Guidelines for Handling Decedents Contaminated with Radioactive Materials

Second Edition
September 2021

U.S. Department of Health and Human Services
Centers for Disease Control and Prevention

Contents

Preface

The first edition of *Guidelines for Handling Decedents Contaminated with Radioactive Materials*[1] was published in 2007. It was the product of a joint effort between the Centers for Disease Control and Prevention (CDC), the New York City Office of Chief Medical Examiner, and the National Funeral Directors' Association. During that time, the National Association of Medical Examiners was preparing its own guidelines for dealing with contaminated decedents,[2] and the National Council on Radiation Protection and Measurements was revising its report on handling contaminated persons to include a chapter on decedents[3]. The authors of these three documents worked together to ensure each provided consistent information.

In the 15 years since these documents were published, CDC and its partners have made considerable advances in the field of public health preparedness and radiation emergency response. This second edition builds on previous works and incorporates new information that federal, state, and local officials can use to advance and refine their mass fatality planning efforts.

[1] Centers for Disease Control and Prevention (CDC). *Guidelines for handling decedents contaminated with radioactive contamination*. 2007. https://emergency.cdc.gov/radiation/pdf/radiation-decedent-guidelines.pdf

[2] Nolte, K. *Medical examiner/coroner's guide for contaminated deceased body management.* Atlanta, GA; National Association of Medical Examiners, 2007.

[3] National Council on Radiation Protection and Measurement. *Management of persons contaminated with radionuclides: Handbook*. (NCRP Report No. 161) Bethesda, MD, 2008. https://ncrponline.org/publications/reports/ncrp-report-161/

1.0 Introduction

Successful mass fatality response operations rely on the careful coordination of mortuary response teams, search and rescue teams, and many supporting entities. These efforts are orchestrated by the incident commander and synchronized through the National Incident Management System.[4]

1.1 Purpose

This document has been developed to assist with planning and response efforts related to mortuary response operations in a radiation emergency. The following chapters provide information and guidance related to establishing field mortuary operations, implementing radiation safety protocols for workers, conducting screening and decontamination of decedents, and preparing decedents for handling, transport, and burial.

1.2 Target Audience

This guide is intended for radiation protection professionals participating in mass fatality planning and response operations. The information in this guide will also benefit coroners, medical examiners, funeral home directors, emergency managers, and public health planners.

1.3 Scope

This guide provides technical information to support radiation safety efforts during a mass fatality response. By definition, mass fatality incidents overwhelm local resources for locating, identifying, and processing decedents for final disposition. The presence of radioactive contamination further complicates these efforts. These guidelines are incident-specific considerations for radiation emergencies, including technical specifications for performing radiological screening and decontamination and establishing dose and dose rate limits.

This guide features tables that summarize capabilities described in the text. These capabilities are organized into three categories — *basic, intermediate,* and a*dvanced* — according to the level of complexity.

- *Basic* capabilities reflect the minimum capabilities needed for mortuary response operations in a radiation emergency. Many of the recommendations in this category are precautionary and are representative of mortuary response operations that might not have access to radiation detection equipment and trained personnel.
- *Intermediate* capabilities reflect enhanced radiation detection capabilities and access to trained personnel. However, these resources might be in limited supply, and mortuary response operations might need to prioritize tasks requiring use of these resources.
- *Advanced* capabilities reflect mortuary operations that have sufficient access to radiation detection equipment and trained staff members to perform tasks requiring use of these resources.

These capabilities can be used to guide mass fatality planning and are not intended to set a rigid benchmark for mortuary response operations. Some mortuary response operations might have basic capabilities in one category and advanced capabilities in another. Mortuary response operations may also choose to work with their state radiation control officials to adopt modified standards for each category. Additionally, these capabilities are intended to be

[4] Additional information about the National Incident Management System is available at https:/www.fema.gov/emergency-managers/nims.

cumulative. Attaining an advanced capability in a functional area implies mastery of the intermediate and basic capabilities as well.

1.4 Assumptions

This guide assumes that jurisdictions already have plans and procedures in place to mount mortuary response operations for a mass fatality incident. This guide also assumes that federal resources, such as Disaster Mortuary Operational Response Teams (DMORT)[5], will respond and support the state and local response.

Additionally, this guide assumes radiation support personnel will fall into one of the following categories:

- *Radiation control authorities*: Local, state, or federal officials who manage the regulatory aspects of radiation exposure and the handling of radioactive materials
- *Radiation safety officers*: Radiation professionals, embedded at multiple levels of the incident command structure, who are trained and certified to track, manage, and limit radiation doses to all responders including mortuary responders.
- *Radiation protection professionals*: Personnel with expertise in health physics, radiation detection, nuclear medicine, or another related field that can operate as a radiation worker to augment the DMORT, either from the response team or attached to the response team from another agency or as a trained volunteer.

Finally, this guide considers the units of measurement for radiation exposure and radiation dose to be equivalent. Thus, 1 gray (Gy) = 1 sievert (Sv); 1 roentgen (R) = 1 rad = 1 rem.[6]

1.5 Objectives

No specific laws regulate the treatment of radioactively contaminated decedents, only best practices from within the mortuary response planning and radiation protection communities. Medical examiners, coroners, funeral directors, and radiation protection professionals will have to devise working procedures that best match their capabilities. The objectives are as follows:

- **Radiation dose to responders who handle and manage the deceased will be kept as low as reasonably achievable.** The goal is to keep radiation exposures below the annual limit for radiation workers.
- **Workers will minimize the spread of contamination. The goal is to manage retrieval, processing, and disposition of contaminated bodies to minimize or eliminate any further spread of contamination.**
- **Radiation exposures to the public will be kept as low as reasonably achievable.** No one should receive a radiation exposure unless there is some benefit, such as respecting the religious or emotional needs of the bereaved family.
- **Human remains will be treated with dignity and respect.** Human remains will be processed as expeditiously as possible and released to the families. If bereaved family members want a funeral with a viewing or the religious practice of the decedent calls for a ceremonial washing, this should be allowed. Appropriate precautions should be taken to protect people attending the service.

[5]Additional information about DMORT is available at https://www.phe.gov/Preparedness/responders/ndms/ndms-teams/Pages/dmort.aspx.

[6] Additional information about units of radiation measurement is available at https://www.cdc.gov/nceh/radiation/emergencies/measurement.htm.

1.6 Radiation Emergencies

This section provides a brief overview of specific types of radiation emergencies that could merit a mass fatality response. References for source documents for each section are included in the footnotes. Planners are encouraged to review the source documents for additional details.

Detonation of an Improvised Nuclear Device

An improvised nuclear device is a crudely developed nuclear weapon that harnesses the power of nuclear fission to generate extreme heat, light, and explosive power. The detonation of an improvised nuclear weapon presents significant response challenges and will require the full resources of the U.S. government. Current response plans are built on a zoned approach. The following information is a summary of the effects of a 10-kiloton nuclear detonation presented in the *Planning Guidance for Response to a Nuclear Detonation*.[7]

Two types of zones are considered:

- *Fallout zones*: These areas are categorized by radiation dose rate.
    - Radiation control zone: Dose rates 0.1–100 mSv/h (0.01-10 rem/h)
    - Dangerous fallout zone[8]: Dose rates exceeding 100 mSv/h (10 rem/h)
- *Damage zones*: These areas are categorized by degree of damage to buildings and infrastructure.
    - Light damage zone: 1.6–4.8 km (1-3 mi) from ground zero
    - Moderate damage zone: 0.8–1.6 km (0.5-1 mi) from ground zero
    - Severe damage zone: Up to 0.8 km (0.5 mi) from ground zero

Figure 1 provides a graphic representation of how the zones overlap. Note that the dangerous fallout zone will shrink significantly during the first 48–72 hours.

Mortuary response resources will need to stage in locations that are structurally and radiologically safe, such as on the outskirts of the light damage zone, upwind from the dangerous fallout zone. Remains recovery teams will need to take additional precautions when working in radiation control zones.

