Managing Chemical, Biological, Radiological, and Nuclear Disasters in a Healthcare Facility

By Carl Jarvis, MSc, MD, CCFP(EM)
Preface

This chapter is intended to provide practical advice for managing disasters involving chemical, biological, radiological, and nuclear (CBRN) contamination by first receivers at healthcare facilities. The term “first receivers” refers to Emergency Department (ED) staff who receive the casualties brought in by first responders (paramedics and fire), and the term “healthcare facility,” as used in this chapter, refers to acute care hospitals. These represent a broad spectrum, from the level 1 trauma centre in a big city to a rural hospital with family physicians providing after-hours on-call coverage for outpatients. Within most local and regional healthcare centers, the ED will be the primary site of the response to a CBRN incident. However, the ED is really just the front door into the hospital during a disaster. Thus, staff throughout the healthcare facility must be equally prepared, and the ED disaster plans must be fully integrated into the broader plan for disaster preparedness for the healthcare facility as a whole.

Contents

Preface ........................................................................................................ 318
Common Issues in CBRN Disasters ...................................................... 319
The Disaster Plan .................................................................................. 321
Disaster Codes ....................................................................................... 323
The “Warm Zone” .................................................................................. 328
The Contaminated Treatment Area ....................................................... 329
Additional Preparations ......................................................................... 330
Triage Team ............................................................................................. 333
Scale of Decontamination Facility ......................................................... 334
The Decontamination Team ................................................................. 338
How to Decontaminate .......................................................................... 338

*CBRN refers to Chemical, Biological, Radiation, and Nuclear disasters. The term “explosive” (referring to the explosions with which CBRN events are sometimes associated) is sometimes appended to the acronym, giving CBRNE.
Common Issues in CBRN Disasters

On July 13, 2006, just after midnight, a Canadian Forces CH-149 Cormorant helicopter was involved in a “hoist exercise” with the Canadian Coast Guard and a local fishing vessel on a foggy night in the Atlantic Ocean off Canso, Nova Scotia. Something went wrong and the aircraft plunged into the ocean. The fishing vessel pulled 4 injured airmen out of the icy water; 3 others died and were later recovered from the partially sunk fuselage. On arrival dockside, the 4 survivors, saturated with jet fuel, were transported to the local hospital prior to any on-scene decon. The receiving hospital had no equipment or plan for managing contaminated casualties and they were brought into the ED. Because it was unprepared, the hospital’s role in providing the necessary medical care for the contaminated casualties while remaining open for the usual heartburn and heart attacks that continued coming in was compromised. This event prompted a reevaluation of the preparedness for CBRN incidents in Nova Scotia, which led to improvements in the ED Disaster Plans, the purchase of advanced capability personal protective equipment (PPE) for some EDs, and exercises focused on chemical decontamination.

In another incident, on January 6, 2005, a train with 42 tanker cars containing chlorine derailed at 2:40 AM in the town of Graniteville, South Carolina, releasing a toxic cloud of the gas that killed 9 and injured scores of others. After receiving an initial phone call from a local resident, “the poison center promptly called the local ED and found on duty a single emergency physician, who was already overwhelmed with 1 critically ill patient, 6 patients who had pulmonary edema, and 100 patients in the waiting room.”

Auf der Heide refers to “the paper plan syndrome,” which he describes as the “illusion of preparedness based on the completion of a written document.” Some efforts at improving disaster preparedness have focused on improving infrastructure and buying supplies (protective suits, safe breathing apparatus, and collapsible decon tents). However, there is no evidence that big capital
Disaster Preparedness for Healthcare Facilities

projects translate directly into improved disaster preparedness on the long term. Thus, adequate ED preparedness for contaminated casualties requires the following:

- Basic knowledge about specific CBRN threats, how to identify and manage the medical issues, and how to mitigate the risks to themselves, their patients, and their ED
- An Emergency Department Disaster Plan that is both accessible and comprehensive, familiar to those who will be called on to use it with very little advance notice, and is fully integrated with the rest of the hospital and with outside stakeholders.
- Equipment for detecting contamination and performing subsequent decontamination, and staff who are trained in the use of that equipment and those facilities, as well as appropriate PPE.
- Practice with the use of the Disaster Plan, the decontamination equipment, and the PPE.

There is ample evidence that healthcare facilities appear to be poorly prepared to manage CBRN disasters.\textsuperscript{8-12} One of the contributing factors to this perception is the difficulty in defining “preparedness.” Should all EDs be prepared for a CBRN disaster on the scale of the 1995 Sarin attack on the Tokyo subway\textsuperscript{13,14} or is any deliberate preparedness a waste of resources better spent on managing daily overcrowding?\textsuperscript{15} The Centre for Excellence in Emergency Preparedness has published a checklist for assessing preparedness for CBRNE incidents,\textsuperscript{16} which could be used as a starting point.

This chapter takes the view that some preparedness for CBRN casualties constitutes “due diligence,” and that with education, training, and minimal (if any) additional resources, every ED can provide essential care in a safe and cost-effective manner in all but the most exceptional circumstances.

The goal of this chapter and the skill set it describes is not to create the expectation that ED staff have to be experts in managing CBRN disasters. As skilled as ED’s might aspire to being at managing contaminated casualties, they will never have the skills or resources of professional CBRN specialists. Thus, one of the first telephone calls made from the ED when facing a CBRN disaster should be to Emergency Services Dispatch to request assistance from the fire department Hazmat team.

**Identifying a CBRN Disaster**

Shortly after a CBRN incident occurs, the first responders (fire, police, and emergency medical services) arrive at the scene. Some supervisory, special operations, and Hazmat vehicles are equipped with chemical sniffers and γ (gamma) detectors, and arriving first responders may rapidly learn of the existence of a hazard. Otherwise, they may have prior intelligence or recognize signs at the scene that are suggestive of a CBRN hazard. It typically falls to EMS to notify the EDs of area hospitals. Despite this infrastructure, however, first receivers may learn about contamination at a disaster scene prior to official...
notification, when casualties arrive on foot or by personal vehicle\textsuperscript{6,17}. The Centers for Disease Control and Prevention (CDC) have published preparedness and response recommendations for hospitals.\textsuperscript{14}

In some cases, recognition of the disaster is overt, when it is obvious that there has been a disaster involving contamination even in the absence of formal notification. At one end of the scale, workers may come from the site of an accident anxious that they may be contaminated with a known agent that they were working with or transporting. They may have triggered a portal monitor (e.g., at a nuclear power facility, research, or industrial site). Patients may come in from their homes near the scene of a train derailment complaining of a “fog” descending on their homes and subsequent respiratory symptoms\textsuperscript{6} (note that both you and they may initially be unaware that there has been a train derailment several miles away). At the other end of the scale, there may have been an explosion at a nearby nuclear power plant or fire at a petroleum refinery that could already have been reported in the local media.

In other cases, the occurrence of a CBRNE disaster may be covert. For disasters with a drawn-out timeline (i.e., days to weeks), syndromic surveillance may provide some warning that there is something extraordinary going on. This surveillance can happen at a variety of levels, from search terms used in public internet searches (e.g., Google FluTrends\textsuperscript{18}) to symptom clusters (i.e., clusters of diarrhea and vomiting with mass food poisoning or neurological dysfunction and respiratory distress with mass botulism poisoning) either called in to EMS or presenting to ED’s equipped with electronic patient tracking. In many cases, syndromic surveillance will consist simply of recognition that patients presenting to the ED are suddenly sharing common symptoms. ED staff should always consider the possibility that this cluster of cases may be due to a mass chemical or biological event and not just that “there must be a Norovirus going around the nursing home…”

Portable monitors are available for certain types of chemical and radiological contaminants. Some monitors are handheld, for example, Geiger counters (for $\gamma$ (beta) and $\gamma$ (gamma) radiation) and certain chemical “sniffers.” Others are portal monitors, the same as the metal detectors that passengers walk through going through security at the airport. It makes sense to have monitors relevant to the setting of the hospital, so that, for example, any ED within 50 miles of a nuclear facility should have a Geiger counter. Staff need to know where their monitors are stored and how to use them. Most use simple batteries that require scheduled replacement.

The Disaster Plan

Why the ED Needs Its Own CBRN Disaster Plan

The role of a functional CBRN Disaster Plan is to provide a means of moving forward when confronted with an extraordinary challenge that is unfamiliar to most staff. The format is important. A fully digital format will allow the plan to be stored on the hospital server and therefore accessible from any terminal in the ED. This type of access also allows staff beyond the ED (e.g., in inpatient...
Disaster Preparedness for Healthcare Facilities

and administrative areas of the hospital) the means of seeing what is going on in the ED during a CBRN disaster response. Finally, it also facilitates ongoing maintenance and improvements. However, it is also essential to have a small number of up-to-date paper copies of the plan placed at strategic locations in the hospital for the inevitable power outage.

Although each type of CBRN disaster has its own specific features, there are many issues that are common to all CBRN events. These issues include the following:

- Safety of staff and other patients
- Maintaining the ongoing function of the ED
- Initial uncertainty regarding the specific contaminants involved, followed by a lack of knowledge about those contaminants once they are identified
- Disproportionate levels of fear and anxiety among staff, patients, and members of the public peripherally affected by the CBRN disaster

The Disaster Plan needs to include specific answers to the following questions:

- What are the risks posed by common CBRN agents?
- What constitutes appropriate PPE when the specific contaminant is unknown?
- What are the key aspects of triaging casualties from a CBRN disaster?
- Decontamination: when, where, who, and how?
- When, if ever, is it safe to bring contaminated casualties into the ED, the diagnostic imaging facilities or the OR?
- How to proceed if the ED does not have the level of PPE required for casualties arriving who are contaminated.
- What resources are available in hospital? Labs, housekeeping, and site engineering all use toxic chemicals and are required to have spill kits and other safety supplies.
- How to manage the disproportionate numbers of psychological casualties in a CBRN disaster.
- Business continuity: how to keep providing care for patients not involved in the CBRN incident, and how to clean up afterwards so that contaminated areas can be put back into general service as soon as possible.

The Disaster Plan should specify an approach to patients from across the spectrum of triage acuities, including high acuity (especially those who require life and limb-saving interventions prior to being decontaminated), low acuity, walk-ins, and psychological casualties. Note that this last group is likely to outnumber the injured and contaminated by a ratio of 10:1 in any CBRN mass casualty incident.
**Disaster Codes**

Broader protocols that are part of the overall hospital disaster plan should be used when appropriate during a CBRN disaster. Specific “code” colors are not universal. Thus, a chemical spill may be a “Code Brown” at one hospital and a “Code Green” at another. “Code Orange” is frequently used for mass casualty reception when the number of affected casualties exceeds the capacity of available resources. Thus, a “Code Orange” should probably be declared for any CBRN disaster that has more than a limited number of casualties, when the contamination requires a large commitment of resources, and when there is a significant proportion of concomitant trauma. Some hospitals also have other “Codes” that should be considered.

“Code Brown” is a hazardous substance spill. Calling this Code will engage resources that the ED may not even be aware of in their own hospital, for example, the hazardous chemical spill kits in hospital laboratories as well as technical experts and equipment. “Code Brown” can be used if a chemical or radioactive agent from a disaster outside the hospital has contaminated the entrance to the hospital, including areas designated for triage and decon.

Finally, a “Code Grey” should be called if chemical fumes, smoke, or a radioactive plume is contaminating the air outside a hospital; it shuts down the intake of ambient air by the hospital heating, ventilation, and air conditioning systems.

**Patient Flow**

Patient flow describes how arriving casualties flow through the physical space while they go through the stages of care, and who will provide that care for each type and scale of CBRN incident. These stages of care include the following:

- Triage (including initial assessment for contamination)
- Registration (keeping track of arriving casualties)
- Decontamination
- Evaluation and management of injuries and medical problems related to contamination
- Disposition (the location to which the patient is eventually discharged)

Patient flow through the ED follows a similar pattern regardless of the specific incident (see Figure 12-1). Casualties are met by the Triage Team at the outer edge of the “Warm Zone” where they are evaluated and assessed for contamination. Stable patients who are contaminated can be grouped together to wait for decon. Their priority should be based on their triage acuity and their risk of ongoing health effects due to the contamination (e.g., contaminated wounds or ingestion or inhalation of contaminant). Patients who are ambulatory are directed into the ambulatory decon shower. Once they have showered, they
Disaster Preparedness for Healthcare Facilities

Figure 12-1: Algorithm for patient flow through the ED during a CBRN disaster.

should be reassessed for contamination. When successfully decontaminated, they are allowed to enter the post-decon area where they dry off with towels and put on clean dry clothing. Then they are brought into clean areas of the ED when a bed is available for their evaluation and management. Those who are nonambulatory go through a similar process but are decontaminated on a stretcher.
Once decontaminated and ready to enter the ED for their full evaluation and management, it is certainly an option to mix these patients with other patients from the disaster who were not contaminated in the first place or with those patients in the ED for reasons unrelated to the disaster. The only reason to continue to cohort decontaminated patients might be in the case of patients with internal contamination, where specific sampling and treatment procedures (e.g., screening urine, emesis, and stool for radiation) might best be done by a group of ED staff prepared for those specific issues.

There are two options for managing unstable patients. First, if they do not pose any significant contamination risk to the staff, other patients, or the facility (e.g., with radiation contamination), they should be brought into an isolated area within the ED (called the “Contaminated Treatment Area”). Otherwise, they should receive whatever interventions are possible in the Warm Zone.

**Cohorting Patients**

When potentially contaminated casualties present to the ED, one way to manage them is to group them based on key parameters that affect where (and how rapidly) they are decontaminated and receive their medical evaluation and management. These parameters include the following:

- **contamination status** (contaminated, not contaminated, or unknown)
- **acuity** (stable—those patients who can wait until after being decontaminated to receive complete medical evaluation and management, and unstable—those patients who require immediate evaluation and/or emergent management)
- **ambulatory status** (ambulatory versus nonambulatory)

Taken together, these parameters define the cohort to which the patient belongs. The key cohorts include the following:

1. Stable, contaminated, and ambulatory
2. Stable, contaminated, and nonambulatory
3. Unstable, contaminated, can be decontaminated immediately and then brought into ED for evaluation and management
4. Unstable, contaminated, requires live or limb-saving intervention prior to being decontaminated
5. Not contaminated
6. Psychological casualties

As mentioned earlier, with the exception of patients with internal contamination, after being decontaminated, patients could be mixed with other patients from the disaster who were not contaminated in the first place or with those patients in the ED for reasons unrelated to the disaster.
Personal Protection Equipment

The risk of working with contaminated patients is that the healthcare worker will become contaminated themselves. This is not a problem provided they are protected from the negative consequences of contamination.

Proper PPE leaves the healthcare worker free to get surface contamination on their PPE, while protecting their skin and personal clothing from requiring decon and protecting themselves from any adverse health effects.

When contamination with an unknown agent is suspected, staff should wear the highest level of PPE available to protect themselves from the type of contaminant involved (i.e., chemical, biological, or radiation). Once the exact contaminant is known, it becomes possible to focus the exact type of PPE required to ensure staff safety (e.g., using databases like WISER²⁰).

Levels of PPE vary from Level A (maximally protective suits with self-contained breathing apparatus (SCBA), typically used by Hazmat technicians) to Level D (basic universal precautions). The Level A and Level B PPE are impractical for assessing patients and providing any interventions and are only used in the field by specialists whose role it is to carry casualties from the “Hot Zone” to the “Warm Zone.” There, first responders with less restrictive PPE (usually Level C) are able to provide initial medical triage and treatment. Resuscitation in the Warm Zone consists of limited procedures such as BVM ventilation, needle thoracostomy, providing intravenous access, immobilizing possible C-spine fractures or straightening angulated fractures with absent distal pulses.

The minimal safe level of PPE for first receivers depends on the contaminant.

The types of PPE accessible for most EDs include Levels C and D. Full Level C PPE includes hooded chemical-resistant clothing, a NIOSH-approved full or half facemask powered air purifying respirator (PAPR), as well as chemical-resistant gloves and rubber boots (see Figure 12-2). Level D PPE is essentially the same PPE used in EDs for contact precautions and is protective against radiation contamination (see Figure 12-3). Note that a Tyvek suit will provide more protection of the first receiver’s personal clothing than just a gown and is quite affordable.

For EDs equipped with Level C protection, a practical approach is to have a core of staff fully trained in its use, acting as leaders and resource people to assist other staff in the correct procedure. It also helps to have demonstration
media (posters, slides, or video) of appropriate PPE for each specific type of CBRN contamination and how to use it. The specific tasks for the use of different types of PPE include donning (i.e., putting it on), use while working, and doffing (i.e., taking it off). For ED’s without any special PPE, it is important to know what is feasible to do with Level D PPE and also what should not be attempted. The sections in this chapter dealing with each specific type of CBRN contamination will address that question.

