

Overview

The human injury consequences of a nuclear detonation in a modern urban area will impact the medical system well beyond any disaster previously experienced by the nation. Large numbers of casualties with traumatic, thermal, and radiation injuries, in all possible combinations, will be generated. The death toll will be high, but there is an opportunity to save tens or hundreds of thousands of injured victims with appropriate mitigation (before symptoms develop) and treatment strategies. Increased survival will necessitate deployment of medical, surgical, burn, and other treatment assets to the location of the mass casualties for several weeks while evacuation to distant care facilities around the entire nation will be necessary to distribute the large number of injured. Assets for evacuation of burn and trauma patients will be very limited. Currently, the majority of clinicians, including emergency medicine physicians and nurses, are not familiar with triage or treatment methods for nuclear casualties.

Maximizing the overall preservation of life will force many paramedics and clinicians to adjust clinical standards of care to the disaster situation. Mass casualty care will be resource limited and require that the response be optimized for the circumstances. Such conditions are to be expected until medical staffing, logistical support, and infrastructure can be restored. Planners can use hospital surge models (e.g. http://www.hospitalsurgemodel.org/) to estimate casualty arrival patterns, number of expected hospitalizations, number of deceased, and the resources that would be consumed to care for the patients (Department of Health and Human Services (DHHS) 2008a).

Initially, the nature of mass casualties will invoke a patient sorting system (i.e., initial triage) to maximize care to the most people. Initial triage and management will be based in part on victim's location history post-detonation, physical examination, dosimetry predictions from initial models and real-time physical dosimetry (dose measurements), and from available clinical laboratory studies. It must be recognized that extremely difficult decisions and actions will be required of responders and clinicians regarding who will receive early treatment, who will not, and who will be classified as expectant.[18] To maximize overall preservation of life with insufficient resources to manage mass casualties, severely injured victims may be placed into an "expectant" (expected to die) category early on although the criteria for "expectant" will vary depending on resources available. Although expectant, palliation (i.e., treatment of symptoms) should be done when possible. The skill and moral courage to designate severely injured victims into the expectant category in the first day following a detonation can serve to maximize overall preservation of life taking into account the lack of resources on hand to manage mass casualties. Implementing broad use of rapid "grab and drag" techniques will allow earlier rescue and treatment of more casualties than will traditional rescue methods. Local and regional preplanning is required to modify emergency response procedures (e.g., when to use or not use backboards and neck braces, etc.) for a mass casualty response. In fallout areas, such techniques will also minimize responder doses during the first hours or days into the response. Consideration should be given to concentrate medical personnel in treatment facilities with plans to avoid using them for first aid type duties. Instead, volunteers, support personnel and possibly minimally injured ambulatory victims can be asked and/or directed to help with a range of tasks including limited first aid, assisting the more severely injured, etc.

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[18] Patients that will die regardless of medical intervention, but should be afforded palliative or comfort care.

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To maximize overall preservation of life with insufficient resources to manage mass casualties, severely injured victims may be placed into an "expectant" (expected to die) category early on although the criteria for "expectant" will vary depending on resources available. Although expectant, palliation (treatment of symptoms) should be performed when possible.

From the medical intervention perspective, survival rates will increase with rapid evacuation of individuals in the damage zone following a nuclear explosion to mass medical triage and staging areas for subsequent transport of stabilized and decontaminated patients to care facilities around the nation. Survival rates will decrease if transportation is constrained by policies imposed by EMS and ambulance providers and medical facilities that will not transport and/or accept potentially contaminated patients. Because typical evacuation assets (e.g., buses, aircraft) will be heavily tasked, additional assets such as rail or water transportation should be included in medical evacuation planning.

Decontamination of personnel and patients from fall out is easy. Brushing off, shaking, washing or wiping off the radioactive dust and dirt is an effective decontamination technique in the field. Removing clothing and appropriately storing it away from people in collection bags, for example, and showers are an exceptionally good way to decontaminate individuals. Internal contamination of people is not a priority concern following a nuclear detonation and should not be considered a priority in medical care for the first few days of response.

Because of the damage to the infrastructure, the limited availability of resources, and presence of radiation paramedics and clinicians will have to bypass conventional clinical standards of care, preferably using predetermined criteria, in order to maximize the overall preservation of life. Such conditions are to be expected until medical staffing, logistical support, and infrastructure can be restored.

Management of serious injury takes precedent over decontamination. Decontamination of personnel and patients from fallout or contaminated debris involves brushing off, shaking, washing or wiping off the radioactive dust and dirt and should not be a limiting factor in providing medical care.

Acute Radiation Syndrome (ARS)

The essential feature distinguishing a nuclear detonation from other types of mass casualty events is the presence of radiation. Radiation produces its own medical effects (called the

Acute Radiation Syndrome, or ARS) and worsens an individual's survival from other injuries (called "combined injury"). The presence of radiation limits the amount of time responders can spend taking care of victims.

Acute radiation sickness is generally seen at whole body doses above approximately one Gy. Temporally, ARS presents in phases. The first phase shows prodromal symptoms (these are general symptoms that indicate a more serious process *may* follow later on) that may be useful during early triage (e.g., nausea, vomiting, heavy fatigue); second with a lethargic but otherwise asymptomatic latent period; and third by a manifest illness phase that results in either recovery or death. More information on ARS is provided in the grey box below.

Acute Radiation Sickness - General Considerations

(Details available in REMM at www.remm.nlm.gov and AFRRI at www.afrri.usuhs.mil)

Phases: Radiation victims may have some initial symptoms, such as nausea or vomiting in the prodromal phase that may then clear for a few days or weeks (the latent phase) followed by the eventual onset of ARS possibly 3-4 weeks later (the manifest illness phase).

Classical Subsyndromes: Hematopoietic (blood and immune system), Gastrointestinal (digestive tract), Dermatological (skin), Cerebrovascular (spinal system and brain)
These are dose related in ascending order with mitigation and treatment of the hematopoietic syndrome being considered at a whole body dose of > 2 Gy.

Good Prognosis:
- Vomiting starts > 4 hours after incident
- No significant change in serial lymphocyte counts within 48 hours after an incident
- Erythema (reddened skin) absent in first 24 hours
- No other significant injuries

Poor Prognosis:
- Central Nervous System (CNS) syndrome (e.g., Coma, Seizures)
- Severe erythema (reddened skin) within 2-3 h of exposure indicates dose of >10 Gy
- Vomiting less than 1 hour after incident
- Serial lymphocyte counts drop more than 50% within 48 hours
- Gastrointestinal syndrome (e.g., bloody vomitus or stool) (> 6 Gray)
- Other serious injuries (so called, combined injury)

$LD_{50/60}$: The radiation dose at which half the victims will die without intensive treatment by 60 days (called the Lethal Dose 50, or $LD_{50/60}$) is approximately 400 rem (4 Gy) (Anno and coauthors 2003)). Vigorous medical management, which would be available for victims of a small-sized radiation emergency can increase the LD_{50} possibly to 600 – 700 rem (6 – 7 Gy), but the capacity to provide this level of care will be limited in a mass casualty nuclear detonation.

DHHS Concept of Operations

A Concept of Operations (CONOPS) model recently developed by DHHS is presented here. The intent of providing this concept is to provide standardized terminology for local and State consideration, and to provide more detailed perspective on the impact of radiation on traditional response.

This CONOPS is for consideration at the State and local level to help organize their response and to best plan for receiving federal medical assets as they arrive in the hours and days that follow a detonation. Familiarity with DHHS CONOPS terminology could prove useful in planning and perhaps provide an opportunity to standardize medical response CONOPS terminology. State and local medical response planners may choose to consider evaluating the DHHS CONOPS for nuclear detonation response as a possible template for State and local plans. The DHHS CONOPS was developed with emergency medical physicians with the idea that this operational theory could be readily used in the community (Hrdina and coauthors 2009).