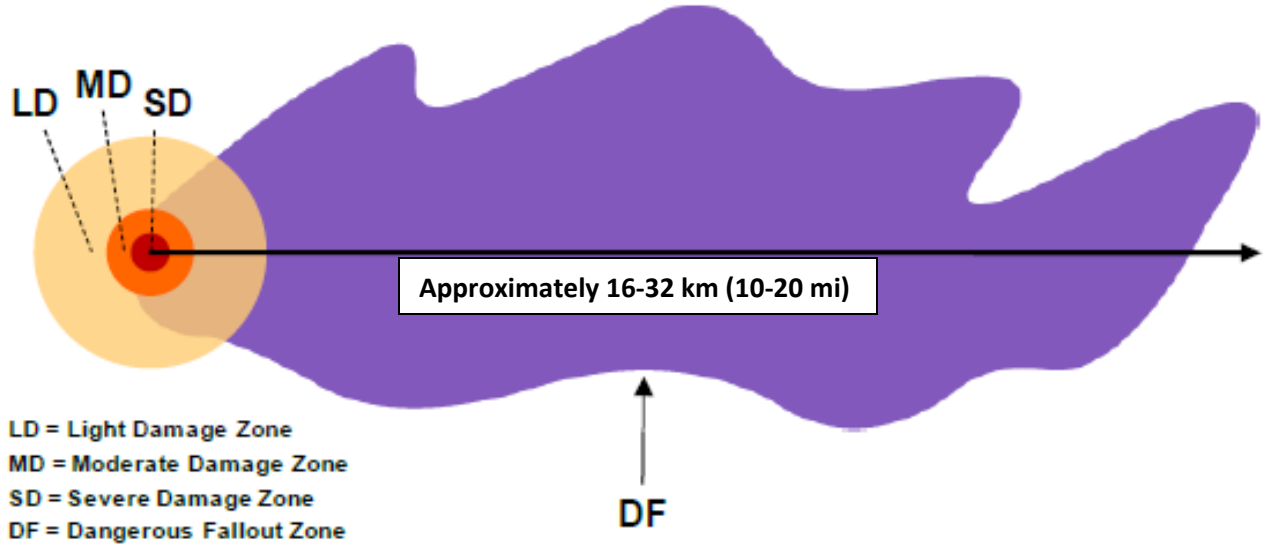
Fatality estimates for this type of incident could exceed 100,000.[9] Because of the magnitude of the incident, commencement of mortuary operations in some locations may be delayed because of high radiation levels or priority of life saving operations. Furthermore, it is possible that many bodies of people killed in this area will need to be interred in place rather than being relocated for mortuary services. Although traditional remains recovery and mortuary response practices will likely need to use altered standards of care for decedents, teams should still strive to provide the highest level of dignity possible.

[7] Additional information about improvised nuclear device planning is available at Planning Guidance for Response to a Nuclear Detonation (May 2022) (fema.gov).

[8] Some guidance documents refer to this as the "dangerous radiation zone."

[9] The *National Response Framework Nuc/Rad Incident Annex* provides fatality estimates for various radiation emergencies and is available at https://www.fema.gov/pdf/emergency/nrf/nrf_nuclearradiologicalincidentannex.pdf.

Figure 1: Improvised nuclear device damage and fallout zones[10]



Detonation of a Radiological Dispersal Device (i.e. Dirty Bomb)

A dirty bomb is a specific type of radiological dispersal device (RDD) that spreads radioactive material using explosives.[11] The size of the blast is thousands of times smaller than that of an improvised nuclear device. Nevertheless, mortuary response teams will be needed to augment state and local resources remains recovery and forensic documentation.

The distribution of radioactive material from a dirty bomb will not be uniform. Responders might encounter hot spots — areas of extremely high dose rates — in various parts of the response area. Furthermore, decedents who were near to the blast might be heavily contaminated, presenting challenges for remains recovery teams and mortuary response teams.

In a response to a terrorist attack using a dirty bomb, the lead criminal investigative agency will require careful documentation of the crime scene and the remains. This requirement is no different than mortuary operations for other criminal mass fatality incidents. However, the presence of contamination or radioactive shrapnel requires additional precautions to ensure the safety of personnel working in the area.

Fatality estimates for a dirty bomb are likely to be due to the blast itself rather than radiation exposure and will be far smaller than for an improvised nuclear device detonation, but the degree of detailed forensic work will require additional resources to complete the task in a timely manner.

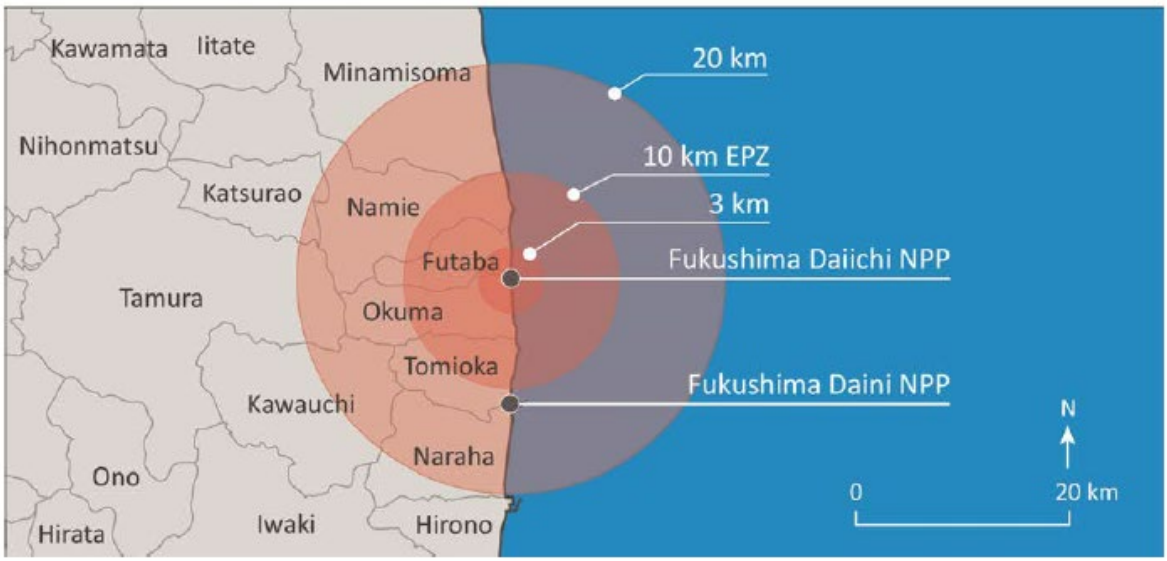
[10] Adapted from *Planning Guidance for Response to a Nuclear Detonation, Second Edition.* https://remm.hhs.gov/IND_Decision_Makers_Guide_2017_guides.pdf

[11] Additional information about the effects of a radiological dispersal device is available at https://www.crcpd.org/mpage/rdd.

Nuclear Reactor Release Following a Natural Disaster

Nuclear power plant accidents are not expected to result in mass fatalities. However, significant natural disasters, such as the earthquake and tsunami that hit Japan in March 2011, have the potential to claim many lives and disrupt nuclear power plant operations. This natural disaster in Japan killed more than 19,000 people, and the resulting infrastructure damage triggered a nuclear meltdown at the Fukushima Daiichi nuclear reactor. During the response, authorities established a 20 km (12 mi) evacuation area (Figure 2). While there were fatalities as a result of the evacuation none were caused by radiation.[12]

Figure 2: Fukushima Daiichi nuclear power plant 2011 evacuation areas[13]



The earthquake, tsunami, and nuclear incident in Japan left many dead across a broad area. Were the contamination plume to overlap a high fatality area, mortuary response teams would need to take additional precautions to minimize cross-contamination and provide adequate radiation safety measures.

[12] Additional information about the Fukushima Daiichi radiation emergency and subsequent response is available at https://www-pub.iaea.org/MTCD/Publications/PDF/AdditionalVolumes/P1710/Pub1710-TV3-Th.pdf.

