

INVESTIGATION OF RADIOLOGICAL INCIDENTS



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Investigation of Radiological Incidents

**Recommendations of the
NATIONAL COUNCIL ON RADIATION
PROTECTION AND MEASUREMENTS**

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Preface

An important component of the reports and commentaries published by the National Council on Radiation Protection and Measurements (NCRP) has been guidance on operational radiation safety in applications using radionuclides and radiation-generating equipment in medicine, educational institutions, research laboratories, nuclear power plants, commercial industries, astronaut space missions, security screening in public locations, in potential acts of radiological or nuclear terrorism, and in protection against environmental radioactive contamination. This Report represents an important extension of guidance on investigating a radiological incident that was provided in NCRP Report No. 127 on *Operational Radiation Safety Programs* (1998). It also contains valuable information of relevance to NCRP Report No. 162 on *Self Assessment of Radiation Safety Programs* (2009).

This Report provides guidance on the process to be followed in the investigation of radiological incidents, whether accidental or deliberate including: responding to the incident, coordinating the incident recovery process, conducting the incident investigation including using cause analysis techniques, determining the consequences, developing a corrective action plan, preparing the investigation report, and scheduling follow-up actions. The Report is expected to be of value to managers, radiation safety program personnel, government regulatory agencies, workers, and interested members of the public.

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1. Executive Summary

The purpose of this Report is to provide guidance for investigating radiological incidents. A radiological incident is an abnormal occurrence or sequence of occurrences that may adversely affect the health and safety of workers or members of the public. It can cause property or environmental damage, interrupt program activities, and result in noncompliance with regulations. It is important that radiological incidents be properly investigated to establish the cause(s), contributing factors, and consequences so that corrective measures can be implemented. Although the primary focus of this Report is the investigation of radiological incidents, it also briefly covers the initial response since the investigation of a radiological incident begins with the initial responders.

This Report provides guidance on the responsibilities, general principles, techniques, and process for conducting an incident investigation. This guidance is sufficient for investigating relatively minor incidents. For more serious or complex incidents it is recommended that investigators also have formal training in the more rigorous levels of cause analysis. This training should be commensurate with the seriousness and complexity of the incident.

Radiological incidents can occur wherever radioactive material is handled, stored, used or transported or where radiation-generating equipment is operated. Most radiological incidents have minor consequences and many of these minor incidents may not require an investigation. Radiological incidents that have (or potentially have) a significant adverse impact on the health and safety of workers or members of the public, or adversely impact the environment, should be investigated. In addition, regulatory agencies require that radiological incidents be investigated if regulatory limits are exceeded. The extent and rigor of an incident investigation should be tailored to the severity and complexity of the incident.

This Report provides guidance for individuals who have the responsibility for investigating a radiological incident. Specifically, it provides information and guidance on the following topics:

- definition of a radiological incident, description of the investigation process, and the purposes of an incident investigation;
- determination of whether the incident warrants an investigation;

- responsibilities for conducting or participating in incident investigations, including upper management, line management, the radiation safety committee, radiation safety program personnel including the radiation safety program manager or radiation safety officer (RSO), and workers;
- initial response to the incident, including the procedures for controlling the incident scene to prevent loss of information, recovering any physical items that may have been removed, and gathering information related to the incident;
- coordination of facility recovery activities and the incident investigation;
- appointment of an individual or an incident investigation team (IIT) to perform the incident investigation, including recommendations for the training and qualifications of investigators and the use of consultants and specialists in conducting the investigation;
- conduct of the incident investigation, including the initial team meeting, interviewing facility representatives and personnel involved in the incident, and collecting physical evidence;
- performance of the cause analysis, including which type of cause analysis to perform (*i.e.*, direct cause, apparent cause, or root cause);
- use of various cause analysis techniques including barrier analysis, task analysis, work change analysis, events and causal factors (ECF) charting, process analysis, and human performance analysis;
- identification of the cause(s) of the incident;
- determination of the consequences of the incident including radiation doses to workers, patients, and members of the public, releases of radioactivity to the environment, property damage, and interruption of program activities;
- development of a corrective-action plan;
- preparation of the investigation report including legal considerations, and
- follow-up actions, including scheduling corrective actions, reviewing, tracking, and trending the effectiveness of corrective actions, and lessons-learned distribution.

2. Introduction

2.1 Definition of a Radiological Incident

A radiological incident is an abnormal occurrence or sequence of occurrences that may adversely affect the health and safety of workers, a patient undergoing medical diagnosis or treatment, or members of the public. It may also result in property damage, negatively impact the environment, interrupt program activities, or result in noncompliance with regulations. A radiological incident also includes an occurrence or series of occurrences that could have led to these adverse or potentially adverse consequences if the circumstances had been slightly different. The majority of radiological incidents have minor consequences. However, as defined in this Report, incidents also include accidents that can result in serious injuries or fatalities.