The DHHS CONOPS includes consideration of the zones that account for damage and radiation introduced in Chapters 1 and 2. It makes sense for planners to account for staging areas designed to receive federal medical response resources that may start to arrive within hours but certainly within days of a nuclear detonation, the following text describes a model for the Emergency Support Function #8 of the National Response Framework: Public Health and Medical Services.

Radiation Exposure Risks Years after the Nuclear Detonation

The precise relationship between radiation dose and cancer risk is the subject of debate. There is a relative long latency between exposure to radiation and development of a radiation-induced cancer, often 5-10 years for leukemia and decades for "solid tumors." As a general estimate, 5 rem, the annual limit for a radiation worker but not necessarily the limit to be used for an event such as this, would increase the lifetime risk of cancer by <0.5%. The average lifetime risk is around 25% so this dose would add <0.5% to that risk. For 25 rem the increased risk is approximately 2%, and for 100 rem, approximately 6-8%.

Federal CONOPS for Nuclear Detonation Response – the RTR System. RTR is a function-oriented care system and not an individual medical triage system (Hrdina and coauthors 2009). It stands for **R**adiation **TR**iage, **TR**ansport, and **TR**eatment and is illustrated in Figure 4.1. Following a nuclear explosion there will be three types of sites that form spontaneously as follows:

- **RTR1** – sites will have victims with major trauma coupled with radiation that limits operational response time and exacerbates victim injuries; many victims may be expectant; the location will be near the no-go (NG) boundary and/or in the moderate damage (MD) zone; rubble may prevent entry into this zone
- **RTR2** – sites will be for triaging victims with radiation exposure only or possibly with minor trauma; the location will be along the outer edges of the dangerous fallout (DF) zone and the light damage (LD) zone and may have ambient radiation; most victims are anticipated to be ambulatory

- **RTR3 –** sites are collection points where radiation is not present and will allow for occupation for many hours or more; victims are anticipated to have limited trauma injuries such as glass injury; most victims ambulatory, including people displaced by the explosion without any injury or exposure; extensive self-evacuation is likely to be observed at these sites; these may occur in the LD zone and beyond

The locations of the RTR sites will be compatible with the infrastructure damage, as outlined in Chapters 1 and 2 and are summarized in Figure 4.1.

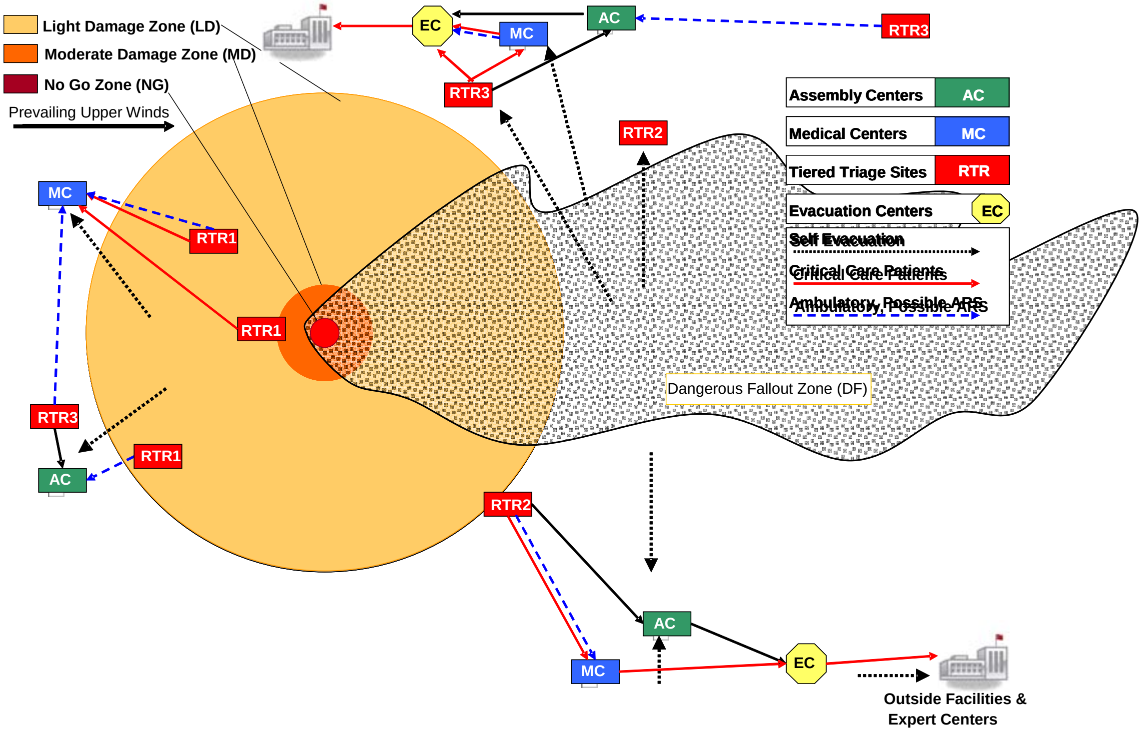


Figure 4.1: The RTR system for a nuclear detonation response; theoretical zones in a 10 KT nuclear explosion at surface level

From the RTR sites victims will be directed and/or transported to appropriate secondary sites as follows: **medical care (MC) sites,** including hospitals, healthcare facilities and alternative care sites for those who need immediate medical care and **assembly centers (AC)** as collection points for displaced persons or those who do not need immediate medical attention. Locations for MC and AC sites will have been largely predetermined as much as possible by an ongoing project at DHHS called MedMap and by the local responders in planning. RTR3 sites will have formed in various locations spontaneously or by direction of the Incident Commander as opposed to preplanned AC sites. From MC sites victims requiring medical care may be sent to medical treatment centers and hospitals nationwide, including the Radiation Injury Treatment Network (RITN - http://www.nmdp.org/RITN/index.html), National Disaster Medical System, Veteran's Administration Hospitals, etc., or to temporary housing using predetermined transportation hubs. Major transportation hubs may include airports, seaports, railroad stations, and designated highway and other road routes. Victim flow will be mainly away from the incident although many people not too far from the incident should remain safely in their buildings. At all RTR, MC and AC sites, efforts will be made to track victims and evacuees as they are moved to MC or AC sites nearby or transported to appropriate destinations regionally and nationally.

The presence of radiation will limit the time that responders can spend at various RTR 1 and 2 locations. A radiation event differs substantially from a non-radiation mass casualty event because of the presence of radiation and the time limit for responders to be within radiation areas. The Department of Homeland Security (DHS) Planning Guidance (DHS 2008) includes time limitations based on the lifetime risk of an exposed person developing a radiation induced cancer, but the decision to enter the zone will be made by the Incident Commander and responders. Planning for response in elevated radiation environments is strongly suggested.

Initial Mass Casualty Triage (i.e., Sorting)

Initial mass casualty triage, also known as sorting, should not be confused with follow-on clinical triage for more specific medical management. There are several established triage systems for a mass casualty events, typically related to trauma, but there are, at present, no USG or internationally agreed upon medical triage systems overlaying radiation issues onto mass casualty trauma categories expected from a nuclear detonation. The Department of Defense (DOD) has done extensive triage planning, some of which is accessible in various documents. The DOD effort serves as an important underpinning for developing a civilian response and has been used by Waselenko and coauthors to assess how radiation may affect the triage of trauma victims (Waselenko and coauthors 2004).

Initial mass casualty triage, also known as sorting, should not be confused with follow-on clinical triage for more specific medical management.

There is as yet no established USG interagency medical triage system specifically validated for an urban nuclear detonation; therefore, existing emergency triage algorithms are used with modification for the impact of radiation.

Recently, a major consensus meeting on mass casualty triage in the US resulted in the publication: "*Mass casualty triage: an evaluation of the data and a proposed national guideline*" (Lerner and coauthors 2008). Based on extensive review of the various systems, this committee proposed a new five-category mass casualty triage system called SALT (Sort, Assess, Life-Saving Intervention (LSI), Treatment and/or Transport). This new system was quickly endorsed by several major US professional societies with expertise in emergency medicine. It must be emphasized that a modified SALT algorithm (or any of the other standard triage algorithms) would be necessary for a nuclear detonation because it may be the ambulatory and responsive victims that would take priority over those with more obvious serious injury because of scarce resources.