[13] Adapted from *The Fukushima Daiichi Accident*, International Atomic Energy Agency, 2015. https://www-pub.iaea.org/MTCD/Publications/PDF/AdditionalVolumes/P1710/Pub1710-TV3-Web.pdf

2.0 Establishing Mortuary Field Operations

While the core components of mortuary field operations and human remains recovery will remain the same, responders will need to take additional steps to protect themselves from exposure to elevated radiation levels and radioactive contamination. This chapter discusses mortuary response resources and considerations for mortuary field operations in areas with elevated radiation levels and radioactive contamination.

2.1 Mortuary Response Resources

Field morgue staff members typically include a pathologist, a morgue technician, a scribe, an anthropologist, medicolegal investigator, evidence collection and law enforcement personnel, and a forensic photographer. During the initial examination the team will do the following:

- Check for identification (e.g., credit cards, driver's license)
- Record observations, including characteristics of the decedent and any notable injuries or identifying marks
- Lay out personal effects, such as clothing, jewelry, wallets, keys, and place them into evidence bags
- Take photographs to document each step of the process
- Collect fingerprints and acquire a specimen for DNA analysis

In a mass fatality response, additional mortuary support might be needed to provide the appropriate level of care for the decedents while collecting the necessary information to support law enforcement investigation. If needed, state and local authorities can request support in the form of Disaster Mortuary Operational Response Teams (DMORT).[14] The DMORT responds at the request of state or local authorities and reports to the coroner or medical examiner with jurisdictional authority over the response. Table 1 provides an overview of DMORT personnel and capabilities.

Table 1: Disaster Mortality Operational Response Team (DMORT) personnel, capabilities, and equipment

Personnel	• Funeral directors • Medical examiners • Pathologists • Forensic anthropologists • Forensic odonatologists • Dental assistants • Fingerprint specialists • Security specialists
Capabilities	• Tracking and documenting of human remains and personal effects • Establishing temporary morgue facilities • Assisting in the determination of cause and manner of death • Collection of medical/dental records/DNA from next of kin • Performing postmortem data collection and dental pathology • Documentation during field retrieval and morgue operations
Equipment	The DMORT might deploy with a disaster portable morgue unit.[15] The unit includes equipment and supplies for establishing a field morgue.
Supporting Teams	Human remains recovery teams[16] specialize in the recovery of decedents after manmade and natural disasters. These teams are organized at the state level or in large metropolitan areas and

[14] Additional information about DMORT and other medical response assets under the National Disaster Medical System is available from https://www.phe.gov/Preparedness/responders/ndms/Pages/calling-ndms.aspx.
[15] Additional information about disaster portable morgue units is available at https://rtlt.preptoolkit.fema.gov/Public/Resource/ViewFile/12-508-1217?type=Pdf&q=fatality%20management.
[16] Additional information about Human Remains Recovery Teams is available at https://rtlt.preptoolkit.fema.gov/Public/Resource/ViewFile/12-508-1218?type=Pdf&q=human%20remains%20recovery.

	may go by different names. After a radiation emergency, these teams recover decedents from the affected area and bring them to the DMORT for processing.

2.2 Field Morgue Site Selection

Depending on the nature of the radiation emergency, field morgues might be located in areas with elevated radiation levels. If possible, these sites should be established in uncontaminated areas or in low-background radiation areas with environmental radiation levels below 1µSv/h (0.1 mrem/h).[17] Within the first few days after the incident, emergency managers and radiation control officials are likely to have maps that identify radiation control zones and can help mortuary response teams determine where to establish their field sites. Table 2 suggests capabilities for establishing a field morgue location in a radiation emergency.

Table 2: Capabilities for establishing a field morgue

Basic	Emergency management officials approve of the field morgue location in coordination with radiation control officials.
Intermediate	In addition to basic capabilities, emergency management and radiation control officials use data from environmental monitoring to establish a field morgue location in low-background radiation areas having less than 1µSv/h (0.1 mrem/h).
Advanced	In addition to intermediate capabilities, radiation professionals or staff members trained in radiation detection can provide ongoing on-site monitoring of radiation levels at the field morgue.

2.3 Conducting a Hazard Assessment

Before establishing the field morgue, emergency management and radiation control officials — working with responders in the field — should conduct a hazard assessment. This assessment is to identify radiation hazards and other potential health and safety concerns. The hazard assessment will help inform the selection of personal protective equipment (PPE), if needed. The assessment also can be used to establish or modify work practices and the area of operation.

2.4 Coordinating with Radiation Protection Professionals

Contamination screening and radiation monitoring in support of mortuary field operations should be conducted by radiation protection professionals or trained staff members. A limited number of radiation professionals are likely to be available to assist mortuary response personnel in a radiation emergency. To address this potential shortfall of radiation professionals, mortuary response teams can cross-train staff members and recruit volunteer radiation professionals to augment staff resources.[18] Mortuary response planners also should consult with their state radiation control officials about pre-incident training options for staff members or volunteers.[19]

[17] U.S. Environmental Protection Agency. *PAG Manual: Protective Action Guides and Planning Guidance for Radiological Incidents.* 2017. https://www.epa.gov/sites/default/files/2017-01/documents/epa_pag_manual_final_revisions_01-11-2017_cover_disclaimer_8.pdf.

[18] Conference of Radiation Control Program Directors, Inc. (CRCPD). *A Plan for Incorporating Local Volunteer Radiation Professionals into Existing Health Volunteer Programs to Assist in Population Monitoring*. 2011. Microsoft Word - Draft RRVC Task Force Report2-27-11LinRev.doc (ymaws.com).

[19] A listing of radiation control program directors for each state is available at http://www.crcpd.org/page/map20.

3.0 Radiation Safety for Mortuary Responders

In response to a radiation emergency, the incident commander will designate a radiation safety officer to set dose and dose rate limits for all workers, establish a dosimetry program, and oversee additional radiological precautions during the response.

3.1 Worker Dose and Dose Rate Limits

Because the responsibilities of mortuary response team members vary, establishing uniform dose and dose rate limits might not be practical. For example, members of a human remains recovery team may encounter exposure to higher dose rates in the field than will workers in the field morgue.

The U.S. Environmental Protection Agency (EPA) *Protective Action Guide (PAG) Manual* provides guidance on acceptable doses to responders in radiation emergencies.[20] According to the *PAG Manual*, occupational exposures for trained workers not involved in life-saving activities or operations to protect critical infrastructure should be limited to 50 mSv (5 rem) for the duration of the response. Radiation safety officers seeking more protective dose limits for the mortuary response staff members should consult state radiation control officials to establish those limits. In many cases, dose limits as low as 1 mSv (100 mrem) may be appropriate for field mortuary staff members.[21]

Table 3 provides recommendations for dose rate limits for the field mortuary staff and human remains recovery teams. If ambient radiation levels are low enough, radiation safety officers may decide to lower these limits to further minimize worker exposures. Because the nature of this response is fatality recovery and not lifesaving, dose limits should not exceed 50 mSv (5 rem). If radiation levels are too high, mortuary response operations might need to be delayed to limit doses to the remains recovery teams. Appendix A provides more information on the technical basis for establishing dose and dose rate limits.

