APPENDIX C: RADIOLOGICAL INCIDENTS

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Radiological incidents are events that disperse ionizing radiation—often called radioactive fallout—into the atmosphere. Mass casualties and long-term poisoning of the environment are common consequences of radiological incidents.

A characteristic that distinguishes radiation hazards from other disaster hazards (such as floods, hurricanes, or other kinds of explosions) is that radiation cannot be detected by the human senses—only by radiation detection instruments. This characteristic means that to be prepared for radiological emergencies requires a full understanding of radiological events and their effects.

Another distinction between a conventional explosion and one involving radiation is the long-term after-effects—both in terms of health effects suffered by disaster victims and in relation to the disaster site. Whereas rebuilding can begin almost immediately after a conventional blast, the radioactive aftermath of a radiological incident could last many years (perhaps a century, depending on the materials used), leaving a large area essentially uninhabitable and a population (those who survive) burdened with long-term health problems.

A worst-case scenario for a detonation of a "dirty bomb" (described under Methods of Delivery in this appendix) in downtown Manhattan at noon could be expected to cause over 2,000 deaths and leave many thousands more suffering from radiation poisoning. Even a small detonation could spread radioactivity across a metropolitan area that, while not strong enough to cause serious health problems, could create panic. Among other impacts, it is expected that such an event would:

- Create a need for mass evacuation of urban centers.
- Paralyze infrastructure and social structures and disrupt normal, day-to-day activities for extended periods.
- Raise the level of concern among first responders regarding long-term health issues.
- Have a huge effect on U.S. foreign and military policy.
- Make complete environmental decontamination difficult, if not impossible. (The target site might not be the only contaminated area. If the method of delivery involves a weapon brought to the target area, the radiological agent would have been produced, packaged, and delivered to the target, broadening the area of potential contamination.)

RADIOLOGICAL INCIDENTS (CONTINUED)

SOURCES OF RADIATION

There are many sources of natural and human-made radiation to which we are exposed everyday, including:

- Cosmic radiation from the sun.
- Terrestrial radiation from radioactive elements in the earth.
- Radioactivity in the body (e.g., radioactive carbon and potassium).
- Diagnostic radiology (e.g., x-rays).
- Therapeutic radiology (e.g., for cancer treatment).
- Fallout from weapons testing—radioactive materials that enter the atmosphere from weapons tests, circulate around the earth, and return to earth over a period of years.
- Occupational exposure in certain industries.

TYPES OF RADIATION

There are three main types of radiation: alpha, beta, and gamma radiation.

Alpha Radiation

Alpha particles are the heaviest and most highly charged of the nuclear radiations. However, alpha particles cannot travel more than a few inches in air and are completely stopped by an ordinary sheet of paper. The outermost layer of dead skin that covers the body can stop even the most energetic alpha particle. Therefore, exposure to alpha radiation outside the body is not a serious hazard. However, ***if ingested*** through eating, drinking, or breathing contaminated materials, they can become an internal hazard, causing damage to internal organs.

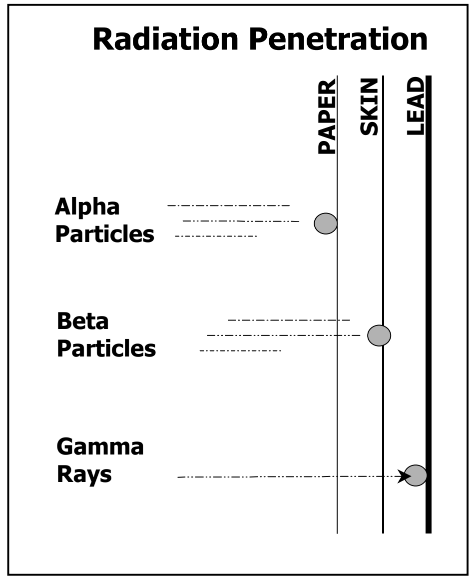
Beta Radiation

Beta particles are smaller and travel much faster than alpha particles. Typical beta particles can travel several millimeters through tissue, but they generally do not penetrate far enough to reach the vital inner organs. Exposure to beta particles from outside the body is normally thought of as a slight hazard.

However, if the skin is exposed to ***large amounts*** of beta radiation for ***long periods*** of time, skin burns may result. If removed from the skin shortly after exposure, beta-emitting materials will not cause serious burns. Like alpha particles, beta particles may damage internal organs ***if ingested*** by eating, drinking, or breathing contaminated materials. Beta-emitting contamination also can enter the body through unprotected ***open wounds*** or the lens of the eye.

RADIOLOGICAL INCIDENTS (CONTINUED)

Gamma Radiation



Gamma rays are a type of electromagnetic radiation transmitted through space in the form of waves that travel at the speed of light. Gamma rays are pure energy and therefore are the most penetrating type of radiation. They can travel great distances (e.g., a mile in open air) and ***can penetrate most materials***. This creates a problem for humans, because gamma rays can attack all tissues and organs.

RADIATION AND EXPOSURE MEASUREMENTS

There are several ways to express measures of radiation:

- **Roentgen:** Roentgen is the unit used to express the amount of gamma radiation exposure an individual receives (e.g., 50 R). This measure is independent of the time over which the exposure occurs. That is, if a person is exposed to 5 R of gamma rays on one occasion and 6 R on another, the person's cumulative gamma radiation exposure is 11 R.
- **Radiation Absorbed Dose (Rad):** Rad is the unit used to express the amount of energy absorbed from exposure to radiation. (Different materials may absorb different amounts of energy from the same exposure.) The dose of one rad indicates the absorption of 100 ergs per gram of absorbing material. One roentgen of gamma radiation exposure results in about one rad of absorbed dose.
- **Roentgen Equivalent Man (Rem):** Some types of nuclear radiation produce greater biological effects than others for the same amount of energy imparted. The rem is a unit that relates the dose of any radiation to the biological effect of that dose. For gamma rays and beta particles, 1 rad of exposure results in 1 rem of dose. For alpha particles, 1 rad of exposure results in approximately 20 rem of dose.

  For the general population, national guidelines recommend dose limits of 0.5 rem/year. International guidelines set dose limits of 0.5 rems/year for short-term exposure and 0.1 rems/year for long-term exposure.

- **Exposure Rate:** The exposure rate is the exposure per unit of time. It is usually expressed as roentgen or milliroentgen per hour (e.g., 60 R/hr). The exposure rate is commonly used to indicate the level of hazard from a radioactive source.
- **Radioactivity:** The radioactivity of a given material is a measure of the rate at which the material undergoes radioactive decay. The unit of measure for radioactivity is the curie (Ci). Specific activity is the amount of radioactivity per unit mass, typically measured in units of curies per gram (Ci/g).