From a practical standpoint, it is a good idea to use the bathroom before donning PPE and to wear light clothing underneath because it can get hot in a gown or suit and opening the zipper to ventilate is not an option. It can be very difficult once a healthcare worker is wearing the appropriate PPE to recognize each other. Therefore, a strip of masking tape with your name or role, taped on the front and back of the gown or suit, can make it easier to find specific individuals. It may also help to use color-coded strategies (e.g., colored tape) to identify key roles as follows: ED leaders, staff qualified to intubate (“intubators”), and so forth. It is important to keep in mind that it is very difficult to hear and to be heard while wearing a full face mask and hood. There needs to be a backup strategy for communication, something as cheap as a dry erase marking board or as expensive as a wireless Bluetooth communications system with individual microphones and ear buds. Finally, there is also a finite period of time that any person can wear PPE in terms of tolerance and filter efficiency.

A thorough discussion of PPE and general decontamination procedures from a first receiver occupational health perspective is available in the OSHA (the US Occupational Safety and Health Administration) 2005 report “Best Practices for Hospital-Based First Receivers of Victims from Mass Casualty Incidents Involving the Release of Hazardous Substances.”

Preparation for the ED for Contaminated Casualties

When the decision is made to prepare the ED for receiving contaminated casualties, the same basic approach applies for most types of contamination. This includes setting up a “Warm Zone” adjacent to the ED and, in the case of radiation casualties, a “Contaminated Treatment Area” inside the ED. A schematic representation of this basic approach is shown in Figure 12-4. Although clinical staff are preparing to triage and decontaminate patients, security should be preparing for the arrival of the casualties by ambulance, private vehicle, and on foot.
Managing casualties from a CBRN disaster typically conjures up images of extensively trained and equipped hazmat technicians wearing space suits, speaking in muffled voices through full face masks as clouds of deadly mist swirl around them. That may actually be the reality in the “Hot Zone” at the site of the disaster. However, the reality in the ED is typically less hostile. Several factors serve to mitigate the risk to first receivers (as opposed to first responders) as follows:

1. The contaminant is typically diluted by the time the casualty arrives at the ED: the ambient concentration of contaminant is highest at the point source of its release, as typically it is stored or transported in a pure or concentrated form prior to the disaster.

2. Casualties with the greatest burden of contaminant may in fact be either dead, or triaged as “expectant” at the site, and may not even be transported to the ED.

3. Most toxic chemicals are fairly volatile. This means that unless the disaster occurs immediately adjacent to the ED, much of the contaminating...
chemical would have evaporated by the time they reach the ED. This is called “off gassing,” and poses a risk primarily to paramedics transporting contaminated casualties.

4. Casualties arriving by EMS may have been decontaminated prior to arrival at the ED. In fact, many EMS organizations have policies prohibiting the transport of contaminated casualties until after they have been decontaminated in the field. Note that this does not apply to ambulatory casualties who will have self-extracted from the scene and will likely arrive prior to the EMS patients.

5. Up to 90% of the contamination on casualties will be on their clothing. By simply removing their clothing and keeping it outside the ED (and away from any hospital air intakes!), most of the contamination will be kept outside the ED decon area.

Thus, the space adjacent to the ED where contaminated casualties are triaged and decontaminated can be referred to more as a “Warm Zone” than a “Hot Zone.” The “Warm Zone” may be on the periphery of the ED (e.g., in an exterior ambulance bay) or can be near the ED (e.g., part of a parkade across from the ED or an adjacent building that does not house patients or essential services). Triage and decontamination functions may be set up at different physical locations, with patients walked from the Triage area to a nearby decon site. When the “Warm Zone” is inside the building that houses the ED, it is essential that dangerous fumes are not allowed to enter the building; most ambulance bays are designed so that there is a flow of air out of the building (i.e., from the inside, through the ambulance bay to the outside), because vehicle exhaust fumes are another type of chemical toxin.

The entry into and exit out of the “Warm Zone” must be clearly identifiable with painted lines or tape on the floor and possibly pylons or other physical barriers. Also, the movement of casualties through the “Warm Zone” into the main ED must be ideally controlled by a surveyor, whose role is to ensure that no staff or patients carry contamination into the ED, recontaminate themselves, or expose themselves to contamination without appropriate PPE.

Consideration should be given to special population who might require more guidance or support such as the blind, the mobility impaired, the mentally handicapped, and patients with psychiatric illness and specifically how to manage children in such a frightening situation (i.e., to keep with relatives, etc.).

The Contaminated Treatment Area

Generally speaking, contaminated casualties should not be brought straight into the ED until they have been decontaminated. One exception to this rule is with unstable patients contaminated with radiation. Although radiation can pose an exposure risk to first responders close to a point source for a sufficient duration of time, this level of exposure would not be expected in the ED setting. This room (or contiguous rooms, in the case of multiple contaminated and unstable patients) is referred to as the “Contaminated Treatment Area.” When patients are brought into the Contaminated Treatment Area, they should (if possible) have their clothing removed and be transferred to a clean stretcher, or at the very least
wrapped in a clean sheet to contain loose contamination prior to being wheeled into the ED.

If a contamination risk becomes apparent only after a patient has been brought into the ED, a Contaminated Treatment Area can be set up as soon as that risk is noted, with the control lines put in place to control the spread of contamination into other parts of the ED.

Be mindful that this task and others outlined in this chapter may take longer than expected, even up to a few hours in large facilities, particularly after hours when staffing is decreased.

**Additional Preparations**

*Security* staff are critical to the ongoing ED function during a CBRN disaster. They should begin by initiating a facility-wide lockdown. Note that this may take a longer time than expected and involve more staff than is usually available on site. It is worthwhile reviewing the process ahead of time with the Chief of Security and perhaps prioritizing the lockdown of specific areas initially so as to save time.

After locking down, their tasks then include the crowd and traffic control issues present with an MCI. In addition, they may be needed to assist the surveyor in enforcing the control lines around the “Warm Zone” and the Contaminated Treatment Area. Security must take responsibility for the bags of contaminated personal belongings (including wallets, watches, cell phones, and jewelry). They may also be responsible for preserving forensic evidence and may be required to work with law enforcement agencies in that regard.

*Signage* will need to be posted designating the various marshalling areas, including the predecontamination undressing and post-decontamination dressing areas on either side of the decon shower, as well as the storage site for bags of contaminated clothing and waste. These signs should be prepared in advance and ideally deployed (such as painted arrows on floors or walls).

Many EDs set up their decon facilities in their Ambulance Bay. In these setups, there is often a *positive pressure air flow* out the inside (ED entry) doors, across the “Warm Zone,” and out the bay doors. There may be a switch to start the fans. In the event that there is an air intake (e.g., for air conditioning systems) in a contaminated area, it may need to be shut down to prevent the spread of contaminants.

Ideally, EDs should try to *control contaminated effluent*. Small numbers of casualties can be decontaminated standing in wading pools (which will then have to be drained). Newer sites sometimes have “skimmer” tanks installed in their ambulance bays that store hundreds or thousands of gallons of effluent. These are usually designed to collect oil-based solvents that float on the water used for decontamination. If the contaminant is aqueous, then it is more difficult to control. In any case, the relatively small amount of contaminant (once the casualties clothing has been removed) is likely to be extremely dilute by the time the effluent enters the municipal water treatment system. Furthermore, environmental remediation is always available as an option of last resort, once the casualties have been attended to.

When there are *fatalities* in the “Warm Zone,” they are likely to be the most heavily contaminated casualties. They will need to be decontaminated prior to being brought into an indoor morgue. However, they are also likely to be of
interest from a forensic and biodosimetry point of view. Therefore, any bodies will likely need to be stored in or near the ED until these requirements have been met and the Medical Examiner’s office is ready to take them. In the case of an MCI, a temporary disaster morgue can be set up in a refrigerated trailer, which can be arranged by the Hospital Emergency Operations Center (EOC).

**Organizing Staff in the ED**

The 2 basic functions carried out in the “Warm Zone” of the ED are triaging arriving casualties and decontamination. Unless it is known that the arrival of the first casualties will be delayed, the staff designated for the Triage Team should begin donning their PPE right away, so that there will be someone to receive them. Security should establish their security perimeters and work out the flow of traffic and arriving self-referred and EMS casualties. The remainder of the available staff (including those on the Decon Teams, the surveyor, and other staff who will not be working in the Warm Zone but are available to help set it up) should break out the CBRN supplies and set up the decon facilities, waiting areas, Contaminated Treatment Area, and control lines. The positioning of staff in the Warm Zone is depicted in Figure 12-4.

There are additional roles that support the 2 basic functions. These include casualty registration and identification, enforcing the control lines, monitoring staff for PPE and casualties for decontamination, and staffing a Contaminated Treatment Area within the ED for unstable casualties of a radiation disaster. Finally, life-saving medical procedures within the “Warm Zone” can be performed by staff from either the Triage or Decon teams or by dedicated medical staff. Table 1 lists the basic staff roles and responsibilities in the “Warm Zone.” Note that the Contaminated Treatment Area (set up during radiation disasters) should be considered as an extension of the “Warm Zone” inside the ED and should be staffed with at least 1 physician, 1 nurse, and a surveyor with a Geiger counter.

Any time remaining after the ED is set up and before the arrival of the first casualty should be spent clarifying roles and reviewing patient flow with the assembled Triage and Decon Team members.

**Table 12-1: Summary of Staff Roles and Responsibilities in the “Warm Zone”**

<table>
<thead>
<tr>
<th>Role</th>
<th>Minimum Number</th>
<th>Responsibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Security</td>
<td>2</td>
<td>Security to control entry into the Warm Zone for assessment by the Triage Team and ensure that movement across the control line between the Warm Zone and the ED is supervised by the surveyor. Ensure that potentially contaminated patients do not bypass the Warm Zone.</td>
</tr>
</tbody>
</table>

PROVIDED COURTESY OF CEEP.CA AND PMPH USA IN RESPONSE TO THE COVID-19 EMERGENCY
### Table 12-1 (continued)

<table>
<thead>
<tr>
<th>Role</th>
<th>Minimum Number</th>
<th>Responsibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triage Team</td>
<td>3</td>
<td>MD and RN assess arriving casualties for stability and contamination; decide which cohort patients belong to; Registration Clerk ensures that patient name is recorded, patient is given ID bracelet, and a second bracelet identifying them as contaminated (or not); may provide life-saving medical interventions as required and as time and conditions permit; with radiation, should also include a surveyor. An alternate model would be to have a more extensive registration after decontamination with only an initial ID number being given to patients in the Warm Zone so as to match them with their belongings. This ID is then integrated into their registration chart (for more details, please see the chapter on Hospital Emergency Surge Capacity).</td>
</tr>
<tr>
<td>Decon Team (per “line”)</td>
<td>3</td>
<td>1 staff to prepare patients for decon and collect/label contaminated clothing and personal items (pre-decon staff); 1 staff to assist with showering and to ensure that showering is adequate (decon staff); 1 to assist patients with getting dried off and clothed in dry clothing (post-decon staff). Note that only 2 decon staff are required for a nonambulatory decon line.</td>
</tr>
<tr>
<td>Surveyor(s)</td>
<td>1</td>
<td>Surveyor to ensure that no contamination is brought across control lines into the inside of the ED by either patients or staff (may be equipped with Geiger counter or other contamination meters as available).</td>
</tr>
<tr>
<td>Contaminated Treatment Area Team</td>
<td>3</td>
<td>For use during radiation disasters; MD and RN to provide medical care for unstable patients referred from disaster Triage, then to carry out decontamination; surveyor to assist with identification of residual contamination.</td>
</tr>
</tbody>
</table>
Arrival of Casualties at the ED

The policy of many EMS organizations is to not transport casualties who are contaminated; to protect their paramedics and their other assets, they require that the casualty be decontaminated in the field prior to putting them in an ambulance. For stable casualties when field decon is being set up in a timely manner, this policy makes good sense. However, there may be instances where a contaminated casualty does get transported by EMS. First, the paramedics involved may be unaware of the policy. Second, they may feel that the patient is so unstable that they cannot wait for a decon process that is not yet operational. Third, they may recognize (in the case of radiation contamination) that there is minimal personal and operational risk in transporting contaminated casualties who are too unstable to wait for decontamination in the field.

In any case, the large majority of casualties arriving at the ED during a CBRN disaster are likely to arrive outside of the official prehospital systems, usually by private car, public transport, or on foot. In general, arriving casualties should be directed to a single point of triage. This need not be (and in some situations should not be) the entrance to the ED. With mass casualties, bullhorn triage can be used to separate arriving patients who can follow verbal instructions from those who cannot when commanded to assemble “over there”; those who do not follow the command are either nonambulatory or cognitively impaired, and thus should be the first to be triaged.

If there are large numbers of contaminated casualties who are low acuity, transporting them to a predesignated nonclinical site, such as a local high school or health club where there are a lot of showers, may be the best strategy.

Triage

During a CBRN disaster, triage should occur at a limited number of sites. The usual triage site may be kept open to assess arriving patients with problems unrelated to the CBRN incident. However, it would be efficient to direct arriving casualties from the disaster to the disaster Triage Team site. In mass casualty CBRN events, this may mean implementing a “pre-triage” process using a bullhorn to direct disaster casualties around the building to the ambulance bay, where they are again provided direction.

Triage Team

The Triage Team must be dressed in the appropriate PPE. They should be prepared to receive unstable casualties from the field as both walk-ins and EHS transports. Then the formal triage process can focus on the highest acuity patients first. The goal should be to identify the appropriate cohort for the patient and those unstable patients who require a life or limb-saving procedure.

The Triage Team has 2 decisions to make about each arriving casualty as follows:

1. What is their acuity? Assigning a triage acuity score can be done using either a familiar ED system (e.g., CTAS) or a mass casualty system such as START. In addition, the Triage Team should identify arriving casualties who need a life or limb-saving intervention.
2. **Are they contaminated?** This can be determined with certainty in the case of radiation (using a Geiger counter), but is often less clear with chemical or biological contamination (especially while wearing Level C PPE). In these cases, the likelihood of contamination is determined by subjective means: a history of exposure and proximity to the contaminant, as well as suggestive physical signs and symptoms.

If the patient is contaminated and requires an emergent life or limb-saving intervention (e.g., CPR, BVM ventilation, needle decompression of the chest, or administration of a chemical antidote) prior to full decontamination, they have several options. First, they can identify an MD or other clinical staff from one of the Decon Teams to deal with it inside the Warm Zone. Second, they can do it themselves, provided that there are no other casualties waiting to be triaged. Third, in a mass casualty situation, they may decide to triage the casualty as “expectant,” in other words, to receive comfort care only prior to their death. Finally, they may decide that the contamination poses little risk to the staff, other patients, and space inside the ED (e.g., with radiation) and direct the patient be taken to the Contaminated Treatment Area.

The final function during triage is to keep track of arriving casualties. If there is sufficient time between arrivals, this can be done using the usual registration procedures. If, however, the casualties are arriving at very short intervals, someone should be assigned to keep a record of the names of arriving casualties on a large dry erase board, assign an identification number, and if possible list where they are being taken. Finally, each casualty should get 2 wristbands: 1 identifying them and the other color coded with their contamination status (i.e., brown = contaminated and green = decontaminated).

**Decontamination**

There are some excellent reviews on how an ED should manage chemical contamination.6,23,24 These strategies apply generally to all CBRN responses. The goals are to remove the toxic material from contact with the patient; to prevent further (secondary) contamination of the patient, other patients, or staff; and to prevent contamination of the ED such that it is unable to continue to carry on “business as usual.” Every ED has the capability to carry out some decontamination depending on what level of protection is offered by the available PPE.

**Scale of Decontamination Facility**

Decontamination can be carried out on a variety of scales. At the smallest scale, a casualty who is identified by a surveyor as having a small area of radiological contaminant on 1 hand just needs to have that hand rinsed under water. At the other end of the scale, a group of refinery workers all sprayed with hydrocarbon solvents would benefit from mass decon in multiple showers (see Table 12-2).