Table 3: Recommended dose and dose rate limits

	Field Mortuary Staff	Remains Recovery Team Staff
Dose Limit	1 mSv – 50 mSv (100 mrem – 5 rem)	Up to 50 mSv (5 rem)
Dose Rate Limit	Up to 20 µSv/h (2 mrem/h)	Up to 1 mSv/h (100 mrem/h)

3.2 Monitoring Radiation Doses for Mortuary Responders

The radiation safety officer will work with mortuary response teams to implement a dosimetry program for mortuary response personnel and remains recovery team personnel working in areas with elevated radiation levels. Each person's dose needs to be measured, recorded, and tracked during the response. Electronic dosimeters that read dose rate and cumulative dose can be used for this purpose. Everyone working in the controlled area should carry a thermoluminescent dosimeter (TLD) or equivalent dosimeter inside their protective clothing and an electronic alarming

[20] U.S. Environmental Protection Agency. Protective Action Guide (PAG) Manual. 2017. https://www.epa.gov/sites/default/files/2017-01/documents/epa_pag_manual_final_revisions_01-11-2017_cover_disclaimer_8.pdf

[21] Nuclear Regulatory Commission. "Radiation Dose Limits for Individual Members of the Public." *Code of Federal Regulations Title 10, Pt. 20.1301, Subpart D*. 1991. http://www.nrc.gov/reading-rm/doc-collections/cfr/part020/part020-1301.html.

dosimeter outside the protective clothing where they can read it. The dosimeter readings will eventually constitute the legal record of exposure.[22]

In addition to the normal protocols for human remains removal, the radiation safety officer should cordon off the area and designate a person to control entry and egress. This person will be responsible for tracking entries into the radiation control area and logging dosimetry readings for each worker at the end of the shift. These efforts will help the radiation safety officer ensure that workers stay within their prescribed dose limits. In the event a worker has exceeded the anticipated dose for a given operational period, the radiation safety officer should consider reassigning that person to another duty station in a lower radiation exposure area.

3.3 Personal Protective Equipment

Personal protective equipment (PPE) requirements will vary depending on work responsibilities. For most tasks in the field morgue, standard medical precautions will provide sufficient protection against radiological contamination. Because remains recovery teams will be working within the affected area, their PPE requirements will likely be more stringent than those for field mortuary staff. As part of the initial hazard assessment, the safety officer will work with radiation control professionals to characterize inhalation hazards to the mortuary response staff and remains recovery teams. The Radiation Emergency Medical Management (REMM) website provides detailed information on PPE selection for radiation emergency response.[23]

3.4 Operational Timing and Work/Rest Schedules

Additional factors that can greatly affect the dose to responders is operational timing and staff rotation. The total accumulated radiation dose for each worker will be affected by

- how soon responders arrive on scene,
- how long they work in an area with elevated radiation levels each day, and
- how many consecutive days they are active in the response.

These variables will be different for each incident but adjusting deployment timelines and work schedules to account for radioactive decay, weathering of contamination, and spreading out workers' radiation doses could provide additional protection. The radiation safety officer should work with the planning section chief to ensure that work and rest schedules account for the radiation hazards present, in addition to other environmental factors that can affect worker safety and health.

3.5 Using Time, Distance, and Shielding as Protective Measures

Workers should aim to minimize their time in areas with elevated radiation levels. Additionally, once an elevated radiation exposure area is identified and cordoned off workers should, as much as practical, maximize their distance from the exposure hazard. Shielding, when available and appropriate, can minimize exposure to workers. For example, the location of field morgue itself may be shielded by strategic placement of equipment to shield the workers inside. Lead aprons may be used to cover and shield contaminated decedents while they await processing.

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[22]Additional information about emergency worker dosimetry is available at https://ncrponline.org/shop/reports/report-no-179-guidance-for-emergency-response-dosimetry-2017/ and https://ncrponline.org/shop/commentaries/commentary-no-28-implementation-guidance-for-emergency-response-dosimetry/.

[23] Additional information about PPE is available at https://remm.hhs.gov/radiation_ppe.htm

An example of these practices in combination would be the efficient division of labor among team members, such as when removing radioactive shrapnel or contaminated debris from a decedent at the field morgue. While one team member conducts contamination screening and isolates the shrapnel or debris, the other mortuary staff members are standing back from the decedent to maximize their distance from the radioactive source. After the screening is complete, the mortuary staff will gather the materials they need to remove the radioactive shrapnel or debris, including long forceps to maximize the distance of their hand from the source and a shielded container to place the source in after it is removed. A best practice is to discuss the order of events with other team members, possibly to include a dry run, to ensure the work proceeds as smoothly and quickly as possible. People who are not actively working to isolate, remove, or mitigate the radioactive source should maintain a safe distance in a lower background radiation area. The combination of division of labor and efficient work practices will help reduce occupational doses to staff members. These concepts can also be applied by human remains recovery teams working in the field.

4.0 Conducting Screening and Decontamination of Decedents

Ideally, anyone or anything leaving the affected area will undergo contamination screening — and, if needed, decontamination — before arriving at a field morgue or funeral home. During the screening and decontamination processes, workers must use good work practices, including the use of appropriate PPE, to minimize the spread of contamination. Contamination screening and decontamination practices for personnel and equipment have been well-established in the occupational and emergency response settings. As such, this section will only discuss screening of decedents.

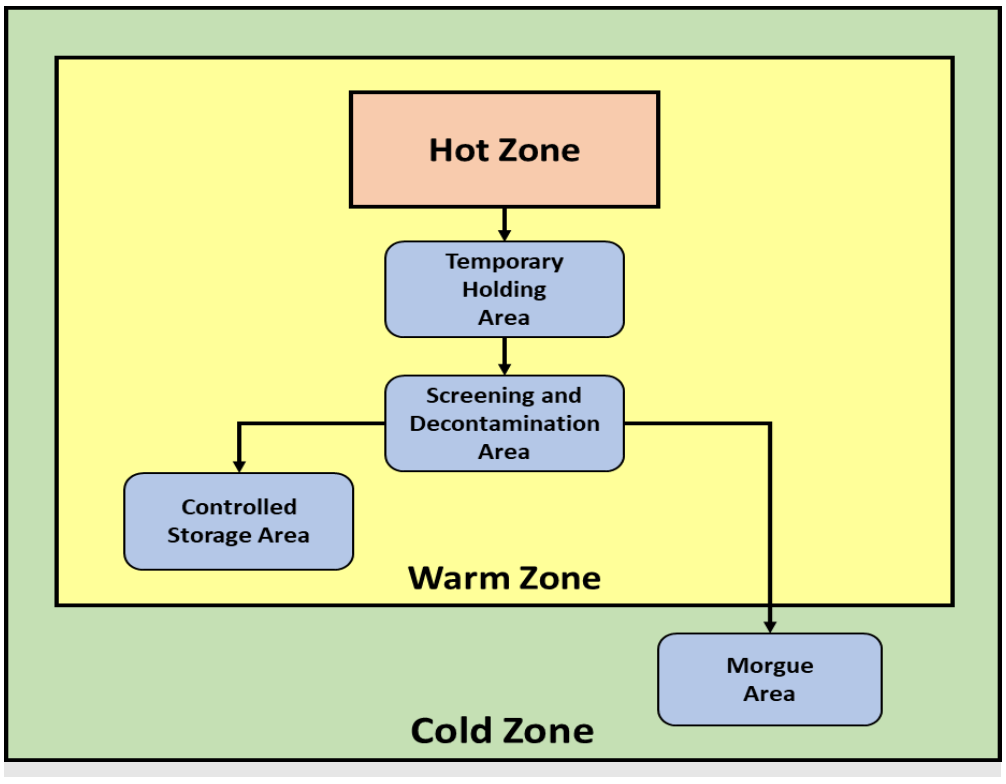
4.1 Contamination Control Zones

Effective provision of screening and decontamination services hinges on the establishment of contamination control zones. Typically, a response to any hazardous materials incident will include establishment of three zones:

- *Hot zone*: The area that presents the greatest hazard due to the presence of hazardous material
- *Warm zone*: The area surrounding the hot zone, where transitional activities, such as decontamination of personnel and victims, take place
- *Cold zone*: The staging area for responders and supporting elements

For a radiation emergency response, the contamination control zone encompasses operations in the hot and warm zones. Screening and decontamination of decedents should take place in the warm zone at dedicated decontamination areas. These steps will help limit the spread of radioactive contamination to the field morgue in the cold zone. Figure 3 shows a general schematic of the arrangement of mortuary response areas in a hazardous materials response.

Figure 3: Placement of screening and decontamination site



In this model, decedents are transferred to staff members working in the warm zone. Stations in the warm zone include a temporary holding area for decedents awaiting processing, a screening and decontamination area, and a controlled storage area for decedents who require special handling because of radioactive contamination. The exact placement of these stations will vary depending on the scale of the incident and the number of resources available.