Radiological incidents can occur at any location where radioactive material is handled, stored, used or transported or where radiation-generating equipment is used. Examples of such locations include government or private research laboratories, hospitals, nuclear power plants or other nuclear fuel-cycle facilities, universities, field radiography operations, and college laboratories.

2.2 Radiological Incident Investigations

An overview of the radiological incident investigation process is presented in NCRP Report No. 127, *Operational Radiation Safety Program* (NCRP, 1998). The present Report provides more detailed guidance for conducting radiological incident investigations.

Radiological incidents can occur in facilities ranging from small (*e.g.*, a small hospital or a college laboratory) to large (*e.g.*, a nuclear power plant or a national laboratory). Generally the larger facilities will have substantial resources for preparing for, responding to, and investigating radiological incidents. Larger facilities can use the present Report as a tool to evaluate their readiness to respond to and investigate radiological incidents. Smaller facilities, with their more limited staff and resources, can use the guidance in this Report to make the best use of the available resources for setting up or upgrading their capability to respond to and investigate radiological incidents.

The decision of whether or not to conduct an incident investigation depends on the specific circumstances surrounding the incident and whether the potential or actual consequences of the incident are minor or of a more serious nature. As noted, the majority of radiological incidents are minor and many of them may not warrant an investigation. A minor incident that may not require an investigation may include the following characteristics:

- an isolated occurrence;
- negligible adverse impact (actual or potential) on the health and safety of workers, patients, or members of the public;
- negligible impact on program activities;
- negligible property damage; and
- negligible potential for adverse publicity.

Examples of minor incidents that may not require an investigation include:

- minor violation of an internal procedure;
- missing or improper posting of a radiation controlled area sign;
- recent expiration of a worker's training;
- minor spill of radioactive material in the workplace that is easily cleaned up;
- survey instrument that is slightly past the due date for recalibration;
- retaking of a medical x-ray radiograph because of patient movement or improper positioning; and
- small radioactive check source that is temporarily misplaced.

Even if it is determined that an incident investigation is not warranted for a minor incident, the situation should be corrected (*e.g.*, proper sign posted, worker updates training, or instrument sent in for recalibration) and documented in a logbook or appropriate record system.

Typically, the radiation safety program manager or RSO will decide whether an incident investigation is necessary. For more significant incidents, upper management generally makes the decision whether or not to conduct an incident investigation with input from radiation safety staff members, a radiation safety committee, and line management.

Regulatory agencies, including the U.S. Department of Energy (DOE, 1997), the U.S. Nuclear Regulatory Commission (NRC, 1992; 1997), the Occupational Safety and the Health Administration (OSHA, 2006), the U.S. Food and Drug Administration (FDA,

2005), and state radiation control programs address the investigation of incidents involving radioactive materials or other sources of radiation that exceed or threaten to exceed the regulatory limits for radiation dose to individuals or for releases to the environment. In addition, regulatory agencies may require incidents to be investigated if they involve the loss or theft of radioactive material, certain equipment failures, fires, or facility damage.

The first individual or individuals (emergency responders) on the scene of a serious incident have the responsibility to rescue any victims, stabilize the situation, secure the incident scene, and make the proper notifications, including notifying the RSO. If the individual or individuals first on the incident scene are unqualified or unable to provide such assistance, they are responsible for notifying those who can provide such assistance.

While carrying out these responsibilities, it is important to preserve the incident scene, to the extent possible, in order to facilitate the investigation process. In addition, the initial responder(s) should gather preliminary information about the incident (*e.g.*, what conditions were found at the scene and what appeared to have happened). Thus, the incident investigation process begins with the initial response. More information on the initial response to an incident is found in Section 4.

Depending on the circumstances and severity of the incident, a single analyst (*e.g.*, RSO) may conduct the entire investigation, or an IIT that consists of several individuals may be needed. The use of the term IIT in this Report can also refer to a single analyst unless it is clear that the term is referring to a team with multiple members.

For more serious incidents, regulators may conduct an independent investigation, or observe or participate in the investigation conducted by the institution. If the regulator conducts an independent investigation, the regulator may still require the institution to perform an investigation or the institution may choose to conduct its own investigation.

There are three commonly defined levels of cause analysis used in incident investigations: direct-cause evaluations, apparent-cause evaluations, and root-cause evaluations. The level of analysis and rigor increases significantly from direct cause to apparent cause to root cause. Each of these investigation types as well as examples of the types of incidents they could be applied to is discussed in Section 8.

The level of analysis performed should be commensurate with the seriousness and complexity of the incident. The guidance contained in this Report is generally sufficient for performing the

direct-cause evaluation of relatively minor incidents. However, for more serious or complex incidents requiring apparent- or root-cause evaluations it is recommended that investigators also have formal training in these more rigorous levels of cause analysis.