The level to which a given healthcare facility decides to provide decon depends on a variety of factors, including size of the facility (smaller facilities have less space, smaller budgets, fewer staff to provide ongoing staffing and maintenance, and perhaps a lower expectation of providing mass...
### Table 12-2: Types of Available Decontamination Facilities

<table>
<thead>
<tr>
<th>Scale of Decon</th>
<th>Type</th>
<th>Pros and Cons</th>
<th>Cost*</th>
<th>Ease of Retrofitting</th>
</tr>
</thead>
</table>
| Small          | Individual shower     | Requires minimal infrastructure once installed  
Can be used for other functions when not being used for decon  
Available in portable format that can be assembled when needed, then disassembled for storage  
Processes one casualty at a time | $     | Easy (if adding portable shower)  |
|                | handheld spray nozzle | Useful for spot decontamination  
Can be built into an existing sink | $     | Easy                             |
| Medium         | Multiple showerheads  | Requires adequate drainage, privacy barriers | $$    | Difficult                         |
| Large          | Specialized decon tent| Flow-through processing model (efficient)  
Requires significant ongoing support  
(equipment, staff, training, and practice)  
Can be owned and operated by healthcare facility or provided by municipal fire service (based on mutual agreement) or provided (with or without staff) by a third-party private contractor | $$    | Easy (provided space available and infrastructure in place) |

*Cost indicates: $ inexpensive, $$ average, $$$ expensive.
Table 12-2 (continued)

<table>
<thead>
<tr>
<th>Scale of Decon</th>
<th>Type</th>
<th>Pros and Cons</th>
<th>Cost(^a)</th>
<th>Ease of Retrofitting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large</td>
<td>Fire hose</td>
<td>Cheap, easy to set up, generally effective for water soluble contaminants on ambulatory patients; Socially less desirable, ineffective for spot decontamination</td>
<td>$$$</td>
<td>Easy (requires access to fire hydrant if an existing hose is not available)</td>
</tr>
<tr>
<td>Large</td>
<td>Local high school, gym, or health club</td>
<td>Suitable for mass casualties, can be distributed widely throughout affected communities; Would likely require orders of government to enable</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

\(^a\)Estimated cost is relative. "\$" could be $500–$2000, "\$$" could be $5000–$10,000, and "\$$\>$40,000 (including supplies).

Decontamination during a disaster), the specific risks identified in a community risk hazard analysis, and a variety of other site-specific factors.

Many ED’s have rooms off their ambulance bays for showering patients who are unhygienic or for hosing down soiled equipment (see Figure 12-5). Note that a decon shower that must be accessed by walking through the hospital cannot be used by casualties contaminated with volatile chemicals, which will compromise the ambient air. Another solution is a collapsible shower system that can be stored in a duffle bag when not in use, but rapidly assembled for use when needed (see Figure 12-6). After assembly (10–15 minutes), a garden hose is run from a temperature-controlled faucet in the ED to

Figure 12-5: Individual decontamination shower off ambulance bay. Halifax Infirmary, QEII HSC.
the showerhead. The effluent can be collected in a plastic wading pool as required. These structures are appropriate when there are a relatively small number of stable casualties to decontaminate. Patient flow through one of these portable showers is shown in Figure 12-4.

When casualties are stable enough to wait for decontamination, they can generally be taken through the shower one at a time. A handheld shower nozzle can speed up the overall decon process for casualties who, for example, have only touched a contaminated object with their hands. This type of individualized approach works best when the contaminant is readily detectable (e.g., radioactive contamination).

As soon as the number of contaminated casualties increases, or if medical issues require a more rapid decon process, a single shower will not suffice. Some ED’s have multiple shower heads that can be used for the simultaneous decon of multiple contaminated casualties (see Figure 12-7). This capacity greatly expands the ability of the ED to decon larger number of patients without relying on assistance from outside agencies that may be preoccupied at the field site. Any such mass decon areas should be fitted with privacy barriers that can be installed quickly and easily so that casualties who are showering have some privacy from each other and from staff and patients outside the decon area. When privacy barriers are missing or will take too much time to set up, modesty becomes a secondary concern to the removal of a potentially toxic contaminant.

Another option is a commercially available decon tent. These are sometimes purchased for regional and provincial trauma centers and are used extensively by professional Hazmat teams and the military. Many hospitals are unprepared to make the up-front or long-term financial commitment to purchase their own mass decon capability and maintaining the skills of the staff involved, so they rely instead on their municipal fire service and its Hazmat team. For hospitals choosing this route, it is important to have memoranda of understanding (MOUs) ahead of time with the fire service outlining details around deploying
their decon capability: How does the hospital request it? What if it is being used on scene by the fire service? Where will it go? What are the infrastructure requirements (i.e., electricity, water, drainage, signage, security, and access for EMS)?

The Decontamination Team

EDs should consider organizing decontamination “Teams” consisting of staff of all types (MDs, RNs, paramedics, registration clerks, maintenance and housekeeping staff, and administrators) who are trained in the use of the PPE and to perform decon. During a disaster, the basic Decontamination Team includes the following:

- One person to control patients entering the decon process: patients can wait in chairs pending their decon; when it is their turn, they remove their clothing and belongings and put them in a bag that is labeled with the patients ID and marked as “contaminated;” then they enter the decon shower as it becomes available.

- One or more persons to perform the actual decon: patients may require assistance.

- One person to control patients leaving the decon process (to make sure that they do not recontaminate themselves); the person controlling which patient gets put in which room (i.e., the charge nurse) should be told that the patient has been decontaminated, so that they can begin the process of moving that patient into a room for their evaluation and management.

How to Decontaminate

For all types of contamination, decontamination begins with removing the patients clothing. This step alone typically removes ~70%–90% of the contaminant. Ambulatory patients can remove their own clothing, being careful not to further contaminate themselves in the process. Nonambulatory patients should have their clothing cut off. This is done with them lying supine on a flat stretcher or board. Cuts are made lengthwise down their front and along all 4 extremities. The clothing is then carefully rolled away from the cut edge so that loose contamination is contained inside the rolled-up clothing. The clothing is then put in a bag, labeled with the patients ID sticker, and another sticker to indicate that it is contaminated. Finally, the bag is taken outside the building and stored away from air currents that might draw toxic fumes back into the building.

There is no clear consensus on how long a patient should be showered. With radiation, it is a simple matter of resurveying the patients, then sending them back into the shower if there is any residual contamination. For chemical contamination, the OSHA report^{21} reviews some of the available studies and concludes that 5 minutes (1 minute rinsing the entire body, followed by 4–5 minutes of focused washing) should generally be adequate. Soap should be used in some cases, but in most it does not matter.
Specific recommendations for decontamination are included in the individual sections on specific CBRN issues.

### Patient Flow During Decontamination

Patient flow during decontamination follows the large red arrows shown in Figure 12-4. In each ED, there should be a flow chart or diagram to show how existing resources and spaces are integrated into the decontamination effort. Figure 12-8 shows the layout for the ED at the Halifax Infirmary for decontaminating arriving casualties.

Patients who are ambulatory are directed into the ambulatory decon showers. Once they have undressed and showered, they should be reassessed for contamination. If successfully decontaminated, they are allowed to enter the post-decon area where they dry off with towels and put on clean dry clothing. Then they are brought into clean areas of the ED as beds become available.

Nonambulatory patients are decontaminated on their stretcher using a spray wand. They should be put on a backboard while being decontaminated, because it is hard and can be decontaminated itself by logrolling the patient to either side.

The most challenging casualties are those that are unstable. A reasonable approach for contaminated patients who require limb- or life-saving procedures that cannot wait until they are fully decontaminated is to don the maximum available PPE, perform brief focused decontamination (e.g., remove the patients clothing and rinse contaminated skin with warm soapy water), then provide the required critical care interventions until the patient can be properly and

![Figure 12-8: Layout for decontamination (taken from Halifax Infirmary ED Disaster Plan).](image-url)
completely decontaminated. It is possible to perform key resuscitating maneuvers prior to decontamination and some authorities would endorse intubating patients while still contaminated. This requires trained and equipped staff.

**What To Do with Minimal Resources**

If the ED or Outpatient Department at your hospital does not have an enclosed area (like an attached ambulance bay) to set up the triage and decon sites, you will have to identify a nearby room or building that is not directly attached to the patient care site. An alternative is a tent or a parking garage. These are both problematic; they may not have accessible water, electricity, or drainage and will require heat in the winter.

**Cleanup of Contaminated Materials and Space**

The cleanup after a CBRN can generate massive amount of contaminated garbage and debris. Housekeeping and commercial industrial cleaners can assist with the cleanup after a chemical disaster. The waste can usually be incinerated. Radiation contamination is easier to remove (it is “visible” to Geiger counters and is not volatile) but impossible to ultimately destroy. The widespread cesium 137 contamination in Goiania, Brazil, in 1987 resulted in 275 truckloads of contaminated waste, which is stored on a special field to this day.

Personal effects (including clothes, purses and wallets, cell phones, laptops, and any other contaminated items) should be in individually labeled bags at the end of the response. Ultimately, they represent contaminated waste and must be disposed of by a certified contractor. However, prior to disposal, there are a number of potential steps that must be taken. First, these items could be required as part of the ongoing analysis of contaminants (both qualitatively and quantitatively). Second, they may be part of the forensic evidence for a terrorism investigation. Finally, it may be possible to obtain critical data from cell phones and laptops using a wireless router before they are destroyed.

Contamination is more likely to be contained when control lines are enforced and when patients have been cohorted. Contaminated areas should be identified and marked. Typically site decontamination is done with the usual cleaning agents (soaps) and water. In some cases where the contamination is ground into the floor or other permanent structure, it may be necessary to remove the structure (e.g., flooring or other surfaces) and replace them.

**Antidotes**

The health effects caused by many CBRN contaminants are managed symptomatically. However, there are some toxins for which there are antidotes that should be used to reduce the health effects. Antibiotics are used in treating and prophylaxing against infections caused by biological agents. These antidotes accomplish this following a variety of strategies, including the following:

- Reducing uptake of the toxin
- Competitively blocking the action of the toxin on its target
- Enhancing the metabolism or elimination of the toxin
- Converting the toxin to a less toxic compound
Specific antidotes are reviewed in each of the sections on chemical and radiologic/nuclear disasters.

**Supplies**

The usual supplies for mass casualty incidents should be available. In addition, supplies specific to CBRN disasters are typically stored on a separate cart that can be rolled out of storage when needed. These supplies include the following:

- Tools for detecting contaminants (sniffers and Geiger counters, if available)
- PPE (various levels, including all sizes)
- Decon supplies (shears for cutting off contaminated clothes, bags to put them in, labels for the bags, soap and shampoo, towels, and clean dry clothing)
- Bracelets for identifying patients’ contamination status (i.e., brown for contaminated and green for not contaminated or recontaminated. In some scenarios, it may be simpler to assume all patients are contaminated and not use brown bracelets, only green)
- Blank pre-numbered charts and ID bracelets (for use when the usual registration is not operational—see chapter 6 on Hospital Emergency Surge Capacity for details)
- Specialized clinical forms and templates for managing specific types of CBRN disasters (e.g., Radiation Casualty Assessment Tool)

**Safety Manager**

Many hospitals have an official Safety Manager and this position is part of the incident management system (see Chapter 4 on IMS and Communications for details). This person is usually responsible for maintaining the mass casualty and CBRN preparedness at the hospital. This person also sets up and operates the hospital emergency operations centre (HEOC) during an actual response. The Safety Manager usually knows what specialized hazardous materials spill kits and other equipment is available in the hospital and where it is kept.

**HEOC**

The HEOC in larger hospitals consists of all senior executives (and their EAs) representing physicians, nurses, other clinical staff, materials management, facilities, food services, and the other operational branches of the hospital. They have the authority (and the resources) to develop contingency plans and mobilize the required resources on short notice. The HEOC is an essential resource during any disaster, particularly a CBRN disaster for procuring assistance with crowd control, decontamination, and making inpatient beds available to admitted patients from the ED (see Chapter 4 on IMS and Communications for details).

**Resources**

Facility support varies with the size and role of the facility. Large teaching hospitals and regional centers have more resources and bigger budgets for
providing support for disaster preparedness as well as during an actual response. Smaller rural or community hospitals probably have a lot less. All the same, there are frequently more resources available within both the institution and the broader community at large than might at first appear.

**Poison Control**

They can offer advice on appropriate use of antidotes. Their contact number should be posted prominently in the ED.

**Other Hospitals**

Hospitals within a specific region can share resources and capabilities. For example, a portable decon unit shared by 2 or 3 small hospitals that can be transported to the required site on short notice. Other benefits can come from being strategic about which hospitals emphasize the various types of preparedness. For example, if 1 hospital in a city is located beside a refinery, the healthcare region should probably pick that ED as the site for an enhanced preparedness for a chemical disaster; there should be a supply of PAPRs and other chemical protective PPE at that site, which can also function as a training site for the other less well-equipped EDs in the city.

**Municipal Hazmat Teams**

Hazmat Teams are generally staffed by firefighters with specialized training and equipment. They have portable chemical sniffers, Geiger counters, and decon equipments that can help during a CBRN disaster. The “Catch 22” is that these same fire departments are usually unwilling to promise mutual aid during a CBRN disaster because that is just exactly when they are most likely to need those resources themselves while attending to their own priorities. It is important for hospital disaster planners to meet with fire departments ahead of time to discuss CBRN support: where their portable decon tent might be placed, what resources it would require (electricity? a water source? drainage?), and so on.

**Provincial Departments of Health**

Provincial departments of health often have stockpiles of disaster supplies (particularly following the preparations for the H1N1 pandemic in 2009). These may include not only basic medical supplies (dressings, syringes, sutures, etc.) but also items like transport ventilators that may be at a premium during some CBRN disasters (e.g., mass botulism poisoning).

**Federal Government**

- Health Canada
- Public Health Agency of Canada (PHAC)
  - Extensive and relevant links to a variety of CBRN resources
The Military

In some communities, Canadian Forces presence can be a significant resource. Military bases, including naval and air bases, are required to have (and to exercise) various Emergency Response Teams (ERT). Military hospitals and clinics also may have much larger supplies of antidotes, antibiotics, and decorporating agents than a hospital could ever hope to carry. Again, meeting with the chief medical officers before a CBRN disaster occurs can clarify what resources are available and the circumstances under which they might be shared.

Industry

Industry has a great interest in mitigating the effects of any accident involving the release of toxic agents into the community. Thus, they have safety committees and ERTs and should be highly motivated to team with the local EDs to mitigate the health effects on the community. They have a lot of knowledge to offer, may have stockpiles of relevant material, and should be approached in the planning stage to provide input into hospital CBRN disaster preparedness.

The Centre for Excellence in Emergency Preparedness

A general portal with extensive links and publications to assist with management of CBRN related issues; accessed at www.ceep.ca.

Software and Web-Based Resources

There are a number of software applications that can assist with solving problems related to specific CBRN disasters. These will be covered in the specific appendices dealing with each type of CBRN disaster later in this chapter. They should be loaded onto a terminal in the ED and made operational prior to a disaster and should also be backed up on some form of safe external storage (e.g., USB memory devices).

CDC

- Portal for a vast array of online information, videos, and “Just-in-Time” educational materials.
- http://www.bt.cdc.gov/

ATSDR (Agency for Toxic Substances and Disease Registry)

- Developed by the CDC.
- A series of extremely comprehensive reviews of specific toxins.

AHQR (Agency for Healthcare Quality and Research)

- Real-time online modeling to provide estimates of casualty numbers and hospital resources needed to treat casualties resulting from a variety of specific CBRN disasters.
- http://www.ahrq.gov/prep/hospsurgemodel/
EMCAPS\textsuperscript{27}

- Modeling software that predicts the number and severity of expected casualties with a trauma or CBRNE MCI based on estimated population density and size of explosion.
- Provides an initial estimate of the number and severity of expected casualties.
- \url{http://www.hopkins-cepar.org/EMCAPS/EMCAPS.html} (can be downloaded and installed on local storage device).

**Maintenance of Proficiency**

For EDs new to enhanced CBRN preparedness, the essential skills and equipment can be challenging to acquire and maintain. Knowledge about the basics of CBRN issues learned through courses and focused educational sessions degrades fairly quickly. Staff forget how to assemble portable equipment. Chemical resistant suits cannot just be folded up and left on a shelf for years on end; they will develop leaks in the fabric around creases, and rubber gaskets can dry and crack over time.

Members of the Triage and Decon Teams must practice regularly to maintain proficiency at donning and doffing the PPE and in performing triage and decon procedures. OSHA recommends that 2-hour training modules be given quarterly and that donning and doffing be practiced twice yearly.

**References**


32. Lavon O, Bentur Y. Does amyl nitrite have a role in the management of pre-hospital mass casualty cyanide poisoning? *Clin Toxicol*. 2010;48:477–484.