4.2 Packaging Decedents

When the remains recovery team has completed the on-scene investigation, they will package decedents for transport out of the hot zone. In some instances, a clean work area can be established by first laying down sheets or tarps, then placing a body bag on top of each. This might help minimize the transfer of contamination to the outside of the body bags.

If decedents will be held in the temporary holding area on arrival to the warm zone, body bags may be placed in a secondary container, such as a second body bag or a plastic remains container, to further reduce the potential for cross-contamination. The exterior of the outer containers will be clean and can be moved within the holding area without spreading contamination.

4.3 Screening Decedents

Establishing an intake process similar to that outlined in Figure 3 will help with managing the flow of decedents into the field morgue and limiting cross-contamination. The physical layout will depend on the capabilities and resources available and the number of decedents that need to be processed. Table 4 suggests capabilities for radiation screening. For mortuary response teams that have radiation detection equipment, staff members will need to be adequately trained to screen people and document contamination levels. Table 5 provides examples of flexible screening criteria and practices to allow staff members to scale their operation to the number of fatalities present.

Table 4: Capabilities for contamination screening

Basic	Contamination screening is conducted as part of the mortuary investigation and documentation process, but resources do not permit establishing a dedicated contamination screening station.
Intermediate	A dedicated contamination screening station is established outside of the field morgue and operated by trained staff members; personal effects are collected, bagged, labeled, and securely stored; and photographs and notes document the process.
Advanced	In addition to intermediate capabilities, staff members use portal monitors to expedite screening.

Table 5: Scaling contamination screening practices to meet operational conditions

Situation	Screening Criteria/Practice
Screening resources available; manageable number of fatalities	Twice existing background[24]
Screening resources available but limited; unmanageable number of fatalities	Raise screening criteria as appropriate (e.g., 1 mSv/h @ 30 cm [100 mrem/h @ 1 ft]); coordinate criteria with state radiation control[25,26,27,28]
Screening resources unavailable	Place decedent in temporary holding until screening resources arrive on scene.

Safety officers, working with radiation control officials, may recommend appropriate PPE according to a hazard evaluation and conditions on the ground. For example, if air sampling indicates the presence of airborne contamination, safety officers may assign respiratory protection. If minimal contamination is detected, safety officers may choose to relax requirements for PPE ensembles to reduce worker fatigue and the risks associated with prolonged use of PPE.

Figure 4 provides a flow diagram outlining the screening process. Radiation protection personnel should first measure the dose rate at 30 cm (1 ft) from the exterior of the body bag or container holding the decedent. If the dose rate exceeds 1 mSv/h (100 mrem/h), the decedent should be placed in controlled storage in the warm zone until radiation safety personnel can develop a plan for further assessment and mitigation.

Next, radiation protection personnel should check for the presence of transferable contamination by swiping the container in multiple locations with a piece of tissue, placing the swipe paper on a clean surface away from the container, and checking it with a pancake probe. This check will help determine if the exterior of the container is contaminated. Radiation protection personnel should focus on swiping high contact areas, such as zippers, handles, and portions of the container that might have been resting on the ground, as these areas are the most likely to be contaminated.

If the outside of the body bag is contaminated, staff members might need to decontaminate the body bag or transfer the decedent into a clean body bag before proceeding with the screening. Otherwise, the results of the screening will be elevated by contamination on the outside of the body bag.

If the outside of the body bag is free of contamination, radiation protection personnel can proceed to screening the decedent. Proper handheld contamination screening involves methodically screening the decedent from head to foot (see Figures 5 and 6) at a rate of 2–5 cm (1–2 in) per second and at a distance of 1–2 cm (0.5–1 in) from the body. This survey takes about 4–6 minutes. Screening for alpha contamination using an alpha scintillator requires more time to

[24] U.S. Environmental Protections Agency. *PAG Manual*. 2017. https://www.epa.gov/sites/default/files/2017-01/documents/epa_pag_manual_final_revisions_01-11-2017_cover_disclaimer_8.pdf

[25] Ibid.

[26] Centers for Disease Control and Prevention. *Population Monitoring in Radiation Emergencies: A guide for State and Local Public Health Planners, Second Edition*. 2014. http://emergency.cdc.gov/radiation/pdf/population-monitoring-guide.pdf.

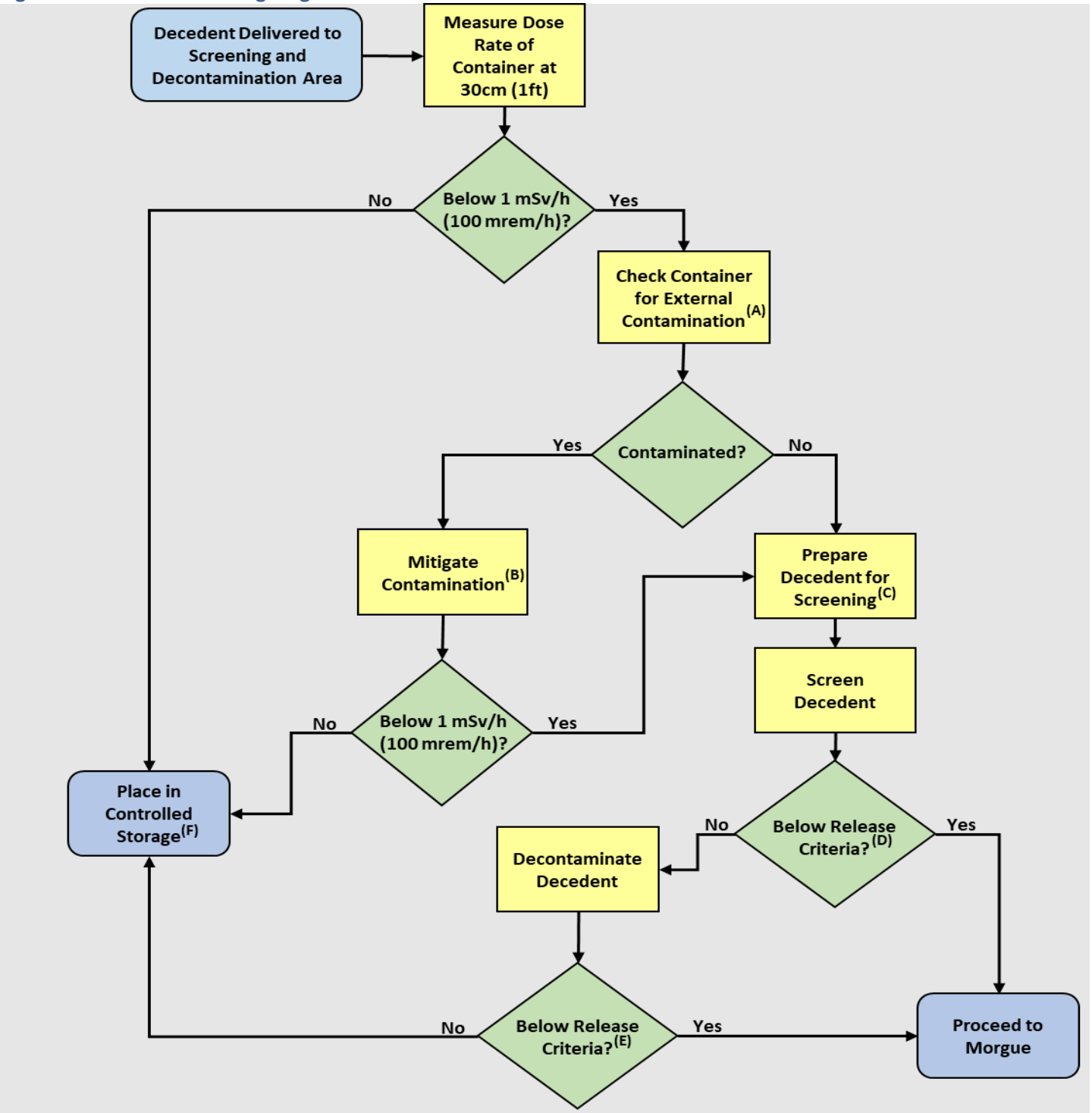
[27] Conference of Radiation Control Program Directors. *Handbook for Responding to a Radiological Dispersal Device*. 2006. Radiological Dispersal Device - Conference of Radiation Control Program Directors, Inc. (crcpd.org).