It is important that “near-miss” occurrences also be investigated, particularly if they had the potential to lead to a serious incident. In a near-miss occurrence, one or more of the administrative or engineered safety barriers fails, but because of at least one remaining barrier or fortunate circumstances, a serious incident does not occur. The investigation of near-miss occurrences and implementation of corrective actions is an excellent opportunity to minimize the likelihood of similar or more serious incidents occurring in the future.

As noted earlier, an incident investigation may not be warranted for a minor incident; however, if an incident investigation is deemed necessary, it should begin promptly after initial responders have completed their activities. The elements of the incident investigation process include discrete phases as follows:

- determine if an investigation is needed, by:
 - obtaining information regarding the incident from the initial responder(s);
 - evaluating the seriousness of the incident to determine if an incident investigation is warranted or required by a regulatory requirements; and
 - evaluating whether it is an isolated incident or a systemic problem.
- conduct the investigation by:
 - selecting and appointing a qualified individual or a team to perform the investigation;
 - initiating investigation activities;
 - conducting the investigation;
 - performing a cause analysis;
 - determining the consequences of the accident;
 - coordinating facility or institution recovery activities and the investigation;
 - preparing the investigation report; and
 - developing corrective action recommendations.
- learn from the incident by:
 - analyzing and trending data from past incidents;
 - following-up on corrective actions; and
 - distributing lessons learned.

Each of these elements of the incident investigation process is discussed in detail in this Report.

This Report is intended to provide guidance for investigating radiological incidents where no illegal activity is involved. In the event that illegal activity is known or suspected, law enforcement personnel should be involved in the investigation. The law enforcement agency will normally have the primary role in the investigation and will use its own investigative methodology. In this situation, the local radiation safety staff will normally be in a supporting role in the investigation.

Because incident investigations are retrospective in nature, they do not include self-assessments that are prospective evaluations of an institution's radiation safety program and entail a separate methodology (NCRP, 2009).

2.3 Purposes of an Incident Investigation

The primary purposes of an incident investigation are to determine what happened, establish the cause(s), contributing factors, and consequences of the incident, as well as to recommend corrective measures. Another purpose of an incident investigation is to improve work processes to minimize the likelihood of future incidents, as opposed to finding fault with or fixing blame on individuals.

When state and federal regulatory agencies and law enforcement agencies conduct investigations, their purposes may include the identification of illegal actions, failures to follow regulations, levying of fines, and identification of possible changes to the regulations to help prevent future incidents.

3. Responsibilities for Conducting Investigations of Radiological Incidents

As discussed in Section 2.2, an incident investigation may not be necessary for a minor incident. However, if an investigation is warranted based on an institutional decision or regulatory requirement, the level of effort that is put into each investigation should be dependent on the nature and severity of the radiological incident. Also, it is important that each person in the organization understands his or her role in the investigation. That role begins when any individual in the organization becomes aware that an incident has possibly or actually occurred. The individual should immediately notify the RSO so that actions and notifications appropriate to the severity of the incident can be initiated. The specific responsibilities for various groups in the organization are discussed below.

3.1 Upper Management

Upper management is responsible for ensuring that an incident investigation is conducted. It is important that upper management understands the legal, regulatory and operational necessities for conducting a thorough and factual investigation of all radiological incidents, and that they strongly and visibly support an institution's investigation by providing the necessary resources of people, time and equipment to conduct the investigation. Upper management is responsible for appointing an individual or team to conduct the investigation (Section 6) and when establishing an incident investigation team (IIT) for a radiological incident, the RSO should be included unless there are conditions or situations that would make the RSO's inclusion impractical or inappropriate.

Although upper management is responsible for ensuring that the investigation is conducted and supported, radiation safety program personnel are commonly tasked with planning and conducting the investigation.

State and federal regulations [*i.e.*, 10 CFR 20.2201, “Reports of theft or loss of licensed material” (NRC, 1991a); 10 CFR 20.2202, “Notification of incidents” (NRC, 1991b); 10 CFR 20.2203, “Reports of exposures, radiation levels, and concentrations of radioactive material exceeding the constraints or limits” (NRC, 1991c); and similar state regulations] mandate the investigation and reporting of incidents involving radioactive materials or other sources of radiation that exceed or threaten to exceed the regulatory limits for radiation dose to an individual or for unintentional and uncontrolled releases of radioactive material to the environment. In addition, the loss or theft of radioactive material and certain equipment failures, fires, and facility damage require reporting and investigation.