41. Carron PN and Yersin B. Management of the effects of exposure to tear gas. BMJ 2009;338:b2283


72. REACTS staff. Personal communication, September 21, 2009.


78. Marcus, Carol S. Administration of decorporation drugs to treat internal radionuclide contamination: medical emergency response to radiologic incidents. 2010. Unpublished work.

79. CRTI. METER course. 2009. Audiovisual material.

Appendix A – Chemical Disasters

Basics of Chemical Disasters
Chemicals are ubiquitous in our modern world. They are being produced, shipped, stored, processed and disposed of in vast quantities just about everywhere; thus, the potential for disasters (accidental or otherwise) is always just around the corner.

In a review of effective strategies for the medical response to a mass chemical exposure, Kirk and Deaton6 identify a series of “myths” that can erode the effectiveness of the response, and the realities that they reflect are as follows:

1. Medical personnel must often operate in the blind during the early stages of an event.
2. The offending chemical may not be identified for hours, or even days.
3. Emergency response personnel seldom have adequate tools or resources to effectively triage, decontaminate, and treat the large number of victims of a large-scale chemical exposure.
4. The first victims arriving at the hospital often arrive under their own power without direct involvement from emergency response personnel on the scene.
5. The public can behave in ways that significantly erode the effectiveness of the emergency medical response.

Although much of the literature deals with the potential for bioterrorism and mass chemical casualties, the same principles apply, for example, to managing a crew of field workers who have been mistakenly sprayed with pesticide by a crop duster, or any other accidental exposure to these agents.

Types of Chemicals
The principal types of chemical toxins are listed below. This list is by no means complete. There are other more novel and unique chemical toxins that are not discussed.29

Nerve Agents
Organophosphate (OPs), Carbamates
   - Pesticides (2,4-D and 2,4,5,-T)

Chemical Weapons
   - GA (Tabun), GB (Sarin), GD (Soman), GF, VX

OP pesticides are not only used extensively in agriculture, but also in suicide attempts; in one review, OP ingestion was identified as causing 175,000 suicides per year in China.30 There were 12 deaths and about 3,000 injuries as a result of the Sarin attack on the Tokyo subway in 1995.17,31 The characteristic smell...
of these liquids is actually due to the hydrocarbon solvent and not the OP itself. Although chemical weapons may seem like an unlikely contaminant to encounter, there are stockpiles of these weapons in most countries that are at risk of misappropriation and misuse.

These agents are almost all cholinesterase inhibitors, and thus produce a cholinergic toxidrome. The bond between the nerve agent and cholinesterase is initially amenable to reversal, but it “ages” over time, becoming irreversible. One mnemonic for remembering the symptoms of the cholinergic toxidrome is SLUDGEM (salivation, lacrimation, urination, defecation, gastrointestinal upset, emesis, and miosis). There are also copious bronchial secretions that can lead to respiratory distress. Finally, CNS symptoms can be significant, including confusion and seizures.

**Intracellular Toxins**

- Systemic asphyxiants
  - Carbon monoxide
- Methemoglobin-forming compounds
  - Nitrites (amyl nitrite, nitroglycerine)
- Cyanides and cyanogens
  - Hydrogen cyanide, acetonitrile
- Sulfides
  - Hydrogen sulfide
- Azides
  - Sodium azide
- Ricin

This group of agents affects oxygen transport (e.g., carbon monoxide and hydrogen sulfide), cellular metabolism (e.g., cyanide), or cellular function (e.g., ricin). Each has its own symptom profile and antidote. Carbon monoxide and concentrated hydrogen sulfide competitively inhibit hemoglobin from carrying oxygen, and thus lead to decreased level of consciousness, nonspecific flu-like symptoms, anaerobic metabolism, and eventually death. Both are treated with oxygen. Cyanide causes oxidative uncoupling and leads to similar symptoms. It does not respond to hyperbaric oxygen and requires sodium nitrite followed by sodium thiosulfate, or more recently hydroxocobalamin. Finally, ricin is produced from the mash remaining after extracting the oil from castor beans (thus is widely available). When administered in even minute doses (usually by aerosol), it inhibits protein synthesis leading to chest pain, cough, dyspnea, joint and muscle pain, abdominal pain, and vomiting and bloody diarrhea. There is no antidote and treatment is supportive.

**Blistering Agents**

Chemical weapons

- Nitrogen and Sulfur mustards
- Lewisite: an organic arsenical compound
- Phosgene oxime
These agents are only seen in the context of war. They extensively damage the skin, eyes, and respiratory tract. As such, they may also function as pulmonary irritants.

**Pulmonary Irritants**

This category includes many familiar industrial chemicals. They all act as mucosal and pulmonary irritants. Symptoms initially include eye irritation, sore throat, coryza, and cough. These symptoms can progress to pulmonary edema, hypoxia, and hypotension. Most fatalities are within the first 24 hours and due to respiratory failure. There are no antidotes and treatment is supportive.

- **Chlorine gas**
  - Chlorine has been released from a variety of sources, including rail tanker cars and swimming pools.
  - Also a significant irritant to the skin and eye
- **Vinyl chloride**
- **Phosgene**
  - Both chlorine and phosgene enter the lungs and then release hydrochloric acid on reaction with water. Both can produce capillary leak with pulmonary edema.
- **Methyl isocyanate (MIC)**
  - Used to produce a variety of chemicals and was the gas released in the Bhopal disaster of 1984.
- **Anhydrous ammonia**
  - Has been released in a number of separate accidents involving road and rail transportation.
- **Arsine**

**Riot Control Agents**

These agents are designed to briefly incapacitate someone by irritating the eyes, nose, mouth, and throat. They generally do not cause systemic symptoms, although they can lead to acute exacerbations of underlying cardiopulmonary problems. The primary treatment is to make sure that the casualty is decontaminated.

**Sedatives**

In 2002, a hostage taking in a Moscow suburb resulted in a 4-day standoff that ended with security forces gassing of approximately 900 hostages and captors with an unknown agent that was felt to be Fentanyl. Approximately 168 people were killed, many from the effects of the incapacitating agent. Other sedatives (including benzodiazepines) could also cause mass poisoning. Clearly, the key to managing these cases lies in recognizing a toxidrome, if present, using available antidotes (e.g., naloxone or flumazenil) and providing good supportive care.

**Petroleum Products**

Chemical exposure to petroleum products can vary from individuals soaked with gasoline, diesel, or jet fuel (98% kerosene) to explosions at refineries.
that refineries use many other industrial chemicals, including hydrofluoric acid, hydrogen sulfide, heavy metals, and PCBs. Petroleum products are typically highly volatile; bringing a contaminated casualty into an ED can quickly shut the ED down due to the strong unpleasant odor and resulting in mucosal irritation. Additives to the petroleum product can also cause heavy metal and other types of toxicity. Decontamination may benefit from cleaning solutions containing dioctyl sulfosuccinate, chlorhexidine gluconate, or polyethylene glycol, but in the absence of these agents, warm water and soap can be used.

Types of Accidents

1. Isolated cases
   - Casualties may become contaminated with petroleum products at service stations and other sites
   - Ingestion of OP pesticides; suicide by intentional ingestion of OP pesticides is relatively rare in North America, but is common in other parts of the world. In China, there are an estimated 175,000 deaths each year from the intentional ingestion of pesticides.

2. Industrial accidents
   - Refinery accident: hydrocarbons and other volatile organic compounds
   - Other industrial chemicals: hydrogen cyanide, hydrofluoric acid, and other organic acids and bases

3. Transportation accidents
   - Train car derailment: hydrochloric acid, ammonium, chlorine, and others
   - Aircraft crash: jet fuel
   - Tanker truck: hydrocarbons

4. Agricultural accidents
   - Poisoning with herbicides and pesticides (e.g., aerial crop dusting accidents, storage building fires, and explosions)

5. Chemical weapons
   - Nerve agent: Tabun (GA), Sarin (GB), VX
   - Asphyxiant: Hydrogen cyanide, Arsine
   - Choking agent: Chlorine, Hydrogen chloride, Phosgene
   - Blistering agent/vesicant: Mustard gas, Nitrogen mustard, Lewisite
   - Incapacitating/mind altering: Agent 15/BZ
   - Sedation: Fentanyl

Identification of Chemical Agents

Chemical identification can be based on known facts from the site (e.g., knowledge about disaster site, first person report, or identifying placards or manifests), by its physical properties (state, smell, etc.), or by its clinical effects (e.g., effect on organ systems or identifiable toxidrome).
Some agents have characteristic smells, which when coupled with the clinical effects of that agent can help to identify the agent (see Table 12-3). Note that caregivers will be unable to smell anything if they are wearing a PAPR, SCBA, or other source of air other than ambient air.

Table 12-3: Identification of Chemical Contaminant Based on Smell

<table>
<thead>
<tr>
<th>Smell</th>
<th>Agent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camphor (i.e., Vicks Vaporub)</td>
<td>Soman (nerve agent GB)</td>
</tr>
<tr>
<td>Garlic, onions, or mustard</td>
<td>mustard gas, phosphorus</td>
</tr>
<tr>
<td>Geraniums</td>
<td>Lewisite</td>
</tr>
<tr>
<td>Fresh mown hay</td>
<td>Phosgene</td>
</tr>
<tr>
<td>Bitter almonds</td>
<td>cyanides</td>
</tr>
<tr>
<td>Mild garlic or slightly fishy</td>
<td>Arsine (at high concentration)</td>
</tr>
<tr>
<td>Bleach</td>
<td>ammonia, bromine</td>
</tr>
<tr>
<td>Swimming pool</td>
<td>chlorine</td>
</tr>
<tr>
<td>Sour</td>
<td>hydrogen sulfide (only at low concentrations)</td>
</tr>
<tr>
<td>Fruity, floral, or sweet</td>
<td>methyl bromide, CN (riot control agent)</td>
</tr>
<tr>
<td>Pepper</td>
<td>CS (riot control agent)</td>
</tr>
</tbody>
</table>

The clinical effects of various chemical agents are described in Table 12-4.44

Table 12-4: Clinical Effects of Various Chemical Agents

<table>
<thead>
<tr>
<th>Category</th>
<th>Clinical Syndrome</th>
<th>Potential Chemical Etiology*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cholinergic crisis</td>
<td>• Salivation, diarrhea, lacrimation, bronchorrhea, diaphoresis, and/or urination</td>
<td>• Nicotine*</td>
</tr>
<tr>
<td></td>
<td>• Miosis, fasciculations, weakness, bradycardia or tachycardia, hypotension or hypertension, altered mental status, and/or seizures</td>
<td>• Organophosphate insecticides—a decreased acetylcholinesterase activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Carbamate insecticides</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Medicinal carbamates (e.g., phsysostigmine)</td>
</tr>
</tbody>
</table>
### Table 12-4 (continued)

<table>
<thead>
<tr>
<th>Category</th>
<th>Clinical Syndrome</th>
<th>Potential Chemical Etiology*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generalized muscle rigidity</td>
<td>Seizure-like, generalized muscle contractions or painful spasms (neck and limbs) and usually tachycardia and hypertension</td>
<td>Strychnine—intact sensorium</td>
</tr>
<tr>
<td>Airway and Breathing</td>
<td>Lip, mouth, and pharyngeal ulcerations and burning pain</td>
<td>Paraquat(^a)—dyspnea and hemoptyis secondary to pulmonary edema or hemorrhage; can progress to pulmonary fibrosis over days to weeks</td>
</tr>
<tr>
<td></td>
<td>Mucous membrane irritation</td>
<td>• Chlorine and other irritant gases</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Caustics (i.e., acids and alkalis)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Inorganic mercuric salts</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Mustards (e.g., sulfur)</td>
</tr>
<tr>
<td>Cellular hypoxia</td>
<td>Mild: nausea, vomiting, and headache</td>
<td>Cyanide(^a) (e.g., hydrogen cyanide gas or sodium cyanide)—bitter almond odor(^b)</td>
</tr>
<tr>
<td></td>
<td>Severe: altered mental status, dyspnea, hypotension, seizures, and metabolic acidosis</td>
<td>• Sodium monofluoroacetate (SMFA)(^a)—hypocalcemia or hypokalemia</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Carbon monoxide</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Hydrogen sulfide</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Sodium azide</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Methemoglobin-causing agents</td>
</tr>
<tr>
<td>Peripheral neuropathy and/or neurocognitive effects</td>
<td>Peripheral neuropathy signs and symptoms: muscle weakness and atrophy, “glove and stocking” sensory loss, and depressed or absent deep tendon reflexes</td>
<td>Mercury (organic)(^a)—visual disturbances, paresthesias, and/or ataxia</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Arsenic (inorganic)(^a)—delirium and/or peripheral neuropathy</td>
</tr>
</tbody>
</table>
PPE for Chemical Contamination

Deciding what constitutes “appropriate” PPE depends on several factors such as the chemical agent and the concentration. Because, frequently, neither are known when the first casualty arrives, staff exposed to contaminated casualties should wear the highest available level of PPE. OSHA has defined a “minimum” level of PPE that hospitals could use to effectively protect first receivers assisting victims contaminated with unknown substances as equivalent to Level C21 (see the section on Personal Protection Equipment discussed earlier).

Off-gassing from clothing and direct chemical contact are the primary threats to healthcare workers. Okumura et al.45 reviewed the PPE requirements in MCI’s with chemical contamination. In 2000, 3 ED staff in Georgia developed severe cholinergic symptoms after inhaling fumes from the emesis of a patient who had intentionally consumed 110 g of pesticide concentrate.46,47 Only 1 of the 3 ED staff actually touched the contaminant, the other 2 were poisoned by off-gassing. In another case in the United Kingdom, a total of 25 healthcare workers (including MDs, RNs, paramedics, and clerical staff) were affected during a similar case of intentional poisoning with a pesticide48; only 10 ED staff became symptomatic and no antidote was required for any. In each case, the original patient and all the secondarily contaminated healthcare workers survived. Little and Murray49 reviewed the published cases of secondary OP poisoning of ED staff and concluded that the risk of adverse health effects is minimal. They suggested

---

Table 12-4 (continued)

<table>
<thead>
<tr>
<th>Category</th>
<th>Clinical Syndrome</th>
<th>Potential Chemical Etiology*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severe gastrointestinal illness,</td>
<td>• Abdominal pain, vomiting, profuse diarrhea (possibly bloody), and hypotension,</td>
<td>• Arsenic\a</td>
</tr>
<tr>
<td>dehydration</td>
<td>possibly followed by multisystem organ failure</td>
<td>• Ricin\a—inhalation an additional route of exposure; severe</td>
</tr>
<tr>
<td></td>
<td></td>
<td>respiratory illness possible</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Colchicine</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Barium—hypokalemia common</td>
</tr>
</tbody>
</table>

*Not intended as a complete differential diagnosis for each syndrome or a list of all chemicals that might be used in a covert chemical release.

\aPotential agents for a covert chemical release based on historic use (i.e., intentional or inadvertent use), high toxicity, and/or ease of availability.

\bUnreliable sign.
the following basic principles to reduce the risk of healthcare workers becoming secondarily contaminated:

- Resuscitation and further treatment should ideally take place in a well-ventilated area with the regular rotation of staff.
- All staff with direct patient contact should observe universal precautions—gloves, gowns, eye protection.
- Patients should undergo external decontamination as soon as practicable; clothes removed and bagged and body washed with soap and water. This process should not take place to the detriment of timely resuscitation and medical assessment.
- Staff inadvertently coming into direct contact with patient’s bodily secretions should immediately and thoroughly wash the affected area.

As with all types of decontamination, undressing the victim will generally remove approximately 90% of the chemical agent. In general, the more symptomatic the patient from the agent, the greater the risk to responding personnel; most patients will be only minimally contaminated or affected. Decontamination, aside from clothing removal, is not necessary for exposure to a vapor (as opposed to liquid on skin) except with nerve agents. In most mass exposure situations, soap and water decontamination is sufficient. Transporting stable patients to a predesignated nonclinical site, such as a local high school or health club, may be the easiest way to decontaminate large number of victims.

Preparing the ED for Chemical Casualties

Preparations follow the general description (see “Preparing the ED for Contaminated Casualties” discussed earlier). It is unlikely that there would be casualties safe enough to bring in to a Contaminated Treatment Area while still contaminated, given the risk of adverse health effects on staff, patients, and regular ED operations. However, under some circumstances, it may be safe to perform a brief focused decontamination (i.e., remove the patients clothing and rinse contaminated skin with warm soapy water), then provide the required critical care interventions either in the Warm Zone or inside the ED in a Contaminated Treatment Area, until the patient can be properly decontaminated.

If blowers are available to push air out of the ambulance bay to the outside, they should be turned on.