The military has traditionally used a mass casualty triage system entitled DIME: Delayed, Immediate, Minimal and Expectant, which includes four of the categories of the SALT (DOD 2003). DOD has developed a triage system for a nuclear detonation such that a future mass casualty triage and treatment approach for an nuclear detonation that is under development would include structure and content from both SALT and DIME.

A landmark series of papers recently addressed how mass casualty planning and resource allocations must address scarcities of “staff, space and stuff” (Chest series and Kaji and coauthors 2006) for pandemic flu. The papers addressed exactly how “optimal care algorithms” would change when resources become progressively more scarce. Similar issues surely need to be addressed for a nuclear detonation as well.

To address the extraordinary complexity of triage and treatment of potentially hundreds of thousands of patients following a nuclear detonation, DHHS is convening a multi-specialty expert group in 2009 with the goal of creating recommendations for national medical planning. Any new or modified triage system suggested will need to account for complexities related to ranges of severity for the following:

- Conventional injury categories (trauma and burns)
- Radiation (alone and/or as part of combined injury)
- Scare resources [staff, stuff, and space (Kaji and coauthors 2006)] and how resource availability and treatment effect triage
- Importance of life-saving interventions including mitigation for acute radiation syndrome that will impact the triage category
- Co-morbidities and special needs in the civilian population

Any new mass casualty radiation triage system must be flexible enough to reflect new medical countermeasures and deployed field technologies and procedures. Optimally any new system should provide responders with easily understood and implementable algorithms that would be available and adaptable on REMM.

The following discussion provides planners with a sense of the current state of the art and science of radiation mass-casualty triage, including information from SALT, scarce resources, and the DOD. The medical care chapter of this first edition planning guidance will be modified significantly over the next year as a result of the progress being made in the following:

- Establishing standard terminology, victim coding, and a response algorithm (such as SALT) for a mass casualty event
- Developing guidance and linking medical response to availability of resources
- Access to a nuclear detonation triage and casualty planning systems developed by the DOD that have potential application to a civilian event.

The SALT system (Figure 4.2) refers to mass casualty triage in general (i.e., mostly trauma). It uses common terminology for triage categories and places them in a five category and color system, adding grey for expectant (Lerner and coauthors 2008).

Figure 4.2 below is included to only illustrate the general organization of mass casualty triage. The nuclear detonation algorithm to be developed in future work will use the general concepts behind SALT (Lerner and coauthors 2008), DIME (DOD 2003) and the DHHS 2009 effort previously described. In Figure 4.2, S is for initial sorting; A is for individual assessment in that the initial sorting may misclassify a person; and LSI is for life-saving intervention (if appropriate). The LSI for a nuclear detonation response could include mitigation of hematopoietic ARS. A triage category is then assigned to one of the 5 categories- Minimal, Delayed, Immediate, Expectant or Dead. Patients then undergo treatment and transport (represented by T). This is presented only as an example of how SALT is used for mass casualty events. A nuclear detonation-related SALT system will have radiation specific interventions and the sorting and triage will depend on the scarcity of resources.

SALT Color Codes

The logic for this specific system and for the use of the grey color for expectant is: “Unlike the other triage categories (i.e., immediate = red, delayed = yellow, minimal = green, and dead = black), the color designation for expectant patients is not common among the existing mass casualty triage systems. Some systems use the color blue; however, that may potentially lead to confusion because blue also has been used to designate patients who need decontamination. In an effort to reflect the fluid nature of this category and to have a distinct color associated with it, the committee selected grey” (Lerner and coauthors, 2008)

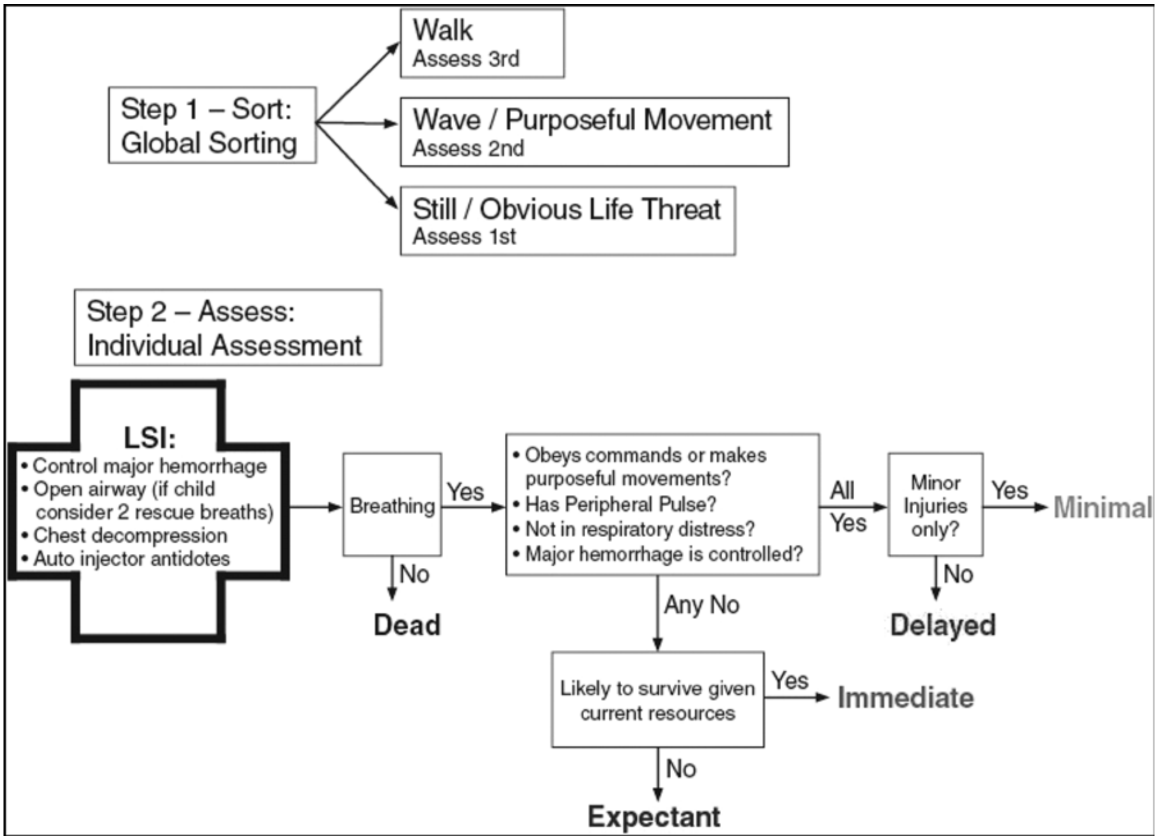


Figure 4.2: Illustrates the steps in the SALT system for mass casualty triage (Lerner and coauthors 2008).

Data on the impact combined injuries have on survivability are limited. However, because of the detrimental effect on the hematological systems (blood cells and immune systems) it is likely that whole body radiation doses above 200 rad (2 Gy) will have a substantial negative impact on survival of patients with significant burn or blast injuries. Additionally, the size of a nuclear detonation and availability of resources and expert care would dictate what treatment would be administered and who might move into the palliative or expectant category (Waselenko and coauthors 2004). Medical management for radiation effects includes drugs for both mitigation of subsequent medical deterioration and treatment. Effective mitigation for ARS that would make fatal injuries survivable by preventing or reducing the serious deterioration in the hematological and immune systems would become a LSI. Similar advances may be possible for the dermatological and gastrointestinal syndromes using drugs or cell-based therapies under investigation. Standard supportive care is perhaps the most important medical intervention and the degree of scarcity of resources will certainly be a critical factor in supportive care decision-making. The scarcity of resources will be extraordinarily variable as one moves away from the zones immediately surrounding ground zero to facilities miles away and then further to facilities around the nation. Therefore, a given set of medical circumstances for a victim would lead to a different triage category, which must be considered as SALT or any other system is applied.