ROUTES OF EXPOSURE

Radiation exposure can occur through four primary routes:

- **Absorption:** Some kinds of radiation can be absorbed directly into the body through the skin. Clothing provides some protection, especially in the case of light exposure. Contaminated clothing should be removed to prevent the radioactive particles from transferring to the body.
- **Inhalation:** Radioactive particles can be inhaled. Radioactive particles that are breathed into the lungs not only provide a direct dose of radiation, but they can concentrate in particular organs (e.g., lungs, bones, or thyroid).
- **Ingestion:** Radioactive particles may be ingested if a person's hands become contaminated and then the person fails to decontaminate before eating. Radioactive material may also be ingested if water or food supplies become contaminated, or if radioactive particles deposited on the ground are eaten by grazing cattle whose meat or milk is consumed by the public. Careful monitoring of water and food supplies is required after a radiological incident.
- **Injection:** Radioactive particles can enter the body through breaks in the skin—through open wounds or if contaminated shrapnel cuts into the skin.

METHODS OF DELIVERY

The threat of terrorists using weapons of mass destruction is increasing. Among the most likely potential methods of creating a radiological terrorist incident are nuclear weapons, radiological dispersal devices, and attacks on nuclear power plants.

NUCLEAR WEAPONS

A nuclear blast differs from a conventional blast in several ways:

- It is caused by an unrestrained fission reaction (not chemical reactions).
- It can be millions of times more powerful than the largest conventional explosions. (A one-kiloton blast is equivalent to the explosive energy of 1,000 tons of TNT.)
- It creates much higher temperatures and much brighter light flashes, causing skin burns and fires at considerable distances.
- It produces highly penetrating and harmful radiation.
- It spreads radioactive debris, so that lethal exposures can be received long after the explosion.

If terrorists were to detonate an actual nuclear bomb, casualties would be enormous. Estimates for even a relatively small nuclear weapon detonated in Manhattan are more than 100,000 immediate deaths and comparable numbers of subsequent deaths from the effects.

METHODS OF DELIVERY (CONTINUED)

Types of Burst

The following table describes four types of burst from nuclear weapons.

TYPE OF BURST	DESCRIPTION
High Altitude Burst	Detonation above 100,000 ft. Destructive forces do not significantly affect the ground.
Air Burst	Detonation below 100,000 ft. Fireball does not touch the ground.
Surface Burst	Detonation at or just above the ground. Blast kicks up considerable radioactive debris.
Sub-Surface Burst	Detonation under ground or under water. Depth determines destructive forces on the surface.

Energy Yield

Energy yield is the total energy released in a nuclear explosion. The energy yield of a nuclear explosion takes three forms:

- **Thermal radiation:** The light and heat of a nuclear blast travel ahead of the winds and overpressure and are so intense that they can cause “flashblindness” and skin burns. There is evidence that temperatures may exceed 3,000°F as far as 3,200 feet away.
- **Blast or shock effect:** The rapid release of energy within a small enclosed space causes a great increase in temperature and pressure, creating huge destructive action.
- **Nuclear radiation:** A nuclear explosion releases both initial nuclear radiation and residual nuclear radiation (radioactive fallout). Explosions near the ground create much greater amounts of fallout—in the form of a mushroom cloud—than explosions at high altitudes. The distribution of fallout (the plume) is affected by the nature of the ground surface over which it travels and the weather conditions (wind speed, direction, precipitation).

METHODS OF DELIVERY (CONTINUED)

Energy Yield (Continued)

The following table shows the typical distances associated with the effects of a 10-kiloton explosion.

Distances of Effects from a 10-Kiloton Nuclear Bomb[1]

EFFECT	RANGE (MILES)	AREA (SQUARE MILES)
Blast and Thermal		
Crater (everything vaporized)	0.25	0.19
Destruction of brick structures	0.9	2.5
Destruction of wooden structures	1.5	7
Forest fires (dry conditions)	3-6	28-113
Nuclear Radiation		
Immediate death from initial radiation	.5	1
Fallout sufficient to kill persons in the open	10	314

Feasibility of Terrorists' Use of Nuclear Weapons

This type of scenario would necessitate the terrorists' either building or obtaining an atomic bomb. Bomb-grade nuclear fissile material (i.e., highly enriched uranium or plutonium) is heavily guarded in most countries that have nuclear weapons. However, massive quantities of such material exist around the world that potentially could be diverted by terrorists and used to build a workable atomic bomb.

The prospect of terrorists actually building an atomic bomb is deemed unlikely because of the difficulty of obtaining enough nuclear material and the advanced technology required to create a workable bomb. However, diversion of existing bombs by terrorists—especially small bombs such as suitcase or attaché case bombs—is a somewhat greater threat.

Pakistan's Arsenal

Pakistan is reputed to have an arsenal of 30 to 50 atomic bombs in the 1-15 kiloton range, and they are believed to lack sophisticated safeguards against unauthorized use. A serious crisis within the country could increase the threat of these weapons falling into terrorists' hands.

[1] *Radiological Emergency Management.* FEMA Independent Study Course IS-3, p. 4-9.

METHODS OF DELIVERY (CONTINUED)

Feasibility of Terrorists' Use of Nuclear Weapons (Continued)

Suitcase bombs. It is possible to create a nuclear bomb small enough to be transported by one person using small amounts of nuclear material such as enriched uranium. Russia allegedly has an arsenal of suitcase-size nuclear bombs that could deliver a one-kiloton explosion capable of killing 100,000 people, and Russia's security and accountability for its weaponry is notoriously lax. As many as 84 such bombs were reported missing from Russia's arsenal in 1997, although it is unclear whether they have been stolen, dismantled, or lost in poorly documented storage. It is conceivable that a suitcase-size bomb could be brought into the U.S. hidden inside containerized imported cargo.

Attaché case bombs. Even smaller and lighter weight atomic bombs—the size of an attaché case—were built by the United States in the 1970s, and it is possible that they have also been produced in Russia. Bombs of this size, of course, would be even easier to smuggle into the country.

State-Sponsored Terrorism

Some believe that state-sponsored terrorism from such countries as Russia, China, North Korea, Iran, and Iraq is well within the range of possibility, as summarized below.

Potential for State-Sponsored Terrorism[1]

- Russia's military doctrine contains provisions for the possible use of nuclear weapons when all other measures are exhausted. There have been assertions that during the Cold War, Russia considered using nuclear terrorism against the United States and actually scouted locations for drop sites for weapons caches inside the United States.
- There is evidence that the Chinese leadership considers asymmetric attacks, including the covert use of weapons of mass destruction (WMD), a viable option against the United States.
- Among North Korea's special operations forces are brigades whose mission includes targeting reconnaissance for WMD and covert delivery of biological weapons. These same units also would have responsibility for operating within the continental United States during wartime.
- The Iranian Revolutionary Guard Corps (IRGC) has the lead in Iran for the production and employment of weapons of mass destruction and their means of delivery and is the primary advocate within Iran for the funding of terrorist groups.
- Iraq conducts terrorist operations through its military intelligence services and trains and sponsors terrorists through its General Intelligence Service. Saddam Hussein has threatened WMD terrorism in the past, and it is deemed highly likely that he would respond to American aggression by threatening to use pre-positioned WMD against the West.