[28] International Atomic Energy Agency. *Manual for First Responders to a Radiological Emergency*. 2006. http://www-pub.iaea.org/mtcd/publications/pdf/epr_firstresponder_web.pdf.

perform a careful assessment. Figure 6 outlines the procedure for conducting contamination screening for decedents and removing contaminated clothing. If the number of fatalities is too great, alternate screening strategies, such as a rapid handheld screening or the use of portal monitors, might be necessary.

If radiation from a decedent reads greater than 1 mSv/h (100 mrem/h) at 30 cm (1 ft), that person should be moved to controlled storage at least 10 m (~30 ft) from the work area (Appendix A). This will help prevent morgue staff members from exceeding their dose limits. Morgue staff members should consult with a radiation protection professional and devise a special work plan before processing these decedents. If the source of the radiation is a mix of short-lived isotopes, radioactive decay will decrease the dose rate over time. Decedents who have measurable dose rates below 1 mSv/h (100 mrem/h) at 30 cm (1 ft) should be sent to the field morgue for processing.

Figure 4: Decedent screening diagram



(A) Screening staff can take a swipe sample to verify exterior of container is free of contamination.

(B) This process may include decontaminating the outside of the container or transferring the decedent into a clean container. See Section 4.4.

(C) This process includes taking photographs, collecting and bagging personal effects, and carefully removing clothing.

(D) Refer to Appendix B for specific contamination release criteria.

(E) If time permits, additional decontamination may be attempted.

(F) Controlled storage will be located in the warm zone. Consult state radiation control authorities for special handling requirements.

Figure 5: Decedent screening

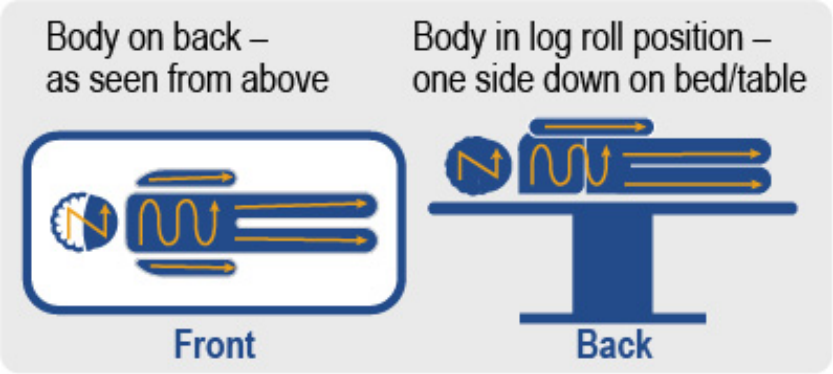


Figure 6: Screening procedure for decedents

	**STEP 1** **Clothing removed from front of decedent**	• Don appropriate PPE. • Lay decedent on double-sheeted table. • Collect personal effects and take photographs. • Working from head to toe, carefully cut away clothing from the front side of the body.
	**STEP 2** **Clothing half removed and covered**	• Log roll decedent onto the outer third of the table. • If clothing does not stay on table after rolling the decedent, carefully remove clothing and lay it on the table. • Cover the clothing with the top sheet and roll the sheet from the outer edge toward the decedent's back.
	**STEP 3** **Clothing fully removed and covered**	• Log roll decedent over the rolled up top sheet and onto the outer third of the table. • With the decedent positioned on the clean bottom sheet, remove remaining clothing and lay it on the top sheet. • With the decedent still on his side, roll up the remaining clothing in the top sheet and carefully remove the sheet from the table. • Place clothing in a bag labeled with the decedent's name and case number and store in a secure location.
	**STEP 4** **Contamination screening of back**	• With the decedent still positioned on his side, conduct contamination screening of the decedent's back (see Figure 5). • If contamination is found in excess of the release criteria, document the location and readings, perform localized decontamination, and screen again (see Section 4.4 for additional information on decontamination) • Contamination screening of the decedent's back is complete.
	**STEP 5** **Contamination screening of front**	• Roll the decedent onto his back. • Conduct contamination screening of the decedent's front (see Figure 5). • If contamination is found in excess of the release criteria, document the location and readings, perform localized decontamination, and screen again (see Section 4.4 for additional information on decontamination). • Contamination screening of the decedent is complete.

NOTE: If contamination is still present after decontamination, document the location and readings and inform mortuary staff. Residual contamination on the decedent may affect how the body is handled and which services are provided after leaving the field morgue.

4.4 Decontaminating Decedents

Decedents are decontaminated to protect personnel handling the decedent and to limit further spread of radioactive contamination in the environment. The extent of decontamination services and the release criteria by which decedents are evaluated (see Appendix B) might need to be adjusted, depending on the number of fatalities and the resources on hand.

Staff members can use multiple methods of decontamination to clean decedents. Initially, carefully removing the decedent's clothing will remove a significant amount of contamination. After the clothing is removed, staff members can determine which methods are necessary to remove contamination from the skin and hair. If radioactive shrapnel is present, consider removing it and safely storing it in a shielded container before attempting decontamination of other parts of the body. This practice will reduce the chances of false detections at other parts of the body. After the decedent's clothing and any radioactive shrapnel have been removed, staff members can focus on reducing loose contamination and characterizing fixed contamination.

Decontamination might be localized to a small area on the decedent or might require more significant cleaning of the skin and hair. In many cases, a combination of dry and wet decontamination methods will be needed. Examples of various decontamination methods include the following:

- Dry decontamination of hair using a vacuum with high efficiency particulate air filter
- Removal of particulates from the skin using tape
- Localized cleaning with moist wipes
- General washing with soap and water

Mortuary staff members will likely need to use multiple methods to clean decedents effectively. Because the size of the incident and the availability of resources will affect the extent of services, decontamination operations will need to remain scalable and flexible to meet the need. Table 6 identifies general capabilities for decontaminating decedents.

Table 6: Capabilities for decontamination

Basic	Screening resources are limited; staff members treat all decedents as contaminated (e.g., remove clothing and transfer decedent into a clean remains container in the warm zone).
Intermediate	In addition to basic capabilities, screening resources are available; staff members can localize contamination and perform spot decontamination using wet wipes or limited washing with soap and water.
Advanced	In addition to intermediate capabilities, staff members can remove and contain radioactive shrapnel.

4.5 Screening and Decontaminating Personal Effects

Normally, the medical examiner or coroner will return personal effects to the family, unless they have some forensic value. In this case, consider returning only personal effects that have monetary or sentimental value and are easily decontaminated.

Examples of personal effects include the following:

- Wallets
- Keys
- Mobile phones
- Debit cards
- Credit cards
- Identification
- Photographs
- Wedding bands
- Religious texts
- Religious symbols

Ensure the free release survey criteria listed in Appendix B are satisfied.

Items that cannot be decontaminated should be stored in a secure location. Storage areas for contaminated items should be located away from occupied spaces, locked, and labeled with appropriate signs to indicate a contamination control zone. Radiation safety personnel should routinely check the dose rate at the perimeter of these storage areas to ensure it does not exceed 20 µSv/h (2 mrem/h).[29] Items placed in contaminated storage areas should be bagged and labeled with the owner's name and tracking information. This information might be necessary for law enforcement and public health investigations.[30]

[29] Nuclear Regulatory Commission. Subpart D—Radiation Dose Limits for Individual Members of the Public. 1991. https://www.nrc.gov/reading-rm/doc-collections/cfr/part020/part020-1301.html

[30] For more information on working with law enforcement after a radiation emergency, see CDC's *Radiological/Nuclear Law Enforcement and Public Health Investigation Handbook*, available at http://www.emergency.cdc.gov/radiation/pdf/radiological-nuclear-handbook-09-01-11.pdf.