The military DIME system (DOD 2003) includes Delayed, Immediate, Minimal and Expectant categories, SALT adds a fifth category, “Dead”, and includes “Individual Assessment”. Because the civilian population has a much wider range of individuals including co-morbidity and special populations, the individual assessment will be more complex. Additionally, the spectrum of injuries will likely differ between a tactical nuclear explosion in a battlefield situation compared to a nuclear explosion within a city.

The DIME categories for a nuclear explosion are defined in the following grey box material for the DOD (courtesy of AFRRI). As noted, the DOD nuclear casualty planning factors are based on a young healthy adult population. The more detailed triage system to be developed by the consensus group to be convened by DHHS in 2009 will include specifics such as percentage of burns, radiation dose, and medical countermeasures and will take into account the scarcity of resources. Note that enhanced availability of resources may remove victims from the expectant category.

DoD DIME Triage for Early Nuclear Casualty Assessments and Planning (Adapted from FM 4-02.283 (DOD 2001) and unpublished DoD reports courtesy of AFRRI) (NOTE: The DoD text below was not designed for use by civilian clinicians. Future work by the USG Interagency is expected to yield civilian-specific information on nuclear casualty planning factors and early nuclear triage assessments)

DIME: D = Delayed, I = Immediate, M = Minimal, and E = Expectant

Triage decisions and classifications for nuclear victims differ from conventionally injured patients and must consider physical injury and radiation exposure. The first step in triage is based primarily on the presentation of conventional injuries and is then modified by radiation injury level. That is, triage and care of any life-threatening injuries should be rendered without regard for the probability of radiation exposure or contamination. Medical personnel must also make a preliminary diagnosis of radiation injury based on those who display the appropriate radiation exposure symptoms, such as nausea, vomiting, diarrhea, hyperthermia, and so forth but also on assessment of their potential exposure based on history, physical location during the event and initial laboratory assessment when possible because **early intervention for those at risk for ARS can effect their ultimate triage category and outcome**. Many of the victims that can benefit from early ARS mitigation will come from the Dangerous Fallout Zone and may have no or only very minor physical injury. Understanding the types of casualties that will receive early triage is also useful in response planning. So both casualty assessments and planning factors are provided for the DIME method of triage codes with the very important caveats that the DoD uses nuclear casualty planning factors designed for young healthy adults and that the spectrum of injuries for civilian IND events is not yet fully determined.

Delayed group (D).

Early Casualty Assessment: Those needing surgery, but whose conditions permit delay without unduly endangering safety. Life-sustaining treatment such as intravenous fluids, antibiotics, splinting, catheterization, and relief of pain may be required in this group. Examples are fractured limbs, spinal injuries, and uncomplicated burns, and all casualties with only radiation injury who do not exhibit gross neurological symptoms. NOTE: Early wound closure for patients with doses above 100-200 rads (1-2 Gy) will improve outcomes. Consequently, combined injury patients become the highest priority immediately after those requiring life or limb-saving surgery.

Casualty Planning Factors: Nuclear casualties in this group are generally those suffering injury that requires professional medical treatment but that is not immediately threatening to life, limb or sight. These injuries include lacerations without extensive hemorrhage, closed fractures, first degree burns covering a moderate to large Body Surface Area (BSA), second degree burns covering a small BSA (perhaps in the 5 to 15% BSA range), and third degree burns covering a very small BSA (perhaps in the 1 to 5% BSA range). Also in this category are patients with moderate to high radiation dose in the 200-600 rads (2-6 Gy) range that have either minimal or no other injuries.

DoD DIME Triage for Early Nuclear Casualty Assessments and Planning (Adapted from FM 4-02.283 and unpublished DoD reports; Courtesy of AFRRI) - continued

DIME: D = Delayed, I = Immediate, M = Minimal, and E = Expectant

Immediate group (I).

Early Casualty Assessment: Those requiring immediate lifesaving surgery. Procedures should not be time-consuming and should concern only those with a high chance of survival, such as respiratory obstruction and accessible hemorrhage. Pure radiation injury is not acutely life-threatening unless the irradiation is massive. If a massive dose has been received, then the patient is classified as expectant (E). NOTE: Early wound closure for patients with doses above 100-200 rads (1-2 Gy) will improve outcomes.

Casualty Planning Factors: Nuclear casualties in this group are generally those suffering serious injury that requires prompt professional medical treatment to save life, limb or sight. These injuries include hemorrhage to a readily accessible site, multiple lacerations, correctable mechanical respiratory defects, fractures of long bones, crushed extremities, incomplete amputations, fractured skull or spine, ruptured internal organ, second degree burns covering a moderate BSA (perhaps in the 15 to 50 % BSA range), and third degree burns covering a small to moderate BSA (perhaps in the 5-25% BSA range).

Minimal group (M).

Early Casualty Assessment: Those with relatively minor injuries who can be helped by untrained personnel, or who can look after themselves, such those who have minor fractures or lacerations. Buddy care is particularly important in this situation. Patients with radiological injury should have all wounds and lacerations cleaned meticulously and then closed.

Casualty Planning Factors: Nuclear casualties in this group are generally those that suffer nonincapacitating injury that requires some kind of medical treatment. Nonincapacitating injuries imply limited lacerations, contusions, concussions, eardrum rupture, first degree burns to a moderate to large BSA (perhaps less than 50% BSA), second degree burns covering a small BSA (perhaps less than 5% BSA), very small third degree burns (perhaps less than 1% BSA), or mild to moderate radiation exposure (roughly 75 to 200 rads or 0.75 to 2 Gy) that may result in mild nausea, anorexia or fatigue four or more hours after being exposed. This initial triage category aligns with the early "treat-and-release" patient load.

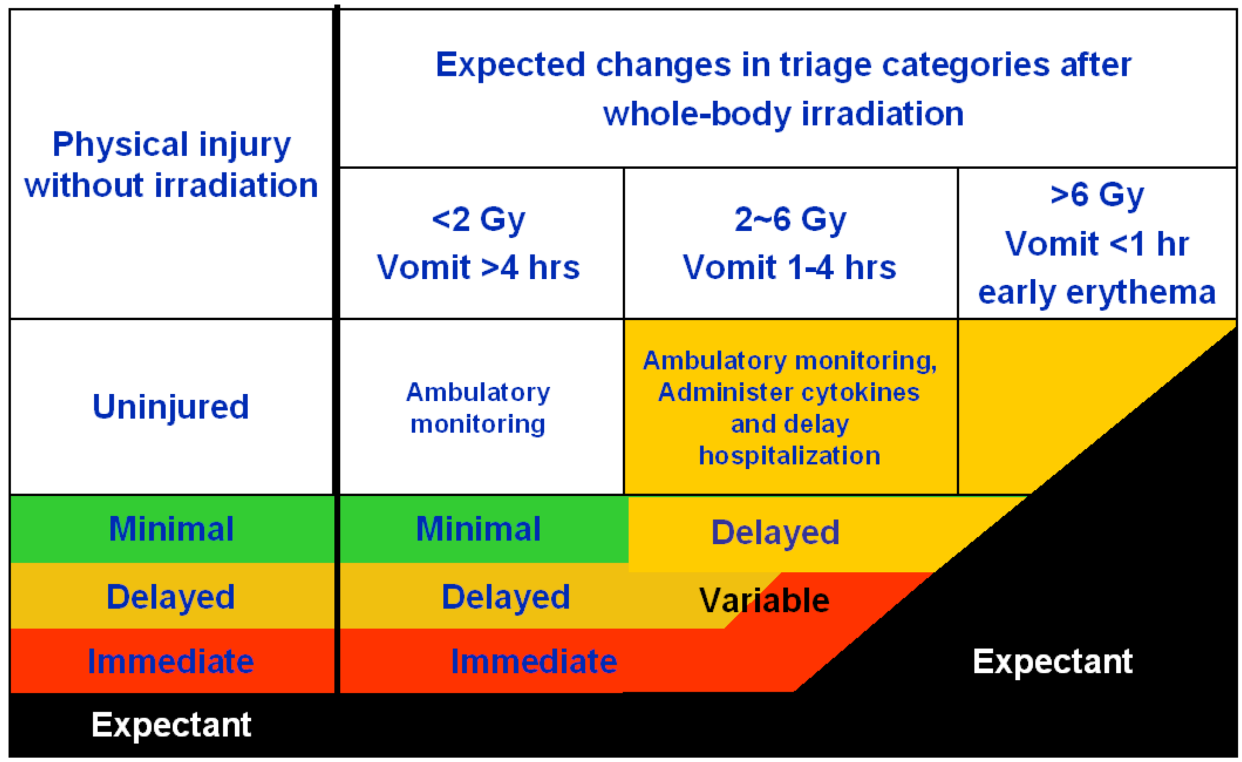
Expectant group (E).