Also, upper management should:

- be aware that independent, coordinated or simultaneous investigations of an incident may also be conducted by regulatory agencies. If there are indications of illegal activities, investigations may also be conducted by law enforcement agencies.
- be aware that the investigation may reveal violations of laws or regulations that could subject the institution and individuals to civil or criminal penalties. Likewise, upper management should insist that no facts be withheld from regulatory and/or law enforcement investigators and realize that making false statements to these officials can result in criminal penalties and possibly disciplinary actions by their employer.
- ensure that the findings of the investigation are brought directly to them for their information and, as appropriate, follow-up action. Management should support the necessary corrective actions, which may include purchase of equipment, hiring of additional individuals, training of personnel, and necessary modification to facilities.

3.2 Line Management

Line managers have the responsibility to understand and support investigations involving their operational units. They should understand that it is not the purpose of the investigation to find fault or fix blame, but rather to aid in the early identification and correction of deficiencies and to improve processes so they run more safely and efficiently.

Line managers may have primary responsibility for participating in investigations and for executing corrective actions for their

areas of responsibility. They should encourage workers to participate in the investigation and ensure that they participate fully without any fear of recrimination for their participation and input.

3.3 Radiation Safety Program Personnel

Commonly, the radiation safety officer (RSO) or program manager has the responsibility as the team leader for conducting the initial response and investigating the incident. Elements of the investigation may be delegated to other radiation safety staff members.

During and following the investigation, those involved should protect proprietary information against inappropriate disclosure. However, during the course of the investigation it may be necessary to disclose proprietary information to governmental agencies or others investigating the incident. Likewise the plans for any increased security requirements mandated by regulatory agencies should be protected against inadvertent or inappropriate disclosure. If appropriate, the radiation safety program manager or RSO should establish a liaison with regulatory and law enforcement officials, who may be simultaneously investigating the incident.

Depending on the nature of the incident and the capabilities of the institution, the RSO or radiation safety program manager may need to engage experts outside of the radiation safety program or outside the institution to ensure that all aspects of the incident are thoroughly investigated. This is discussed in more detail in Section 6.

3.4 Workers

It is important that all workers including those not classified as radiation workers support the investigation. This will require that workers be informed about the investigation through briefings or written material, as appropriate.

Workers should be encouraged to cooperate openly and fully with investigators from the institution and regulatory or law enforcement agencies. Workers should understand that only by their full and candid participation in the investigation can the investigation be successful and proper corrective actions be implemented.

4. Initial Response to the Incident

The priorities during the initial response to a radiological incident are to rescue personnel, stabilize the situation, preserve the incident scene, and secure the area.

4.1 Incident Response Preparation

The response to an incident should be commensurate with the significance of the incident. Incident preparation plans should attempt to provide an appropriate response over the entire spectrum of possibilities. Some incidents may be minor and the response of only one or two individuals may be appropriate. Other incidents with more serious consequences may require the response of the entire organization. However, it is likely that most incidents will be minor (*e.g.*, a spill, a small contaminated area, a single contaminated worker, or a minor unplanned exposure to a worker).

Regardless of the magnitude of the incident, an effective response begins with planning and establishing the critical resources required (NCRP, 1998). Response planning should address several basic functions: command and control, notification and communication with responders (and, in some cases, members of the public), assessment of the incident, mitigation of the hazardous condition, and protective actions for the responders (and members of the public). A critical part of response planning may be coordination with off-site resources and communications with regulatory agencies. In 2004, The U.S. Department of Homeland Security established the National Incident Management System (FEMA, 2012) which provided a template for tribal, local, state and federal governments and private-sector and nongovernmental organizations to work together effectively and efficiently to prepare for, prevent, respond to, and recover from domestic incidents, regardless of cause, size or complexity (DHS, 2004).

There are many documents that provide guidance for responding to terrorist incidents involving radioactive material (EPA, 2010; NA/IOM, 2009). Much of the information contained in these reports is directly applicable to response planning for other incidents involving radiation or radioactive materials (NCRP, 2001; 2005; 2010). In addition, a recent Report provides extensive guidance on the handling of contaminated individuals (NCRP, 2008). Several

documents published by the International Atomic Energy Agency also focus on preparedness and response to radiological or nuclear emergencies as well as exercises to test preparedness (IAEA, 2000; 2002; 2005; 2006). While all of these reports are intended to be stand-alone documents, effective response planning should take advantage of all of the available national and international guidance. Good planning and preparedness before an emergency can lead to effective emergency response.

Investigation of a radiological incident begins with the initial responders and these individuals could very well be those involved in the incident. The responders should be well trained to carry out their responsibilities based on the specifics of the incident. In minor incidents, these responsibilities may include actions such as containing a spill or mitigating a release of material; in more severe incidents, these duties may include rescuing the victims and more significant efforts to mitigate the situation, if necessary. But, these responders also have to understand the incident investigation process so that their activities do not modify and/or destroy the incident scene unnecessarily. These individuals must also be trained to preserve the integrity of the incident scene and the various types of evidence available at the scene while, at the same time, responding to the incident.