[1] "State-Sponsored WMD Terrorism: A Growing Threat?" Chris Quillen, The Terrorism Research Center, Inc., www.terrorism.com.

METHODS OF DELIVERY (CONTINUED)

Prevention

Preventive measures relative to nuclear bombs are a Federal rather than a State or local concern and potentially include such measures as:

- Shoring up possible sources of nuclear material.
- Increasing monitoring at ports.
- Using nuclear materials detectors at borders.
- Increasing security around nuclear power plants, including expanding perimeters of restricted airspace around them.
- Building intelligence capabilities to warn of possible attacks.
- Activating bomb detection teams if credible threats emerge.
- Maintaining pressure on state sponsors of terrorism.

RADIOLOGICAL DISPERSAL DEVICES ("DIRTY BOMBS")

A radiological dispersal device (RDD), or dirty bomb, consists of conventional explosives packaged with nuclear materials. Upon detonation, the device spews deadly radioactive particles into the atmosphere.

The explosives could be plastic explosive, dynamite, TNT, or a grenade, rocket, or other munitions. The nuclear materials would most likely be nuclear waste by-products (e.g., from nuclear reactors). Some RDDs also include a substance such as napalm or industrial glue to ensure that radioactive particles will not easily be washed away after the incident.

Dirty bombs are multi-hazard weapons. In addition to radiation exposure, they may inflict thermal and explosive hazards as well as mechanical hazards from shrapnel (e.g., nails) included in the munitions or resulting from building collapse.

Radiological dispersal devices are sometimes referred to as Improvised Nuclear Devices (INDs).

METHODS OF DELIVERY (CONTINUED)

Feasibility

In some ways, dirty bombs are thought to be better potential weapons of terrorism than nuclear bombs because they can be developed cheaply, simply, and quickly. And whereas the use of nuclear bombs is considered abhorrent to the civilized world, there are some who feel that dirty bombs would carry slightly less of a stigma (or at least that radical terrorist organizations would make such a distinction).

Radioactive materials are relatively easy to obtain, and a dirty bomb can be constructed with a very small amount. There reportedly are more than 10,000 possible sources of radioactive material around the world for a terrorist to steal—some in well-guarded military facilities but others (e.g., hospital radiotherapy rooms and college physics laboratories) essentially wide open.

Nuclear reactors produce toxic plutonium in the form of spent fuel rods. In the United States alone, radioactive waste is located at more than 70 commercial nuclear power sites in 31 States. In general, radioactive waste is not as well guarded as actual nuclear weapons. Tons of waste are transported long distances (including between continents) with fairly lax security. Security for nuclear materials is especially poor in Russia.

Radiological Bomb Tests by Iraq

There is evidence that in 1987 Iraq tested a series of 12-foot bombs that used conventional explosives to cast radioactive material. The intent was to create a radioactive cloud that would cause radiation sickness, long-term health effects, and slow death. The project reportedly was abandoned because the bombs' radioactive effects weren't sufficiently lethal and persistent.

METHODS OF DELIVERY (CONTINUED)

ATTACK ON NUCLEAR POWER PLANTS

There is the potential for commercial nuclear power plants, fuel factories, and spent-fuel facilities to be used as weapons of terrorism. Although there is no danger of a nuclear explosion at a plant, an attack on a plant could be carried out in several ways:

- Crashing a hijacked airplane into the plant.
- Conducting a commando-style raid to sabotage a nuclear plant or fuel factory.
- Detonating heavy munitions (e.g., a truck bomb) near the plant.
- Detonating explosives near radiological cargo (e.g., nuclear waste) while in transit.
- Causing an "intentional accident" (e.g., by bringing down the power grid).

Any of these scenarios could cause an event in which the power plant would be the source of the radiological contamination and the munitions or aircraft would be the explosive mechanism. The results would be similar to those of radiological bomb, with far greater casualties.

Feasibility

There are 104 nuclear power plant reactors in the United States. Although reactors are shielded and have safeguards, designers were not contemplating terrorism when they designed them.

Aircraft attack. Before the events of September 11, 2001, the extent of damage that could be inflicted by an aircraft with full fuel tanks might not have been fully anticipated. Today we are well aware of both the feasibility of commandeering such an aircraft and the enormous damage it can cause. The Three Mile Island nuclear power facility was designed to withstand the impact of a Boeing 707. However, it could be vulnerable to a full-speed, direct hit from one of today's commercial jetliners.

Threat on Three Mile Island

It was reported that terrorist threats were made against the Three Mile Island nuclear power plant in Harrisburg, PA, in October 2001. Military aircraft were dispatched to protect the plant, the facility was placed on a high state of alert, local airports were shut down, and airspace was restricted in response to the threats.

METHODS OF DELIVERY (CONTINUED)

Feasibility (Continued)

Use of explosives. Until 1994, vehicle barriers were not required at nuclear plants. Even now, some vehicle barriers at U.S. facilities are very close to vital parts of the plant. It is thought that a large bomb—for example, a truck bomb such as was used in the Oklahoma City bombing—detonated nearby could cause damage leading to a release of radiation or possibly a meltdown. The Nuclear Regulatory Commission (NRC) chairman, after a 1993 intrusion at Three Mile Island and the 1993 bombing of the World Trade Center, stated, "The attack on the World Trade Center was a surprise. We can't rule out unexpected vehicle attacks."[2]

Power grid failure. The Nuclear Regulatory Commission has warned of the dangers inherent in a potential power grid failure. It is felt that in the wake of deregulation of the power industry, the electrical grid may become unreliable. (In fact, Loss-of-Offsite-Power events have occurred in the Northwest in recent years.) When the grid fails, a nuclear plant shuts down unless it is operating at low power. The reactor trips and the plant stops producing electricity. Because of the failed grid, there is no offsite source of power to operate the equipment necessary for bringing the reactor to a safe shutdown. Nuclear plants rely on their own diesel generators in such a situation, but those generators are notoriously unreliable. The second line of defense—battery back-up—provides only four hours of critical power. If the power grid is not restored in that time, a major reactor accident may occur. And to make matters worse, if the power is out, the emergency sirens in surrounding communities will not operate.

Although the situation envisioned is one caused by a power blackout resulting from problems in the power industry, there is potential for terrorist attacks to cause similar power grid failures.

[2] Source: "Three Mile Island North Gate." TMI Alert, www.tmia.com/whygate.html.

METHODS OF DELIVERY (CONTINUED)

Effects

If a meltdown of the reactor core (similar to the Chernobyl disaster) or a dispersal of the on-site spent fuel waste occurred, lethal radiation could be spread over large areas, with huge numbers of casualties and long-term poisoning of the environment.