Decontamination

Decontamination of chemical agents is generally rinsing with copious amount of water. Note that scrubbing the skin can lead to an increase in percutaneous absorption, an effect referred to as the “wash-in” effect. There are a few contaminants for which special decontaminating solutions (such as dilute chlorine bleach), lotions, or “dry decontamination” (using special powders like “Fullers Earth”) have been recommended. There are even some contaminants (like elemental sodium) that react violently with water. In all but the most remarkable situations, however, the appropriate solution for decontamination is to use water, and lots of it. Soap may be helpful when the contaminant is oil based. The most effective soaps are those with the greatest surfactant activity, such as dish detergent. Shampoo can also be used, but conditioner should be avoided because it can aggregate heavy metals and prevent them from rinsing off during decontamination.
What To Do with Minimal Resources
It is a fairly recent phenomenon for EDs to equip themselves with specialized decontamination showers and Level C PPE. The hospital in Canso, Nova Scotia, had none of these resources when they received their 4 airmen soaked in jet fuel. The staff found that N95 masks provided some benefit to the strong fumes. They cut off the casualties clothing and put them outside the ED in plastic bags. They were able to provide the necessary medical care and to decontaminate their patients prior to sending them on to other hospitals. Some of the paramedics reported headaches from the strong fumes inside the ambulance, but there were no reported adverse health effects amongst the hospital staff.2

The basic steps that any ED can take include the following:
1. All staff should wear Level D PPE (gowns, gloves, booties, and a facemask (N95) may provide some benefit over regular surgical masks).
2. Undress the patients before bringing them into the ED, leaving bagged clothes outside.
3. Decontamination can be done with soap and warm water within or outside the ED. The effluent (along with contaminated clothing and garbage) can be stored in containers outside the ED.

Cleanup of Contaminated Materials and Space
Volatile chemicals will become less concentrated over time, and with doors and windows open and fans installed, many contaminants can be cleaned up with warm water and detergents using Level D PPE. Commercial cleaners can be hired to assist with more complicated site recovery. All of these resources (fans and commercial cleaners) can be accessed through the HEOC. Some equipment (e.g., mattresses on ED beds) may have to be replaced.

Antidotes
General references on the management of chemical toxicities are included.8,51,52 Minimum stockpiles can be defined in a variety of ways, but variously require adequate amount of the most time-sensitive antidotes (Atropine, 2-PAM, and cyanide kits) on hand to manage 5–50 severely poisoned patients.53,54 Most ED’s do not have adequate stockpiles.11,12 Some communities may chose to share antidote stockpiles between different hospitals that are geographically close together.

Nerve Agents
For general reviews, see Rodgers 201051,52 and Lawrence 2000.42

- Atropine
  - Blocks acetylcholine receptor sites
  - Alleviates muscarinic (parasympathetic) effects (salivation, lacrimation, urination, defecation, gastrointestinal upset, emesis, and miosis)
  - Mark 1 autoinjectors contain Atropine (2 mgs in 0.7 mL) and 2-PAM (600 mg in 2 mL)
  - Initial dose: 2 mg for adults (pediatric dose 0.02 mg/kg) IM/IV q5mins prn severe poisoning
Recommended stockpile for most hospitals: 45–165 mg\textsuperscript{28,54,55}

Pralidoxime

- Interacts with and breaks the nerve agent–enzyme bond; can reverse effect of nerve agent if given soon enough
- Alleviates nicotinic symptoms (tachycardia, weakness)
- Give ASAP with any systemic effects

Initial dose: 1 to 2 g diluted in 100 mL normal saline (pediatric dose is 20 to 50 mg/kg up to 2 g) given over 15 to 30 minutes

Recommended stockpile for most hospitals: 2–18 g\textsuperscript{28,54,55}

Benzodiazepines

- For preventing and treating seizures related to CNS effects of cholinesterase inhibition

### Intracellular Toxins

#### Cyanide

- Sodium Nitrite
  - Generates methemoglobin, which competitively binds cyanide; rapid onset
  - Dose: 10 mL of 3% solution (300 mg) IV over 2 to 4 minutes (pediatric dose 6–10 mg/kg)

- Sodium Thiosulfate
  - Increases the rate of endogenous metabolism; slow onset
  - Dose: 50 mL of 25% solution IV over 10 minutes (provides 12.5 g of sodium thiosulfate; pediatric dose 1.65 mL/kg of the 25% solution)

Recommended stockpile for most hospitals: 12.5 g

- Hydroxycobalamin
  - Chelates cyanide; can be used in prehospital setting
  - Given as 5 g infusion IV (pediatric dose 70 mg/kg, up to 5 g)

### Blistering Agents

#### Nitrogen and Sulfur Mustard

- For skin effects: consider Thiosulfate, \textit{N}-acetyl-l-cysteine, Amifostine
- For eye effects: topical NSAIDs (e.g., Voltaren eye gtts 1 gtt ou qid)
- For respiratory effects: consider steroids and antibiotics, to reduce long-term sequelae
Lewisite

- BAL (British anti-Lewisite: dimercaprol or 2,3-dimercaptopropanol)

Pulmonary Irritants
Humidified oxygen and bronchodilators; positive pressure ventilation as needed; ibuprofen and N-acetyl-l-cysteine may be useful with Phosgene toxicity.

Resources
Software and Web-Based Resources

**WISER**
- Downloadable searchable database of 400 + toxic chemicals using key characteristics for identifying unknown chemicals and treating known chemical exposures; provides a wide range of information on identification and clinical management of different chemicals.
- Produced by the National Library of Medicine.

**MSDS (Materials Safety Data Sheets)**
- MSDS for toxic chemicals used in the hospital (including laboratory supplies and cleaning agents) are required to be kept in binders at strategic locations.
- These are the basic source of technical information on all chemical products.
- Available without charge online from chemical producers.

**WHMIS (The Workplace Hazardous Materials Information System)**
- Canada’s national workplace hazard communication standard.

**ATSDR (Agency for Toxic Substances and Disease Registry)**
- Developed by the CDC.
- [http://www.atsdr.cdc.gov/csem/csem.html](http://www.atsdr.cdc.gov/csem/csem.html) has extensive case studies on selected heavy metals and other toxins.

Courses

- Advanced Hazmat Life Support
  - an excellent course focused on clinical toxicology
Appendix B – Biological Disasters

Basics of Biological Disasters
In the dusty hills looking down on the Columbia River, a religious cult led by Bhagwan Sri Rajneesh established the community of Rajneeshpuram in 1981 near the Oregon community of The Dalles and began to look out at the surrounding county. The cult was interested in gaining political influence and decided that the quickest way to achieve that would be if local voters (most of whom did not support the cult’s chosen candidates) were all sick on election day. Thus began an event that started with the purchase of cultures of Salmonella typhimurium from a biological supply house and ended with the intentional infection of 751 people with Salmonella gastroenteritis over a 3 week period in 1984. This incident was not recognized as bioterrorism for more than one year afterwards. In another incident, US Postal workers were targeted with anthrax spores during 2001, resulting in 5 deaths.

First receivers are unlikely to receive warning that arriving casualties are the victims of bioterrorism or laboratory accident. They will have to recognize the cluster of similar cases or benefit from some other type of syndromic surveillance that herald the onset of a biological disaster. There is evidence that we are not very good at this. Surveillance by the pharmacy may detect the increased use of specific antibiotics. Once a bioterrorism event is suspected, the laboratory must be capable of testing for anthrax, plague, smallpox, brucellosis, botulism, tularemia, SARS, viral hemorrhagic fever, as well as unknown agents. The pharmacy must have an adequate stockpile of antibiotics, antivirals, and antidiarrheals.

As with other types of CBRN disasters, a large biological disaster would generate a huge surge of psychological casualties who would threaten the function of the ED. There are strategies, however, that can reduce the large number of people in the community who have not been exposed from flooding local medical facilities in search of reassurance or unnecessary treatment. These include providing clear information about who should and should not attend hospital; using telephone services to provide more detailed information and initial screening; employing rapid triage at hospital entrances based, where possible, on exposure history and objective signs of illness; and following up by telephone those judged to be at low risk.

There are a number of excellent reviews of bioterrorism and preparedness. Epidemics and pandemics (e.g., SARS and H1N1) that arrive with some advance notice and whose cases are spread over a prolonged time present a different type of challenge to the ED and are covered elsewhere.

Biological Agents
The various biological agents can be divided into different categories based on their potential severity from a public health perspective. These categories and the agents that make them up are summarized in Table 12-5.
<table>
<thead>
<tr>
<th>Category</th>
<th>Characteristics</th>
<th>Agents</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A</strong></td>
<td>Highest priority agents:</td>
<td>• Anthrax (<em>Bacillus anthracis</em>)&lt;br&gt;• Botulism (<em>Clostridium botulinum</em> toxin)&lt;br&gt;• Plague (<em>Yersinia pestis</em>)&lt;br&gt;• Smallpox (variola major)&lt;br&gt;• Tularemia (<em>Francisella tularensis</em>)&lt;br&gt;• Viral hemorrhagic fevers (filoviruses [e.g., <em>Ebola</em>, <em>Marburg</em>] and arenaviruses [e.g., <em>Lassa</em>, <em>Machupo</em>])</td>
</tr>
<tr>
<td></td>
<td>• easily disseminated or transmitted from person to person&lt;br&gt;• result in high mortality rates and have the potential for major public health impact&lt;br&gt;• might cause public panic and social disruption&lt;br&gt;• require special action for public health preparedness</td>
<td></td>
</tr>
<tr>
<td><strong>B</strong></td>
<td>Second highest priority agents:</td>
<td>• Brucellosis (<em>Brucella</em> species)&lt;br&gt;• Epsilon toxin of <em>Clostridium perfringens</em>&lt;br&gt;• Food safety threats (e.g., <em>Salmonella</em> species, <em>Escherichia coli</em> O157:H7, <em>Shigella</em>)&lt;br&gt;• Glanders (<em>Burkholderia mallei</em>)&lt;br&gt;• Melioidosis (<em>Burkholderia pseudomallei</em>)&lt;br&gt;• Psittacosis (<em>Chlamydia psittaci</em>)&lt;br&gt;• Q fever (<em>Coxiella burnetii</em>)&lt;br&gt;• Staphylococcal enterotoxin B&lt;br&gt;• Typhus fever (<em>Rickettsia prowazekii</em>)&lt;br&gt;• Viral encephalitis (alphaviruses [e.g., <em>Venezuelan equine encephalitis</em>, eastern equine encephalitis, western equine encephalitis])&lt;br&gt;• Water safety threats (e.g., <em>Vibrio cholerae</em>, <em>Cryptosporidium parvum</em>)</td>
</tr>
<tr>
<td></td>
<td>• moderately easy to disseminate&lt;br&gt;• result in moderate morbidity rates and low mortality rates&lt;br&gt;• require specific enhancements of CDC’s diagnostic capacity and enhanced disease surveillance</td>
<td></td>
</tr>
</tbody>
</table>
Appendix B

Identifying a Biological Agent

An excellent algorithm for identifying probable pathogens in a bioterrorism event based on the presenting clinical syndrome has been published elsewhere\textsuperscript{66} and is summarized in Table 12-6.

### Table 12-6: Identification of Possible Pathogens Based on Presenting Syndrome

<table>
<thead>
<tr>
<th>Syndrome</th>
<th>Pathogen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gastrointestinal illness</td>
<td>Salmonella</td>
</tr>
<tr>
<td>Febrile respiratory illness</td>
<td>Pneumococcal pneumonia</td>
</tr>
<tr>
<td></td>
<td>Pneumonic plague</td>
</tr>
<tr>
<td></td>
<td>Tularemia</td>
</tr>
<tr>
<td></td>
<td>Brucellosis</td>
</tr>
<tr>
<td></td>
<td>Q-fever</td>
</tr>
<tr>
<td></td>
<td>Inhalational anthrax</td>
</tr>
<tr>
<td>Neurological symptoms</td>
<td>Venezuelan encephalitis</td>
</tr>
<tr>
<td></td>
<td>Botulism</td>
</tr>
<tr>
<td>Skin changes</td>
<td>Smallpox</td>
</tr>
<tr>
<td></td>
<td>Hemorrhagic fevers</td>
</tr>
<tr>
<td></td>
<td>Cutaneous anthrax</td>
</tr>
<tr>
<td></td>
<td>Bubonic plague</td>
</tr>
</tbody>
</table>

Abbreviation: CDC, Centers for Disease Control and Prevention.
PPE for Chemical Contamination

Biological agents are ubiquitous in the ED. ED staff are already familiar with the different levels of protection, which are summarized in Table 12-7. A key requirement (one that was addressed as a result of the H1N1 pandemic) is for an adequate supply of N95 masks and staff who have been fit tested. In addition, basic measures like frequent hand washing and not eating in patient care areas of the ED are common sense, but essential.

Table 12-7: Levels of PPE for Different Biological Hazards

<table>
<thead>
<tr>
<th>PPE Level</th>
<th>Method of Transmission</th>
<th>Precautions Required to Prevent Transmission</th>
</tr>
</thead>
</table>
| Standard  | Basic level of risk from direct or indirect contact with a patient with an unknown level of contamination | • Hand washing pre and postcontact  
• Using gloves when coming into contact with any secretions, blood, or other body fluids |
| Contact   | Transmission can be direct (e.g., body-to-body contact with patient) or indirect (e.g., touching a contaminated object, such as dressing or bedrail) | • All standard precautions  
• Gloves should always be used  
• Gowns should be worn if:  
  - body-to-body contact, or  
  - patient has diarrhea, an ostomy, or excessive drainage from a wound |
| Droplet   | Produced when patient talks, coughs, or sneezes. Droplets do NOT remain suspended in air; risk of transmission is high with procedures like succioning, PPV, aerosols, and bronchoscopy | • All contact precautions  
• Put mask on patient if sneezing or coughing  
• Place patient in private room (if not possible, then keep 2 m from other patients or place curtain around patient)  
• Minimize patient transport, make sure patient has mask on when being transported  
• H1N1 |
Preparing the ED for Biological Casualties

The planned layout of the ED at the Halifax Infirmary is shown in Figure 12-9 (taken from the ED Disaster Plan).

Negative Pressure Rooms

Health Canada recommends that every ED in Canada have at least 1 negative pressure room, with a recommended minimum of 9 air changes per hour and with air exhausted outside the building. Of interest, testing of negative pressure rooms often reveals less negative pressure than was believed. Also note that some rooms (e.g., trauma rooms) are deliberately kept under positive pressure.

ED layout: Biological Disaster

Table 12-7 (continued)

<table>
<thead>
<tr>
<th>PPE Level</th>
<th>Method of Transmission</th>
<th>Precautions Required to Prevent Transmission</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airborne</td>
<td>Airborne microorganisms or contaminated dust particles that remain suspended in air for long period of time</td>
<td></td>
</tr>
<tr>
<td>Examples:</td>
<td>- Tuberculosis, SARS</td>
<td>- All droplet precautions</td>
</tr>
<tr>
<td></td>
<td>- Smallpox, viral hemorrhagic fever</td>
<td>- Place patients in negative pressure rooms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Use of N95 masks at all times in patient care room</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Use PAPR if available</td>
</tr>
</tbody>
</table>

Abbreviation: PPE, personal protective equipment; MRSA, methicillin-resistant Staphylococcus aureus; PAPR, powered air purifying respirator.

Figure 12-9: ED setup for a biological disaster.
pressure to reduce the risk of exposing open wounds to airborne pathogens and
would be very efficient at distributing airborne pathogens throughout the rest of
the ED.

Many EDs and smaller Outpatient Departments do not have any negative
pressure rooms. The reality in these institutions is that casualties will have to be
managed in regular rooms. Fans can be used to attempt to direct air through the
ED in a predictable manner, although these can distribute airborne hazards in
less helpful ways.

Cohorting Patients

Most guidelines recommend that patients suspected of infection during an
epidemic, pandemic, or bioterrorism event be cohorted inside the ED. The
cohorted area can be any series of adjacent rooms that have been identified
and labeled as being contaminated. This strategy was used during the H1N1
pandemic at the Halifax Infirmary to facilitate patient management and speed
up turnover of rooms between patients; when a series of patients are all infected
with the same pathogen, the room does not necessarily need to be completely
cleaned between patients. Also, the medical staff may be more likely to follow
protocols consistently when they are seeing consecutive patients with the same
infection-control requirements.

Consideration should be given to the site of a morgue for bodies that are a
risk for further transmission of the disease.

