HEALTH AND SAFETY

1. GENERAL. A nuclear weapon accident or incident is different from other accidents due to the possibility of radioactive contamination at the immediate accident site and extending beyond the accident vicinity. The complexities of a nuclear weapon accident or incident are compounded further by general lack of public understanding of radiological hazards. The IC must quickly establish a vigorous and comprehensive health physics and industrial hygiene/safety program to manage the health and safety aspects of a nuclear weapons accident. A good health and safety program provides for civil official involvement in the cooperative development of response efforts and a site remediation plan. The Safety Officer is the DoD IC's focal point for ensuring health and safety of the overall recovery operation. The ASHG is a valuable resource to the Safety Officer for addressing health and safety for the on-site weapon recovery operations portion of the response .

a. The Safety Officer monitors accident or incident operations and advises the DoD IC on all matters relating to operational safety, including the health and safety of emergency responder personnel. The ultimate responsibility for the safe conduct of accident management operations rests with the DoD IC or UC and supervisors at all levels of accident management. The Safety Officer is, in turn, responsible to the DoD IC or UC for the set of systems and procedures necessary to ensure ongoing assessment of hazardous environments, coordination of multiagency safety efforts, and implementation of measures to promote emergency responder safety, as well as the general safety of accident operations. The Safety Officer has emergency authority to stop and/or prevent unsafe acts during accident or incident operations. In a UC structure, a single Safety Officer should be designated, in spite of the fact that multiple jurisdictions and/or functional agencies may be involved. Assistants may be required and may be assigned from other agencies or departments constituting the UC. The Safety Officer, Operations Section Chief, and Planning Section Chief must coordinate closely regarding operational safety and emergency responder health and safety issues. The Safety Officer must also ensure the coordination of safety management functions and issues across jurisdictions, across functional agencies, and with private-sector and nongovernmental organizations. Agencies, organizations, or jurisdictions that contribute to joint safety management efforts do not lose their individual identities or responsibility for their own programs, policies, and personnel. Rather, each entity contributes to the overall effort to protect all responder personnel involved in accident or incident management operations.

2. PURPOSE AND SCOPE. This chapter provides information on health physics and industrial hygiene/safety and guidance on the radiological and other hazards associated with a nuclear weapon accident or incident. Also included is information on the resources available, the hazards and characteristics of radioactive and other hazardous materials potentially present, and suggested methods for detecting these hazards and protecting personnel from them. This information assists the IC in the operations under his or her control. The ASHG provides both direct health and safety support to weapon recovery operations and serves as the IC's organizational means to task on-site hazard and radiological data collection and analyze data collected for the most accurate and complete hazard and/or radiological assessment in support of the response effort. This chapter provides recommendations, advice, and assistance to civil authorities with jurisdiction over areas affected by the accident for both radiological and non-radiological hazards of a nuclear weapon accident. The ASHG is the on-site equivalent of the Federal Radiological Monitoring

and Assessment Center (FRMAC), and the two organizations coordinate closely if both are present. The FRMAC supports the IC with coordinated off-site monitoring and assessment. In accordance with reference (ad), the FRMAC may also be activated under a direct request from SLT governments and other Federal agencies. When activated, plume modeling conducted by the FRMAC will be used by DoD.

3. <u>SPECIFIC REQUIREMENTS</u>. DoD and DOE/NNSA response activities include protecting response force personnel and the public from on-site hazards associated with a nuclear weapon accident and to lessen potential health and safety problems. To accomplish this, DoD and the DOE/NNSA establish an ASHG to:

a. Initiate and manage on-site hazard and radiation health assessments, support weapon recovery operations, and provide on-site safety and environmental monitoring capabilities.

b. Obtain initial hazard plots (HPAC and/or ARAC) for an assessment of potential contamination and potential public dose; make the plot available to the IC; correlate the plot with survey results for confirmation and/or validity; and rerun the model(s), as needed, to update the projections. Once the FRMAC or IMAAC is on scene and operational, HPAC or ARAC plots will no longer be used.

c. Determine if radioactive contamination has been released.

d. Determine the presence of non-radiological hazards associated with the accident.

e. Advise the IC of precautionary measures for on-site personnel (residents, impacted individuals, security personnel, responders and others) in potentially contaminated areas. Convey risk assessment information.

f. Coordinate and integrate the capabilities of specialized teams working on-site.

g. Implement applicable health and safety standards and monitor the safety procedures of all personnel taking part in weapon recovery operations.

h. Monitor the tempo of the response effort and, if required, recommend a safety stand-down period to prevent undue physical and mental fatigue.

i. Manage and advise for actual and potential medical casualties in coordination with the medical response element and in accordance with guidelines in the AFRRI's "Medical Management of Radiological Casualties" (reference (bs)); Army FM 4-02.283, Navy NTRP 4-02.21, Air Force Manual (AFMAN) 44-161(I), Marine Corps MCRP 4-11.1B "Treatment of Nuclear and Radiological Casualties" (reference (bt)); and other accepted medical practice. See the Medical page for specific discussion of the medical aspects of nuclear weapon accident or incident response activities.

j. Brief and train people not previously designated as radiation workers who are called upon to work in the contaminated area on the subjects of PPE, hazards, and safety measures before they enter potentially contaminated areas.

k. Establish dosimetry and documentation procedures as early as Phase II, and especially during personnel decontamination and remediation operations.

l. Determine levels of contamination present and boundaries of the on-site contaminated areas through ground and air surveys. Establish a CCL that marks the approximate perimeter of the on-site contamination area.

m. Develop and provide on-site contamination plots to the IC.

n. Consolidate all radiological and non-radiological assessment information for on-site recovery operations and provide it to the IC.

o. Analyze and correlate all contamination data collected to identify inconsistencies requiring further investigation.

p. Establish contamination control procedures and operate a CCS for personnel, equipment, and vehicles. If necessary, additional CCSs may be established.

q. Establish a bioassay program (in conjunction with the medical response element). Upon arrival, the RAMT will provide advice and oversight for the bioassay program.

r. Review and correlate records from CCS(s) and other personnel processing points to ensure bioassays or other appropriate follow-up actions are taken.

s. Recommend methods and procedures to reduce or prevent resuspension and spread of radioactive contamination in case of wind shifts or disturbance by recovery activities.

t. Refer all unofficial and media requests for information to the JIC/CIB. However, be prepared to present radiological contamination findings and results at press conferences and community forums, as directed. Present data in clear, concise, and non-technical briefings, outlining hazards, precautionary measures, business recovery, and where to get more information and/or assistance.

u. Liaise with the FRMAC and with SLT authorities on off-site issues and on-site activities with the potential for off-site consequences.

v. When the NDA, NSA, or Security Area is dissolved, transfer applicable control of ASHG personnel and equipment as requested to support FRMAC and/or SR operations (if on U.S. territory) or to the corresponding host nation authorities off-site.

w. With the EPA, support the FRMAC in the development and coordination of the SR plan.

x. Track all medical and radiological casualties in coordination with medical response personnel (see the Medical page).

RESOURCES

a. Response Force Resources. Response forces should have a full complement of operable and calibrated radiological and industrial hygiene/safety monitoring equipment. Sufficient quantities of materials should also be available for replacement or repair of critical or high-failure-rate components such as Mylar® probe faces. For the Department of Defense, replacement plans are necessary as RADIAC equipment available to IRFs may not meet initial operational needs after a large release of contamination. Although IRFs are equipped and trained to conduct radiation surveys for low levels of radioactive contamination, this is difficult to do over rough surfaces like rocks or plants, or over wet surfaces. Specialized DoD and DOE/NNSA teams are better equipped to monitor for low-level contamination, and more detailed monitoring should wait until these specialized teams arrive. The Radiological Monitoring Equipment page has a list of radiological monitoring equipment used by the Services, with a summary of their capabilities and limitations. Additionally, personnel should know the various units in which contamination levels might be measured or reported and the method of converting from one unit to another. A conversion table for various measurements is provided in the Conversion Factors for Weapons Grade Plutonium page.

b. Specialized Teams. Several specialized teams are available within the Department of Defense and the DOE/NNSA with substantial radiological monitoring and hazard assessment capabilities; these teams may also provide field laboratories and analytical facilities. Specialized teams, when integrated into the response, provide adequate technical resources to completely assess the on-site hazards. Additionally, specialized DOE/NNSA teams, which have off-site responsibilities, should be integrated into the response as appropriate. HPAC development support is through the DTRA Operations Center as well as the CMAT, which is an established and trained specialized team of advisors deployed to help the response manage all phases after a nuclear weapon accident. Specialized team operations are best integrated by establishing an ASHG, as discussed in section 3. above. When not required on-site, DoD specialized teams should assist in the off-site radiological response efforts, as requested. The capabilities of the specialized teams are highlighted in the Specialized Radiological Monitoring and Hazard Assessment Capabilities page.

5. CONCEPT OF OPERATIONS

This concept of operations assumes that a nuclear weapon accident or incident has resulted in a release of contamination to areas beyond the immediate vicinity of the accident site. The distinction between on-site and off-site is significant for security and legal purposes; however, for effective collection and meaningful correlation of radiological data, the entire region of contamination must be treated as an entity. Therefore, although the DoD IC is normally responsible only for activities occurring inside the NDA/NSA, the nature of the safety mission and its direct link to operations inside the NDA/NSA necessitate that RTF safety personnel remain under the authority of the DoD IC. The on-site and off-site distinction should be considered only when assigning areas to monitoring teams. Possible response force actions are addressed in this concept of operations. Only limited equipment and expertise may be available to the IRF.

a. IRF or DOE RAP Team Actions. Within the constraints of available resources, the IRF or the DOE RAP team arriving on-scene should determine the absence or presence of any radiological problem and its nature; recommend reducing possible radiation hazards to the public and response force personnel as appropriate; identify all persons who may have been contaminated; establish traceable records of such personnel for follow-up; begin decontamination actions as resources permit; recommend public confirmation of the accident to the IC and provide appropriate news releases and; notify local officials of potential hazards.