The Chernobyl Disaster

In 1986 at the Chernobyl Power Plant in the Ukraine (former Soviet Union), the reactor overheated, causing a meltdown of the core. Two explosions blew the top off the reactor building, releasing clouds of deadly radioactive material in the atmosphere for over 10 days. The people of Chernobyl were exposed to radioactivity 100 times greater than the Hiroshima bomb. Acute radiation sickness killed 29 people in the first few weeks, and 203 were hospitalized (primarily plant operation, fire fighting, and cleanup personnel).

Clouds of radioactive material blew northward. Seventy percent of the radiation is estimated to have fallen on Belarus, where serious birth defects are still above normal more than 10 years later. Increased incidence of thyroid cancer has been noted, and other long-term health effects are being tracked.

It is estimated that over 15 million people have been victimized by the disaster in some way and that it will cost over 60 billion dollars to make these people healthy. More than 600,000 people were involved with the cleanup—many of whom are now dead or sick.

For more information, refer to *Effects of Radiation Exposure* in this appendix.

EFFECTS OF RADIATION EXPOSURE

Exposure to radiation may be acute or chronic.

- **Acute exposure** is received within a short period of time. Generally, large acute exposures can result in observable effects, such as radiation sickness or death, shortly after exposure. They can also cause long-term, delayed effects such as cancer. The severity of the effects depends on the amount of radiation dose.
- **Chronic exposure** is continuous or repetitive exposure, such as occurs from natural background radiation.

In the context of terrorist incidents, we are more concerned with acute exposure, although chronic exposure could occur as a result of environmental contamination caused by such an incident. Chronic exposures received over an extended period of time can be tolerated by the body with much less biological effect than acute exposures.

There are also differences in the way individuals are affected by exposure to radiation. Biological factors which may influence the effect of radiation on an individual include age, sex, diet, body temperature, and health.

ACUTE EFFECTS

Large acute exposures to gamma radiation (approximately 100 rem) cause very distinctive, short-term symptoms. ***Acute radiation sickness*** occurs when an individual is exposed to a large amount of radiation within a short period of time. Symptoms of acute radiation sickness include:

- Changes in blood cells and blood vessels.
- Skin irritation (similar to sunburn but lasting 3 weeks).
- Gastrointestinal system effects.
- Nausea and vomiting.
- Diarrhea.
- High fever.
- Hair loss.
- Dermal burns.
- Severe injury to internal organs.
- Long-term physiological effects.

EFFECTS OF RADIATION EXPOSURE (CONTINUED)

ACUTE EFFECTS (CONTINUED)

Symptoms may appear shortly after exposure, then disappear for a few days, and reappear in a much more serious form in a week or so. Later symptoms may include:

- Malaise, fatigue, and drowsiness.
- Weight loss.
- Fever.
- Abdominal pain.
- Insomnia, restlessness.
- Blisters.

The severity and course of acute radiation sickness depends on how much total dose is received, how much of the body is exposed, and the radiosensitivity of the individual. The following table indicates the varying lethality of different radiation exposure levels.

Lethality of Radiation Exposure Levels

ACUTE EXPOSURE	EFFECT
< 200 R to the whole body	Lethal for some people
350 R	5% may die within a month without medical attention.
450 R	Half of those exposed would probably die without medical attention.
650 R	Most would die.
> 1000 R	Irreparable damage to the central nervous system cells and death within hours to days.

LONG-TERM EFFECTS

The probability of experiencing long-term effects increases as the level of exposure increases. Long-term effects may include various forms of cancer (leukemia, bone cancer, thyroid cancer, lung cancer), cataracts, and shortened life span.

DETERMINING NUCLEAR INCIDENTS AND MONITORING RADIATION

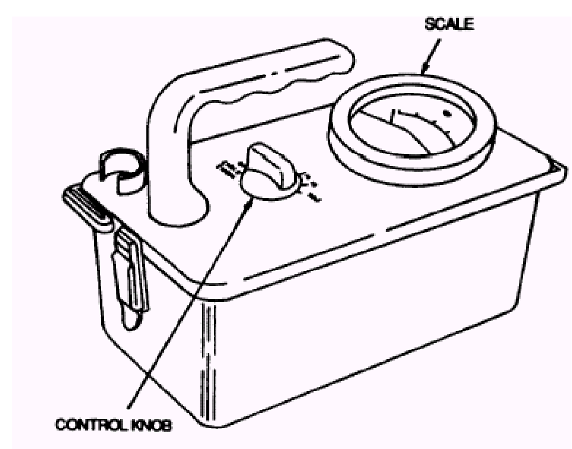
Radiation cannot normally be seen by the human eye. It cannot be smelled, heard, felt, or otherwise detected by our normal senses. Therefore, other indicators must be used to determine that radiation may be present. The following are potential indicators of a nuclear incident:

- Evidence of detonation—blast, fireball, and/or mushroom cloud; large-scale damage or blown-out windows and widely scattered debris.
- Presence of DOT placards and labels—for example, in the case of the bombing of nuclear materials in transport.
- Radiation detected by survey instruments and monitoring devices.

RADIATION SURVEY INSTRUMENTS

Different types of electromagnetic radiation have unique wavelengths and frequency. By measuring these characteristics, the type of radiation can be identified. Radiation survey instruments are carried by most fire department HazMat teams, and many county agencies, the State, and Department of Energy Radiological Assistance Program (RAP) teams have access to a variety of radiation survey instruments. These include:

- Scintillation counters.
- Geiger-Mueller counters.
- Ionization chamber instruments.



Ionization chamber instruments (shown here) consist of a chamber in which nuclear radiation interacts, yielding an electric pulse or current, and electronic circuitry which converts the current into a readout. Most survey instruments maintained for emergency management are powered by standard D cell batteries, making them portable and fairly easy to maintain in operational condition.

A methodology for evaluating the response of survey instruments was developed and applied to the widely available CD V-700 and CD V-715 survey meters distributed by FEMA.

DETERMINING NUCLEAR INCIDENTS AND MONITORING RADIATION (CONTINUED)

DOSIMETRY

Dosimetry is the monitoring of individuals (e.g., response workers) to determine their radiation dose equivalent. A dosimeter is a portable device that measures total radiation dose received. The dosimeter keeps track of the total charges created by radiation interactions in it. Three main types of dosimetry systems are used to monitor radiation dosage in emergency situations: pocket ionization chambers, film dosimeters, and thermoluminescent dosimeters. There are also combination systems that combine two or more of these types.

Pocket Ionization Chambers

This type of system consists of a small, air-filled chamber in which a quartz fiber is suspended, a small microscope, and a graduated scale. The quartz fiber is pre-charged. Exposure to radiation discharges the fiber by creating ions. The dosimeter scale then reads the amount of ionization.

Film Dosimeters

Film dosimeters, or film badges, consist of layered components, including the badge front (with a window for exposure), filters that screen out certain types of radiation, films to detect radiation, and the badge cover. The device clips to a person's clothing. After a designated period of exposure, the film is removed, developed, and read on a densitometer.