4.2 Rescuing the Victims

In serious incidents involving injuries, the first priorities of the initial responders are to rescue and treat the victims and mitigate or stabilize the incident. Life-saving must take priority over other concerns such as contamination control and preserving the incident scene (NCRP, 2005; 2010). Contamination on the victims is usually not a significant hazard to initial responders, who should be trained to understand the importance of treating seriously injured or traumatized incident victims within the first “golden hour” (Goans, 2004). On-site decontamination could delay treatment of the victims and even be life-threatening. Simple removal of the outer garments can often reduce the contamination by 80 % or more (NCRP, 2005) and is generally sufficient for initial decontamination efforts. The goal of the responders is to rescue the victims, stabilize them medically, and transport them to an emergency medical facility as soon as possible.

4.3 Stabilizing, Securing and Preserving the Incident Scene

Stabilizing the incident scene may be an important part of the initial response, depending on the type and severity of the incident.

Small institutions are unlikely to have significant resources to bring to bear on an incident, thus the response may involve only one or two individuals. Large institutions are more likely to have well-organized response teams, and in some cases incident response professionals. While some members of the response team may take on the responsibility for rescue and treatment of the victims (if necessary), others focus their efforts on mitigation of the incident to begin the process of preserving the scene for the investigation. The priorities here are to rescue personnel and stabilize the situation, preserve the incident scene, and secure the area.

In some serious or complex radiological incidents, readiness teams (DOE, 1997) may coordinate and/or be integrated with the emergency response personnel. These special teams would participate in the early response to an incident and have the responsibility to assist in securing, preserving and documenting the incident scene. Photographs and video evidence should be obtained as soon as practicable and additional visual information should be obtained routinely as the cleanup and investigation proceed. The readiness team should train with the emergency response team to ensure smooth functioning and, in some cases, take responsibility for certain important functions, relieving the emergency response team for more important, time-critical duties such as life-saving or mitigating the incident.

Preserving the incident scene and securing the area are important and these tasks must be accomplished as quickly and safely as possible; otherwise, important evidence may be compromised or lost. The incident scene should be isolated as soon as possible to prevent it from being disturbed or altered. Isolating the scene also prevents the removal of important evidence as well as protecting people from any hazards that may remain at the scene. A number of approaches can be used to accomplish this isolation. Simple actions such as locking doors or gates or cordoning off the area and posting warning signs can be effective. Some situations may require the posting of guards to prevent unauthorized entry into the area.

It may be necessary to control the incident scene for long periods of time. In these cases, entry in the area must be carefully controlled and documented. A log to document and justify each entry should be maintained. Such an approach will also be extremely valuable if it is necessary to control access to the incident area by several different agencies.

4.4 Notification of Management and Regulatory Agencies

As soon as possible, the RSO should notify the appropriate level of management about the incident and provide any known details.

Information should include a description of the incident, the emergency response actions being taken, the condition of any victims, and the status of facilities and vital equipment, if available. Minor incidents may not require notification of an institutional spokesperson responsible for working with the news media. However, in major incidents, it will be necessary to provide information to the spokesperson so that accurate information that is as complete as possible can be provided to the news media. In these cases, regular situational updates should be scheduled for both management representatives and for those responsible for public information. In some situations, it may be useful to employ the IAEA's *International Nuclear and Radiological Event Scale* in communicating the severity of the incident to the news media and the general public (IAEA, 2009).

In many cases, state or federal law requires reporting of incidents to regulatory agencies within specified periods, depending on the severity of the incident. A significant effort may be required to provide timely and accurate information to these agencies, especially for incidents unfolding over a period of time. Open lines of communication should be maintained and these agencies should be kept informed of the status at a regular frequency. It is recommended that a single individual be responsible for communications with the employees, the news media and the regulatory agencies to minimize the possibility of erroneous information being released (Section 5).

4.5 Transition from Initial Response to Investigation

The initial responders should have gathered preliminary information about the incident. This information includes conditions found at the scene, and what appeared to have happened. If a readiness team (DOE, 1997) responded to the incident, it may have taken many of the following actions:

- identified, collected, inventoried and protected physical evidence;
- collected necessary biological specimens;
- obtained initial witness statements in writing;
- created a photographic or videotape record of the incident scene;
- established a chain of custody for all the physical and documentary evidence;
- recorded signs and symptoms of suspected exposed individuals; and
- compiled a list of all witnesses or people on-site who may have information or may be affected.

After the initial response to the incident has been concluded, the investigation of the incident should transition to the IIT (or analyst) as appropriate. The IIT should obtain any available information from the initial responder(s). The responders and the readiness team should remain available to assist the IIT in their tasks by:

- providing a brief description of the incident;
- summarizing the emergency response actions taken;
- providing a status report on the incident scene;
- providing information on the collection and chain of custody of the evidence; and
- providing any other assistance required by the IIT.