(1) Pre-Deployment Actions.

(a) Before leaving for the accident site, hazard plot delivery should be arranged to help determine potential areas of contamination to avoid contamination of response teams and equipment. ARAC and HPAC plots can provide theoretical (conservative) estimates of the radiation dose to personnel downwind during the accident and also the expected location and level of maximum contamination deposition on the ground. As more details of the accident become known, specific accident data should be provided to the ARAC facility at DOE's Lawrence Livermore National Laboratory to update and refine these estimates of deposition and dose. These follow-on plumes generated by the IMAAC or FRMAC will be used instead of the preliminary HPAC plots.

(b) If an advance party is deployed, at least one trained person should have radiation detection instruments to determine if alpha-emitting contamination was dispersed and to confirm that no beta and/or gamma hazard exists. The sooner that confirmation of released contamination is established, the easier it is to develop a plan of action and communicate with involved civil authorities.

(2) Initial Actions.

(a) If the IC, or an advance party, deploys by helicopter to the accident site, an overflight of the accident or incident scene and the downwind area may provide a rapid assessment of streets or roads in the area and the types and uses of potentially affected property. During helicopter operations, flights should stay above or clear of any smoke and at a sufficient altitude to prevent resuspension from the downdraft when flying over potentially contaminated areas. The landing zone should be upwind, or crosswind, from the accident or incident site.

(b) After arrival at the site, a reconnaissance team consisting of an EOD element and/or other specialties should enter the accident site to inspect the area for hazards, determine the type(s) of contamination present, measure levels of contamination and initiate air sampling, mark a clear path, mark hazards, perform initial site stabilization and emergency procedures, and assess weapon status. The approach to the scene should be from upwind, if at all possible. The accident situation indicates whether the initial entry teams requires PPE or respiratory protection. PPE and respiratory protection should always be donned before entering a suspect area. Every consideration should be given to both protecting the initial entry team and preventing undue public alarm. Until the hazards are identified, only essential personnel should enter the possible contamination or fragmentation area of the specific weapon(s). The generally accepted explosive safety distance for nuclear weapons is 770 m (2,500 feet); however, contamination may extend beyond this distance. Specific fragmentation safety distances may be found in classified EOD publications. At this point, a temporary CCL should be considered. Later, when the boundary of the contaminated area is defined and explosive hazards are known, the control line may be moved for better access to the area. Contamination, or the lack thereof, should be reported immediately to the IC.

(c) If radiation detection instruments are not yet on-scene, observations from firefighters and witnesses and the condition of the wreckage or debris may indicate the possibility of contamination. Questions that may be asked to evaluate the potential for release of contamination are:

1. Was there an explosive detonation?

2. Has a weapon undergone sustained burning?

3. How many intact weapons or containers have been observed?

4. Do broken or damaged weapons or containers appear to have been involved in an explosion or fire?

(d) If no contamination was released by the accident or incident, the remaining radiological actions become preparation for response in the event of a release during weapon recovery operations and support of non-destructive evaluation operations (i.e., radiography). Ruling out the release of contamination shall be confirmed by a Specialized Team (i.e., AFRAT, RAMT, DOE-RAP, DOE-ARG).

(3) If contamination is detected, authorities should be notified and the assistance of specialized radiological teams and the DOE/NNSA AMS requested. The highest priority should be action to initiate general public hazard abatement. Do not delay or omit any life-saving measures because of radioactive contamination. If precautionary measures have not been implemented to reduce the hazard to the public, civil officials should be advised of the situation and consider possible actions. Actions that should be initiated include:

(a) Deploy monitoring teams, with radios if possible, to conduct an initial survey of the security area after EOD personnel have found the area free of hazards or have identified and marked hazards. Before EOD inspection of the area, all downrange personnel must be accompanied by EOD personnel.

(b) Recommend public confirmation of the accident to the IC. Prepare appropriate news releases (see examples on the Public Affairs page).

(c) Determine if medical treatment facilities receiving casualties have a suitable radiation monitoring capability. If not, deploy a monitor to determine if the casualties, and subsequently the surrounding area, were contaminated. Initiate notification of monitoring teams available in the private sector. Also help ensure that contamination has not spread in the facility. Procedures that a medical treatment facility may use to reduce the spread of contamination are described at sections 4.a.(12)(a) – 4.a.(12)(c) of the Medical page.

(d) Identify any witnesses, bystanders, or others present at the accident, in coordination with civil officials.

(e) Establish a CCS and a personnel monitoring program. If available, civil authorities and/or officials should have monitoring assistance provided at established personnel processing points.

(f) Arrange to have a fixative applied as soon as possible to reduce resuspension and the associated inhalation hazard (consistent with any weapon recovery operations).

(g) Implement procedures to protect response personnel. Protective coveralls (personal protective clothing), hoods, gloves, and boots are necessary to protect response personnel from contamination and to prevent its spread to uncontaminated areas. Respiratory protection is required if airborne contamination is detected above certain levels (see paragraph 6.c). Using Service-approved protective masks may provide respiratory protection in most instances. If extremely high contamination levels of tritium are suspected in a confined area, firefighting and other special actions require a positive pressure Self-Contained Breathing Apparatus (SCBA). Unless an accident is contained within an enclosed space, such as a magazine, only those personnel working directly with the weapon need take precautions against tritium.

(h) Develop and implement plans for controlling the spread of contamination. Administrative controls must stop contamination from being spread by personnel or equipment and protect response force personnel and the general public. This control is usually established by determining a contamination control area and limiting access and exit through a CCS. The perimeter of the CCA shall be near the line defined by the perimeter survey; however, early in the response before a full perimeter survey is completed, a buffer zone may be considered. If the contamination control area extends beyond the NDA or NSA, civil authorities and/or officials shall help to establish and maintain the control area perimeter. Personnel and equipment should not leave the control area until monitored and decontaminated. Injured personnel should be monitored and decontaminated to the extent their condition allows. A case-by-case exception to this policy is necessary in life-threatening situations, in which case emergency medical treatment takes precedence over contamination control (see section 4.a. of the Medical page).

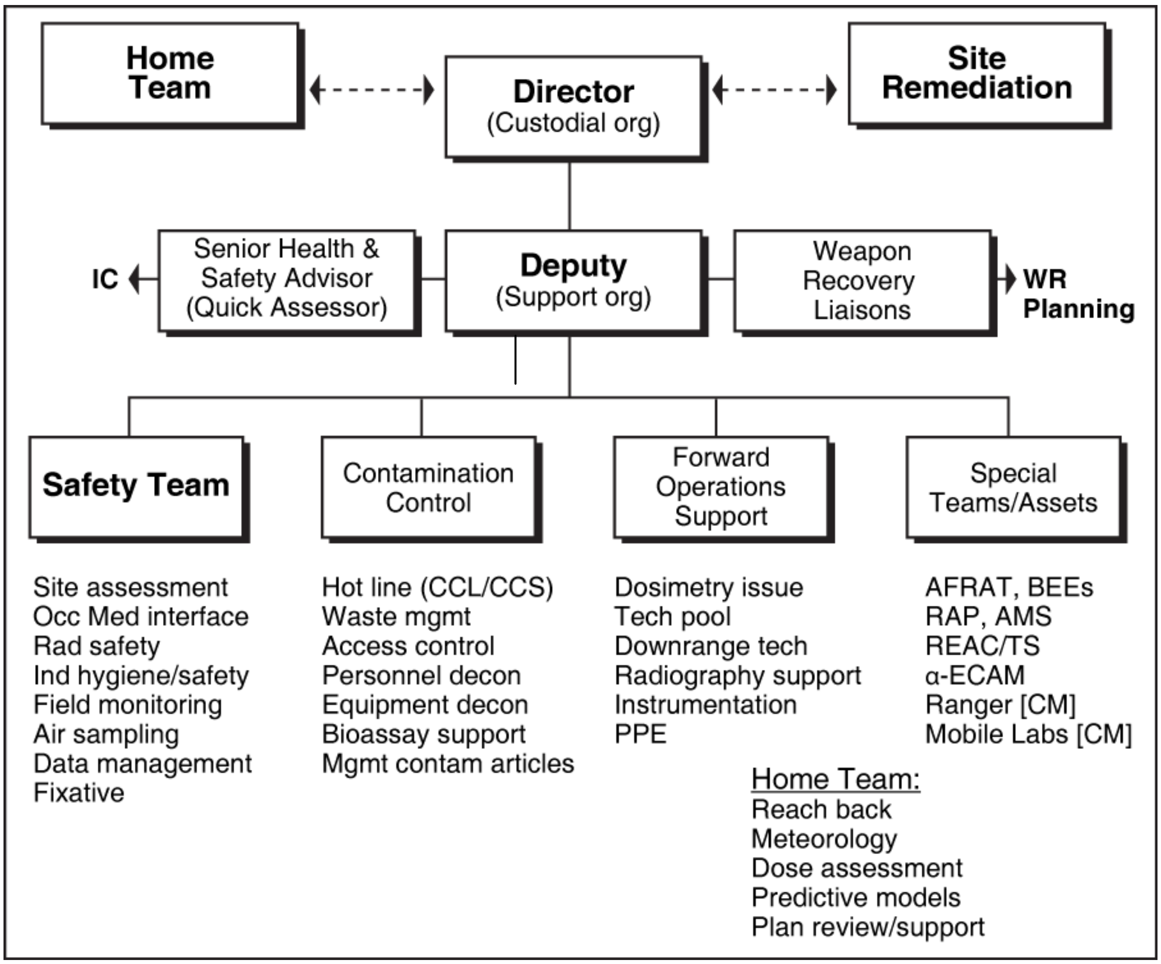
(i) Establish the location and initial operation of the Command Post, Operations Area, ASHG, and Base Camp. This is discussed in Enclosure 2, section 2. of DoD 3150.08-M.