5.0 Considerations for Disposition and Handling of Decedents

The amount of contamination — either external or internal — and the resulting dose rate from the body will affect how a decedent is handled and which services are provided. This section outlines considerations for various services, such as transport, autopsy, embalming, burial practices, and cremation, that might have to be altered because of radiation safety concerns.

Table 7 provides a matrix for determining the appropriate practices for handling and disposition of contaminated decedents. Mortuary staff members will need to work closely with radiation safety personnel to determine which services can be provided, based on the dose rate from and residual contamination present on the decedent. Note that while some practices are not recommended, they do not conflict with EPA's position on the disposal of contaminated human remains under the Resource Conservation and Recovery Act.[31]

Table 7: Disposition and handling of decedent (dose rate at 30 cm [1 ft])

Gamma Dose Rate	Transport	Shielded Casket	Sealed Casket	Embalm/ View[32]	Autopsy	Natural Burial[33]	Cremation
> 1 mSv/h (100 mrem/h)	Consult with a radiation protection professional	Permissible	Not recommended	Not recommended	Not recommended	Not recommended	Not recommended
> 0.05 mSv/h (5 mrem/h)	Permissible	Permissible	Permissible	Consult with a radiation protection professional	Consult with a radiation protection professional	Not recommended	Not recommended
> 0.02 mSv/h (2 mrem/h)	Permissible	Permissible	Permissible	Permissible	Consult with a radiation protection professional	Not recommended	Not recommended
< 0.02 mSv/h (2 mrem/h)	Permissible	Permissible	Permissible	Permissible	Permissible	Refer to free release contamination limits in Appendix B	Refer to free release contamination limits in Appendix B

5.1 Transporting Decedents

Decedents are normally transported in sealed containers, which are effective at controlling radioactive contamination. However, the dose rate outside the container might present a hazard to personnel involved in transporting the decedent. Labeling the container with the dose rate will help morgue and funeral home staff members limit their risk from radiation exposure. The measured dose rate 30 cm (1 ft) from the container can be used to determine the appropriate transportation plan, as outlined below:

[31] U.S. Environmental Protection Agency. *Management of Contaminated Human Remains and Personal Effects from Homeland Security Events* (interdepartmental memorandum). Jan 15, 2010. https://rcrapublic.epa.gov/files/14811.pdf.

[32] See Section 5.4.

[33] In the context of this guide, the term "natural burial" encompasses all forms of burial that do not inhibit the decomposition of the body in the soil. For example, decedents are not embalmed and caskets or other burial containers are biodegradable.

- For dose rates above 1 mSv/h (100 mrem/h), consult state radiation control authorities to develop a special transportation plan for the decedent. The container should be labeled to appropriately warn of the elevated radiation hazard. At a minimum, the label should include the dose rate, date, and time of measurement.
- For dose rates below 1 mSv/h (100 mrem/h), radiation protection personnel should place a label on the exterior of the container displaying the dose rate, date, and time of the measurement.

Table 8 provides recommendations for actions regarding transportation for contaminated decedents.

Table 8: Recommendations for transport

Dose Rate at 30 cm (1 ft)	Recommendation	
Above 1 mSv/h (100 mrem/h)	Consult state radiation control authorities to develop specialized transportation plan.	**Radiation consultation recommended**
Below 1 mSv/h (100 mrem/h)	Label container with dose rate, date, and time of measurement before transport.	**Permissible**

Although the U.S. Department of Transportation has regulations for the transport of radioactive materials,[34] it might not be feasible to adhere to these regulations following a mass fatality radiation emergency. In certain circumstances, state and local authorities might need to request an exemption to existing transportation regulations to expedite the movement of decedents from the field morgue.

5.2 Autopsy

An autopsy normally entails extensive handling of internal organs by gloved hands. Radioactive material inside the body, whether from shrapnel or contamination in internal organs, might cause avoidable and unnecessary radiation exposure to the pathologist's hands. Do not perform an autopsy if radiation protection personnel have identified or suspect significant levels of internal contamination.

In the absence of definitive measurements for internal contamination, the measured dose rate 30 cm (1 ft) from the decedent can be used as an indicator, as outlined below:

- For dose rates above 1 mSv/h (100 mrem/h), autopsy is not recommended until dose rates are reduced.
- For dose rates between 0.02–1 mSv/h (2–100 mrem/h), medical examiners should consult a radiation protection professional before proceeding.
- For dose rates below 0.02 mSv/h (2mrem/h), autopsy will present little radiation hazard to the medical examiner, as long as appropriate PPE is used to control cross-contamination.

Table 9 provides recommendations for actions regarding performing autopsies on contaminated decedents.

[34] Additional information regarding transport of radioactive materials is available at https://www.govinfo.gov/app/details/CFR-2010-title49-vol2/CFR-2010-title49-vol2-part172.

Table 9: Recommendations for autopsy

Dose Rate at 30 cm (1 ft)	Recommendation	
Above 1 mSv/h (100 mrem/h)	Autopsy is not recommended until dose rates are reduced	**Not recommended**
0.02–1 mSv/h (2-100 mrem/h)	Consult a radiation protection professional before proceeding with autopsy	**Radiation consultation recommended**
Below 0.02 mSv/h (2 mrem/h)	Autopsy is permissible with use of proper personal protective equipment	**Permissible**

5.3 Embalming

Embalming is required for aesthetic reasons if there is to be a viewing. Most funeral directors will not allow the public to view an unembalmed decedent during viewing or visitation. A decedent who has residual contamination on or inside the body might present a potential hazard to the embalmer. Although the use of standard medical precautions will mitigate the potential for cross-contamination, embalmers will be working close to the decedent and will need to be mindful of their radiation dose.

The measured dose rate 30 cm (1 ft) from the decedent can be used to determine if embalming is permissible, as outlined below:

- For dose rates above 1 mSv/h (100 mrem/h), embalming is not recommended until dose rates are reduced.
- For dose rates between 0.05–1 mSv/h, embalmers should consult a radiation protection professional before proceeding.
- For dose rates below 0.05 mSv/h (5 mrem/h), embalming will present little radiation hazard to the embalmer, as long as appropriate PPE is used to control cross-contamination.

Table 10 provides recommendations for actions regarding embalming contaminated decedents.

Table 10: Recommendations for embalming

Dose Rate at 30 cm (1 ft)	Recommendation	
Above 1 mSv/h (100 mrem/h)	Embalming is not recommended until dose rates are reduced	**Not recommended**
0.05–1 mSv/h (5–100 mrem/h)	Consult a radiation protection professional before embalming	**Radiation consultation recommended**
Below 0.05 mSv/h (5 mrem/h)	Embalming is permissible with use of proper personal protective equipment	**Permissible**

5.4 Preparation for Viewing

A viewing for decedents after a radiation emergency might not be possible for multiple reasons. Those might include traumatic injury to the body, delayed recovery efforts, and residual contamination. The first two factors are beyond the scope of this guide. For residual contamination, the measured dose rate 30 cm (1 ft) from the decedent can be used to determine if holding a viewing for the decedent is advisable, as outlined below:

- For dose rates above 1 mSv/h (100 mrem/h), public viewing is not recommended.
- For dose rates above 0.05 mSv/h (5 mrem/h), a short viewing may be appropriate. Consult a radiation protection professional to establish a plan to limit the dose and dose rate to attendees.[35]
- For dose rates below 0.05 mSv/h (5 mrem/h), a normal viewing is permissible.

Table 11 provides recommendations for actions regarding holding viewings and visitations for contaminated decedents.