Decontamination

Decontamination of casualties or patients is generally not necessary with
biological agents. The only patients who require decontamination are those
who have been sprayed or come into physical contact with the infectious
agent. They would not be symptomatic with the infection at that point, but
could have traumatic injuries in the case of an improvised explosive device (IED)
with an associated biological contaminant. Undressing the victim will remove
approximately 90% of the biological agent. Decontamination, aside from
clothing removal, should be done with soap and water. If the patient is unstable
and there is no time to further decontaminate them, they should be unclothed
and have a clean sheet placed over them before being brought into the ED.

Managing a “White Powder” Incident

The following steps are for managing incidents in which an envelope containing
suspicious powder is found in the ED and is felt to represent a potential threat
(modified from the CDC Guidelines):58

- Do not shake or empty the contents of a suspicious package or
  envelope.
- Do not carry the package or envelope, show it to others, or allow others
to examine it.
- Put the package or envelope on a stable surface; do not sniff, touch, taste,
or look closely at it or any contents that may have spilled.
- If possible, cover the powder with a concave object (bowl or hat), being
careful not to touch or spread powder in the process.
■ Alert others in the area about the suspicious package or envelope. Leave the area, close any doors, and take actions to prevent others from entering the area. If possible, shut off the ventilation system.

■ Wash hands with soap and water to prevent spreading potentially infectious material to face or skin. Seek additional instructions for exposed or potentially exposed persons.

■ If at work, notify a supervisor, a security officer, or a law enforcement official. If at home, contact the local law enforcement agency.

■ If possible, create a list of persons who were in the room or area when this suspicious letter or package was recognized and a list of persons who also may have handled this package or letter. Give the list to both the local public health authorities and law enforcement officials.

Cleanup of Contaminated Materials and Spaces
Cleanup of rooms between consecutive cohorted patients does not require a complete decontamination; linens should be changed and any personal effects (e.g., used Kleenex, water cups, and medical supplies) discarded. However, if a room is being used for patients unrelated to the biological disaster after having been used for infectious patients, then it will require a complete cleaning (bed, chairs, medical equipment, surfaces, floors, and in the case of droplet and aerosol transmission, curtains as well).

Antibiotics and Other Treatments
Other than the PPE, there are no special supplies for a biological disaster. Additional antibiotics may be requested from the pharmacy. Antibiotics that should be stockpiled for bioterrorism events include Doxycycline, Tetracycline, Ciprofloxacin, Levofloxacin, Oseltamivir, Zanamivir, and Penicillin. For further information on this issue, refer to the chapter on Readiness Assessment/CBRNE.

Resources
Laboratory
Laboratory testing (including serology and cultures) is essential to arriving at a diagnosis. The laboratory should work together with the ED, the consulting Infectious Disease service, and Public Health to identify and screen for the pathogen.

Infection Control
For any disaster involving a biohazard, call Locating and have them page the Infection Control nurse on call.

Public Health
Public Health provides essential guidance to the ED on the epidemiology and expected course of the disaster. They also follow up with recommendations regarding prophylaxis for ED staff and arranging immunization programs, essential components of both the medium- and long-term response. The contact number for Public Health should be posted in the ED.
Provincial Department of Health
The provincial departments of health usually have stockpiles of specific antibiotics for managing events like outbreaks and bioterrorism. They could be accessed through the HEOC or through Public Health.

Software and Web-Based Resources
CDC Bioterrorism site
- http://www.bt.cdc.gov/bioterrorism/
- http://www.bt.cdc.gov/agent/agentlist-category.asp#a

PHAC
Basics of Radiation Disasters

Healthcare workers are usually the most anxious about radiation. They perceive a significant threat from a contaminant that they cannot see, smell, or feel, but one that they know can cause acute injuries, cancer, and death. Yet, if one looks at Chernobyl (presumably a worst-case scenario), there were no documented attributable health effects to any of the frontline ED staff who cared for the contaminated casualties.\textsuperscript{70,71} Nor do there appear to have been any other documented cases of significant exposure to healthcare workers in any of the other accidents involving radiation around the world,\textsuperscript{41} including the mass contamination in Goiania, Brazil, in 1987.\textsuperscript{25,72}

Radiation comes from energized isotopes of the same elements that are used as building blocks of the compounds that make up all matter. An isotope is a nuclide of an element having the same number of protons but a different number of neutrons. These isotopes give off high energy particles (\(\alpha\) [alpha] and \(\beta\) [beta] particles or neutrons) or waves (\(\gamma\) [gamma] or x-rays) that can damage or kill cells. The isotopes behave biochemically exactly the same as their stable cousins. For example, H\textsuperscript{3} (tritium) forms tritiated (heavy) water that follows the exact same metabolic pathways and distribution as regular water molecules. Thyroid receptors cannot distinguish iodine\textsuperscript{131} (released following nuclear explosions and reactor core breaches) from stable iodine and it is rapidly absorbed by the thyroid gland. The half-lives of different isotopes (the time it takes for half of the quantity of radioisotope to decay) vary from 6 hours for technetium (Tn\textsuperscript{99m}, used in nuclear medicine) to \(7.1 \times 10^8\) years for uranium (U\textsuperscript{235}, used in reactors and nuclear weapons).

The health effects of radiation include several distinct syndromes. Acute Radiation Syndrome (ARS) refers to the acute effects of whole-body exposure to radiation. The types of cells that are most sensitive to radiation include those that are most rapidly dividing and the most undifferentiated: bone marrow, lymphocytes, mucosal, and reproductive cells. Thus, the initial symptoms include GI effects (nausea, vomiting, and diarrhea), and the earliest laboratory changes include a drop in the Absolute Lymphocyte Count (ALC). If the radiation exposure is primarily to a defined area of skin, the effect may be a local radiation injury (erythema, hair loss, and eventual necrosis) without ARS. This is referred to as the Cutaneous Syndrome.

Radioactive contamination does not travel through the ED by diffusion and on air currents in the way that strong chemical odors and airborne biological agents are carried. The only theoretical risk to ED staff is if the patient has a point source of radiation on them (e.g., on their clothing) or in them (e.g., ingestion or radioactive shrapnel). These sources are easily identified with a Geiger counter and removed before the source has a chance to expose first receivers to any significant amount of radiation. Thus, there is no good reason to deny the radiation-contaminated patient who requires life-saving interventions a place inside the ED, provided that their treatment area is kept within control lines that are scrupulously enforced and the staff are wearing appropriate PPE.\textsuperscript{72}
Exposure versus Contamination

A key concept in managing disasters involving radioactive material is to understand the difference between exposure and contamination.

The term “exposure” refers to patients who have been close to a source of radiation and as a result have been exposed to ionizing particles or waves. As an example, sunbathers are exposed to UV light (and might have an associated injury, i.e., sunburn), but are NOT contaminated. Exposure above a certain threshold can cause the Cutaneous Syndrome, ARS, or death.

The term “contamination” refers to traces of radioactive material on or inside casualties or objects. Contamination can be external (on their clothing, hair, or skin) or internal (entering through the nose, mouth, lungs, GI tract, or open wounds). The treatment for external contamination is decontamination and for internal contamination is the use of decorporating agents and the medical treatment of the concomitant exposure.

Although most patients who have been contaminated have not received a significant exposure, the two problems are by no means mutually exclusive.

Measuring Radiation Contamination

There are several properties of radioisotopes that actually make them easier to deal with in the ED than with chemical or biological contaminants. The first concept is that radiation, unlike either chemical or biological contaminants, is easy to detect. Geiger counters are relatively cheap and easy to use and reliably detect even traces of γ particles and γ rays. They do have their limitations, though they do not reliably detect γ particles and do not detect neutrons at all. There are other types of portable contamination meters as well as a variety of nuclear medicine imaging devices (e.g., scintillation counters and whole-body scanners) that can be used to quantitatively assess the presence of a variety of particles with a variety of energy levels.

A key role during the ED response to a disaster involving radiation is that of the “surveyor”: a trained healthcare worker equipped with a functioning contamination meter. These surveyors identify patients, staff, and objects that are contaminated (and those that are not) and control the movement of patients out of contaminated areas into the remaining uncontaminated areas of the ED.

Given that radiation contamination is easily detected and has never caused known health effects in hospital-based healthcare workers, it is entirely feasible to bring contaminated casualties with limb- or life-threatening injuries into the ED. Thus, contamination within the ED (which should be limited to controlled areas and only for those highest acuity patients) is not a health hazard to ED staff and other patients, but rather a housekeeping problem.

Finally, any hospital with a nuclear medicine department has the tools on hand to identify contamination with a pure γ emitter, to identify most isotopes, and to semi-quantitatively assess partial or whole-body internal contamination with γ emitters. Taken together, these features make radiation a lot easier to work with than the invisible and often more dangerous chemical and biological agents.

Measuring Radiation Exposure

Workers who work with radiation wear personal dosimeters and dose rate meters. Dosimeters measure the cumulative dose and include the film badges traditionally worn by radiologists and radiology technicians. They provide a retrospective estimate of the amount of exposure to the healthcare worker.
Dose rate meters, on the other hand, provide an ongoing estimate of the rate of radiation (measured as milliSieverts per hour, mSv/hr). To give a sense of scale for different doses, some estimated doses (including the allowable exposure limits in Canada\textsuperscript{73,74}) are as follows:

<table>
<thead>
<tr>
<th>Exposure Dose</th>
<th>Dose (in mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average annual dose received by Canadians</td>
<td>2.6</td>
</tr>
<tr>
<td>Maximum dose received by healthcare workers in Goiania accident\textsuperscript{25}</td>
<td>5</td>
</tr>
<tr>
<td>Computed Tomography (CT) scan</td>
<td>10</td>
</tr>
<tr>
<td>Annual nuclear energy worker dose limit</td>
<td>50</td>
</tr>
<tr>
<td>Dose limit during an emergency</td>
<td>500</td>
</tr>
<tr>
<td>Minimum dose at which acute health effects observed</td>
<td>0.5–1</td>
</tr>
<tr>
<td>LD\textsubscript{50–60} (dose at which 60-day mortality for optimally treated casualties is 50%)</td>
<td>4.0–4.5</td>
</tr>
</tbody>
</table>

\textsuperscript{2}In this context, 1 Sievert (the equivalent dose) is equal to 100 rems and equivalent to 1 Gray (the absorbed dose equal to 100 rads)

The dose rate meters worn by specialized technicians and first responders include alarms that warn of high dose rates, and are called Personal Alarming Dosimeters (PADs) and are the size of a small cell phone. Most healthcare workers will not have access to personal dosimeters. During a radiation disaster response, however, it is likely that some of the specialists who will arrive to assist will be equipped with PADs, and their exposure dose rate will be similar to that of the healthcare workers they are supporting.

Biodosimetry refers to estimating the exposure dose based on the patients’ signs and symptoms as well as laboratory investigations. An initial rough estimate of a patient’s exposure dose can be based on 2 readily observed features. First, how soon after the exposure did the patient begin to vomit? Casualties receiving a significant dose of radiation will generally have started to vomit as a symptom of ARS within 6 hours of their exposure. The second is the rate of decline of the ALC as measured in a CBC. Interpretation of these clues is included in the Radiation Casualty Assessment Tool (see Appendix D) and the Radiation Emergency Medical Management (REMM) Tool.

The most accurate means of quantifying a significant exposure dose is to perform cytogenetic biodosimetry. This involves counting the genetic changes in lymphocytes. For this reason, patients suspected of having received a significant radiation exposure should have 2 blood tubes drawn with their initial laboratories. Cytogenetic biodosimetry is done in only a few specialized laboratories across Canada and takes about 50 hours to perform, and it is used to support ongoing medical decision making.

**Types of Accidents**

**Medical**

Radioisotopes as point sources of radiation are used widely throughout larger hospitals. The types of accidents that can occur include the following:

- Displacement of brachytherapy device or high-dose local radiation source in a cancer patient
Malfunction or error in use of diagnostic imaging modalities
Accidental exposure to staff while handling source materials
Common isotopes involved include cobalt-60, cesium-137, and Iridium-192

Industrial
There are over 1 million sources of radiation in the United States that are routinely monitored; each year more than 500 of these sources are lost.\(^2\)
- Radiation gauges, gamma cameras, food and equipment sterilization, either on site or during transportation
- Activation of radiation portal monitors at industrial sites (e.g., airport, landfill, and ports)
- Common isotopes: cobalt-60, strontium-90, cesium-137, and iridium-192

Research
Radioisotopes have a wide range of research applications. Common isotopes include hydrogen-3 (tritium), carbon-14, phosphorus-32, cobalt-60, iodine-125, iodine-131, and californium-252.

Criticality Accidents and Loss of Containment in Reactors
Criticality happens when fissionable isotopes are present in sufficient concentration and configuration that a chain reaction starts. This is the basic operating principle of nuclear reactors, but can also happen unintentionally in laboratories that deal with sufficiently enriched solutions of fissionable materials. A key distinguishing feature is whether containment (i.e., the integrity of the reactor or container holding the fissioning material) is preserved or not. When there is no loss of containment, the issue is only exposure (albeit extremely high). During the criticality accident in Tokaimura, Japan, in 2003,\(^7\) workers were mixing a solution in a vat of about 100 L, which went critical. There was a flash of blue light and the casualties were exposed to massive doses of \(\gamma\) and \(X\)-ray radiation as well as neutrons. They were not directly contaminated; the solution remained in the vat the whole time. In contrast, accidents with loss of containment (e.g., Chernobyl) cause widespread contamination with the isotopes listed below, in addition to the exposure to \(\gamma\) and \(\gamma\) particles, \(\gamma\) and \(X\)-ray radiation, and neutrons.

The setting of accidents includes the following:
- Laboratories involved in the production, processing, or disposal of fissionable material
- Commercial nuclear power plants and research reactors
- Reactor accident aboard nuclear powered vessels (NPV). Note that accidents involving nuclear weapons (e.g., the crash of a nuclear capable aircraft or vessel) in which there is no detonation is not a criticality accident, rather it is one with contamination and exposure to the plutonium-239 and other isotopes found in the weapon.

Common isotopes found in criticality accidents with loss of containment include strontium-90, iodine-131, cesium-137, and uranium-235, plutonium-239, americium-241.
Terrorism

The use of IEDs to spread radioactive contamination (referred to as a Radiation Dispersion Device [RDD]) or “dirty bomb”) is a real threat that will almost certainly occur. This type of event would contaminate some casualties and property at some future point, certainly create mass panic, but would lead to few significant radiation exposures. The isotopes most likely to be employed in an RDD (i.e., “dirty bomb”) would include cobalt-60, cesium-137, and iridium-192. There is also the possibility of a low-yield improvised nuclear explosive device being detonated.

Identification of Isotope

The exact isotope is unlikely to be known when contaminated casualties begin arriving during a radiation disaster. Because the type of accident will likely be known, it may be possible to narrow down the range of possibilities (see “Types of Accidents” discussed earlier). For example, if casualties are arriving from a criticality accident with loss of containment, then contaminants may include strontium-90, iodine-131, cesium-137, uranium-235, plutonium-239, and americium-241. Because there is really no difference in preparing the ED or in PPE requirements (unlike with chemical or biological disasters), the only difference is in choosing decorporating agents. The exact identification of the isotope will be provided by technical experts in the hours after the response begins.

The Geiger counter can be used to provide a rough estimate of the type of radiation being emitted. Alpha particles are generally only detectable when the source is less than 3–5 cm from the membrane (and not at all if it is in solution). Beta particles travel further, but can be stopped by several pieces of paper or tin foil. Gamma rays, on the other hand, require several centimeters of lead to stop them. Some Geiger counters have a thickness of lead on the back of the tube: activity that is not stopped by holding tin foil between the source and the tube, but is stopped by flipping the tube over so that it is shielded by the lead is likely coming from a γ emitter. In fact, most isotopes emit more than one type of radiation. Thus, by experimenting with the amount of distance and shielding between the contaminated surface and the Geiger counter tube, a contaminant can be identified as emitting γ, γ, or γ radiation. γ particles are primarily a risk for internal contamination, γ particles for skin burns, and γ radiation for ARS.

PPE for Radiation

Proper PPE for managing patients contaminated with radiation is readily available in all EDs. It is equivalent to Level D, or droplet precautions, and includes the following:

- A gown or Tyvek suit
- Booties, with the leg cuffs taped outside the booties
- A mask (N95 if readily available, but regular surgical mask will suffice)
- Goggles and face shield (especially if involved in patient decontamination, which potentially involves splashes of contaminated water hitting the face)
- Cap
Gloves, with the wrist cuffs taped outside the gloves; a second untaped pair of gloves should be worn outside the first and changed frequently (e.g., when grossly contaminated and between patients)

If personal dosimeters or dose rate meters are available, they should be worn under the outer layer of PPE, on the surface of the underclothing.