Early Casualty Assessment: Those with serious or multiple injuries requiring intensive treatment, or with a poor chance of survival. These patients receive appropriate supportive treatment compatible with resources, which will include large doses of analgesics as applicable. Examples are severe head and spinal injuries, widespread burns, or neurological symptoms from massive doses of radiation. These casualties may be removed from this category as additional medical assets become available.

Casualty Planning Factors: Nuclear casualties in this group are generally those that suffer from obvious injuries to the respiratory and central nervous system, significant penetrating abdominal wounds, multiple severe injuries, second degree burns covering a large BSA (perhaps more than 50 % BSA), and third degree burns covering a moderate BSA (perhaps in more than 25% BSA), high radiation doses that result in obvious cerebrovascular dysfunction or vomiting within one hour of being exposed.

Figure 4.3 below illustrates the following concepts:

- How radiation can impact triage categories
- Importance of appropriate early intervention for radiation mitigation of ARS



Physical injury without irradiation	Expected changes in triage categories after whole-body irradiation		
	<2 Gy Vomit >4 hrs	2~6 Gy Vomit 1-4 hrs	>6 Gy Vomit <1 hr early erythema
Uninjured	Ambulatory monitoring	Ambulatory monitoring, Administer cytokines and delay hospitalization	
Minimal	Minimal	Delayed	
Delayed	Delayed	Variable	
Immediate	Immediate		Expectant
Expectant			

Figure 4.3: Illustrates how radiation can impact triage category and the importance of appropriate early intervention for radiation mitigation of ARS (courtesy of AFRRI).

Emergency Care

For managing mass nuclear casualties with blast and thermal injuries, the focus is first to provide only emergency medical care and essential surgical procedures. Expect a setting of resource constraints to extend for several days. Time consuming procedures must be deferred initially in order to direct attention to many others that can be saved. **Current recommendations are that all wounds should be closed within 36 to 48 hours for patients with doses above 1-2 Gy**. If this is not possible, wound closure should be delayed until hematopoietic recovery is evident although newer approaches to care of immunosuppressed patients may alter this recommendation.

Although doses in the higher ranges [500-800 rad (5-8 Gy)] are most often fatal within six weeks, nearly all of these patients will exhibit a latency (asymptomatic) period of days to weeks immediately following their initial symptoms. Finding opportunities to provide definitive care, to include treatment during the latency period, will improve survival rates among these patients. Currently available data indicate that to mitigate the acute hematological syndrome, drug treatment with cytokines is recommended for the >2 Gy dose range and should be administered within 24 hours. In general, experts in hematology and oncology are involved in medical management as the cause of morbidity and death is usually a result of sepsis and bleeding days to weeks following exposure, similar to that seen in cancer treatment. Note that cytokines are not of benefit to people with lower doses (<2Gy) and would take resources from those who need it. Thus, cytokines must not be used without clinical indication. Also, regardless of whether or not cytokines are available, supportive care alone will increase survivability to as much as 50% for patients with ARS. Supportive care includes fluids, cytokines, antibiotics when needed. Overall supportive care is the most important aspect of victim management. Additional details are on the REMM website (http://www.remm.nlm.gov).

The currently used US follow-on clinical triage and medical management system is dose-based, recognizing that there will be heterogeneity in exposure, dose-rate, combined injuries and special populations (e.g., age, co-morbid diseases, etc). To estimate dose, the use of medical history, physical dose reconstruction (location during the event), dose-plots such as those from Interagency Modeling and Atmospheric Assessment Center (IMAAC) and on-site measurement, and blood studies will be used. The latter includes complete blood counts (CBCs) and cytogenetic biodosimetry. Research is being done to develop technologies for high throughput screening.

Referral to Expert Centers

Following the initial sorting and the subsequent identification of those either already with manifestations of ARS or at risk for developing it over days to weeks, medical management will require highly specialized expertise. The medical specialties most familiar with diseases that require similar treatment to ARS are hematology, medical oncology, and radiation oncology. The Radiation Injury Treatment Network (http://www.nmdp.org/RITN/) is working with DHHS and also with international partners to develop medical management protocols (REMM - http://www.remm.nlm.gov.). As noted above, the current US clinical triage and medical management system at tertiary care centers (e.g., bone marrow transplant and cancer centers) for managing radiation patients is dose-based. While specific organ syndromes are usually noted (e.g., hematological, gastrointestinal, dermatological and central nervous system), victims will have some degree of multi-system injury so that medical management will be both algorithm-based and individualized. Tertiary care may be done with international partners. In Europe, a tertiary triage and management system has been developed based on organ system dysfunction, which is presented here as an example for consideration by planners (Fliedner and coauthors 2001). Aspects of both dose-based and organ-dysfunction are mutually compatible and subject matter experts are working to further harmonize the medical management approaches.

METREPOL: This approach is an example of the European system (Medical Treatment Protocols) for radiation casualty triage at tertiary care centers. The METREPOL system for radiation management depends on medical signs and symptoms and requires serial analysis to determine the ultimate response category (1-4) for each of the four systems (H for hematological, G for gastrointestinal, N for neurovascular, and C for cutaneous); see Figure 4.4). This current system is not based on radiation dose but on clinical manifestations. Figure 4.4 illustrates how the METREPOL response category based system could be used for triage. It is emphasized that this system is intended for limited size events such as industrial accidents and the applicability to the initial triage at a nuclear detonation is limited. However, once victims are under the care of medical experts, the METREPOL system could be employed to refine the initial triage category and treatment plans

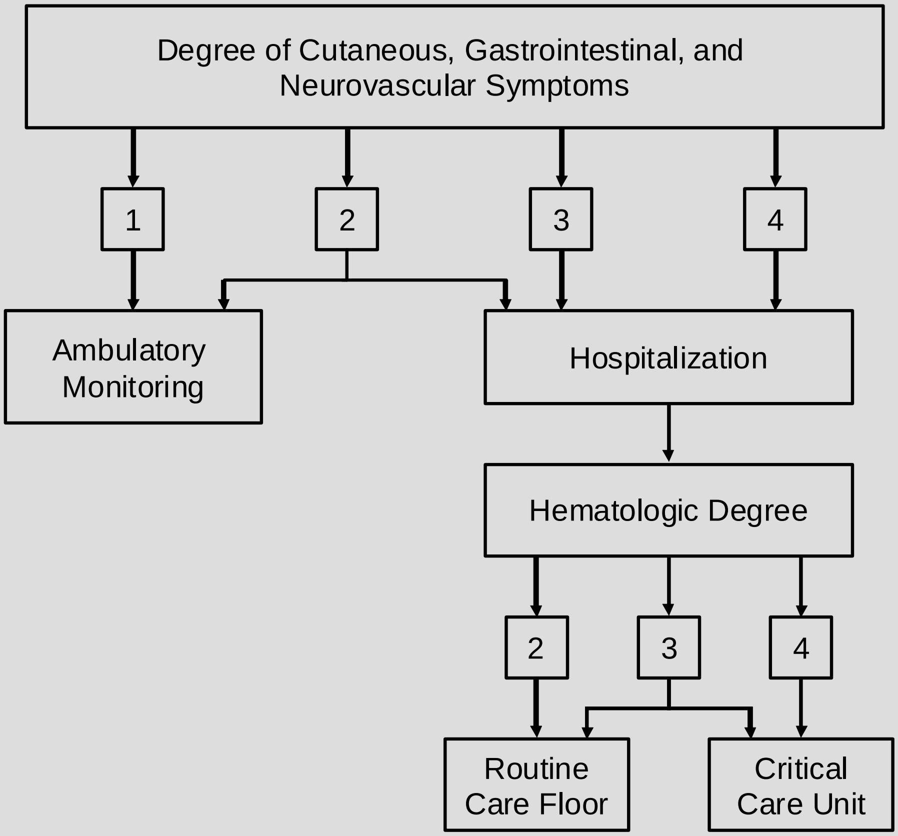


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Figure 4.4: METREPOL response category based system (Fliedner and coauthors 2001)