b. RTF Actions. RTF personnel shall review IRF or DOE RAP team actions once they arrive on-scene. Actions include determining the status of the following: identification and care of potentially contaminated people, casualties, and fatalities; the results of radiation surveys and air sampling or an ARAC- and/or HPAC-computed assessment if the survey is not completed; radiological response assets on-scene or expected; logs and records; and the location for the ASHG. Representatives from the DOE/NNSA, the FEMA, the EPA, and SLT governments come together to serve as the primary off-site health and safety interface with the public. However, the Department of Defense should continue to provide assistance and radiation monitoring support, as necessary. During those periods early in the response when EOD operations limit access to the accident site, radiological survey teams should only support the weapon recovery efforts. Off-site radiological surveys require coordination with civil authorities. This arrangement may be understood by explaining the role of the ASHG and the FRMAC and by inviting civil government-approved radiological response organizations to participate in FRMAC operation. DoD specialized teams and the DOE/NNSA ARG are integral parts of the response. The IC should integrate DOE/NNSA ARG radiological assets into the ASHG organization.

(1) Accident Site Health Group ASHG. The ASHG provides health and safety support to and oversight of on-site recovery operations—weapon recovery activities, protection of

responders, and characterization and assessment of radiological and non-radiological hazards. The ASHG Director is a senior DoD health physicist if the Department of Defense is the custodial organization of the item(s) involved in the accident or incident with the DOE/NNSA providing the Deputy Director. If the DOE/NNSA is the custodial organization, it provides the Director and the Department of Defense provides the Deputy. These personnel should be knowledgeable about data on-site and how to best use the technical resources available. The recommended functional diagram is shown in Figure 1.

Figure 1. ASHG Functional Diagram



(a) Technical notes on Figure 1.

1. This figure is intended as a functional diagram and not as an organizational chart. Not all of the functions may need to be done in response to a particular accident. Some of the functions may take a number of personnel to do. Others may be combined under a single person. All are scenario dependent.

2. The ASGH Director is provided by the organization in custody of the item(s) which caused the problem (the DoD or DOE/NNSA). The ASHG Deputy Director comes from the other (supporting) organization.

3. DOE/NNSA will coordinate the functional areas on this diagram, whether or not it is the custodial organization, with inputs from and supported by DoD responders as needed. Joint operations are expected in most functional areas.

4. As the Safety Officer will be a member of the DoD IC's staff, the Safety Officer will be collocated with the DoD IC at the ICP. As the ASHG is a robust organization with considerable expertise in field health and safety, the Safety Officer should maintain close communication with the ASHG in order to keep the IC apprised of health and safety issues in the on-site (weapon recovery) area and to ensure appropriate support to ASHG operations. While safety is everyone's responsibility, the variety of safety professionals participating in the response efforts in various venues should position themselves or allocate their time and priorities such that they can best ensure health and safety oversight of all accident site operations.

(b) On-site monitoring data are processed through and further distributed by the ASHG to the FRMAC. (Exercise appropriate communications security (COMSEC) in the exchange of on-site data and/or information because of the potential for classification issues).

(c) The ASHG is the single control point for all on-site hazard and/or radiological data, and they shall provide the most rapid information available to both military and civil users. After the initial response, the ASHG establishes the worker health and safety program, to include radiation protection, industrial hygiene/safety, and a dosimetry program that meets the needs and requirements for personnel working in or entering the on-site CCA. The responsibilities of the ASHG are detailed in section 3.

(2) Hazard Assessment and Control. The primary radiological hazard associated with a nuclear weapon accident is from fissile material, particularly alpha emitters. Quantities of beta and/or gamma emitters sufficient to pose a significant health problem are not usually present at a nuclear weapon accident. Other, non-radiological, hazards may be present as well, either from weapons components or from other objects involved in the accident (e.g., aircraft, vehicles). Some of the recovery operations may themselves introduce hazards (e.g., radiography, heavy equipment, heat or cold stress). Assessing such hazards and taking measures to control or mitigate them, both for the responder and for the potentially impacted members of the public, are key priorities.

(a) Radiological Surveys. Radiological surveys and other radiological data are required by the IC and civil authorities and/or officials to identify actions to reduce hazards to the response force and the public. Site characterization and decontamination and remediation planning will also need this information. Radiological survey results will be shared with the FRMAC to present a consistent picture of accident site contamination. During the emergency phase of the response, the emphasis of radiation surveys is on worker and public protection. Before beginning an extensive survey, select appropriate detection equipment, calibrate instruments, and determine the background readings. Early survey priorities may include establishing the edges of the contaminated area, surveying the NDA perimeter, assessing contamination levels in recovery operations areas, and resource and/or facility surveys. Ultimately, more detailed surveys will need to be conducted to support SR planning and operations, which may require days to weeks to complete. Survey procedures are in the Area and Resource Surveys page.

1. Radiological Hazard Assessment. From the outset, concern exists about the potential health hazard to the general public, particularly to those persons residing near the accident site. Considering possible radiation exposures is the primary method of estimating the potential health hazard. If no beta and/or gamma radiation is present, the primary risk is inhalation of alpha emitters that may cause a long-term increase in the likelihood of radiation-related diseases. Initial hazard assessments shall, of necessity, be based on limited information, assumptions, and worst-case projections of possible radiation doses received. The ARAC and the HPAC provide theoretical projections of the maximum internal radiation dose people may have received if outdoors without respiratory protection from the time of release to the effective time of the predictive plot. Exposure to resuspended contaminants usually results in doses that are a small fraction of the dose that could be received from exposure to the initial release for the same time period. Contamination released by the accident should not usually affect the safety of public water systems with adequate water treatment capability.

2. Reduction of Public Exposure. A hazard assessment must be followed promptly by recommended precautionary and safety measures to protect the public from any avoidable exposure. To control and reduce exposure, radioactive contaminants must be prevented from entering the body and confined to specific geographic areas so that the contamination may be removed systematically. Methods for reducing the exposure to the public should be implemented by, or through, civil authorities and/or officials. Although political and possibly international issues may be involved, the ultimate decisions on measures to be taken should be based on health and safety considerations.

3. The first Federal officials to arrive at the accident or incident scene (typically the IRF or DOE RAP team) may need to advise civil authorities and/or officials of recommended actions and provide technical assistance until appropriate civilian assets arrive. When contamination has been released, or when probable cause exists to believe that contamination was released, implementing precautionary measures to reduce exposure to radiation or contamination is appropriate, even though the RTF personnel may not arrive for some time.

4. Protective measures include:

a. Establishing a CCA. This operation requires identifying people in the area during the accident and/or restricting access to the area. Any vehicles or people exiting the area should be identified and directed to go to a monitoring point immediately (see section 5.a.(3)(h) above).

b. Sheltering. Sheltering is used to reduce exposure to the initial release of contamination as it moves downwind and to reduce exposure to resuspended contamination before an evacuation. Officials advising people to seek shelter and providing the procedures to follow constitutes sheltering. The effectiveness of sheltering depends on the timeliness of the recommendations and on following the procedures provided. Pets should also be gathered and sheltered to prevent spread of contamination. Livestock may continue to range free since they have little intimate contact with the general public.

c. Evacuation. Contaminated areas must be defined and civil authorities must develop and implement an evacuation procedure if warranted. Civil authorities are responsible for an evacuation of the public but may require radiological advice and assistance. Immediate evacuation of downwind personnel should be discouraged, since the likelihood of contaminant inhalation may increase. Explosive or toxic materials may present an immediate hazard to people near the accident site and immediate evacuation should then be required.

d. Fixing Areas of High Contamination. Areas of high contamination must be controlled to prevent spread by resuspension, water runoff, or personnel movement. Although fixing of contamination is part of the SR process, some fixing procedures may be necessary long before SR plans are implemented (see section 5.b.(6) above).

(b) Materials Sampling.

1. Environmental Sampling. Radiological survey data should be used to the greatest extent possible to determine areas and objects that must be sampled and for screening samples after collection. The use of radiological survey data is necessary to reduce personnel radiation exposure.

a. Air sampling is conducted to determine if airborne contamination is present. It serves as the basis for protection decisions for response workers and also provides a basis for estimating the radiation dose and/or exposure that people without respiratory protection may have received since the air sampling instruments were emplaced.

b. Soil, water, vegetation, and swipe sampling of hard surfaces will be required. Initial sampling is for the purpose of worker and public protection during weapon recovery operations. Samples must also be taken at locations remote from the contaminated area to verify background readings. After this, samples are required periodically during the recovery process to determine radioactive material migration and dispersion and to substantiate decontamination and/or recovery completion. The ASHG, in cooperation with the FRMAC, will determine on-site sampling boundaries, such as sample location(s), method, frequency, volume of sample, and size.