Care must be taken removing PPE. It needs to be done with a surveyor present with a Geiger counter. The outer layers are gradually removed, with the booties and inner pair of gloves left to the last. Then, after the surveyor has given the all clear, the healthcare workers step across the control line and remove their booties one at a time, putting first one clean foot, then the other, on the clean side of the line. At any time, if the surveyor comes across a localized area of contamination, that area must be either covered up or decontaminated before the healthcare worker can resume their duties.

Preparing the ED for Radiation Casualties

The same basic preparations are taken for radiation contamination as for other CBRN disasters. With radiation disasters, however, surveyors play a key role. During a radiation disaster in which unstable patients who are contaminated are a possibility, a Contaminated Treatment Area should be set up. At the Halifax Infirmary ED, both triage and decontamination are carried out in the ambulance bay (where the showers are located), while the Contaminated Treatment Area is a contiguous group of ED beds including both regular rooms and several trauma rooms (see Figure 12-10).

The only difference in staffing is the addition of surveyors equipped with Geiger counters, who will gradually appear in the ED as the broader disaster response rolls out. They should be deployed to those points in the Patient ED layout: Radiation Disaster

Figure 12-10: Set-up for managing radiation contaminated casualties at the Halifax Infirmary ED.
Flow algorithm where decisions are made based on whether the patient is contaminated or whether they have been successfully decontaminated. These include the Triage Team, the Decon Team (at post-decon station), the control line at the back of the “Warm Zone” into the ED, and as part of the Contaminated Treatment Area Team (to survey the patient for contamination and departing staff crossing the control lines). For radiation mass casualty incidents, portal monitors are the most efficient and should be set up some distance from the triage area to allow an appropriate staging area.

The Contaminated Treatment Area should be established right away, so that it will be ready when the first casualty arrives (in case they are unstable).

**Triage**

In addition to triaging arriving casualties, a Radiation Surveyor should quickly identify patients who are contaminated. The triage survey does not need to be detailed. Casualties who are contaminated with radiation and so unstable that there is no time to remove the contaminated clothing and thoroughly decontaminate them prior to receiving interventions for life or limb-threatening injuries should be taken immediately to the Contaminated Treatment Area.

If there is no Geiger counter available yet, and the available information indicates any possibility of contamination, they should be treated as if they are contaminated and sent to the Contaminated Treatment Area. The risk of spreading contamination can be minimized by wrapping the casualty in a clean sheet prior to bringing them into the ED.

The Registration Clerk should register the patients in some way, put bracelets on patient to identify them and to indicate contaminated (brown) versus noncontaminated (green). Finally, he/she should put a copy of the Radiation Casualty Assessment Tool (or other clinical template) on each patient’s chart to assist with the ongoing patient evaluation and management.

**Decontamination Team**

Prior to decontamination, the patient should be surveyed by a surveyor with a Geiger counter and the degree of contamination (measured in “counts per minute”) should be recorded on a diagram. Note that the Decon Teams should also swab patient’s nostrils and mouth if the presentation is suggestive of internal contamination (i.e., swallowed or inhaled dust that is suspected).

Those who are stable and ambulatory should be directed to the Ambulatory Decon shower to remove contamination. Patients who are nonambulatory must be decontaminated on stretchers. If they are also unstable, this will be done in the Contaminated Treatment Area. The clothing must be removed as described earlier (see “How to Decontaminate” in the first section). The surveyor should be recording the location and amount of contaminant (measured in “counts per minute,” which are read off the gauge on the counter) ahead of the staff performing decontamination. Decontamination efforts should begin with the mouth and nose, then open contaminated wounds, and finally intact skin and hair. Focal areas of solid contamination should be removed with baby wipes, moist 4 × 4’s, or makeup removal pads. For more widespread areas of contamination, use saline; control the effluent with waterproof drapes that drain into garbage buckets lines with plastic bags and keep as contaminated waste.
Decontamination is considered complete when residual contamination is less than twice the background level or consecutive attempts fail to reduce it further. If areas of significant contamination remain (including open wounds), they can be covered with a bio-occlusive dressing (e.g., Op-Site) and labeled with a permanent marker; this will contain the contamination until further measures can be taken (such as surgical debridement).

Contaminated samples (i.e., vomit, urine, or stool) should be put into sealed labeled specimen containers or plastic bags and surveyed as soon as possible. These can then be put in labeled red hazardous waste bag.

The Decontamination Team Surveyor should survey patients with a Geiger counter after they emerge from the decon shower. If they are still contaminated, then they are sent back to the pre-decon staff to have further decon done; if they are no longer contaminated, then they are told to dry off and to put on available clean dry clothing.

**Contaminated Treatment Area**

The Contaminated Treatment Area includes contiguous treatment rooms that are used for treating patients who arrive unstable and require emergent treatment prior to being decontaminated. The room(s) are set up as follows:

- Brown paper taped to floor (optional)
- Designated entrance (contaminated) and exit (transition to clean area)
- Mark perimeters of Contaminated Treatment Area (i.e., control lines) with masking tape and surveyor to control in the movements of staff and patients across the control lines
- Plastic covering to block off shelving and supplies not likely to be needed (to facilitate cleanup afterwards)
- Decon supplies (baby wipes, bottles of saline, drapes, bags for contaminated waste, Ziplock bags, and gloves)

The staff who make up the Contaminated Treatment Area Team include the following:

- MD and RN(s): carry out evaluation and management of contaminated casualties brought into the of Contaminated Treatment Area (using Radiation Casualty Assessment Tool or other clinical management templates); decontaminate patients once they have been medically stabilized.
- Radiation Surveyor: identify patients who are contaminated. The triage survey does not need to be detailed.

Consultant and service staff as well as portable equipment (e.g., ECG machine, portable X-ray, and ventilators) can enter and leave the contaminated treatment areas, but they must leave across the control line under the supervision of the surveyor. Once a piece of portable equipment is contaminated with radiation, it can continue to be used within the Contaminated Treatment Area until it is ultimately cleaned.

Decontamination carried out in the Contaminated Treatment Area follows proceeds the same as in the nonambulatory decon area.

376 Appendix C
What To Do with Minimal Resources

If there is only 1 Geiger counter, it should initially be used by the surveyor stationed with the Triage Team.

Cleanup of Contaminated Materials and Space

There are no real special requirements in site remediation after radiation contamination; it proceeds similarly to the cleanup after a chemical disaster. A Geiger counter is used to identify the contamination, then basic cleaning to remove it. Wax strippers may be required for floors. In some cases, floor tiles and other durable pieces of infrastructure may have to be removed, treated as contaminated waste, and replaced. Extensive or complicated site remediation requires professional contractors.

Decorporating Agents

There are several comprehensive reviews of the medical management of radiation casualties. Decorporating agents are used for treating internal contamination. They are most effective when used early. Some decorparing agents are commonly available in most EDs. These include sodium bicarbonate (used for uranium-235), calcium gluconate (used for strontium-90 and radium-226), Dimercaprol (also called BAL or British Anti-Lewisite; used for heavy metals, including isotopes of mercury, lead, arsenic, gold, and strontium-210), sodium alginate (used for strontium-90 and radium-226), antacids (aluminum phosphate and aluminum hydroxide), and water (used for tritium). Others are less commonly available. Basic information on these specific decorporating agents is given below. More specific information (including dosing, precautions, contraindications, and alternate therapies) is available from a variety of resources (including the REMM application) and should be sought prior to actual use.

Prussian blue (Radiogardase)
- Used for cesium-137 and thallium-201
- Exchanges ions with isotopes, removing them from enterohepatic circulation, resulting in excretion in stools
- Not approved by Health Canada; available only under Special Access Program; stockpiled at Health Canada and specific military dispensaries

Potassium iodide
- Used for iodine-131
- Competitively binds iodine receptors in thyroid; allows unbound iodine to be excreted prior to being incorporated; most effective when used within the first 1–2 hours after ingestion and should be used prophylactically with any reactor accidents in which there is external contamination (as a proxy for loss of containment)

Calcium and Zinc DPTA
- Used for plutonium-239, americium-241, curium-244, californium-252, thorium-232, and yttrium-90
Chelating agent: binds isotope, allows excretion prior to being incorporated

Use Ca-DPTA for first dose (more effective), then switch to Zn-DPTA for subsequent doses (less toxic); best within 1 hour, should administer within 6 hours

Table 12-8 summarizes the decorporating agents for use when the isotope is known. It is taken from a REMM supporting document. If the isotope is unknown, some experts recommend covering the range of expected isotopes based on the type of incident (see “Types of Accidents” discussed earlier). Others recommend waiting several hours until there is some information about the isotope. The most time-urgent isotopes requiring decorporating agents are iodine-131 and uranium-235.

Table 12-8: Summary of Decorporating Agents for Use with Known Isotope

<table>
<thead>
<tr>
<th>Radioisotope</th>
<th>Decorporating Agent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Americium</td>
<td>parenteral Ca-DTPA, Zn-DTPA</td>
</tr>
<tr>
<td>Cesium</td>
<td>oral Prussian blue</td>
</tr>
<tr>
<td>Cobalt</td>
<td>nothing too good, but oral penicillamine worth trying</td>
</tr>
<tr>
<td>Iodine</td>
<td>KI within about first 4 hours. Consider PTU = propylthiouracil</td>
</tr>
<tr>
<td>Iridium</td>
<td>unknown; try oral penicillamine</td>
</tr>
<tr>
<td>Palladium</td>
<td>unknown; try oral penicillamine</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>oral Na phosphate or K phosphate</td>
</tr>
<tr>
<td>Plutonium</td>
<td>parenteral Ca-DTPA, Zn-DTPA</td>
</tr>
<tr>
<td>Radium</td>
<td>oral calcium to reduce gastrointestinal absorption and increase urinary excretion. Alginates are also useful to reduce gastrointestinal absorption</td>
</tr>
<tr>
<td>Strontium</td>
<td>intravenous calcium gluconate, oral ammonium chloride for acidification. Alginates are useful to reduce gastrointestinal absorption</td>
</tr>
<tr>
<td>Tritium</td>
<td>force water to promote diuresis</td>
</tr>
<tr>
<td>Uranium</td>
<td>Ca-DTPA and Zn-DTPA within 4 hours only. Na bicarbonate to alkalinize urine</td>
</tr>
<tr>
<td>Yttrium</td>
<td>parenteral Ca-DTPA, Zn-DTPA</td>
</tr>
</tbody>
</table>

Supplies

Supplies specific to managing radiation disasters in the ED include the following:

- Geiger counter (or other contamination meter)
- Personal dose meters and dose rate meters (if available)
 Copies of Radiation Casualty Assessment Tool (or any other clinical template used)

 Patient bracelets to apply after being surveyed, to indicate “Contaminated” (i.e., brown) or “Not Contaminated” (i.e., green)

 Equipment for preparing Contaminated Treatment Area
  - Kraft paper for floor (and masking tape to hold it in place)
  - Plastic sheets (to cover equipment that is not needed, to protect it from becoming contaminated)

 Equipment for marking control lines
  - Masking tape and black felt tipped markers
  - Signage
  - Yellow barrier tape (i.e., with “caution” printed to augment tape on floor)

 PPE
  - Tyvek suits (or equivalent, with full legs and sleeves)
  - Gloves (2 colors if possible, e.g., blue for permanent layer against skin, regular color for second pair of gloves over first)
  - Masks, booties, caps, and goggles
  - Masking tape and black felt tipped markers

 Equipment for ambulatory decontamination
  - Privacy barriers
  - Portable decon shower (if applicable)
  - Large plastic bags (for contaminated clothes and personal belongings)
  - Labels for bags (patient ID and contamination status) or black felt tipped pen to mark same information
  - Op-Site (or other bio-occlusive dressing) in variety of sizes to place over open wounds prior to general decontamination
  - Towels and facecloths
  - Liquid soap and shampoo (without conditioner)

 Equipment for nonambulatory decontamination (including in Contaminated Treatment Area)
  - Baby wipes, bottles of saline, drapes, bags for contaminated waste, Ziplock bags, and gloves
  - Long-handled forceps (for picking radiation sources out of wounds) and a lead container (also called a “pig”) into which to place them

 Supplies of decorporating agents
Resources

Hospitals

Hospitals with Nuclear Medicine or Radiation Oncology departments always have a Radiation Safety Officer (RSO) on call. In the event of a radiation accident, the RSO on call should be contacted immediately through Central Locating. The RSO can be either a Radiation/Radiology/Nuclear Medicine technologist or a Health Physicist. There is also usually a Nuclear Medicine physician on call. They can help to identify the isotope and provide access to Geiger counters.

Local Industry

There may be local industries that have Geiger counters or other contamination meters and PADs or other dosimeters. Where there are Geiger counters, there are often personnel with special skills and training. The HEOC or municipal EOC can assist in identifying those resources.

Federal Government

Health Canada

- Responsible for providing support to civilian physicians managing radiation cases. They have an on-call system for radiobiologists to be available to answer questions about biodosimetry
- Phone (613) 954-6647, 24/7/365

Canadian Nuclear Safety Commission (CNSC)

- Regulatory body to oversee safety and security of nuclear materials in Canada
- http://www.nuclearsafety.gc.ca/eng/

METER course

- A course in “Medical Evaluation and Treatment for Exposure to Radiation” sponsored by CRTI
- Focuses on using the Radiation Casualty Assessment Tool to provide clinical guidance during evaluation and management of radiation casualties

Radiation Trauma Unit (University Health Network in Toronto)

- A network of Emergency Physicians available on call to help answer clinical questions regarding the management of patients from a radiation accident
- Phone (416) 603-5800 (extension 5098), 24/7/365

Radiation Emergency Assistance Center/Training Site (REAC/TS)

- REAC/TS (located in Oak Ridge, TN) is a WHO funded global Center of Excellence in Radiation Medicine. It is mandated to provide assistance to any member country (including Canada).
Include algorithms showing the appropriate evaluation and management of casualties arriving from the scene of a radiation disaster

- Phone (865) 576-1005, 24/7/365

**Radiation Casualty Assessment Tool**

- Multipage clinical evaluation and management template
- Developed for METER course (funded by CBRNE Research and Technology Initiative [CRTI])

**Software and web-based resources**

**REMM**

- Developed by the US Department of Health and Human Services
- Comprehensive package of linked .pdf and .avi files that cover a broad array of topics relevant to the clinical management of patients from a radiation disaster
- Downloadable as standalone application for Windows and Apple platforms, BlackBerry, Palm, or iPhone/iPod
- http://www.remm.nlm.gov/ (can be downloaded and installed on local storage device)

**Biodosimetry Assessment Tool (BAT)**

- Developed by the US Armed Forces Radiobiology Research Institute (USAFRRI)
- Designed primarily for tracking large numbers of casualties during a radiation MCI
- http://www.afrri.usuhs.mil/outreach/biodostools.htm (can be downloaded and installed on local storage device; requires a password [readily granted] from AFRRI to log onto the download site)
Appendix D – Radiation Casualty Assessment Tool

Instructions on use of RADIATION CASUALTY ASSESSMENT TOOL

This information packet (‘tool’) is designed to help with the assessment and management of casualties of an incident involving radiation. Use one packet per casualty, labelling each page. It should become part of the permanent record for that casualty. You do not have to use those parts of the tool that do not apply to that casualty.

1. Triage Guide

<table>
<thead>
<tr>
<th>Question 1: Is patient 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ “NO” then</td>
</tr>
<tr>
<td>□ “YES” then go to Question</td>
</tr>
</tbody>
</table>

- filled out by triage MD or RN
- used to establish initial priority (i.e. immediate treatment vs. immediate decontamination vs delayed treatment and/or decontamination)
- designed to look and function like the SARS screening tool

2. History and Physical form (2 pages)

<table>
<thead>
<tr>
<th>Name</th>
<th>Time of Arrival</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M/F</td>
</tr>
<tr>
<td>Physician</td>
<td>Time seen</td>
</tr>
<tr>
<td>Mode of arrival</td>
<td>EMS</td>
</tr>
</tbody>
</table>

- filled out by treating MD
- used to record findings on history and physical
- prompts physician to obtain specifics relevant to treatment and disposition decisions unique to radiation exposure and/or contamination
- includes biodosimetry estimates using three clinical measures

3. Body Mapping form for Skin Contamination and Injury

<table>
<thead>
<tr>
<th>Name</th>
<th>Time of Arrival</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M/F</td>
</tr>
<tr>
<td>Physician</td>
<td>Time seen</td>
</tr>
</tbody>
</table>

- filled out by treating MD or RN
- used to facilitate recording location of skin contamination
- contaminated areas are recorded (with initial count and description) as they are discovered by person performing survey. All contaminated areas must be decontaminated, with final counts recorded as well
- also used to record location of injuries

4. Standing Orders

<table>
<thead>
<tr>
<th>Allergy Alert</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ No Known drug allergy</td>
</tr>
<tr>
<td>□ Known allergies:</td>
</tr>
</tbody>
</table>

- filled out by treating MD
- prompts physician to order specific labs, specimens, and medications relevant to treatment of radiation exposure and/or contamination

5. Severity Scoring form (2 pages)

<table>
<thead>
<tr>
<th>SEVERITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time of Exposure</td>
</tr>
<tr>
<td>Time of Symptom Onset</td>
</tr>
<tr>
<td>Time of Assessment</td>
</tr>
</tbody>
</table>

- reference material for treating MD
- allows physician to estimate severity of injury due to radiation exposure when the exposure dose has not been determined. This may help with disposition decision
- lists some decorporating agents for internal contamination, table of ‘time of onset of vomiting’ as biodosimetry marker
RADIATION CASUALTY ASSESSMENT TOOL

Name ____________________ Age _______ M/F
Date ________________ Time of Arrival _______ h
Triaged by: ____________ Time seen __________ h
Mode of arrival: self □ EMS □ ambulatory □ stretcher □

PLACE ID
STICKER HERE

METER Course, v.2.4 (5/09)

TRIAGE

Question 1: Is patient medically stable?