Fatality Management

In a nuclear detonation, fatality management may be one of the most demanding aspects of the incident response, and the way it is executed will have a direct impact on the recovery of the community and the nation. The catastrophic significance of a nuclear detonation is quickly understood through the number of casualties it produces, including fatalities. Fatalities from the detonation can come about in essentially two ways: (1) those who are promptly killed by the blast, and possibly vaporized; and (2) those who die from mortal wounds later, either in the field or in the care of emergency personnel. This second group includes the "walking dead" and its effect should not be underestimated because it is likely that large numbers of people directly affected by the blast or fallout who would seemingly benefit from medical intervention are in fact expectant resulting from their combined injuries or radiation exposure. The quantity and phenomenon of "walking-dead" were not understood in the Hiroshima atomic bomb attack because large numbers of people died after varying latency periods following the detonation. Because of the potentially high number of deceased persons produced by a nuclear detonation, there is a complexity that stems from the overwhelming numbers of bodies versus the scarce resources available to manage them and our national values that lead us to respect the traditions of the deceased. This dichotomy means fatality management has the potential to become one of the most demanding aspects of the nuclear detonation response because of the concerns of respect for the deceased versus capability limitations to provide these gestures. Incident commanders must consider means to fairly accommodate public expectations while efficiently and appropriately handling human remains in a way that is consistent with their capabilities.

While fatality management is a very significant concern, it is also important to note that in the first 72 hours of the response, which is the time frame covered by this guidance, the processing of the deceased will likely not be a priority in lieu of saving lives. However, personnel in the field and in definitive care centers, assembly centers, etc. must have an option for handling persons who die in their care. Because bodies in the field do not pose a significant biohazardous threat to response personnel (Morgan 2004), it is not necessary to immediately begin fatality management operations. The main priority should be saving lives. When fatality management becomes a feasible operational capability, a few days after the response, incident commanders should consider the following:

1. Determine capabilities (e.g., personnel, equipment, supplies)
2. Develop a strategy for proper identification and respectful handling of the deceased victims including transport, storage, and disposition in the context of the available capabilities
3. Strive to keep cross-contamination to a minimum including the use of radiation monitors (DHHS 2008b)
4. Develop and disseminate a public communications strategy that outlines the efforts to respect the bodies and discusses the outcomes of the body handling, especially where survivors will not be able to recover family members who are deceased and contaminated, or unidentifiable

The Centers for Disease Control *Guidelines for Handling Decedents Contaminated with Radioactive Materials (Centers for Disease Control)* details points for consideration to appropriately manage remains. Additionally the *Mass Fatality Management for Incidents Involving Weapons of Mass Destruction* (DOD 2005) and Joint Publication 4-06, *Mortuary Affairs in Joint Operations*, (DOD 2006), provide guidance that primarily focuses on chemical, biological, and nuclear detonations, and may be useful for planners as well. However, DOD doctrine may not always be applicable to civilian planning and should be considered appropriately.

In summary, fatality management will be one of the most demanding aspects of the nuclear detonation response, because:

- There will be an overwhelming need for immediate care for those who can be treated
- Many people who are expectant will live for a period of time and then die
- Concerns of respect for the deceased versus limited capability to provide these gestures

For the time frame covered by this guidance processing of the deceased will likely not be a priority in lieu of saving lives; however, fatality management will be one of the most demanding aspects of the nuclear detonation response and should be planned for as early as possible.

Additional Resources

REMM: A comprehensive set of medical management guidelines is available at the Radiation Event Medical Management (REMM) website (http://www.remm.nlm.gov). **Emergency Room and other medical response assets should download REMM and join the Listserve.** The REMM system was created in collaboration between the National Library of Medicine and DHHS, with input from subject matter experts worldwide. REMM provides radiation, algorithms for medical evaluation and management. Detailed support information can be readily updated as new information becomes available, assuring just-in-time and up-to-date information for medical personnel. REMM is available online as a download to a laptop or other computer, and as a PDA.

In addition to REMM, the AFRRI Medical Management of Radiological Casualties Handbook, the **AFRRI Emergency Radiation Medicine Pocket Guide** (DOD 2008), the AFRRI Biodosimetry Assessment Tool and a few other useful and free products are available for download at www.afrri.usuhs.mil. As well, the Centers for Disease Control and Prevention (CDC) (http://www.bt.cdc.gov/radiation) and the Radiation Emergency Assistance Center/Training Site (REAC/TS) (http://orise.orau.gov/reacts) websites address several key aspects of radiological emergencies.

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Chapter 5 – Population Monitoring and Decontamination

KEY POINTS

1. Radiation survey methods, screening criteria used for radiation screenings, and decontamination guidance or services offered or recommended should be adjusted to reflect the prioritized needs of individuals and availability of resources at any given location.
2. Identification of individuals whose health is in immediate danger and require urgent care is the immediate priority of any population monitoring activity.
3. The primary purpose of population monitoring, following a nuclear detonation, is detection and removal of external contamination. In most cases external decontamination can be self performed, if straightforward instructions are provided.
4. Prevention of acute radiation health effects should be the primary concern when monitoring for radioactive contamination.
5. Population monitoring and decontamination activities should remain flexible and scalable to reflect the available resources and competing priorities.
6. Radioactive contamination is not immediately life threatening.
7. Self-evacuating individuals will require decontamination instructions to be communicated to them in advance of the event (e.g., public education campaign) or through post-event public outreach mechanisms. Instructions should be provided with consideration of languages appropriate for the affected community.
8. Planning must provide for consideration of concerned populations because it is anticipated that a significant number of individuals, who should remain safely sheltered, will begin to request population monitoring to confirm that they have not been exposed to radiation.
9. Use of contaminated vehicles (e.g., personal or mass transit) for evacuation should not be discouraged in the initial days following a nuclear detonation; however, simple instructions for rinsing or washing vehicles once decontamination can be achieved without impeding evacuation should be provided.
10. There is no universally accepted threshold of radioactivity (external or internal) above which a person is considered contaminated and below which a person is considered uncontaminated.
11. State and local agencies should establish survivor registry and locator databases as early as possible. Initially, the most basic and critical information to collect from each person is his or her name, address, telephone number, and contact information.
12. Planners should identify radiation protection professionals in their community and encourage them to volunteer and register in any one of the Citizen Corps or similar programs in their community.

Overview

Population monitoring is the process of identifying, screening, and monitoring people for exposure to radiation or contamination with radioactive materials. Decontamination is the process of washing or removing radioactive materials on the outside of the body or clothing and, if necessary, facilitating removal of contamination from inside the body.

The population monitoring process begins soon after a nuclear emergency and continues until all potentially affected people have been monitored and evaluated as appropriate for the following:

- Needed medical treatment
- Presence of radioactive contamination on the body or clothing
- Intake of radioactive materials into the body
- Removal of external or internal contamination (decontamination)
- Radiation dose received and the resulting health risk from the exposure
- Long-term health effects

Assessment of the first five elements listed above should be accomplished as soon as practical. However, long-term health effects are usually determined through a population registry and an epidemiologic investigation that will likely span several decades, and are beyond the scope of this guidance.