2. Bioassay Program.

a. Bioassay methods estimate the amount of radioactive material deposited in the body. The methods use either direct measurement, e.g., sensitive X-ray detectors placed over the chest (lung counting) and/or other organs, or detection of radioactivity in the excreta (nasal mucous, feces, or urine).

b. A bioassay program for potentially affected individuals is recommended to determine if an internal uptake occurred. Implementation of a bioassay program and the documented results will be important in the fair settlement of any legal action that may occur in the years after a nuclear weapon accident or incident. Personnel monitoring and bioassay programs are conducted by the ASHG in conjunction with medical personnel and are discussed at section 4.e of the Medical page.

(c) Work Force Protection. Standard radiation accident and incident response procedures guide personnel protection during the first few days. Protecting the general public, response force members, and workers in the accident or incident area from exposure through inhalation is extremely important. As conditions stabilize, regulations governing work in radiation areas should be implemented. Participating organizations' or Services' methods and previous doses, and whether their procedures jeopardize health and safety or unduly impair operations, must be considered. The ASHG implements the IC's health and safety standards and closely monitors the safety procedures of all participating organizations. Personnel entering the contaminated areas, if not trained to work in a contamination environment, should be given specific guidance.

(d) Radiological Advisory to the JIC/CIB. All public release of information shall be processed in accordance with reference (bu) and made through the JIC/CIB. Public interest in the actual or perceived radiological hazard from a nuclear weapon accident or incident is expected to produce intense public concern and media scrutiny of response operations. The JIC/CIB requires assistance from the ASHG and the FRMAC in preparing press releases to reduce and allay these concerns. Any part of the public that may have been advised to take precautionary measures will seek clear, understandable explanations of methods to protect their health and property. The public must be informed through the JIC/CIB and a public outreach program explaining the potential hazards, in terms that recognize the populace's knowledge level and understanding of radiation and its effects. Selected ASHG personnel (usually the Senior Health & Safety Advisor or designee) should be made available to support development and delivery of publicly released hazard information.

(e) Protective Action Recommendations (PARs) and Re-entry Recommendations (RERs). Provide appropriate protective action and RERs to the public. PARs are usually provided to the State through the Coordinating Agency. The State then has the final determination in what PARs are issued and/or enacted. The PARs and RERs shall have been coordinated and/or reviewed by the cognizant Federal authority (the DoD or the DOE/NNSA) and responsible civilian authorities and/or officials. Additionally, the ASHG and FRMAC will consult with the EPA Advisory Team on determining appropriate PAGs/PARs. If possible, all Federally developed PAGs/PARs should be consistent with any PAGs/PARs issued by SLT authorities. In an accident, PARs for initial notification or evacuation are likely not to have been prepared formally. The notification in the accident area should occur through visual means or word of mouth. Evacuation of about a 600m disaster cordon might occur automatically or at the direction of civilian law enforcement personnel. A PAR for a controlled evacuation might be formalized in anticipation of a later release of HAZMAT or radioactive contamination. The PAR/RER format may at least include problem, discussion, action, coordination, and approval sections (the format should be site and situation specific). A sample PAR for controlled evacuation is shown in Figure 6. below.

(f) Fixing of Contaminants. Fixatives should be used to reduce resuspension and the spread of contamination. If water is readily available, a water fog may be used as a temporary fixative to reduce resuspension, consistent with weapon recovery operations. Other more permanent fixatives may be used to reduce the spread of contamination by resuspension and runoff from highly contaminated areas. The use of fixatives in areas of low-level contamination is usually inappropriate. Fixatives may enhance or hinder subsequent decontamination and SR operations and affect radiation survey procedures and, in fact, may generate mixed waste or conflict with EPA regulations. The DOE/NNSA ARG may provide information on the advantages and disadvantages of different types of fixatives and methods of application. They should be consulted before applying any fixatives.

(g) Site Remediation (SR). Procedures and/or methods to return the accident scene to a technically achievable and financially and politically acceptable condition begin early in the response effort. SR becomes a major issue after classified information, weapons, weapon debris, and other hazards are removed. Several factors have significant influence on SR decisions and procedures, such as size of the contaminated area and topographical, geological, hydrological, meteorological, and demographic information. Other important aspects are use of the area and civil authorities' and/or officials' prerogatives for the area. Remediation shall include those measures to remove or neutralize the contamination. Removal and/or decontamination may be time-consuming and require an extensive workload to implement. Monitoring is required during the decontamination process to document clean-up progress. Follow-on resampling, remonitoring, and/or resurveying will also be required to verify that cleanup levels have been achieved. See Enclosure 2, section 3.e.(3) of DoD 3150.08-M for additional information.

(h) Disposal of Contaminated Waste. CCS operations and ASHG field laboratory operations can create significant quantities of contaminated waste. Provisions are required to store this waste temporarily in the contaminated area until it may be moved to a disposal site. Procedures for disposing of contaminated waste are addressed as part of SR. The SRWG shall develop a plan to dispose of contaminated waste as part of SR.

(i) Logistics Support for Radiological Operations. Radiological response assets arrive with sufficient supplies to last a few days. High-use items that soon require resupply include potentially large quantities of personal protective clothing, 2-inch masking or duct tape, varied sizes of polyethylene bags, marking tape for contaminated materials, and respirator filters. Personal protective clothing may be laundered in special laundry facilities and reused. The turnaround time, when established, determines the approximate amount of anti-contamination clothing required. Close liaison is required between the ASHG and the IC's logistics section. Disposable personal protective clothing may prove more logistically practical in some circumstances.

6. SAFETY AND HEALTH HAZARDS INFORMATION. Hazards resulting from a nuclear weapon accident or incident vary in complexity depending primarily on the presence or absence of radioactive contamination. Regardless of the presence of contamination, several other weapon-specific substances may be present that are toxic hazards to personnel. Of primary non-radiological concern are: beryllium, lithium, lead, and smoke or fumes from various plastics. In addition, there may be hazards associated with non-weapon materials involved in the accident (such as aircraft or vehicles). There can also be serious workplace hazards such as heat and cold stress and industrial safety concerns.

a. Radiological Hazards.

(1) Plutonium and Americium. Plutonium is a heavy metal with a shiny appearance similar to that of stainless steel when freshly machined. After short exposure to the atmosphere, it oxidizes to a dark brown or black color. Americium is a progeny product of plutonium decay and is always a constituent of weapons-grade plutonium.

(a) Radiological Characteristics. With the exception of Pu-241, the plutonium isotopes in weapons-grade plutonium are alpha emitters. Pu-241 is primarily a beta emitter. Americum-241 is an alpha emitter that also emits detectable X-rays as part of its decay process.

Table 1. Radiological Characteristics of Plutonium and Americium

Isotope	Primary Particle Emitted	Half-Life* in Years
Pu-239	alpha	24,100
Pu-240	alpha	6570
Pu-241	beta	14.4
Pu-242	alpha	376,000
Am-241	alpha	432

*See Definition List

(b) The americium-241 in weapons-grade plutonium emits two detectable photons: a 17-keV X ray and a 60-keV gamma ray. The 17-keV X ray is difficult to detect because it is easily shielded. The 60-keV gamma ray is usually detectable.

(c) A critical mass may be obtained from several hundred grams or more of plutonium, depending on the geometry of the container and the material surrounding or near the mass. Recovery personnel should consult EOD technical publications and the DOE/NNSA ARG to ensure that the possibility of aggregating a critical mass of recovered material is considered and avoided.

(d) When dispersed in an accident, plutonium is considered the most significant radiological hazard. The primary hazard results from inhalation and later deposition in the lungs. From the lung, plutonium enters the bloodstream and is deposited in the bone and liver. Bone deposition may lead to bone diseases many years later. Due to its extremely long physical and biological half-lives, plutonium is held within the body for a lifetime. The hazards from americium are comparable to those of plutonium.

(e) Plutonium is eliminated from the body extremely slowly. If a person contaminated internally is given prompt medical treatment with a chelating agent, plutonium retention may be significantly reduced.

(f) A properly fitted respirator and standard personal protective clothing may provide adequate protection from plutonium contamination expected at an accident site.

(g) Smoke from a fire or explosion involving plutonium may carry fine particles of plutonium into the air, causing an inhalation hazard.

(2) Uranium. Uranium is a heavy metal that occurs in nature in significant quantities. When newly machined, it has the appearance of stainless steel. After short exposure to the atmosphere, it oxidizes to a golden-yellow color and from that to black. The natural uranium isotopes are primarily alpha emitters; however, the progeny of uranium-238 and uranium-235 decay are short-half-lived beta emitters that can be readily detected using appropriate instrumentation. It should also be noted that most U.S. uranium contains trace amounts of uranium-236. Uranium-236 is an alpha emitter with a half-life of 23,420,000 years that is introduced during the U.S. manufacturing process.

Table 2. Radiological Characteristics of Uranium

Isotope	Primary Particle Emitted	Half-Life in Years
U-238	alpha	4,500,000,000
U-235	alpha	710,000,000
U-234	alpha	2,150,000

(a) Types of Uranium. Three forms of uranium have been used in nuclear weapons: natural uranium, depleted uranium (DU), and enriched uranium.

1. Natural Uranium. Natural uranium has 0.006% U-234, 0.72% U-235 with the remainder (99.28%) U-238. When uranium is separated from its ore, the isotopic ratio is maintained but trace amounts of U-236 are added as a result of the manufacturing process. Natural or depleted uranium in metal form is sometimes referred to as tuballoy.

2. Depleted Uranium (DU). DU is defined as uranium with less than 0.7% by weight U-235. U.S. DU has approximately 0.2% by weight U-235.