Thermoluminescent Dosimeters (TLDs)

Thermoluminescence is the property of emitting light upon heating after having been exposed to ionizing radiation. The amount of emitted light can be measured, and the amount is directly proportional to the radiation absorbed dose. TLD badges are issued on a monthly or quarterly basis to people who have the potential to be exposed to radiation.

The following table compares advantages and disadvantages of these three systems.

DETERMINING NUCLEAR INCIDENTS AND MONITORING RADIATION (CONTINUED)

Thermoluminescent Dosimeters (TLDs) (Continued)

Dosimeter Devices: Advantages and Disadvantages

SYSTEM	ADVANTAGES	DISADVANTAGES
Pocket Ionization Chambers	▪ Cumulative exposure can be read at any time or location without ancillary equipment. ▪ The chambers can be used repeatedly by recharging or rezeroing. ▪ They have a long shelf-life with little or no maintenance requirements. ▪ They measure gamma exposure accurately. ▪ They are sealed at the time of manufacture and are relatively insensitive to environmental conditions.	▪ The exposure readings on the devices may be sensitive to a significant mechanical shock. ▪ The initial cost is high.
Film Dosimeters	▪ The dose measurements for various film badges have ranges of 10-1500 mrem for gamma and x-radiation, and 50-1000 mrem for beta radiation. ▪ They can distinguish between penetrating and non-penetrating radiation. ▪ They are small, lightweight, and relatively inexpensive.	▪ The response of the film to radiation is energy dependent. ▪ The films cannot be read immediately. ▪ Environmental conditions (e.g., heat, humidity) will affect the film's response to radiation. ▪ They may be left or lost at the incident site. ▪ They may be contaminated with radioactive materials, which will lead to a false higher result.
TLDs	▪ They can be used with radiation fields of widely varying energy and intensity. ▪ They can store information for long periods of time without fading. ▪ They are reusable and can be used for many applications because of their small size. ▪ They are less energy dependent than the other systems.	▪ They cannot be analyzed immediately. ▪ Environmental conditions (e.g., heat, humidity) may affect the results. ▪ They may be left or lost at the incident site. ▪ They may be contaminated with radioactive materials, which will lead to a false higher result.

RESPONSE ACTIONS FOR RADIOLOGICAL INCIDENTS

When a radiological incident occurs (whether by accident or terrorism), certain procedures must be implemented to limit the harmful health effects and to control the spread of radioactive contamination. The following are some of the specialized responses to this type of incident:

Response Actions

- Activate HazMat teams and Radiological Response Team.
- Notify the National Response Center, Department of Energy (DOE), and the FBI. (Sites of non-natural incidents must be treated as scenes to be investigated.)
- Determine the size of detonation, radii of damage, and/or plume size and direction.
- Determine the location and identity of the radioactive material using survey meters and plume projection models.
- Determine the types of radiological technical expertise needed (e.g., National Strike Force, DOE, Army Technical Escort Unit (TEU), nuclear power plant response teams, mutual support agreements with other local and State governments).
- Determine the extent of contamination from radioactive material (i.e., fallout).
- Obtain an accurate weather forecast. (Weather will affect the movement of radioactive particles in the atmosphere.)
- Establish incident site control zones based on safety and degree of hazard—e.g., hot zone (exclusion zone), warm zone (decontamination zone), and cold zone (support zone). DOT ERG 163 recommends an exclusion zone of at least 80 to 160 feet.
- Ensure availability of required equipment (e.g., sensing or detection equipment, Level A PPE suits, decontamination equipment, impermeable storage containers for contaminated items).
- Provide appropriate protection to on-scene responders. Most HazMat teams have the ability to respond to two different radiological emergency sites simultaneously. Beyond that, responders will be equipped only with standard emergency response gear.
- Initiate victim decontamination procedures.
- Prevent the spread of the material from contaminated persons who spontaneously evacuate (secure the crime scene, control access, ingress/egress).
- Arrange for fast medical treatment for victims.
- Identify medical facilities that will accept and treat radiation contamination victims.
- Determine appropriate measures (e.g., evacuation of the area inside the radii of damage, in-place sheltering outside the radii of damage, post-emergency sampling, protocols for relocation, reentry and return).

RESPONSE ACTIONS FOR RADIOLOGICAL INCIDENTS (CONTINUED)

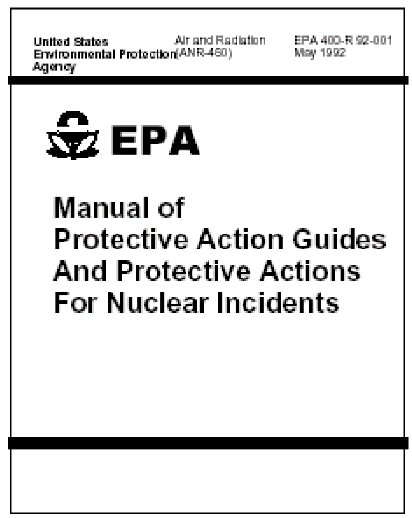
PROTECTIVE ACTION GUIDES

A Protective Action Guide (PAG) is a decision level for public officials during a nuclear incident. More specifically, it is the projected radiation dose to a standard individual, or other defined individual, from an unplanned release of radioactive material at which a specific protective action to reduce or avoid that dose is warranted.

Projected radiation dose is the dose estimated to be received in a specific time in the absence of protective actions or natural shelter.

The Environmental Protection Agency considers four principles when selecting PAGs:

- Avoid acute effects on health.
- Keep the risk of delayed effects of health within upper bounds that are adequately protective of public health, under emergency conditions, and reasonably achievable.
- Reduce any risk to public health that is achievable at acceptable costs.
- Regardless of the above principles, the risk to health from protection action should not exceed the risk to health from a dose that would be avoided.



PAGs apply to all radiological incidents (except nuclear detonation), including incidents involving a nuclear power plant or other nuclear facility, weapons, transportation, and satellite. The guidance for implementing the PAGs is intended primarily for nuclear power facility accidents.

RESPONSE ACTIONS FOR RADIOLOGICAL INCIDENTS (CONTINUED)

Incident Phases

The EPA's Manual of Protective Actions and Protective Action Guides defines three time phases that are generally accepted as being common to all nuclear incident sequences:

- **Early phase:** From the beginning of the incident to a few days later, when deposition of airborne materials has stopped. This phase is when immediate decisions on protective actions are required. The period may last from hours to days. (For purposes of dose projection, it is assumed to last 4 days.)
- **Intermediate phase:** From the point the source and releases have been brought under control and environmental measurements are available until protective actions are completed. This phase may last from weeks to many months and may overlap with the early and late phases. (For purposes of dose projection, it is assumed to last 1 year.)
- **Late phase:** The recovery phase, from the point when recovery actions (to reduce radiation levels in the environment to permit unrestricted, long-term use of property) begin until all recovery actions have been completed. This phase may last from months to years.