□ "NO" then ————
1. Cover with sheet, assume contaminated
2. Move immediately to Contaminated Treatment Area

□ "YES" then go to Question 2

Question 2: Does patient have measurable skin contamination during 2 minute survey with Geiger Counter in triage?

□ "YES" then ————
1. Identify as contaminated (i.e. red bracelet)
2. Record sites/activity of contamination (p 5)
3. Prioritise for decon, move patient to decon site, then integrate into cohorted stream of uncontaminated ED patients
4. Further assess for Exposure ASAP

□ "NO" then ————
1. Identify patient as uncontaminated (i.e. green bracelet)
2. go to Question 3

Question 3: Does patient have history, signs and symptoms of possible exposure to radiation?

□ "YES" □
[checkboxes with options: New onset of nausea, vomiting, diarrhea or skin changes? New onset of weakness, confusion, unexplained low BP?]

□ "NO" □
1. Prioritise for treatment
2. integrate into cohorted stream of uncontaminated ED patients

PROVIDED COURTESY OF CEEP.CA AND PMPH USA IN RESPONSE TO THE COVID-19 EMERGENCY
## RADIATION CASUALTY ASSESSMENT TOOL

**Name**

**Date**

**Time of Arrival**

**Physician**

**Time seen**

### HISTORY AND PHYSICAL Form

<table>
<thead>
<tr>
<th>Vitals: HR</th>
<th>BP</th>
<th>Temp</th>
<th>RR</th>
<th>sats</th>
<th>% on</th>
<th>RA/Lpm</th>
</tr>
</thead>
</table>

### Chief complaint:

### HPI:

### Details of radiation contamination/exposure:

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Known:</th>
<th>Type of particle:</th>
<th>α</th>
<th>X-rays</th>
<th>β</th>
<th>neutrons</th>
<th>unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td>State:</td>
<td>solid/powder</td>
<td>liquid</td>
<td>gas/steam</td>
<td>unknown</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Contamination

- External contamination: yes | no | unknown
- Extent of contamination (see diagram):
  - localised (skin/hair)
  - Wound
  - Generalised
- Internal contamination: yes | no | unknown

### Decontamination

- Location: in field | at ED | done by

### Exposure

- yes | no | unknown
- Time of exposure: h
- Duration: h in h min
- Whole body | Parts of Body

### Past Medical History

- Immunosuppression: yes | no | unknown
- Cancer: yes | no | when?
- Previous fluoroscopy/Nuc Med testing/occupational exposure:

### Review of Systems (selected)

<table>
<thead>
<tr>
<th>Neuro:</th>
<th>Confusion</th>
<th>Fatigue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changes in: speech</td>
<td>vision</td>
<td>dizzy</td>
</tr>
<tr>
<td>Vomiting:</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>(began at</td>
<td>h</td>
<td>=</td>
</tr>
</tbody>
</table>

### Blood:

- Active bleeding: yes | no | Petechiae
- Bruising: yes | no

### Derm:

- Redness or Rash: yes | no | (Time of onset: h)
- Blisters
- Ulcers
- Desquamation
- Hair loss
- Onycholysis
- Dysesthesia/pruritis

### GI:

- Nausea (severity: | severity/10)
- Anorexia
- Abdominal pain: yes | no | Blood | mucus | in stool
- Diarrhea: yes | no | (began at | h | # of times: )

### Social history:

if female: LMP | no | Pregnant: yes/no?

### Medications

(include dose & freq if known):

### Allergies to meds:

- NKDA

### Social history:
RADIATION CASUALTY ASSESSMENT TOOL

Name __________________________ Age ______ M/F
Date ___________ Time of Arrival _______ h
Physician: ______________ Time seen _______ h

Physical exam:

-------------------------------------------------
-------------------------------------------------
-------------------------------------------------
-------------------------------------------------

BIODOSIMETRY using different methods of estimating severity of exposure; use REMM Tool or tables p7–8 to calculate estimated dose (in Grays)

1. Time of onset of vomiting (see Table on page 8)
   - Interval between exposure & onset vomiting: ______ h
   - Estimated dose: ______ Gray

2. Absolute Lymphocyte depletion rate (use REMM)
   - single ALC: ______ ×10^3, hrs post-exposure
   - serial ALC’s: 2nd ______ ×10^3, hrs post-exposure
   - Estimated dose: ______ Gray

3. Response Category: Neurological: 1 2 3 4
   Hematologic: 1 2 3 4
   Dermatological: 1 2 3 4
   Gastrointestinal: 1 2 3 4

OVERALL RESPONSE CATEGORY: 1 2 3 4
(Select highest value from 4 individual categories above)

Consistent biodosimetry estimate using all 3 methods is suggestive of radiation exposure at the indicated dose

(Source: REMM, other:

Resources (available 24/7 throughout Canada):
- Health Canada: (613) 954-6646
- Radiation Trauma Unit (UHN in Toronto): (416) 603-5800 ext 5098

Labs & Investigations:

Blood samples
- CBC: WBC ______ ×10^3, Abs Lymphocytes ______
- Abs Neutrophils ______, Hgb ______ mg/dL, PR ______ ×10^3
- Chem 7: Na ______ Cl ______ K ______ CO2 ______
- BUN: ______ Creat ______ Glc ______
- Pregnancy test (all females): neg/pos
- Thyroid: TSH, T3, free T4
- Cytogenetics (green-top tube; keep at room temp; send ASAP if exposure potentially > 0.5 Gray
- HLA typing (green-top tube; hold if potential for requiring bone marrow transplant)

Specimens
- Nasal swabs (labeled L&R; activity: yes/no
- Mouth Swab: activity yes/no
- Stool sample: activity yes/no
- Emesis sample: activity yes/no
- ECG:
  imaging studies:

Course in ED:

Reassessed: Time ______ h:

Diagnosis: 1) ______  2) ______  3) ______
Decorporating agent considered: Yes ☐ No ☐
Disposition: home ☐ transfer ☐ to: ______), admit ☐
Follow-up: RTED if: FP/ED in ______ days (pt aware ☐
outpt labs ☐ ☐
Prescriptions

see RADIATION STANDING ORDERS ☐
Signature: __________________________ time ______ h

see continuation sheet ☐
## RADIATION CASUALTY ASSESSMENT TOOL

**Name:**

**Age:** M/F

**Date:**

**Time of Arrival:** h

**Physician:**

**Time seen:** h

---

**BODY MAPPING Form**

1. **Injuries, burns, or skin changes**

   - Circle location of injuries, number consecutively, list details

<table>
<thead>
<tr>
<th>Site #</th>
<th>Details of Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. **Contamination**

   - Initial survey done by at h
   - Final survey done by at h

   - Background counts per minute:

<table>
<thead>
<tr>
<th>Site #</th>
<th>Description</th>
<th>Counts/min (initial)</th>
<th>Counts/min (final)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**PLACE ID STICKER HERE**

METER Course, v2.4 (5/09)

---

PROVIDED COURTESY OF CEEP.CA AND PMPH USA IN RESPONSE TO THE COVID-19 EMERGENCY
### SEVERITY SCORING Form

**Based on Waselenko JK et al. Ann Internal Med 2004;140(12):1037–1051,**
also Fliedner TM et al. Oxford: British Institute of Radiology; 2001: 64pp
also refer to REMM website (www.remm.nhs.gov)

#### 1. NEUROLOGICAL (Circle most appropriate description for each symptom)

<table>
<thead>
<tr>
<th>Acute Symptom</th>
<th>1 (mild)</th>
<th>2 (moderate)</th>
<th>3 (severe)</th>
<th>4 (most severe)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nausea</strong></td>
<td>Mild</td>
<td>Moderate</td>
<td>Severe</td>
<td>Unbearable</td>
</tr>
<tr>
<td><strong>Vomiting</strong></td>
<td>1 per day</td>
<td>2–5 per day</td>
<td>6–10 per day</td>
<td>&gt;10 per day</td>
</tr>
<tr>
<td><strong>Anorexia</strong></td>
<td>Mildly decreased appetite</td>
<td>Moderate decreased appetite</td>
<td>Severely decreased appetite</td>
<td>Unable to eat</td>
</tr>
<tr>
<td><strong>Fatigue Syndrome</strong></td>
<td>No functional impairment</td>
<td>Moderate functional impairment</td>
<td>Severe functional impairment</td>
<td>Unable to function</td>
</tr>
<tr>
<td><strong>Fever</strong></td>
<td>37.5–38 °C</td>
<td>38.1–40 °C</td>
<td>&gt; 40 °C for &lt; 24 h</td>
<td>&gt; 40 °C for &gt; 24 h</td>
</tr>
<tr>
<td><strong>Headache</strong></td>
<td>Mild</td>
<td>Moderate</td>
<td>Severe</td>
<td>Unbearable</td>
</tr>
<tr>
<td><strong>Hypotension</strong></td>
<td>HR &gt; 100, BP &gt; 100/70</td>
<td>BP &lt; 100/70</td>
<td>BP &lt; 90/60 (transient)</td>
<td>BP &lt; 80/60 (persistent)</td>
</tr>
<tr>
<td><strong>Neurological deficits</strong></td>
<td>Minor deficit, no functional impairment</td>
<td>Moderate deficit: moderate functional impairment</td>
<td>Marked deficit: marked functional impairment</td>
<td>Severe deficit: loss of consciousness</td>
</tr>
<tr>
<td><strong>Cognitive deficits</strong></td>
<td>Mild cognitive impairment</td>
<td>Moderate cognitive impairment</td>
<td>Severe cognitive impairment</td>
<td>Profound cognitive impairment</td>
</tr>
</tbody>
</table>

#### 2. HEMATOLOGIC (Circle most appropriate description for each symptom)

<table>
<thead>
<tr>
<th>Acute Symptom</th>
<th>1 (mild)</th>
<th>2 (moderate)</th>
<th>3 (severe)</th>
<th>4 (most severe)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abs Lymphocyte</strong></td>
<td>≥ 1.5 × 10⁹/l</td>
<td>1.0–1.5 × 10⁹/l</td>
<td>0.5–1.0 × 10⁹/l</td>
<td>&lt; 0.5 × 10⁹/l</td>
</tr>
<tr>
<td><strong>Abs Granulocyte</strong></td>
<td>≥ 2.0 × 10⁹/l</td>
<td>1.0–2.0 × 10⁹/l</td>
<td>0.5–1.0 × 10⁹/l</td>
<td>&lt; 0.5 × 10⁹/l</td>
</tr>
<tr>
<td><strong>Abs Platelet count</strong></td>
<td>≥ 100 × 10⁹/l</td>
<td>50–100 × 10⁹/l</td>
<td>20–50 × 10⁹/l</td>
<td>&lt; 20 × 10⁹/l</td>
</tr>
<tr>
<td><strong>Infection</strong></td>
<td>Local; no antibiotics required</td>
<td>Local, topical or oral antibiotics</td>
<td>Systemic; oral antibiotics</td>
<td>Septic; i.v. antibiotics</td>
</tr>
<tr>
<td><strong>Bleeding</strong></td>
<td>Petechiae; easy bruising; normal Hgb</td>
<td>Mild blood loss; &lt;10% decrease in Hgb</td>
<td>Gross blood loss; 10–20% decrease in Hgb</td>
<td>Spontaneous bleeding; &gt; 20% decrease in Hgb</td>
</tr>
</tbody>
</table>

**Approximate equivalent exposure doses** corresponding to different overall Response Categories:
1~ 1–2 Gy, 2~ 3–4 Gy, 3~ 6–7 Gy, and 4~ > 8–10 Gy (note: high individual variability)

---

2 Acute symptoms are those that began after the radiation exposure, and not thought to be attributable to another acute cause
3 Only present subacutely

---

Appendix D 387

PROVIDED COURTESY OF CEEP.CA AND PMPH USA IN RESPONSE TO THE COVID-19 EMERGENCY
RADIATION CASUALTY ASSESSMENT TOOL

<table>
<thead>
<tr>
<th>Acute Symptom²</th>
<th>1 (mild)</th>
<th>2 (moderate)</th>
<th>3 (severe)</th>
<th>4 (most severe)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erythema</td>
<td>Minimal; transient</td>
<td>Moderate; isolated patches &lt; 10cm², &lt; 10% of body surface area (BSA)</td>
<td>Marked; isolated patches or confluent, 10-40% BSA</td>
<td>Severe; isolated patches or confluent, erythroderma, &gt;40% BSA</td>
</tr>
<tr>
<td>Sensation/itching</td>
<td>Occasional pruritis</td>
<td>Slight, intermittent pain</td>
<td>Moderate; persistent pain</td>
<td>Severe, persistent pain</td>
</tr>
<tr>
<td>Swelling/Edema</td>
<td>Mild, asymptomatic</td>
<td>Moderate, symptomatic</td>
<td>Severe, symptomatic</td>
<td>Compartment syndrome</td>
</tr>
<tr>
<td>Blistering</td>
<td>Vesicles, with sterile fluid</td>
<td>Vesicles, with haemorrhage</td>
<td>Bullae, with sterile fluid</td>
<td>Bullae, with haemorrhage</td>
</tr>
<tr>
<td>Desquamation</td>
<td>Mild</td>
<td>Patchy, dry</td>
<td>Patchy, moist</td>
<td>Confluent, moist</td>
</tr>
<tr>
<td>Ulcer/necrosis</td>
<td>Epidermal only</td>
<td>Dermal</td>
<td>Subcutaneous</td>
<td>Muscle/bone involvement</td>
</tr>
<tr>
<td>Hair loss³</td>
<td>Thinning, not striking</td>
<td>Patchy, visible</td>
<td>Extensive</td>
<td>Complete and most likely irreversible</td>
</tr>
<tr>
<td>Onycholysis²</td>
<td>Minimal</td>
<td>Moderate</td>
<td>Severe</td>
<td>Complete</td>
</tr>
</tbody>
</table>

3. CUTANEOUS (Circle most appropriate description for each symptom)

4. GASTROINTESTINAL (Circle most appropriate description for each symptom)

Decorporating agents (for use with internal contamination)⁴:
- Cesium → Prussian Blue (1g in 200mL of water tid × 2–3 days)
  - Iodine → KI (note: dose of KI is age dependent; 50–130mg given po)
- Plutonium, Americium → DTPA (given as Ca-DTPA initially, then Zn-DTPA)
- Uranium → Sodium bicarbonate (250mL of 1.4% NaHCO₃)
- Tritium → water (> 6 litres/day)
- Radium → Ca-glucurate (10mL of 20% solution bid)
- Strontium → Barium sulphate (300g po single dose), Ca-glucurate
- Other decorporating agents: Deferoxamine, Dimercaprol (BAL), and Penicillamine

Dose (Grays) | Onset of vomiting (hours after exposure) | duration hours
-------------|----------------------------------------|----------|
0.5 – 2.0    | > 6, or absent                         | < 24     |
2.0 – 3.5    | 2 – 6                                 | 12 – 24  |
3.5 – 5.5    | 1 – 2                                 | 24       |
> 5.5        | Minutes                               | 48       |

Time interval prior to onset of vomiting for initial biodosimetry

² Acute symptoms are those that began after the radiation exposure, and not thought to be attributable to another acute cause
³ Only present subacutely
⁴ For prescribing information and other decorporating agents, refer to REMM; for local availability refer to Disaster Plan