3. Enriched Uranium (also referred to as "oralloy"). Enriched uranium contains more than the naturally occurring weight percentage of U-235. It is enriched through chemical and metallurgical processes. When uranium has been highly enriched, it can be used in a nuclear explosive device

(b) A critical mass may be obtained from several hundred grams or more of enriched uranium, depending on the isotopic mix and geometry or enrichment level, the geometry of the container, and the material surrounding or near the mass. Recovery personnel should consult with EOD technical publications and with the DOE/NNSA ARG to ensure that the possibility of aggregating a critical mass of recovered material is considered and avoided.

(c) Radiological hazards associated with any uranium isotope are usually less severe than those of plutonium. If uranium is taken internally, a type of heavy metal poisoning may occur. Lung contamination due to inhalation may cause a long-term hazard.

(d) When involved in an extremely hot fire, uranium melts and forms a slag, with only a part of it oxidizing; however, the possibility of hazardous airborne contamination exists, and protective measures must be taken to prevent inhalation or ingestion. A protective mask and standard personal protective clothing will protect personnel against levels of uranium contamination expected at an accident site.

(3). Tritium. Tritium is a radioactive isotope of hydrogen and diffuses very rapidly in the air. The diffusion rate is measurable even through very dense materials such as steel. Tritium combines chemically with several elements. This chemical reaction produces heat. Tritium when in the water vapor form is a health hazard when personnel are engaged in specific weapon RSPs, when responding to an accident that occurred in an enclosed space, and during accidents that occurred in rain, snow, or a body of water. Tritium reservoirs can also present a high-pressure hazard.

(a) Radiological Characteristics. Tritium emits a weak beta particle and decays into stable helium-3.

Table 3. Radiological Characteristics of Tritium

Isotope	Primary Particle Emitted	Half-Life in Years
H-3	beta	12.26

(b) Like stable hydrogen, tritium may combine in a combustive reaction with air, forming tritiated water and releasing large amounts of heat. In a fire, tritium combines spontaneously with oxygen in the air and also replaces ordinary hydrogen in water or other hydrogenous material (grease or oil), causing these materials to become radioactive.

(c) In its gaseous state, tritium (like stable hydrogen gas) is not absorbed by the skin to any significant degree. The hazardous nature of tritium is due to its ability to combine with other materials. Tritiated water (HTO) is readily absorbed by the body by inhalation and absorption through the skin. The radioactive water entering the body is chemically identical to ordinary water and is distributed throughout the body tissues. The body usually eliminates and renews 50 percent of its water in about 8 to 12 days. This biological half-life varies with fluid intake. Since HTO is water, its time in the body may be significantly reduced by increasing the fluid intake. Under medical supervision, the biological half-life may be reduced to 3 days. Without medical supervision, a recommended procedure is to have the patient drink 1 quart of water within 1-half-hour of exposure. Thereafter, maintain the body's water content by drinking the same amount as excreted until medical assistance is obtained.

(d) Metals react with tritium in two ways: plating, the deposition of a thin film of tritium on the surface of the metal; or hydriding, the chemical combination with the metal. In either case, the surface of the metal becomes contaminated. Tritium that has plated on a surface or combined chemically with a material is a contact hazard. Metal tritides, when aerosolized as the result of an explosion or fire, or when ingested/inhaled as a result of the contact hazard, deposit in the lung. The tritium involved is bound with the metal. Only after an extended period of time is the tritium available for absorption and elimination through the urine. The low-energy betas continue to deposit energy in lung tissue until the material is removed from the lung.

(e) A SCBA and protective clothing will protect personnel against tritium for a short time. An air-purifying respirator (APR) with a combination filter (*i.e.*, HEPA plus activated charcoal) provides only limited protection.

(4) Thorium. Thorium is a naturally-occurring, heavy, dense radioactive gray metal that is about three times as abundant as uranium. Th-232 is the naturally occurring radioactive isotope of thorium. There are 28 artificially produced isotopes of thorium with a wide range of radiological characteristics.

(a) Radiological Characteristics. Th-232 is the principal isotope. It decays by a series of alpha emissions to radium-225. Th-232 is not fissionable but is used in reactors to produce fissionable U-233 by neutron bombardment. A non-nuclear property of thorium is that, when heated in air, it glows with a dazzling white light.

Table 4. Radiological Characteristics of Thorium

Isotope	Primary Particle Emitted	Half-Life in Years
Th-223	alpha	14,100,000,000

(b) Thorium presents both a toxic and radiological hazard. Toxicologically, thorium causes heavy metal poisoning similar to lead or uranium isotopes. Thorium accumulates in the skeletal system where it has a biological half-life of 200 years.

(c) A properly fitted respirator and standard personal protective clothing will protect personnel against levels of thorium contamination expected at an accident or incident site.

(5) Fission Products. The materials considered so far are used in weapons construction in pure forms and in combinations with other elements. Due to weapon design, the likelihood of a nuclear detonation because of an accident is extremely low. However, in the unlikely event that some fission occurs as a result of the accident, the products of the reaction may pose a severe hazard. In general, fission products are beta and gamma emitters and are hazardous, even when external to the body. It is difficult to predict and estimate the quantity of fission products since the amount of fission is unknown and, to further complicate the situation, the relative isotopic abundances change with time as the shorter-lived radioisotopes decay. The hazard may be estimated by gamma and beta monitoring.

(a) Gamma Monitoring. When approaching a nuclear weapon involved in an accident, always survey for gamma radiation because some fission products may be present. Ensure maximum permissible exposure limits are observed.

1. Off-scale Gamma Survey. If the gamma survey instrument being used has a meter capable of indicating a maximum of 3 R/hr (or less) and the meter goes off scale, do not enter the area because the actual radiation level is unknown.

2. Saturated Gamma Survey Instrument. Many gamma survey instruments become saturated when placed in a strong field. A saturated instrument may indicate a false low or zero reading. When approaching a radiation field, begin monitoring in a low exposure area and then move toward the higher exposure area. If the meter reading drops using this survey technique when approaching the high exposure area, it is likely that the meter electronic processors are becoming saturated from too much data load (e.g., too much radiation).

3. Inverse Square Law. The radiation intensity emitted from a given point source is inversely related to the square of the distance from that source. If a dose rate, R1, is taken at distance, D1, from the source, a second unknown dose rate, R2, may be computed for a second (different) distance, D2, using the equation shown in Figure 2., below. Rule of thumb: Doubling the distance from a point source will reduce the dose rate to ¼ of the dose rate at the original distance.

Figure 2. Inverse Square Law

R2 = R1 X ((D1/D2) squared)
R1 = Dose rate at distance D1 from a point source of gamma. R2 = Unknown dose rate at distance D2 from a point source of gamma. D1 = Known distance from point source of gamma where R1 was measured. D2 = Known distance from point source of gamma for which R2 shall be computed.

4. Stay Time. No individual less than 18 years of age or women known to be pregnant shall be occupationally exposed to radiation in excess of that allowed to any individual in the general population. The MPE for an individual in a given radiation field before reaching a predetermined maximum cumulative dose is computed as follows in Figure 3. Use the highest maximum reading to determine stay time:

Figure 3. Stay Time

T = D/R
T = Time of exposure to ionizing radiation expressed in hours or decimal fractions thereof. R = Dose rate expressed in R/hr or mR/hr, as determined from the beta/gamma instrument. D = The predetermined maximum yearly cumulative dose: 0.5 rem 100 mrem: non-occupational (general public) 5 rem: occupational dose limit 25 rem: to save valuable property 100 rem: to save lives Other: as decided by the IC consistent with operational considerations.

Note: Working in an area with airborne radioactive materials at a concentration of one DAC, without respiratory protection, results in a Committed Effective Dose Equivalent (CEDE) rate of 2.5 mrem per hour of exposure (which would equate to reaching the 5 rem occupational exposure limit in a 2,000-hour working year).

5. Cumulative Dose. The dose an individual receives over a specific period of time in a given radiation field is computed as follows in Figure 4.:

Figure 4. Cumulative Dose

D = R(T)
D = Cumulative dose received expressed in R or mR. R = Dose rate expressed in R/hr or mR/hr, as determined from the beta and/or gamma instrument. T = Time of exposure to ionizing radiation expressed in hours or decimal fractions thereof.

b. Non-radiological Hazards. Several weapon-specific non-radiological hazards may be present because of a nuclear weapon accident or incident. The DOT's Emergency Response Guidebook (reference (bv)) is a source document for hazardous response, evacuation, hazard descriptions, and protective actions for non-radiological HAZMATs. Reference (bv) was developed jointly by the U.S. DOT, Transport Canada, and the Secretariat of Communications and Transportation of Mexico for use by firefighters, police, and other emergency services personnel who may be the first to arrive at the scene of a transportation accident involving a HAZMAT. It is mainly a guide to aid first responders in quickly identifying the specific or generic classification of the material(s) involved in the event, and protecting themselves and the general public during this initial response phase of the accident or incident.

(1) Beryllium. Beryllium is a light, gray-white nonradioactive metal that is hard and brittle and resembles magnesium. In its solid state (normal state), beryllium is not a personnel hazard. However, in powder, oxide, or gaseous form, it is highly toxic. Inhalation is the most significant means of entry into the body. Because it oxidizes easily, any fire or explosion involving beryllium liberates toxic fumes and smoke. When beryllium enters the body through cuts, scratches, or abrasions on the skin, ulceration often occurs. The most common beryllium disease symptoms seen today are associated with chronic beryllium disease – an obstructive lung disease that develops many years following exposure. The symptoms of shortness of breath, chronic cough, cyanosis, loss of weight, and extreme nervousness are characteristic of this disease and *not* seen immediately following exposure. A wound contaminated with traces of beryllium does not heal until the metal is removed. Beryllium or its compounds, when in finely divided form, should never be handled with the bare hands but always with rubber gloves. An M40-series, or equivalent protective mask and/or respirator, and personal protective clothing must be worn in an area known, or suspected, to be contaminated with beryllium dust. An SCBA is necessary when beryllium fumes or smoke are present. Decontamination of personnel or facilities is similar to radiological decontamination. An effective method, when applicable, is vacuum cleaning, using a cleaner with a HEPA filter. Since beryllium is not radioactive, its detection requires chemical analysis in a properly equipped laboratory. Direct detection in the field is impossible.

