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 Deaton 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.

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. There were 12 deaths and about 3,000 injuries as a result of the Sarin attack on the Tokyo subway in 1995. 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. Note
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>
</table>
| Cholinergic crisis    | • Salivation, diarrhea, lacrimation, bronchorrhea, diaphoresis, and/or urination | • Nicotine<sup>a</sup>  
|                       | • Miosis, fasciculations, weakness, bradycardia or tachycardia, hypotension or hypertension, altered mental status, and/or seizures | • Organophosphate insecticides<sup>a</sup>—decreased acetylcholinesterase activity  
|                       |                                                                                  | • Carbamate insecticides  
|                       |                                                                                  | • Medicinal carbamates (e.g., physostigmine)                                                 |
### Table 12-4 (continued)

<table>
<thead>
<tr>
<th>Category</th>
<th>Clinical Syndrome</th>
<th>Potential Chemical Etiology*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Generalized muscle rigidity</strong></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><strong>Airway and Breathing</strong></td>
<td>• Lip, mouth, and pharyngeal ulcerations and burning pain</td>
<td>• Paraquat—a—dyspnea and hemoptysis 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><strong>Cellular hypoxia</strong></td>
<td>• Mild: nausea, vomiting, and headache</td>
<td>• Cyanide—a (e.g., hydrogen cyanide gas or sodium cyanide)—bitter almond odor</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><strong>Peripheral neuropathy and/or neurocognitive effects</strong></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—a—visual disturbances, paresthesias, and/or ataxia</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Arsenic (inorganic)a—a—delirium and/or peripheral neuropathy</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>
</table>
| Severe gastrointestinal illness, dehydration | • Abdominal pain, vomiting, profuse diarrhea (possibly bloody), and hypotension, possibly followed by multisystem organ failure | • Arsenic*  
• Ricin—a—inhaled an additional route of exposure; severe respiratory illness possible  
• Colchicine  
• Barium—hypokalemia common |

*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.

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

*Unreliable sign.

**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 C2. (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
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.13,12 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/k, up to 5 g)

**Blistering Agents**

**Nitrogen and Sulfur Mustard**
- For skin effects: consider Thiosulfate, 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
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 12-5: Categories of Bioterrorism Agents

<table>
<thead>
<tr>
<th>Category</th>
<th>Characteristics</th>
<th>Agents</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</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., Ebola, Marburg] and arenaviruses [e.g., Lassa, Machupo])</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>B</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., Venezuelan equine encephalitis, eastern equine encephalitis, western equine encephalitis])&lt;br&gt;• Water safety threats (e.g., <em>Vibrio cholerae</em>, <em>Cryptosporidium parvum</em>)</td>
</tr>
</tbody>
</table>
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 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>
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</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 suctioning, 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 |

Examples:

- regular patient interactions
- anthrax, botulism, plague
- MRSA carrier, acute gastroenteritis
- Intentional food poisoning of unknown etiology
- 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,\(^67\) with a recommended minimum of 9 air changes per hour and with air exhausted outside the building.\(^68\) Of interest, testing of negative pressure rooms often reveals less negative pressure than was believed.\(^69\) Also note that some rooms (e.g., trauma rooms) are deliberately kept under positive pressure.

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>
</table>
| Airborne  | Airborne microorganisms or contaminated dust particles that remain suspended in air for long period of time | • All droplet precautions  
• Place patients in negative pressure rooms  
• Use of N95 masks at all times in patient care room  
• Use PAPR if available |

Examples:
- Tuberculosis, SARS
- Smallpox, viral hemorrhagic fever

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

ED layout: Biological Disaster

![Figure 12-9: ED setup for a biological disaster.](image-url)
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):  

- 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
Appendix C – Radiation Disasters

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. 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, including the mass contamination in Goiania, Brazil, in 1987.

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 (α particles or neutrons) or waves (γ or x-rays) that can damage or kill cells. The isotopes behave biochemically exactly the same as their stable cousins. For example, H3 (tritium) forms tritiated (heavy) water that follows the exact same metabolic pathways and distribution as regular water molecules. Thyroid receptors cannot distinguish iodine (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 (Tn99m, used in nuclear medicine) to 7.1 × 108 years for uranium (U235, 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.
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>LD50–60 (dose at which 60-day mortality for optimally treated casualties is 50%)</td>
<td>4.0–4.5</td>
</tr>
</tbody>
</table>

\textsuperscript{4}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.\textsuperscript{72}

- 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,\textsuperscript{75} 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

![Diagram of ED layout with annotations for Radiation Disaster](image)

Figure 12-10: Set-up for managing radiation contaminated casualties at the Halifax Infirmary ED.