RESPONSE ACTIONS FOR RADIOLOGICAL INCIDENTS (CONTINUED)

Protective Actions

The principal protective actions for each phase are listed in the following table.

PHASE	PROTECTIVE ACTIONS
Early Phase	▪ Evacuation (urgent removal of people from an area to avoid or reduce high-level, short-term exposure) ▪ Sheltering-in-place ▪ Bathing and changes of clothing ▪ Protective action for the milk supply if appropriate
Intermediate Phase	▪ Relocation (removal or continued exclusion of people from contaminated areas to avoid chronic radiation exposure) ▪ Decontamination ▪ Restrictions on the use of contaminated food and water
Late Phase	▪ Relocation ▪ Decontamination ▪ Food and water controls

There are separate PAGs (i.e., projected radiation doses) for each incident phase and for each protective action, along with recommended dose reduction techniques.

WORKER PROTECTION

Protection from the effects of radiation is based on the principle of ***time, distance, and shielding*** (TDS):

- Spend the shortest amount of time possible exposed to the radiological hazard.
- Distance yourself from the hazard area, upwind and uphill, whenever possible. The greater the distance from the source of harm, the less the exposure.
- Take advantage of any available shielding from radiation exposure, including vehicles, buildings, walls, and Personal Protective Equipment (PPE).

PERSONAL PROTECTIVE EQUIPMENT

Respiratory protection is an absolute requirement when working with areas potentially affected by fallout. Standard gear does not include respiratory protection and does not constitute adequate protective equipment.

Simple respiratory protection is adequate for fallout (dust) in most cases. The use of PPE, including Self-Contained Breathing Apparatus (SCBA), will greatly enhance the emergency responder's safety when dealing with alpha or beta radiation.

Full Nuclear/Biological/Chemical (NBC) Suit (Military)

Military Respirator

CONTAMINATION CONTROL AND DECONTAMINATION

Contamination control and decontamination are major concerns in a radiological incident. There may be an induced radiation pattern at the site of detonation, and some nuclear materials have a long half-life (i.e., they persist in the environment for a very long time).

CONTAMINATION CONTROL

It will be important to isolate the incident site and set up ingress/egress control to prevent the spread of radiological contamination beyond its borders. People, materials, and equipment must be decontaminated before they leave the hot zone.

It may also be necessary to evacuate the incident area and to effect in-place sheltering in adjacent areas. Recommended evacuation distances provided in the North American Emergency Response Guidebook (ERG) for transportation incidents (ERG 163) may be relevant to radiological terrorist incidents.

PERSONAL DECONTAMINATION

Contamination should be removed as soon as possible. Standard clothing provides some protection, although the longer radioactive material is allowed to remain on clothing or on the skin, the greater the level of exposure and risk of short- and long-term health effects.

Gross decontamination consists of carefully removing contaminated clothing to get rid of the bulk of the contamination. If surveying or monitoring indicates that radioactivity levels remain high, it may be necessary to wash and rinse the body.

DECONTAMINATION FACILITIES

The decontamination system should be located upwind and uphill from the incident scene. Decontamination facilities for response workers in PPE should have the following features:

- Decontamination corridor.
- Containment and collection system for decontamination run-off.
- Drop-off area (e.g., plastic ground cover or lined can) for contaminated tools and equipment. Items place in the area will be decontaminated and surveyed/monitored to verify freedom from contamination.
- Step-off pads between hot zone and warm zone.
- If multiple contaminants are present: multiple (sequential) wash areas where personnel are scrubbed and rinsed with appropriate solutions before removal of PPE, stripped of gear, and further decontaminated.

CONTAMINATION CONTROL AND DECONTAMINATION (CONTINUED)

DECONTAMINATION FACILITIES (CONTINUED)

- Contamination survey (checking decontaminated persons for radiation levels).
- Documentation of personnel and personal property dosimetry and contamination results.

All contaminated materials (e.g., clothing, tools) must be packaged and removed from the hot zone for proper disposal or decontamination at a later date.

DISPOSAL OF CONTAMINATED WASTE

The Department of Energy (DOE) is responsible for disposal of nuclear and radioactive materials. It is possible that large amounts of contaminated waste generated during incident response and decontamination will need to be transported to disposal sites. The State and local EOPs should provide details on how the local HazMat teams will interface with DOE to coordinate removal and disposal operations.

HANDLING CONTAMINATED BODIES AND HUMAN REMAINS

When radiological contamination is present at an incident scene, bodies and human remains must be handled with special precautions, which may include:

- Surveying and/or monitoring of bodies for the presence of radioactivity.
- Gross decontamination of bodies and human remains (i.e., removal of clothing) before removal from the hot zone. Care must be taken to preserve items that will assist in victim identification.
- Tagging of bodies and/or remains to indicate presence and levels of radiation contamination.
- Placement of body and/or remains in body bags or pouches with a radiation tag.
- Monitoring of body bags before crossing zone lines, and decontamination if radiation levels warrant.
- Decontamination (dry or wet) of bodies and/or remains at an off-site facility. If wet decontamination is required, run-off must be collected and properly disposed of.
- Collection of internal samples, if necessary, to identify internal contamination and determine safe embalming procedures.
- Proper packaging, labeling, and disposal of all contaminated items and materials.
- Documentation of contaminated bodies and/or remains.

MEDICAL TREATMENT

The medical priorities in a radiological incident will be gross triage, transportation, and limited life-saving efforts. Triage stations are used to manage the flow of casualties through the community health system.