(2) Lithium. Lithium and its compounds, usually lithium hydride, may be present at a nuclear weapon accident. Due to its highly reactive nature, naturally occurring lithium is always found chemically with other elements. When exposed to water, a violent chemical reaction occurs, producing heat, hydrogen, oxygen, and lithium hydroxide. The heat causes the hydrogen to burn explosively, producing a great deal of damage. Lithium may react directly with the water in the body tissue causing severe chemical burns. Also, lithium hydroxide is a caustic agent that affects the body, especially the eyes, in the same manner as lye (sodium or potassium hydroxide). Respiratory protection and firefighter clothing are required to protect personnel exposed to fires involving lithium or lithium hydrides. An SCBA is necessary if fumes from burning lithium components are present. The eyes and skin must be protected for operations involving these materials.

(3) Lead. Pure lead and most of its compounds are toxic. Lead enters the body through inhalation, ingestion, or skin absorption. Inhaling lead compounds presents a very serious hazard. Skin absorption is usually negligible, since the readily absorbed compounds are seldom encountered in sufficient concentration to cause damage. Once inside the body, lead concentrates in the kidneys and bones. From the bone deposits, lead is slowly liberated into the bloodstream causing anemia and resulting in a chronic toxic condition. Lead poisoning displays several specific characteristics and symptoms. The skin of an exposed individual turns yellowish and dry. Digestion is impaired with severe colicky pains and constipation results. With a high body burden, the exposed individual has a sweet, metallic taste in his mouth and a dark blue coloring of

the gums from a deposition of black lead sulfide. Lead concentrations within the body have been reduced successfully by using chelating agents. An M17 or equivalent protective mask protects personnel against inhalation of lead compounds.

(4) Plastics. When involved in a fire, all plastics present varying degrees of toxic hazards due to the gases, fumes, and/or minute particles produced. The gaseous or particulate products may produce dizziness and prostration initially, mild to severe dermatitis, severe illness, or death if inhaled, ingested, placed in contact with the skin, or absorbed through the skin. Any fire involving plastics that are not known to be harmless should be approached on the assumption that toxic fumes and particles are present. This includes all nuclear weapon fires.

(5) High Explosives (HE). Information on pressed and cast HE and Insensitive High Explosives (IHE) may be extracted from reference (bg), after a DOE/NNSA classification review.

(6) Hydrazine. Hydrazine is used as a missile fuel or as a fuel in some aircraft emergency power units. Hydrazine is a colorless, oily fuming liquid with a slight ammonia odor. It is a powerful explosive that, when heated to decomposition, emits highly toxic nitrogen compounds and may explode by heat or chemical reaction. Self-igniting when absorbed on earth, wood, or cloth, the fuel burns when a spark produces combustion; any contact with an oxidized substance such as rust may also cause combustion. When hydrazine is mixed with equal parts of water, it does not burn; however it is toxic when inhaled, absorbed through the skin, or taken internally. Causing skin sensitization as well as systemic poisoning, hydrazine may damage the liver or destroy red blood cells. The permissible exposure level is l part per million, although a lower concentration causes nasal irritation. After exposure to hydrazine vapors or liquids, remove clothing immediately and spray exposed area with water for 15 minutes. An SCBA is required in vapor and/or liquid concentrations.

(7) Red Fuming Nitric Acid. Red nitric acid is an oxidizer for some missile propellant systems. It is a reddish brown, highly toxic corrosive liquid with a sharp, irritating, pungent odor. Dangerous when heated to decomposition, it emits highly toxic fumes of nitrogen oxides and reacts with water or steam to produce heat and toxic corrosive and flammable vapors. The permissible exposure level is two parts per million, although a lower concentration causes nasal irritation and severe irritation to the skin, eyes, and mucous membranes. Immediately after exposure, wash acid from skin with copious amounts of water. An SCBA is required in vapor and/or liquid concentrations.

(8) Solid Fuel Rocket Motors. Rocket motors (composed of dimeryl diisocyanate, cured hydroxyl terminated polybutadine polymer, ammonium perchlorate, and aluminum powder or other cyanate, butadiene, perchlorate, or nitrate-based compounds) present severe explosive hazards if accidentally ignited. If rocket motors ignite or catch fire, evacuate to a safe distance.

(9) Composite Fibers (CFs). CFs are carbon, boron, and graphite fibers that are milled into composite epoxy packages that are integral aircraft structural members. If the epoxy outer layer breaks or catches fire, CF strands may be emitted into the environment and become a respiratory tract, eye, and skin irritation hazard. In the immediate accident area or location where a composite package has broken open, the fibers may cause severe arcing and shorting of electrical equipment. For additional information, refer to Technical Order (TO) 00-105E-9, Aerospace Emergency Rescue and Mishap Response Information (reference (bw)).

(10) JP-10. JP-10 is used as a missile fuel. It is a clear liquid and has a kerosene-like odor. Recommended special firefighting procedures are to use a water spray to cool fire-exposed surfaces and to protect personnel. Wear an SCBA when firefighting in confined spaces. JP-10 is an aspiration hazard. It is slightly toxic by inhalation. Do not allow liquid or mist to enter lungs. Vapor contact causes very little to no eye irritation. High heat, sparks, open flame, or strong oxidizers may ignite JP-10 fuel.

(11) TH Dimer. Similar to JP-10, TH Dimer (RJ-4) is also a missile fuel with the same color and odor characteristics. The hazards and firefighting precautions are also similar. TH Dimer may cause gastrointestinal irritation (vomiting and diarrhea) and nausea. For prolonged and/or repeated skin contact, appropriate impervious clothing is required (gloves, boots, pants, coat, face protection, etc.).

(12) Composite Materials. Composite materials are solids that are composed of two or more substances having different physical characteristics. Such materials might be at the site of a nuclear weapon accident and pose additional health and safety hazards if involved in a fire or explosion. Composite materials are broken down into three categories:

(a) Composite. A physical combination of two or more materials, i.e., fiberglass (glass fiber and epoxy).

(b) Advanced Composite. A material composed of high strength and/or high stiffness fibers (reinforcement) with a resin (matrix). Examples include Graphite/Epoxy, Kevlar®/Epoxy, and Spectra/Cyanate Ester.

(c) Advanced Aerospace Material. A highly specialized material used to fulfill unique aerospace construction, environment, and/or performance requirements. Examples include Beryllium, DU, and Radar Absorbent Materials.

c. Respiratory and Personnel Protection. During a radiological emergency, health officials must act to protect the public and response forces from potential health hazards associated with the emergency. The following paragraphs address respiratory protection to include Protection Factors (PFs), Protective Action Guides (PAGs), Resuspension Factors (RFs) and protective clothing.

(1) Respiratory Protection. Plutonium and uranium particulates are the most serious source of airborne radioactivity at an accident or incident site unless fission has occurred. These particulates may be present in the cloud and smoke from a breached or burning weapon, but settle to the ground shortly thereafter. The radioactive particles may become resuspended in the air by surface winds and by soil-disturbing operations, including vehicular traffic. Resuspension is highly dependent on specific conditions (for example, type and condition of soil or surface, vegetation, moisture present, and time since deposition) and is difficult to measure and predict. Respiratory protection prevents airborne contamination from entering the lungs and is provided by a SCBA or APRs that filter particulates out of the ambient air. Respiratory protection devices adversely affect productivity and effectiveness and their use is not recommended except when airborne contamination is present or expected. In hot climates, respiratory protection devices may result in heat injuries, including death, and a heat injury prevention program, should be implemented when temperatures exceed 70° F.

(2) Protection Factors. The assigned protection factor (APF) is defined as the expected workplace level of respiratory protection that would be provided by a properly functioning respirator or a class of respirators to properly fitted and trained users. The APF for a full-face APR is 50. The APF for a pressure-demand SCBA is no more than 10,000. A full-facepiece SCBA operating in demand mode is assigned an APF of 100. The fit factor (FF) is a quantitative estimate of the fit of a particular respirator to a specific individual, and typically estimates the ratio of the concentration of a substance in ambient air to its concentration inside the respirator when properly worn. A fit test is conducted on the individual, either qualitatively or quantitatively, to evaluate the fit of a respirator. A fit test chamber/hood, using probed face pieces and a nontoxic particulate, is required for quantitative tests. The fit-test chamber/hood is used to determine the fit-factor for each individual with a particular size and make/model of mask. The fit factor is determined by dividing the Ambient Air Concentration (AAC) of a particulate by the Inhaled Concentration (IC) or amount of particulate that enters the mask. Quantitative fit-factor pass limits are set by the Department of Defense. Units may use an M-41 Protection Assessment Test System or commercial equivalent to verify fit-factors for first responders. A qualitative fit-factor can be determined by conducting a smoke test around the edges of the mask. If the mask passes a qualitative smoke test it is assumed to have a fit factor above the nominal value set by the Department of Defense.

(3) Protective Action Guides (PAG). PAGs are developed to identify protective devices to limit exposure to the lungs from inhaling contaminants to agreed-on limits. The appropriate Derived Air Concentration (DAC), should be that in reference (bx). For plutonium in non-chemically active forms that should be expected after a fire, the DAC is 0.222 Bq/m^3 or 13.32 dpm/m^3, which corresponds with the lower level in table 5.