4.6 Facility Recovery Activities During Investigation

Once the initial response to an incident has been completed, there are a number of activities that may require coordination. These might include the following:

- ensuring the incident scene is stabilized;
- ensuring the incident scene is preserved;
- evaluating whether operations in the facility not directly associated with the incident can be continued or resumed;
- coordinating IIT activities with any continuing facility operations;
- notifying regulatory authorities, if required; and
- notifying the media, if advisable.

Management authorization is normally required to restart operations in nonimpacted areas. Also, regulatory approvals may be required for restarting operations or it may be necessary to obtain phased regulatory authorizations for activities conducted during the recovery process.

5. Coordinating Facility Recovery Activities

During facility recovery and the incident investigation phase, recovery activities, as well as communications with outside organizations and the media, should be well coordinated. Chains of command, control and communication should be established to prevent confusion during the incident or recovery operations. Communication control will also help manage the flow of information outside of the immediate incident to those that need or want it. To that end, a single spokesperson for the facility should be designated. If it is necessary to have more than one, the actions of each should be carefully defined and coordinated. The spokesperson should be the sole point of contact for management, regulators, the media, and others who may need information. However, depending on the nature of the incident, the spokesperson should be prepared to direct specific inquiries to further points of contact. Any information transmitted should be clear, factual, nonemotional, and consistent with regulatory and other legal requirements. Because the spokesperson's task is to convey information, ideally that individual should not have any other incident- or recovery-related duties. However if that is not feasible, his or her other duties should be minimized as much as possible.

A key step in the recovery process is to determine when operations that were directly affected by the incident may restart. Before this can occur, the incident should be investigated and a causal analysis performed. While it is not necessary to wait for all corrective actions to be fully implemented before authorizing resumption of operations, a phased restart should include consideration for additional administrative or physical controls until such time as all corrective actions are complete.

If work environments in locations other than those immediately impacted by the incident are disrupted due to equipment malfunction, heat/cold, water, smoke, or other ramifications that would render the area uninhabitable, decisions as to evacuation of those areas and return-to-service will be required. Unaffected alternate work locations should be utilized to maintain normal work flow to the greatest extent possible.

Depending upon the facility and the operations performed therein, there are a number of actions that should be considered in a procedure for recovery from an incident. These might include:

- restart of operations:
 - determining whether the shut-down order extends to the entire facility, to a portion of the facility, or a single room or laboratory;
 - cordoning off laboratories, rooms or areas to permit work to resume elsewhere;
 - allowing selected personnel to return to work (*e.g.*, in the case of a presumed over-exposure, after personnel dosimeters have been processed and evaluated, and/or internal doses assessed);
 - securing management authorization to resume operations in nonimpacted areas, while keeping in mind that regulatory approvals for restart or phased regulatory authorizations during the recovery process may be necessary; and
 - basing restart decisions in nonimpacted areas on sound health physics judgment and with the concurrence of the RSO.
- resource requirements:
 - developing a list of equipment providers for critical items that may require replacement because they cannot be decontaminated;
 - listing monitoring and dosimetry needs (internal and external) and agency(ies) providing support and/or technical assistance if not available in-house;
 - identifying alternate sources of administrative support and equipment (*e.g.*, telephones, copiers, work areas, internet access) in the event normal resources become unavailable;
 - establishing a supply of needed equipment and documents and replacing them as necessary;
 - establishing and maintaining a communication network particularly for remote areas or where power has been lost; and
 - identifying sampling procedures, processes, methods and analysis including identification of analytical labs and protocols that can be used to provide data for incident mitigation.
- decontamination and waste disposal:

- listing organizations participating in incident scene restoration (*e.g.*, cleanup contractors or other agencies that have radiological experience and the necessary licensing);
- developing plans for handling, storing and transporting contaminated waste to a disposal location; and
- listing waste handling and transportation regulatory requirements, including permits, manifest requirements, and disposal site(s) locations.
- documentation:
 - documenting the location, confinement and collection techniques used to contain released or spilled hazardous and/or radioactive material;
 - consulting with local, state and federal authorities to determine organizations responsible for completion and proper maintenance of incident scene documentation including incident response reports, personnel accounting and exposure records; and
 - documenting any identified secondary contamination of soil, water, plants, and/or other adverse environmental conditions that may occur during restoration activities.
- external considerations:
 - developing a list of key agencies, responsible persons, and stakeholders that should participate in the recovery planning and mitigation process; and
 - identifying the potential impact to the environment and address special concerns relative to the location and proximity to sensitive cultural, ecological or population areas.

Note that some of these actions may actually start during the initial response; however, they should still be considered throughout the recovery process.