Table 11: Recommendations for viewing

Dose Rate at 30 cm (1 ft)	Recommendation	
Above 1 mSv/h (100 mrem/h)	Public viewing is not recommended; consult a radiation protection professional	**Not recommended**
Above 0.05 mSv/h (5 mrem/h)	Consult a radiation protection professional	**Radiation consultation recommended**
Below 0.05 mSv/h (5 mrem/h)	Normal viewing is permissible	**Permissible**

5.5 Preparation for Burial

Ideally, decedents will be buried in a casket or other container that will delay the release of radioactive material to the environment as long as practical. Wooden caskets are not sealed. Typical metal caskets have a seal that will release pressure from inside the casket but will retard the entry of ground water. Although they are metal, they are not designed to provide additional shielding to reduce radiation dose rates outside of the casket. In extreme circumstances, highly radioactive bodies should be buried in a shielded metal casket lined with plastic. These specialized caskets provide shielding that reduces the radiation dose rate outside of the casket.

The type of burial and casket will be determined in part by the amount of residual contamination on the decedent. Extremely contaminated decedents that have high dose rates might require burial in a shielded casket. For dose rates under 1 mSv/h (100 mrem/h), shielded caskets are not necessary. The measured dose rate 30 cm (1 ft) from the decedent can be used to determine which type of burial is permissible, as outlined below:

- For dose rates above 1 mSv/h (100 mrem/h), consult a radiation protection professional to determine if a specialized shielded casket is necessary for burial.
- For dose rates under 1 mSv/h (100 mrem/h), use of a traditional sealed casket is appropriate.
- For dose rates below 0.02 mSv/h (2 mrem/h), a natural burial is permissible.

[35] The EPA PAG Manual (2017) establishes a 0.02 mSv/h (2 mrem/h) dose rate limit for members of the public.

Table 12 provides recommendations regarding different types of burial for contaminated decedents.

Table 12: Recommendations for burial

Dose Rate at 30 cm (1 ft)	Recommendation
Above 1 mSv/h (100 mrem/h)	Use of a shielded casket is recommended, but is not essential for burial
Below 1 mSv/h (100 mrem/h)	Use of a sealed casket is recommended, but is not essential for burial
Below 0.02 mSv/h (2 mrem/h)	Natural burial is permissible; see Appendix B for contamination limits

5.6 Cremation

Cremation is not recommended for contaminated decedents. However, cremation may be requested or merited under certain circumstances. In these instances, the following criteria should be met:

- Dose rate at 30 cm (1 ft) from the decedent is below 0.02 mSv/h (2 mrem/h).
- No radioactive shrapnel is present in the body.
- Levels of residual contamination are below the free release criteria provided in Appendix B.

Mortuary staff members will need to work with radiation control officials to determine if cremation is permissible for decedents on a case-by-case basis.

Table 13 provides recommendations for actions regarding cremation of contaminated decedents.

Table 13: Recommendations for cremation

Dose Rate at 30 cm (1 ft)	Recommendation	
Above 0.02 mSv/h (2 mrem/h)	Cremation is not recommended	**Not recommended**
Below 0.02 mSv/h (2 mrem/h)	Consult radiation control authorities to assess for contamination	**Refer to Appendix B**

Appendix A: Technical Basis for Dose and Dose Rate Limits

Limits on radiation dose and dose rate for radiation workers and members of the public are found in 10 CFR 20, *Standards for Protection Against Radiation*. Specific references are listed and cited in the table below. Radiation workers are generally limited to an annual radiation dose of 50 mSv (5 rem). Members of the public, including workers who have not been trained in radiation work, are generally limited to an annual radiation dose of 1 mSv (100 mrem) and a dose rate of 20 µSv/h (2 mrem/h).

Radioactive contamination (fixed or removable) on the decedent may lead to elevated dose rates in the general vicinity of the decedent. General contamination limits are found in Appendix B, *Technical Basis for Contamination Screening and Release Limits*. Elevated dose rates may indicate that small pieces of radioactive shrapnel are present. The radiation safety officer should be consulted regarding procedures for removal and storage of shrapnel.

Item	**Limit**
Occupational radiation dose limit	50 mSv/y (5 rem/y) total effective dose equivalent[36]
Occupational radiation dose limit to declared pregnant worker	5 mSv (500 mrem) during gestation period[37]
Public radiation dose limit	1 mSv/y (100 mrem/y)[38]
Public radiation dose rate limit	20 µSv/h (2 mrem/h)[38]
Radiation area	50 µSv/h (5 mrem/h) at 30 cm (1 ft)[39]
High radiation area	1 mSv/h (100 mrem/h) at 30 cm (1 ft)[39]

[36] 10 CFR 20.1201, "Occupational Dose Limits for Adults" https://www.nrc.gov/reading-rm/doc-collections/cfr/part020/part020-1201.html

[37] 10 CFR 20.1208, "Dose Equivalent to an Embryo / Fetus" https://www.nrc.gov/reading-rm/doc-collections/cfr/part020/part020-1208.html

[38] 10 CFR 20.1301, "Dose Limits for Individual Members of the Public." These limits are "exclusive of the dose contributions from background radiation, from any medical administration the individual has received, from exposure to individuals administered radioactive material and released under § 35.75, from voluntary participation in medical research programs, and from the licensee's disposal of radioactive material into sanitary sewerage in accordance with § 20.2003." https://www.nrc.gov/reading-rm/doc-collections/cfr/part020/part020-1301.html

[39] 10 CFR 20.1003, "Definitions" https://www.nrc.gov/reading-rm/doc-collections/cfr/part020/part020-1003.html

Appendix B: Technical Basis for Contamination Screening and Release Limits

The primary goal of limits on fixed and removable radioactive contamination on decedents is to limit dose to the public — including mortuary staff members — to 1 mS/y (100 mrem/y) or less, including the inhalation or inadvertent ingestion of radioactive materials. Removable contamination up to 10 times the limits provided in the table below, might be present on decedents during in-mortuary processing. Contamination levels on decedents may be reduced using wet or damp decontamination techniques. Significant contamination levels might indicate the need for air sampling in work areas.

Free release limits are applied to items released for unrestricted use, including possessions returned to families. These limits can also be used to determine whether a decedent can be cremated without presenting undo risk to personnel or the environment. These levels of radioactive contamination are extremely low, and measurement may only be achieved by trained personnel using specialized equipment. Furthermore, it might be appropriate to return items of significant sentimental or monetary value to family members of decedents, even if those items are contaminated beyond these limits. In these instances, special consideration and evaluation should be given to the degree of residual contamination and the risk it poses to the recipients of those items.

Item	Limit
Removable surface beta-gamma / low-toxicity alpha contamination	4 Bq/cm^2 (24,000 dpm/100 cm^2)[40,41]
Removable surface high-toxicity alpha contamination	0.4 Bq/cm^2 (2,400 dpm/100 cm^2)[40,41]
Fixed surface beta-gamma contamination	Dose rate ≤ 50 µSv/h (5 mrem/h) at 30 cm (1 ft)
Fixed surface alpha contamination	Consult radiation safety officer for guidance. Special instrumentation required to determine compliance
Free-release limit for removable beta-gamma contamination	0.2 Bq/cm^2 (1,000 dpm/100 cm^2)[42]
Free-release limit for removable high-toxicity alpha contamination	0.003 Bq/cm^2 (20 dpm/100 cm^2)[42]
Free-release limit for fixed beta-gamma contamination	Average: 0.8 Bq/cm^2 (5,000 dpm/100 cm^2)[42] Maximum: 2.5 Bq/cm^2 (15,000 dpm/100 cm^2)[42]
Free-release limit for fixed high-toxicity alpha contamination	Average: 0.02 Bq/cm^2 (100 dpm/100 cm^2)[42] Maximum: 0.05 Bq/cm^2 (300 dpm/100 cm^2)[42]

[40] 49 CFR 173.443 Table 9, "Non-Fixed External Radioactive Contamination Limits for Packages." https://www.govinfo.gov/content/pkg/CFR-2015-title49-vol2/pdf/CFR-2015-title49-vol2-sec173-443.pdf

[41] As prepared for transport. During transport, removeable contamination levels associated with "exclusive use" shipments may legally increase by as much as a factor of 10.

[42] Regulatory Guide 1.86, "Termination of Operating Licenses for Nuclear Reactors," Table 1, "Acceptable Surface Contamination Levels." Levels cited are above background. https://www.nrc.gov/docs/ML0037/ML003740243.pdf