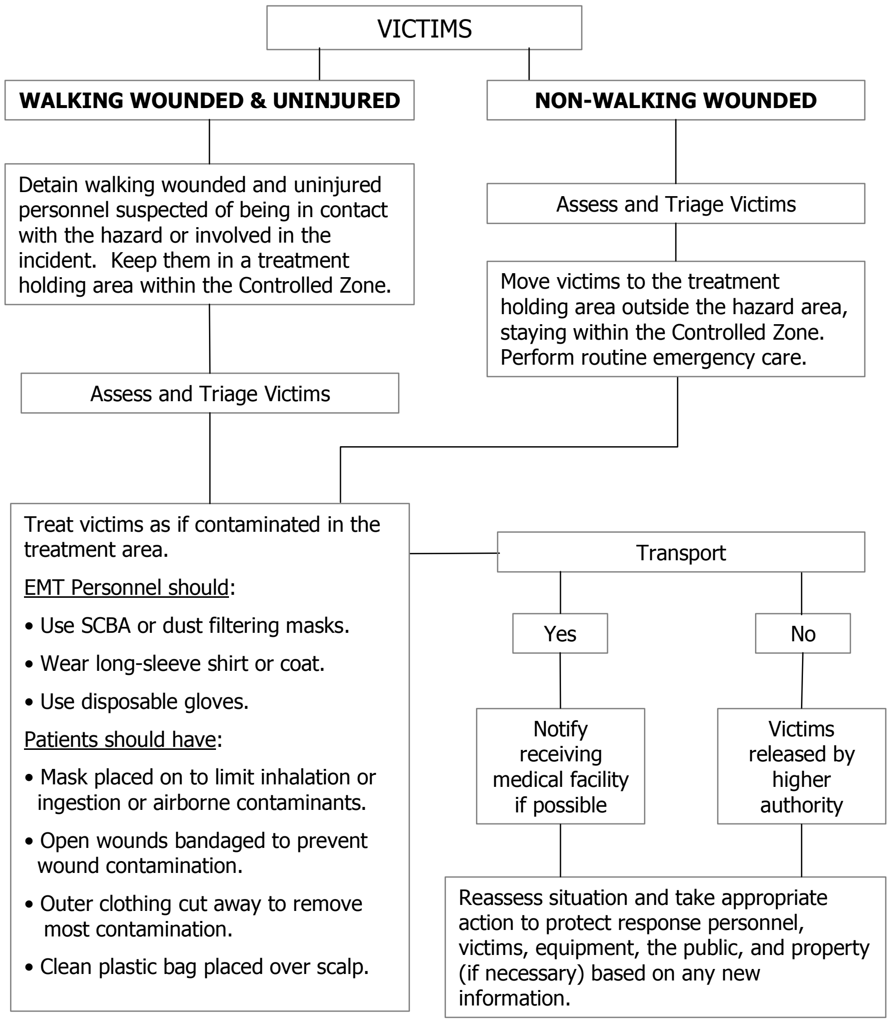
Appropriate procedures for handling radiologically contaminated patients should be followed, including:

- Use of multiple protective barriers for patients and patient carrying devices.
- Protective clothing for medical response workers (Body Substance Isolation Clothing or firefighting gear).
- Treatment of life-threatening injuries and other injuries as required.
- Patient surveying or monitoring and decontamination (i.e., removal of clothing) if needed, in hot zone.
- Removal of contaminated protective barriers, resurveying, and transfer to other personnel at zone borders.
- Use of protective clothing and protective barriers in ambulances.
- Transport to hospital facilities that have the capability to treat and care for potentially radiologically contaminated patients.
- Surveying or monitoring, and decontamination as necessary, before placing equipment back into service.

The following flow chart illustrates a recommended approach for handling victims at a radiological incident.

MEDICAL TREATMENT (CONTINUED)

Handling Victims at a Radiological Incident[2]



[2] *Model First Responder Procedure for Radiological Transportation Accidents*. Department of Energy, Office of Transportation and Emergency Management, 2000, p. 8.

MEDICAL TREATMENT (CONTINUED)

HOSPITAL TREATMENT

Radiation damage can be repaired if the dose received is not too high and if the dose is received over a long period of time. Injured victims who are suspected of being contaminated by radiological hazards should be treated at hospital facilities that have the capacity for this specific type of treatment. Local officials must ensure that such facilities are identified in the EOP.

Note: The U.S. medical community is currently ill-equipped to deal with a large-scale incident involving radiation poisoning. Only one hospital emergency room—in Oak Ridge, TN—is dedicated to treatment of this type of injury.

MENTAL HEALTH AND CHRONIC HEALTH ISSUES

A radiological incident can be expected to cause widespread public panic and fear related both to the current dangers and to the possibility of long-term health effects. Crisis counseling should be available for incident victims, and a greater demand can be expected on long-term mental health services.

Exposure to radiation has the potential for very long-term health effects, including cancer and many other types of illness. The local medical community should expect an upsurge in patients seeking treatment, and anyone exposed to unsafe levels of radiation will require long-term monitoring.

POST-EVENT ACTIVITIES

ENVIRONMENTAL MONITORING

Ongoing environmental monitoring and testing will be required to determine when it is safe to reenter the area, and certification of safe entry must be obtained. The environmental monitoring program should be run by a facility staffed by personnel capable of directing field operations and interpreting analytical and measured results. This facility must have reliable communications capability to primary and backup monitoring personnel, emergency directors, laboratory facilities, transportation agencies, and weather services.

Environmental monitoring facilities must be licensed. The license will spell out the extent of the required environmental measurements. Many licenses require that monitoring play a limited role because the radionuclide involved poses little risk to the public. In contrast, facilities such as waste burial grounds, nuclear power stations, and fuel processing plants require extensive monitoring programs.

POST-EVENT ACTIVITIES (CONTINUED)

RECOVERY AND REENTRY

There are numerous concerns related to fallout. For example, fallout is a mixture of heavy metals and other radioactive materials and may be toxic in its own right—beyond the long-term effects on humans and animals. The local HazMat plan should identify sanitation procedures related to radiological operations.

In the case of an induced radiation pattern, the area will likely remain radioactive for an extended period, and it may not be possible to return the area to the way it was before the incident. In some cases, shielding with massive amounts of concrete or other materials may be the best option.

EPIDEMIOLOGICAL SURVEILLANCE

Epidemiological surveillance is important in determining the number of people that were exposed to the radiological material associated with fallout. Community health planning should account for locating personnel within the incident area that may be asymptomatic at this point, especially in light of the potential long-term health effects.

Long-range health issues are of great concern whenever radioactivity is involved. The community should consider establishing a database to track the health of those members of the community, including responders, who may have been exposed to fallout.

AGRICULTURAL PROTECTION AND MONITORING

Following a radiological incident, it may be necessary to initiate protective action for the milk supply and to monitor the water and food supplies for possible contamination.

After emergency monitoring of surface-deposited radioactivity defines the boundaries of contaminated areas, non-dairy food and drinking water within the boundaries should be sampled and analyzed.

EVALUATING PREPAREDNESS FOR RADIOLOGICAL TERRORIST INCIDENTS

	YES	NO
PLANNING		
1. Have hazard assessments been conducted to determine vulnerable areas where radioactive materials are present or may transit?	☐	☐
2. Are nuclear facilities or radioactive materials present in the jurisdiction?		
▪ Nuclear power plant	☐	☐
▪ Nuclear fuel production	☐	☐
▪ Nuclear waste storage	☐	☐
▪ Spent fuel pond	☐	☐
▪ Research/treatment facilities using nuclear materials	☐	☐
▪ Transport of radioactive materials	☐	☐
▪ Industrial use of radioactive materials	☐	☐
▪ Other:	☐	☐
3. If nuclear facilities exist, have security measures been reviewed and upgraded if necessary?	☐	☐
4. Has the potential for cyberterrorist attacks on the computer systems that control the regional power grid been considered?	☐	☐
5. Does the EOP currently address:		
▪ Transportation incidents involving radioactive materials?	☐	☐
▪ Accidental release of radioactive material from a nuclear facility?	☐	☐
▪ Nuclear detonation (nuclear weapon, dirty bomb)?	☐	☐
▪ Terrorist incident involving radioactive materials?	☐	☐
6. Has a hazardous materials drill been conducted within the last 12 months?	☐	☐
7. If yes, did this drill involve a radioactive material?	☐	☐