It is important to recognize that early decisions by emergency responders and response authorities related to monitoring for radioactivity and decontamination should be made in the context of the overall response operations. For example, as stated in Chapter 4, survival rates will decrease if evacuation is constrained by policies for nontransportation or acceptance of potentially contaminated patients imposed by ambulance providers and medical facilities. Furthermore, the needs of a displaced population and concerned citizens hundreds of miles away are different from those of the immediate victims near the site of detonation. Therefore, radiation survey methods, screening criteria used for radiation screenings, and decontamination guidance or services offered or recommended should be adjusted to reflect the prioritized needs of individuals and availability of resources at any given location.

> Radiation survey methods, screening criteria used for radiation screenings, and decontamination guidance or services offered or recommended should be adjusted to reflect the prioritized needs of individuals and availability of resources at any given location.

The recommendations in this chapter are derived from the Department of Health and Human Services (DHHS) Centers for Disease Control and Prevention (CDC) publication *"Population Monitoring in Radiation Emergencies: A Guide for State and Local Public Health Planners"* (http://emergency.cdc.gov/radiation/pdf/population-monitoring-guide.pdf) (DHHS 2007). The relevant portions of the CDC guidance are summarized here; however, readers are referred to that document in its entirety for more information.

Primary Considerations

There are several priority considerations that should be applied in any radiation emergency, especially in a nuclear emergency where life-threatening conditions exist for a potentially large number of individuals.

1. **Identification of individuals whose health is in immediate danger and require urgent care is the immediate priority of any population monitoring activity.** Near the incident scene, this monitoring need is accomplished as part of the medical triage already described in Chapter 4. Management of serious injury takes precedence over radiological decontamination.

2. **The primary purpose of population monitoring, following a nuclear detonation, is detection and removal of external contamination. In most cases external decontamination can be self performed, if straightforward instructions are provided.** There are two types of decontamination. External decontamination removes fallout particles and other radioactive debris from clothes and external surface of the body. Internal decontamination, if needed, requires medical treatment to reduce the amount of radioactivity in the body.

3. **Prevention of acute radiation health effects should be the primary concern when monitoring for radioactive contamination.** Population monitoring personnel should offer or recommend gross external decontamination, such as brushing away dust or removal of outer clothing. Cross-contamination issues (e.g., from transport vehicles) are of secondary concern, especially in a nuclear emergency where the contaminated area and the potentially impacted population are large.

4. **Population monitoring and decontamination activities should remain flexible and scalable to reflect the available resources and competing priorities.** For example, if water is a scarce commodity or is needed to fight fires, dry methods can be used for decontamination. Moist wipes can be used to wipe the face and hands in addition to a change of outer clothing. Instead of pouring water as in a shower, small amounts of water can be used to wet paper towels and clean the skin.

5. **Radioactive contamination is not *immediately* life threatening.** Individuals who are self evacuating may be advised to self decontaminate. Suggestions for monitoring and decontamination in this chapter assume radioactivity is the only contaminant, and that there are no chemical or contagious biological agents present.

Identification of individuals whose health is in immediate danger and require urgent care is the immediate priority of any population monitoring activity.

The primary purpose of population monitoring, following a nuclear detonation, is detection and removal of external contamination. In most cases external decontamination can be self performed, if straightforward instructions are provided.

Prevention of acute radiation health effects should be the primary concern when monitoring for radioactive contamination.

Population monitoring and decontamination activities should remain flexible and scalable to reflect the available resources and competing priorities.

Radioactive contamination is not immediately life threatening.

Impacted Population

Victims who may be suffering from severe burn and trauma injuries are addressed in Chapter 4. Evacuating those critical patients away from the scene should not be hindered by lengthy or restrictive decontamination and transport policies. People who are not critically injured may fall into four broad categories that can be linked with general decontamination considerations as follows:

1. **Individuals who self evacuate from the affected and surrounding areas and who are not under the direction of emergency response officials —** These are individuals who self evacuate before emergency responders arrive. Even after responders arrive, there may not be sufficient responders to direct all of the individuals who may continue to self evacuate. For this group of individuals, responders will not have an opportunity to provide on-the-scene decontamination assistance before they leave the area. Decontamination instructions will need to be communicated to these individuals in advance of a nuclear detonation (e.g., public education campaign) or through post-event public outreach mechanisms. Some of these individuals may go directly to hospitals or seek care in public shelters.

2. **Individuals who leave the affected areas under the direction of emergency response officials —** These are people leaving the immediate impact zone (e.g., moderate damage (MD) or light damage (LD) zones) of the incident may require assistance from responders to evacuate (e.g., search and rescue, emergency medical service). Some people may be able to leave unassisted but will be part of an organized immediate evacuation. Responders will need to make decontamination decisions regarding these individuals. As stated earlier, these decisions must be made in the context of the overall response effort and reflect the prioritized needs of the evacuating individuals and available resources.

3. **Individuals who initially sheltered, both in the immediate impact area as well as in the fallout zone, then evacuate as part of an organized evacuation** — As in the previous category, these individuals will be dependent on responders to make and communicate decontamination decisions.

4. **Individuals who are in the surrounding area of the detonation, have not received an evacuation notice, but who are concerned about possible contamination and seek screening from public officials to confirm that they have not been exposed** — These individuals may report to hospitals or public shelters. This group could represent a significant number of individuals and planners will need to ensure they adequately address this group's concerns. Community reception centers, as described in CDC's publication "*Population Monitoring in Radiation Emergencies: A Guide for State and Local Public Health Planners*," recommend an infrastructure to address the needs of this population, as well as those of the displaced population reporting to reception centers (DHHS 2007).

Self-evacuating individuals will require decontamination instructions to be communicated to them in advance of the event (e.g., public education campaign) or through post-event public outreach mechanisms.

Planning must provide for the consideration of concerned populations because it is anticipated that a significant number of individuals, who should remain safely sheltered, will begin to request population monitoring to confirm that they have not been exposed to radiation or contaminated with radioactive materials.

The public may self evacuate using personal vehicles that may be contaminated. Although this evacuation may result in the spread of some contamination, such actions should not be discouraged during the initial days following a nuclear detonation. Simple rinsing or washing of vehicles in a common location before or after use should be considered; however, these actions should be implemented so that they do not restrict or inhibit necessary evacuations. The public should be directed to rinse or wash down vehicles as soon as practical once they are out of danger. In communities where people do not speak English as their primary language, instructions should be provided in languages appropriate for the affected community. At later times following the detonation, more detailed instructions should be provided along with protective action guidance basing mitigation measures on potential for contamination, dose, and residual risk.

If public mass transportation (e.g., rail, bus) is used to evacuate individuals from contaminated areas, the vehicles should be surveyed and controlled, to the extent practical, to minimize the potential for contaminating land and people. During the early phase, simple rinsing or washing of mass transit equipment in a common location before or after use should be considered; however, these actions should be implemented in a manner so they do not restrict or inhibit necessary evacuations. If there is a potential that these simple protective actions will inhibit needed evacuations then they should be delayed.

Use of contaminated vehicles (e.g., personal or mass transit) for evacuation should not be discouraged in the initial days following a nuclear detonation; however, simple instructions for rinsing or washing vehicles once this can be achieved without impeding evacuation should be provided.

External Contamination

The first step in external monitoring is to check people for radioactive contamination on their bodies and clothing. Note that detailed radiological surveys are not necessary and initial screenings for external contamination can be done in a matter of seconds by trained professionals using proper radiation detection instruments. Depending on the situation, and if adequate staff and decontamination resources are available, more restrictive radiological screening criteria may be used.

There is no universally accepted level of radioactivity (external or internal) above which a person is contaminated and below which a person is uncontaminated at a ‘safe’ level. A discussion of key considerations in a selecting a contamination screening criterion and a number of benchmark screening criteria are described and referenced in Appendix C of the CDC population monitoring guide (DHHS 2007). Screening values may also be found in other agency documents such as Federal Emergency Management Agency (FEMA)-REP-21 (1995) and FEMA-REP-22 (2002), National Council on Radiation Protection (NCRP) Commentary 19 (2005), International Atomic Energy Agency (IAEA) (2006), and Conference of Radiation Control Program Directors (CRCPD) (2006) (DHS 1995; DHS 2002; NCRP 2005; IAEA 2006; CRCPD 2006), as well as military manuals.