6. Selecting and Appointing the Incident Investigation Team

6.1 Selecting the Incident Investigation Team

Once the initial situation has been stabilized and the immediate response to an incident has been completed (Section 4), upper management should appoint an incident investigation team (IIT) and team leader to conduct the radiological incident investigation. A single individual may investigate low to moderate consequence and less complex incidents. A team representing applicable technical disciplines should investigate high consequence or more complex incidents. In either case, the investigation should be conducted by individuals who have had some level of training or introduction to the basic principles of cause analysis.

It would be desirable for a team leader to have supervisory or management experience. It would also be desirable for team members to have knowledge of the facility where the incident occurred and the type of incident that occurred. If a root-cause analysis will be performed, then at least one of the team members should have completed formal training in root-cause analysis (Section 8). Formal training and qualification in root-cause analysis generally consists of completion of one to two weeks of classroom training and participating on an IIT or a tabletop exercise in cause analysis.

An IIT should be sufficiently large to include experts in the major affected disciplines. For example, a maintenance engineer might be needed for an incident involving equipment failure. However, the team should not become so large that it becomes unwieldy or inefficient. Generally, IITs should be limited to no more than five or six members. The IIT leader and members should be independent from the incident itself to the extent possible. A balance must be achieved between independence from the incident and adequate knowledge of the processes being examined. Consideration should be given to including members who are external to the institution in order to enhance impartiality and transparency.

Technical experts can be called upon to supplement the team's skills and disciplines on a limited basis without being formally

appointed to the team itself. Table 6.1 provides examples of additional expertise that may be needed during the course of the investigation.

Management should ensure that the individuals conducting the investigation are given sufficient time and resources to do a credible job. This may involve reassigning duties to other workers and dedicating resources to the completion of the investigation.

6.2 Investigation Charter

An investigation charter is an agreement between the chartering official and the team regarding expectations for the conduct and completion of the investigation. An investigation charter template can be prepared in advance, as a part of emergency and incident response planning for the institution. The charter should include the definition of the problem and the scope of the investigation. It should also identify the chartering official, leader, and members of the IIT, and specify the timeline for completion. Once the IIT has been identified, upper management should then complete the charter with information specific to the investigation. Even in simple investigations where a single investigator is appointed, a charter is helpful for setting expectations regarding the scope of the investigation. In this case, the charter may be less formal (*i.e.*, letter or email).

The charter's problem statement should be carefully developed, as it is important to clearly define the problem that the IIT is trying to solve. Taking the time to formulate a good problem statement is the key to solving the correct problem, as it forms the foundation for the scope and direction of the investigation. Guidance on formulating a clear problem statement is given in Appendix A.

The leader of the investigation should be given an opportunity to provide some input into the specifics of the charter, particularly on the timeline and resources allocated to the investigation. The IIT should be briefed on the charter once upper management approves it.

6.3 Team Leader Responsibilities

The leader of the IIT is responsible for the overall management and coordination of the activities of the team. The leader should assign specific responsibilities to team members in concert with the members' area(s) of expertise and interest. The leader should work with team members to identify specific tasks to be performed during the investigation and develop a detailed schedule (timeline with milestones and deliverables) for the work of the team. Typical activities of the team may include, but not be limited to, the following:

TABLE 6.1— *Additional expertise that may be needed to support the IIT.*

Type of Incident	Expertise
Internal exposure	Internal dosimetry
External exposure	External dosimetry, time and motion
Environmental release	Air plume modeling, hydrology, dose modeling, environment sampling and analysis
Equipment failure	Material science, mechanical engineering, electrical engineering, industrial engineering, specific facility knowledge
Computer software/hardware failure	Computer systems engineering, computer programming, forensic analysis
Fire/explosion	Chemistry, process engineering, fire protection, industrial hygiene
Lost/stolen source	Loss control, security
Contamination	Decontamination
Cause analysis	Root-cause analysis

- identifying and reviewing relevant documents;
- participating in the initial team meeting and progress review meetings;
- visiting the incident site and related facilities;
- interviewing personnel involved in or affected by the incident; and
- preparing progress, draft and final reports.

The leader should emphasize to the team that the goal is to conduct a fair and impartial investigation, and should stress the importance of keeping an open mind regarding the cause(s) of the incident. The focus should be on gathering the facts so that they may be carefully reviewed to develop the cause of the incident. This should be stated both to the members of the IIT and to representatives of the management of the facility where the incident occurred. The leader should coordinate with the designated spokesperson for all outside

communications with organizations (*e.g.*, media representatives). The leader should ensure that the work of the team is maintained as confidential until such time that facility management authorizes internal and external release of the team's reports or findings.