(4) The guidelines provided in table 5. are intended for use until health physics personnel at the scene are able to develop situation-specific instructions. In deriving the respiratory protection guidelines, a PF of 50 was assumed for full-face APR. Such computations assume possible exposures to radiation workers of 13.32 dpm/m^3 of Pu-239/40-hour week, averaged over the period of a year (2,000 hours), which would result in 5 rem CEDE. The general public guidelines are 100 mrem/year dose equivalent from normal radiological operations. Early phase PAGs recommend evacuation during an emergency when one additional rem of projected dose could be avoided by evacuation. One rem corresponds to an airborne concentration of approximately 31.67 dpm/m^3 of Pu-239 for one week (168 hours). Radiological dose equivalent is a function of both activity and exposure time, so emergency response personnel may be allowed to enter an area of higher activity without respiratory protection for a short period of time without exceeding regulatory dose equivalent limits (10 rem for protection of property, 25 rem for protection of personnel, and >25 rem for protection of personnel on a voluntary basis by personnel fully briefed on the associated risk of receiving >25 rem). Situation-specific guidelines will be developed by the ASHG for weapon recovery operations.

(5) In many areas, especially during thermal inversions, radon progeny products may be detected in air samples. A background sample of the same length and counted the same time after collection as the on-scene sample allows proper background subtraction; however, typical radon concentrations would completely mask the 13.32 dpm/m^3 plutonium DAC value above. Samples should be recounted at 30-35 minute intervals, the rough half-life of radon progeny products. When, after a 20-minute decay period, the residual sample activity is within 1% of the previous activity, all of the sample activity can then be considered long-lived activity.

(6) The time versus dose approach should be applied in emergencies, as appropriate; that is, if a person suffers heat stroke, the respirator should be removed immediately to meet the urgent medical requirement to cool the person, since the short unprotected exposure during evacuation from the area for treatment limits the amount of contaminant that is inhaled. Table 5. shows respiratory protection guidelines to use when air sampling data provide a basis for assessing airborne contamination levels. Computed activity levels should be corrected for background activity before entering the table.

Table 5. Recommended Respiratory Protection Levels for Emergency Workers as a Function of Airborne Contamination

Airborne Alpha Activity dpm/m^3 above background	**Respiratory Protection**
Below 13.32 dpm/m^3	No respiratory protection needed.
13.32 to 665 dpm/m^3	Full-face respiratory protection required (M-series Protective Mask or National Institute of Occupational Safety and Health/ Mine Safety and Health Administration approved High Efficiency Particulate Air (HEPA) respirator).
Above 665 dpm/m^3	Pressure demand SCBA or limited entry restricted to essential personnel wearing full-face respiratory protection. Source of contamination should be fixed as soon as possible.

(7) Air sampling data are unavailable until some time after response personnel have arrived on-scene. During the initial response, and when working in areas where available air sampling data may not be applicable, the use of table 6. is recommended. Table 6. provides guidelines for protective requirements based on measurements of average surface contamination levels. The recommendations in Table 6. provide guidelines for personal protective measures that may be taken by first responders until the situation may be evaluated by health physics personnel. Using Table 6. is appropriate during the initial approach to the area when using respirators in uncontaminated areas may create undue public alarm. If contamination levels detected during the initial approach show high levels of contamination, people entering the contaminated area should wear respirators until air sampling data are available to assess the actual airborne hazard. Table 6. guidelines should not be used in the downwind area until after the contamination cloud released by the accident or incident has dispersed (several hours after the fire is extinguished or after the explosion).

Table 6. Protective Devices for Emergency Workers as a Function of Surface Contamination

Surface Contamination			**Respiratory Protection**
Activity μCi/m2	**dpm per 100 cm^2**	**cpm (ADM-300)**	
< 6	< 133,200	< 20,000	No respiratory protection. If there is detectable contamination, gloves and booties should be worn at a minimum, and coveralls depending on the activity being performed.
6 to < 60	133,200 to 1,332,000	20,000 to 200,000	No respiratory protection for limited entries of up to 4 hours. Full protective clothing.
60 to 300	1,332,000 to 6,660,000	266,400 to 1,332,000	Air-purifying respirator (APR) and full protective clothing.
Above 300	Above 6,660,000	Above 1,332,000	Wear pressure-demand SCBA and full protective clothing. Source of contamination should be fixed as soon as possible.

Note: The above (revised) numbers are based on the corrected DAC of 13.32 dpm/m^3, the revised APF of 50, and an assumption of a 10^{-6} resuspension factor.

Table 7. Instrument Comparisons for Surface Contamination Levels in Table 6.

Instrument	**Probe (area, in cm^2)**	**Activity (μCi/m2)**	**Instrument indication**
AN-PDR-56	*DT224B (17)	6.0	~10,200 cpm
ADM-300	#ASP 100 (100)	6.0	~26,500 cpm
E-600	‡SHP 380 (100)	6.0	~66,500 cpm
AN-PDR-56	*DT224B (17)	60	~100,000 cpm
ADM-300	#ASP 100 (100)	60	~250,000 cpm
E-600	‡SHP 380 (100)	60	~650,000 cpm
AN-PDR-56	*DT224B (17)	300	~500,000 cpm
ADM-300	#ASP (100)	300	~1,300,000 cpm
E-600	‡SHP 380 (100)	600	**Off Scale (>1.0E6 cpm)

**The instruments with 100/square cm scintillation probes are incapable of measuring deposited activities much greater than 60 microcuries/square meter, because the instrument goes off-scale high.
*assumed α efficiency (4π) for DT224B is 45%
#assumed α efficiency (4π) for ASP 100 is 20%
‡assumed α efficiency (4π) for SHP380 is 50%
If α efficiencies are different from those assumed above, instrument indications must be re-calculated. Additionally, the use of activity, instead of instrument-specific count rates, will eliminate problems associated with inconsistencies in instrument calibration from facility to facility or from service to service (Air Force, Navy, National Lab, etc.).

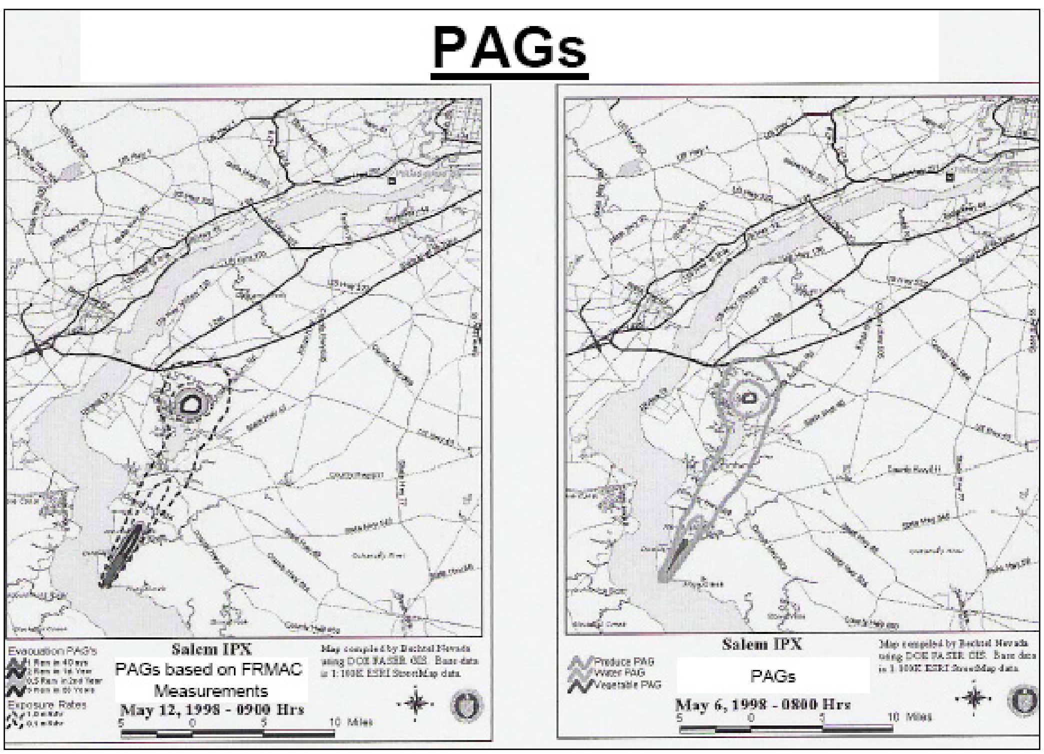
(8) EPA and FDA Protective Action Guides (PAGs). To ease decision making during radiological emergencies, EPA and the FDA have developed PAGs to guide the actions (e.g., sheltering, evacuation, food embargoes, etc.) taken to lessen the health consequences of an accident and/or emergency. These guides allow for various actions to be taken to protect human health, and for State and local officials to develop emergency response plans. A PAG is the

projected dose (to a reference individual) from an unplanned release of radioactive material at which a specific protective action to reduce or avoid that dose is warranted. It is important to note that PAG dose values include only the future dose that may be avoided by taking the specific protective action considered. Example PAGs are shown in Figure 5. Not all PAGs are the same as those in Figure 5.; some may be depicted as charts, graphs, tables, etc.