There is no universally accepted threshold of radioactivity (external or internal) above which a person is considered contaminated and below which a person is considered decontaminated.

As uncontaminated people are referred to discharge stations and contaminated people to washing (decontamination) stations, care must be taken not to co-mingle contaminated and uncontaminated people while making sure families are not separated. Wrist bands or similar tools can be used to distinguish people who have been cleared through decontamination.

It would be prudent to assume that most people will be able to self decontaminate, but provisions for those who cannot, such as people using wheelchairs or people with other disabilities, must also be made. A best practice during the decontamination process would be to determine if parents can assist their children with washing. For people who do not have wounds, direct them to perform the following actions:

- Remove contaminated clothes and place them in a bag
- Wash with warm water

- Use the mechanical action of flushing or friction of cloth, sponge, or soft brush
- Begin with the least aggressive techniques and mildest agents (e.g., soap and water)
- When showering, begin with the head and proceed to the feet
- Keep materials out of eyes, nose, mouth, and wounds; use waterproof draping to limit the spread of contamination
- Avoid causing mechanical, chemical, or thermal damage to skin

Use of pumper fire truck systems for mass decontamination (Capitol Region Metropolitan Medical Response System 2003), although effective in decontaminating large numbers of people at a hazardous materials scene, is not necessary and may not be even advisable when other decontamination methods are considered. If water resources are scarce or not available, a change of outer clothing or carefully brushing off the fallout dust can significantly reduce exposure. When cold temperatures or poor weather conditions exist, the use of water-based decontamination techniques may not be advisable. Furthermore, firefighting resources may be more urgently needed to fight fires or to conduct search and rescue operations.

To the extent possible, responders should take reasonable measures to control the spread of contamination from runoff or solid waste generated by decontamination activities. However, these control measures should not slow down or delay the processing of contaminated individuals or contaminated vehicles leaving the impacted area to address imminent threats to human life or health. Addressing people's needs and facilitating their decontamination or evacuation to protect human life or health takes priority (EPA 2000).

People with wounds must be directed to a medical treatment facility or to a designated medical triage station, if established. Supporting response organizations should be prepared to provide for the security of the designated monitoring, decontamination, and staging areas as well as items of personal value.

Internal Contamination

Internal contamination is radioactive material that has entered the body through, for example, ingestion or inhalation, or through a wound. In a nuclear detonation scenario, a radiation dose received from internal contamination will not be a major concern relative to burn and traumatic injuries received or relative to potentially large external radiation doses from prompt radiation or nuclear fallout. However, there is potential for internal contamination and regardless of how significant or insignificant it may be, internal contamination can be a source of anxiety and concern for the public. After all, while people can self decontaminate themselves from external contamination, any internal contamination stays with them and does not go away quickly.

While certainly not an immediate priority, following a nuclear detonation, having accurate information about the levels of internal contamination is important in deciding whether medical intervention is warranted (see www.remm.nlm.gov for more information). The methods and equipment needed for assessing internal contamination are more advanced than the equipment required to conduct external monitoring. Collectively, internal contamination monitoring procedures are referred to as "bioassays," and in general these bioassays require off-site analysis by a clinically certified commercial laboratory or hospital. Although some results will be available quickly, monitored individuals should be advised that depending on the size of the population monitored and the radionuclides involved, it may be some time, perhaps weeks or months, before all results are available. Knowledge of the physical location of the individuals during the incident or the extent of external contamination on their bodies prior to washing can be helpful indicators of the likelihood and magnitude of internal contamination. However, laboratory results can provide definitive information, especially in the case of alpha-emitting radionuclides.

Registry – Locator Databases

State and local agencies should establish a registry system as early as possible. This registry will be used to contact people in the affected population who require short-term medical follow-up or long-term health monitoring. Initially, the most basic and critical information to collect from each person is his or her name, address, telephone number, and contact information. If time permits, other information can be recorded, including the person's location at time of the incident and immediately afterwards and other epidemiological information, but this is not essential and should not become a bottleneck in the registration process. Additional information can be collected later as individuals are processed and evacuated out of the area, sent to shelters or when they report to community reception centers. Extensive resources will be required, and federal agencies, specifically CDC and the Agency for Toxic Substances and Disease Registry (ATSDR), will provide assistance in establishing, coordinating and maintaining this registry. Emergency responders should be registered and monitored through a mechanism provided by their respective employers.

State and local authorities must work with Emergency Support Function #6 (Mass Care, Emergency Assistance, Housing, and Human Services) and the American Red Cross to establish an evacuee tracking database system. This system will assist in promptly locating evacuees, patients, fatalities and any other survivors or displaced persons. Extensive experience from response to hurricanes can be used to meet this need.

State and local agencies should establish a survivor registry and locator databases as early as possible. Initially, the most basic and critical information to collect from each person is his or her name, address, telephone number, and contact information.

Volunteer Radiation Professionals

As stated in the National Response Framework, population decontamination activities are accomplished locally and are the responsibility of local and State authorities (DHS 2008). Federal resources to assist with population monitoring and decontamination are limited and will take some time to arrive. Radiation control staff, employed by local and State governments, are few in number. However, there are tens of thousands of radiation protection professionals across the country that can be tapped into and encouraged to volunteer and register in any one of the Citizen Corps programs in their community (www.citizencorps.gov). Specifically, the Medical Reserve Corps (www.medicalreservecorps.gov) offers a mechanism to recruit and train radiation professionals already in the community who can assist public health and emergency management agencies in population monitoring or shelter support operations. The Emergency System for Advance Registration of Volunteer Health Professionals (ESAR-VHP) is a program to establish and implement guidelines and standards for the registration, credentialing, and deployment of medical professionals in the event of a large scale national emergency. The same infrastructure can be used to recruit and register radiological health professionals (health physicists, medical physicists, radiation protection technologists, nuclear medicine technologists, etc.) for response to a potential nuclear emergency. The ESAR-VHP program is administered under the Assistant Secretary for Preparedness & Response (ASPR) within the Office of Preparedness and Emergency Operations of the Department of Health and Human Services (www.hhs.gov/aspr/).

Planners should identify radiation protection professionals in their community and encourage them to volunteer and register in any one of the Citizen Corps or similar programs in their community.

Mutual Aid Programs

Many States, especially those with nuclear power plants, have established mutual aid agreements with their neighboring and other States to provide assistance in case of a radiation emergency. The Emergency Management Assistance Compact (EMAC) is a Congressionally ratified organization that provides form and structure to interstate mutual aid and addresses key issues such as liability and reimbursement (www.emacweb.org). Through EMAC, a disaster impacted State can request and receive assistance from other member States quickly and efficiently. EMAC has been used effectively to respond to natural disasters, but resources specific to nuclear emergency response has not yet been incorporated into EMAC.

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SubPCC Membership – January 2009

Interagency Members	Department or Agency
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Julie Bentz	Department of Defense, Office of the Deputy Assistant to the Secretary of Defense for Nuclear Matters
David Bowman	Department Of Energy, National Nuclear Security Administration, Office of Emergency Response
Norman Coleman	Department of Health & Human Services, Office of Planning and Emergency Operations, Office of the Assistant Secretary for Preparedness and Response
Donald Daigler	Department of Homeland Security, Federal Emergency Management Agency, Disaster Operations Directorate
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John Mercier	Department of Defense, Armed Forces Radiobiology Research Institute
Patricia Milligan	Nuclear Regulatory Commission, Office of Nuclear Security and Incident Response

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Emily Snyder	Environmental Protection Agency, National Homeland Security Research Center
Colby Stanton	Environmental Protection Agency, Office of Radiation and Indoor Air, Office of Air and Radiation
Thomas Strother	Department of Homeland Security, Federal Emergency Management Agency, Radiological Emergency Preparedness Program
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