6.4 Incident Investigation Team Member Responsibilities

Incident investigation team (IIT) members are responsible for notifying the leader of their areas of expertise and interests relative to the incident investigation, and for working with the leader to identify the specific tasks for which they will be responsible. Each member is responsible for performing assigned tasks and reporting observations and findings to the leader promptly and in accordance with the investigation schedule. Each member of the IIT should focus on the specific area(s) of the investigation they have been assigned, but look for information that may be relevant to other tasks of the investigation and convey such information to the member(s) assigned to those tasks. Only the leader should speak on behalf of the team, and even then, only with the authorization of institution's upper management. IIT members shall ensure that the work of the team is maintained as confidential until such time that institution's upper management authorizes release of the team's reports or findings. Care should be taken when using email and other forms of electronic communications, as these can become part of the legal record. It is important to minimize email communications (and replies) when attaching privileged or confidential information. All preliminary reports, findings and facts should be labeled as "preliminary" or "draft" to prevent them from being interpreted as final findings before the IIT had made its final decisions.

6.5 Interface Between Incident Investigation Team and Management

It is important that incident investigation team (IIT) activities be clearly communicated to facility management through the leader in a timely fashion. Team members will meet and interact with facility personnel during the course of the investigation; members should maintain a record of those meetings and any information received during those meetings. Findings, observations and opinions by individual members of the IIT should not be conveyed to facility personnel or management during the investigation. Such information should be presented to the other members of the IIT, and if appropriate, the team leader should report the information to facility management.

If at any time during the investigation, a team member learns of previously unknown exposures or determines that personnel exposures are potentially ongoing and can be reduced or eliminated with proper action, the member should immediately notify the leader. The leader should immediately review the information and notify facility management and the RSO so that facility radiation safety personnel can make an appropriate evaluation and response.

If any member of the team suspects illegal activities may have occurred as part of the incident or incident follow-up, the team member should immediately notify the leader in confidence and document the notification. The leader should review the information on which the notification is based and advise management. At that time, management has the responsibility to evaluate the evidence provided and notify law enforcement as appropriate.

7. Conducting the Investigation

7.1 Incident Investigation Team Initial Meeting

The initial meeting of the incident investigation team (IIT) should be conducted as soon as possible after the team is formed. At the initial meeting, the leader should:

- introduce the members and review their respective areas of expertise;
- review the charter with the team;
- review the schedule for meetings;
- summarize the investigation tasks;
- discuss who is assigned to each task;
- discuss the need for good communications among members;
- share any documents, initial reports, survey results, or media coverage that discuss the incident;
- discuss any regulatory reporting requirements, the required time intervals for reporting, or any legal implications involved with the incident;
- state any limitations or constraints about the investigation, such as finances, ending dates, resources available; and
- emphasize the need to treat all information obtained during the investigation as confidential from individuals outside the IIT, including personnel in the facility where the incident occurred.

If any members of the IIT, because of their unique experiences, education or training are to be involved in directing parts of the investigation, this should be made known to the members of the IIT. If IIT members suggest additional resources, the leader should discuss this with the chartering entity or the management of the institution. Although the IIT has been selected (Section 6.1), it may be determined that certain areas of expertise important to conducting the investigation are not represented, and acquisition of the services of specialized consultants may be necessary.

Arrangements should be made to obtain any additional or specialized radiological instrumentation that may be required for the investigation. If photography or videography is approved, the

necessary equipment should be acquired or rented. The IIT should discuss the need to interview individuals who witnessed or were directly involved in the incident and any other individuals who are able to provide information about the incident.

7.2 Initial Meeting with Facility Representatives

If the IIT is comprised of nonfacility employees, an initial meeting between the IIT and the representatives of the facility in which the incident occurred should be scheduled. During this initial meeting, the IIT leader should describe the purpose and scope of the investigation and explain how the investigation will be conducted. Contact information (*e.g.*, telephone numbers, email addresses, etc.) should be shared to aid both the IIT and the facility representatives in the investigation.

Facility representatives should have the opportunity during the initial meeting to present the facts regarding the incident from their perspectives, since they have the most direct knowledge of the operations, conditions, training, policies and procedures, etc., relating to the incident. Also, giving the facility representatives the opportunity to present their initial findings encourages cooperation with the IIT, which could be particularly important if the IIT members are not employees of the affected facility or institution.

If feasible, the IIT should tour the incident site. This tour would enable the IIT to orient itself to the location of the incident, so that they may visualize how the incident may have unfolded and to observe the physical conditions that may have contributed to the incident.

If the investigation requires access to information to which access is restricted by law or regulation (*e.g.*, information classified from a national security perspective, information regarding radioactive materials subject to increased controls, or individually identifiable health information), or to other restricted information (*e.g.*, trade secrets), appropriate security measures should be employed to protect the information from release to unauthorized individuals or to members of the public.

7.3 Daily Briefings

The IIT should schedule time to conduct a morning briefing (or whenever time is available before the business day's activities) to review notes, to discuss the progress that has been made, and what is being planned for the day. This briefing does not need to be formal, but should be done so that IIT members who may not be working on the same aspects of the investigation can be brought up to date.