Table 8. Protective Action Guide Hazard Values

Dose Levels	**Recommended Actions**
> 25 rem	same as below except voluntary only (NARAC > 25 rem contour)
> 5 rem to 25 rem	Workers performing emergency services for saving lives or protecting large populations. (NARAC > 5 rem contour)
1 – 5 rem	evacuate and/or consider sheltering (NARAC > 1 rem contour)
< 1 rem	consider sheltering

Figure 5. Aerial Survey Results: PAGs, Evacuation PAGs, and Quarantine Areas



(9) Air Sampler Equipment. Commonly referred to as a Staplex®, the TF-1A is capable of sampling air for particles down to 0.01 micron in diameter, depending on the filter paper used. A flow meter is used to determine rate of air flow. Cellulose filters are usually used and kept for laboratory analysis. Field estimates of airborne contamination may be derived from measuring filter contamination with field survey instruments.

(10) Resuspension Factors (RFs). Other than during the initial release of contamination, airborne radioactivity is caused by resuspension. One means of estimating the potential airborne hazard caused by a given level of surface contamination is by using RFs. The RF is defined as the activity in the air (μCi, dpm, etc.) per unit volume (usually m^3) divided by the activity on the ground below expressed in the same activity unit per unit area. The dimension of the RF is then inverse length, usually m^{-1}.

Table 9. Equation for Calculating Resuspension Factors

$$RF = \frac{\text{airborne activity}}{\text{ground activity}} = \frac{dpm / m^3}{dpm / m^2} = m^{-1}$$

(a) In theory, the surface is assumed to have an infinite plane of uniform texture with a uniform level of contamination. In practice, the contaminated area has varied levels of contamination, is finite in size, and may contain a variety of surfaces with different resuspension characteristics. For wind speeds below 20 mph, only those surfaces within about 200m may contribute to the airborne contamination. For wind speeds of more than 30 mph, surfaces as much as 900m away may contribute.

(b) Averaging ground activity levels from these areas may be considered when computing RFs. RFs may provide a method of roughly estimating airborne contamination levels for use with Table 6. in areas where air sampling data are unavailable. When using RFs to estimate airborne contamination levels, the types and levels of contamination on surfaces in the area where the RF was computed and those in the area of interest should be considered. RFs may vary from 10^{-5} to 10^{-7} for plutonium newly deposited on soil and up to 10^{-3} on pavement. RFs are affected by:

(c) Soil Disturbing Operations. Mechanical disturbance, such as vehicular traffic, may increase RFs by as much as 100 times in the vicinity of the disturbance.

(d) Wind. RFs vary proportionally to the cube of the wind speed.

(e) Rain or Moisture. Leaching of plutonium into the soil by rain or sprinkling may reduce RFs by 10 to 100 times or more. Surface and airborne alpha contamination levels may not be measurable with an alpha meter for some time after rain or sprinkling due to the shielding action of the moisture.

d. Protective Clothing. Any close-weave cotton material or disposable suits may protect against contamination. The outfit includes the standard anti-contamination coveralls, boot covers, gloves, mask, and hood. The outfit openings should be taped using masking or other appropriate adhesive tape. The Battle Dress Overgarment or Chemical Protective Overgarment with protective mask, overboots, gloves, and hood also provides protection from contamination. Refer to Service guidelines for use of this equipment. For identification, the person's name and team should be written on tape and placed on his or her back and chest.

e. Personal Safety Precautions.

(1) Do not eat, chew, smoke, or drink in areas where radioactive materials are handled.

(2) Handle radioactive material only when necessary and keep handling time as short as possible. Health hazards are increased by extended exposure. Flaking, scratches, and fractures of radioactive material are sources of contamination. Do not handle radioactive materials with bare hands.

(3) If wounded by a contaminated item or while in a contaminated area, take the following steps (the steps in subparagraphs 6.e.(3)(d) through 6.e.(3)(g) do not apply to tritium exposure or contamination):

(a) Leave the contaminated area.

(b) Remove contaminated clothing or contaminated material at the decontamination line.

(c) Get medical assistance as soon as possible.

(d) Irrigate the wound with copious amounts of water. Do not induce bleeding. Pack the wound with gauze and wrap tightly with a Curlex® or Ace® bandage. Remove the dressing at a medical treatment facility and check the dressing for contamination. To detect the presence of contamination in the wound, you must swab it with a cotton-tipped applicator, dry the applicator, and monitor it in a counting chamber. The liquids present in the wound mask almost all emissions.

(e) Wound debridement should not be attempted outside of a medical treatment facility. The wound should only be irrigated, packed loosely with sterile gauze, and wrapped. Debridement must take place in an emergency room or operating room. An appropriate survey instrument and technician must be available during treatment to confirm the wound has been decontaminated before closure. Wound debridement must not be continued to the point of functional compromise. If contamination is still suspected, again, pack the wound with sterile gauze, wrap, and redress the wound in 24 hours. The wound should not be sutured closed but should be allowed to heal by second intention (tissue granulation).

(f) Do not check the wound for contamination without a cotton-tipped applicator or gauze swab. It must be allowed to dry before being counted.

(g) Any metallic particles must be assumed to be radioactive unless confirmed otherwise. Handling tongs and a lead pig should be standing by during wound debridement to receive a "discrete particle" or metal foreign body.

(4) If any form of internal contamination is suspected, immediately report to a medical authority.

f. Hot and/or Cold Weather Operational Conditions. The reduction in natural cooling of the body caused by wearing full personal protective clothing with hoods and respirators increases the likelihood of heat injuries. Heat injuries (stroke, exhaustion, or cramps) may occur with the ambient air temperature as low as 70° F when wearing full protective gear. Preventive measures to reduce heat injuries include acclimatization, proper intake of salt and water, avoiding predisposing factors to heat illness, monitoring temperatures, scheduling adequate rest or cooling periods, and educating the work force on heat injury symptoms and remedial actions. Adequate water intake is the single most important factor in avoiding heat injuries. Frequent drinks are more effective than the same quantity of water taken all at once. Table 10. provides information necessary to estimate recommended work-rest cycles and fluid replacement cycles for various environmental conditions (using the Wet Bulb Globe Temperature (WBGT) Index), clothing levels, and work intensities. The work-rest cycles specified in the table are based on keeping the risk of heat casualties below 5 percent. Under some operational conditions, work-rest cycles offer no advantage to continuous work (see No Limit (NL)) entries in table 10. Use the information in table 10. and guidance provided by the medical staff to estimate work-rest cycles and fluid replacement requirements.

Table 10. Work-Rest Cycles and Fluid Replacement Guidelines

Heat Category	**WBGT Index ºF**	**Light (Easy) Work**		**Moderate Work**		**Hard (Heavy Work)**	
		Work/ Rest	**Water Intake (Quart/hr)**	**Work/ Rest**	**Water Intake (Quart/hr)**	**Work/ Rest**	**Water Intake (Quart/hr)**
1	78-81.9	NL	1/2	NL	3/4	40/20 min	3/4
2 (Green)	82-84.9	NL	1/2	50/10 min	3/4	30/30 min	1
3 (Yellow)	85-87.9	NL	3/4	40/20 min	3/4	30/30 min	1
4 (Red)	88-89.9	NL	3/4	30/30 min	3/4	20/40 min	1
5 (Black)	>90	50/10 min	1	20/40 min	1	10/50 min	1

1. If wearing Mission Oriented Protective Posture 4, add 10º F to WBGT.
2. If wearing personal body armor, add 5º F to WBGT in humid climates.
3. Daily fluid intake should not exceed 12 quarts.
4. Caution: Hourly fluid intake should not exceed one quart.
5. Rest means minimal physical activity (sitting or standing), accomplished in shade if possible.
6. NL = no limit to work time per hour.
7. These work/rest time and fluid replacement volumes sustain performance and hydration for at least 4 hours of work in the specified work category. Individual water needs may vary ±1/4 qt/hr.

(1) Specialized personnel cooling equipment (for example, cooling vest) should be used to allow additional stay-time for personnel in extreme heat conditions.

(2) The use of cold-weather gear, personal protective clothing, and respiratory equipment presents severe demands on personnel. Personnel must be monitored closely to prevent frostbite and other cold-weather effects.

Figure 6. Sample PAR Form

(Sample PAR)

Protective Action Recommendation

For

Major Accident ____________________________ at (location)

Issued by:

Problem. An accident involving a propane truck and two Safe Secure Trailer (T1 and T2) vehicles carrying ___________(type)_____________ nuclear weapons occurred at (time, date, and location). The propane truck sideswiped T1 and collided with T2. A fire erupted causing the propane truck to explode. Shortly afterwards, the weapon in T2 experienced a conventional high explosive detonation, resulting in widespread contamination. The T1 vehicle sustained damage and skidded into a ditch, preventing access through its doors to the stored weapon inside.

Discussion. Actions to gain access into T1 and remove the weapon have been hampered. It is still possible, though highly improbable, that a second explosion might occur during access and removal of the weapon in T1. In the unlikely event of an explosion, debris might be thrown 2,500 feet with additional contamination released. As a result, an evacuation of (outline the specific area) has been ordered by the (civilian authority office).

Action. With the possibility of an explosion during access and removal operations involving the weapon in T1, the following area shall be evacuated. (Indicate the specific area to be vacated and a schedule indicating evacuation start, completion, verification of evacuation, work start, work completion, and return to the area). All personnel are required to sign in at a specific location(s) during evacuation to help local law enforcement and/or response force personnel verify that all personnel are out of the area before access and removal procedures begin. A holding area, for example, a gymnasium or school, may be a temporary area for evacuees. Also, the evacuees might be released for shopping or other activities outside the area. Once access and removal procedures are completed, the civil authorities shall determine when evacuees may return to their houses and/or businesses, if outside the contaminated area.

Release of this "Protective Action Recommendation" may not precede confirmation of the presence of a nuclear weapon by the IC and should be coordinated with local officials and the IC's Public Affairs Officer before release.