EVALUATING PREPAREDNESS FOR RADIOLOGICAL TERRORIST INCIDENTS (CONTINUED)

	YES	NO
COMMUNICATIONS AND COORDINATION		
1. Does the EOP include contact information and protocols for contacting the following?		
▪ County Environmental Official	☐	☐
▪ State Nuclear Safety Official	☐	☐
▪ State Environmental Official	☐	☐
▪ Hazardous Materials Team	☐	☐
▪ Radiological Response Team	☐	☐
▪ Nuclear Regulatory Commission (NRC)	☐	☐
▪ Department of Energy	☐	☐
▪ Nuclear power plant response teams (if applicable)	☐	☐
▪ FBI	☐	☐
2. Do coordination agreements exist among all agencies that may be requested to assist during a radiological incident?	☐	☐

EVALUATING PREPAREDNESS FOR RADIOLOGICAL TERRORIST INCIDENTS (CONTINUED)

	YES	NO
HAZARDOUS MATERIALS TEAM		
1. Does the jurisdiction have a HazMat team?	☐	☐
2. Has the HazMat team:		
▪ Completed a self-evaluation as outlined by EPA Regulation 540-G90-003?	☐	☐
▪ Been trained to the 1910.120 Technician Level?	☐	☐
▪ Been trained for response to radiological materials incidents/releases?	☐	☐
▪ Been trained for response to transportation incidents involving radiological materials?	☐	☐
▪ Been trained for response to multi-hazard incidents involving radiological materials (i.e., blast, thermal, radiation effects)?	☐	☐
3. Are HazMat response services available 24 hours a day?	☐	☐
4. Are mutual aid agreements developed to support HazMat incidents?	☐	☐
5. Do HazMat response organizations use an incident scene accountability system?	☐	☐
6. Does the HazMat team have radiological instrumentation in its equipment inventory?	☐	☐
7. Is the equipment routinely tested, calibrated, and maintained?	☐	☐
8. Has the HazMat team been trained on the use of each type of radiation instrument, and is a program in place to maintain/demonstrate proficiency?	☐	☐
9. Have response procedures been developed that include Site Safety Plans and Radiation Exposure Guidelines?	☐	☐

EVALUATING PREPAREDNESS FOR RADIOLOGICAL TERRORIST INCIDENTS (CONTINUED)

	YES	NO
FIRE RESPONSE ORGANIZATIONS		
1. Are all emergency response vehicles equipped with the latest copy of the Emergency Response Guidebook?	☐	☐
2. Have response organizations been trained to the OSHA 1910.120 operations Level?	☐	☐
3. Have response organizations been trained for response to:		
▪ Radiological materials incidents/releases?	☐	☐
▪ Transportation incidents involving radioactive materials?	☐	☐
▪ Multi-hazard incidents involving radiological materials (i.e., blast, thermal, radiation effects)?	☐	☐
▪ Radiological incidents involving a crime scene (i.e., preservation of evidence, coordination with investigative personnel)?	☐	☐
4. Do response organizations have radiological monitoring equipment in their equipment inventory?	☐	☐
5. If yes, is there a program to routinely test and maintain equipment calibration?	☐	☐
6. Have fire department responders been trained on the use of each type of radiation instrument, and is a program in place to maintain/demonstrate proficiency?	☐	☐

EVALUATING PREPAREDNESS FOR RADIOLOGICAL TERRORIST INCIDENTS (CONTINUED)

	YES	NO
LAW ENFORCEMENT RESPONSE ORGANIZATIONS		
1. Are all emergency response vehicles equipped with the latest copy of the Emergency Response Guidebook?	☐	☐
2. Have response organizations been trained to the OSHA 1910.120 Awareness Level?	☐	☐
3. Have response organizations been trained for response to:		
▪ Radiological materials incidents/releases?	☐	☐
▪ Transportation incidents involving radioactive materials?	☐	☐
▪ Multi-hazard incidents involving radiological materials (i.e., blast, thermal, radiation effects)?	☐	☐
▪ Radiological incidents involving a crime scene (i.e., preservation of evidence, coordination with investigative personnel)?	☐	☐
4. Do response organizations have radiological monitoring equipment in their equipment inventory?	☐	☐
5. If yes, is there a program to routinely test and maintain equipment calibration?	☐	☐
6. Have law enforcement responders been trained on the use of each type of radiation instrument, and is a program in place to maintain/demonstrate proficiency?	☐	☐

EVALUATING PREPAREDNESS FOR RADIOLOGICAL TERRORIST INCIDENTS (CONTINUED)

	YES	NO
EMS AND CARE FACILITIES		
1. Do EMS organizations have SOPs for treatment and transportation of a potentially contaminated patient?	☐	☐
2. Do EMS organizations operate and maintain radiological monitoring equipment as part of their equipment inventory?	☐	☐
3. If yes, is there a program to routinely test and maintain equipment calibration?	☐	☐
4. Have EMS responders been trained on the use of each type of radiation instrument, and is a program in place to maintain/demonstrate proficiency?	☐	☐
5. Have hospitals with treatment/care capabilities for radiologically contaminated patients been identified?	☐	☐
6. Has the hospital staff been trained in the handling, decontamination, and treatment of radiologically contaminated patients?	☐	☐
7. Has a hospital drill been conducted with radiologically contaminated patients in the past 12 months?	☐	☐
8. Has the potential for a surge in mental health needs been considered?	☐	☐
PROTECTIVE ACTIONS		
1. Are protocols in place for determining and implementing appropriate response actions for a radiological incident, including:		
▪ Evacuation?	☐	☐
▪ Sheltering-in-place?	☐	☐
▪ Preventing spread of contamination through use of zones, access control, decontamination, etc.?	☐	☐
▪ Patient decontamination?	☐	☐
▪ Site decontamination?	☐	☐
▪ Handling of contaminated bodies/remains?	☐	☐
▪ Crime scene control?	☐	☐

EVALUATING PREPAREDNESS FOR RADIOLOGICAL TERRORIST INCIDENTS (CONTINUED)

	YES	NO
POST-EVENT AND RECOVERY		
1. Are protocols in place for determining and implementing appropriate post-event and response actions for a radiological incident, including:		
▪ Environmental monitoring and post-emergency sampling to determine when the site is safe for reentry?	☐	☐
▪ Certification for safe return?	☐	☐
▪ Relocation of evacuees?	☐	☐
▪ Long-term medical monitoring of response personnel and victims?	☐	☐
▪ Monitoring of water, food supplies, dairy industry?	☐	☐
▪ Restrictions on use of contaminated food and water?	☐	☐