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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 lined 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 a 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 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.
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 decorporating 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 radium226), 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 alkalinate 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 (USAFRRRI)
■ 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
   - 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)
   - 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
   - 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
   - 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)
   - 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 ☐

METER Course, v2.4 (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” ☐ New onset of nausea, vomiting, diarrhea or skin changes?
☐ “YES” ☐ New onset of weakness, confusion, unexplained low BP?

☐ “NO” ☐ 1. Prioritise for treatment
2. integrate into cohorted stream of uncontaminated ED patients
### Radiation Casualty Assessment Tool

<table>
<thead>
<tr>
<th>Name</th>
<th>Age</th>
<th>M/F</th>
<th>Date</th>
<th>Time of Arrival</th>
<th>Physician:</th>
<th>Time seen</th>
</tr>
</thead>
</table>

**Vitals:** HR, BP, Temp, RR, sats % on RA/Lpm

**Chief complaint:**

**HPI:**

**Review of Systems** (selected)

- **Neuro:** Confusion ☐, Fatigue ☐
- Changes in: speech ☐, vision ☐, dizzy ☐, headache ☐
- Vomiting: yes ☐ or no ☐, # of times:
  - (began at ___ h, = ___ h after exposure)
- Motor/sensory deficits?
- Cognitive deficits?
- **Blood:** Active bleeding ☐, Bruising ☐, Petechiae ☐
- **Derm:** Redness or Rash ☐, Blister ☐, Ulcer ☐
- Desquamation ☐, Hair loss ☐, Onycholysis ☐
- Dysesthesia/pruritis ☐
- **GI:** Nausea ☐(severity: ___/10), Anorexia ☐
- Abdominal pain ☐, Blood ☐, Mucus ☐, in stool
- Diarrhea ☐ (began at ___ h, # of times: ___)
- if female: LMP ___, Pregnant: yes/no?

**Details of radiation contamination/exposure:**

- **Isotope** (known: unknown)
- Type of particle: α, β, γ, X-rays, α-rays, neutrons
- State: solid/powder, liquid, gas/steam

**Contamination** (see diagram)

- 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, ___ min
- Whole body ☐, Parts of Body ☐

**Past Medical History**

- Immunosuppression ☐
- Cancer ☐ (radiotherapy ☐, chemo ☐, when? ___)
- Previous fluoroscopy/Nuc Med testing/occupational exposure? __________
- Other: __________

**Medications** (include dose & freq if known):

**Allergies to meds:** NKDA/___

**Social history:** __________

---

Provisional courtesy of CEEP.CA and PMPH USA in response to the COVID-19 emergency.

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### Radiation Casualty Assessment Tool

**Name:**

**Date:**

**Physician:**

**Time of Arrival:** 

**Age:**

**M/F:**

<table>
<thead>
<tr>
<th>Physical exam:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Biodosimetry</th>
</tr>
</thead>
</table>
| Using different methods of estimating severity of exposure; use REMM Tool or tables p7–8 to calculate estimated dose (in Gray).

#### 1. Time of onset of vomiting
- Interval between exposure & onset vomiting: 
- Estimated dose: 

#### 2. Absolute Lymphocyte depletion rate
- Single ALC: 
- Serial ALCs: 
- Estimated dose:

#### 3. Response Category:

<table>
<thead>
<tr>
<th>Category</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neurological</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hematological</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dermatological</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gastrointestinal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**OVERALL RESPONSE CATEGORY:**  

(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) 954-66467
- Radiation Trauma Unit (UHN in Toronto): (416) 603-5800 ext 5098

#### Labs & Investigations:

<table>
<thead>
<tr>
<th>Blood samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBC: WBC ( \times 10^3 ), Abs Lymphocytes, Abs Neutrophils, Hemoglobin,</td>
</tr>
<tr>
<td>Chem 7: Na, Cl, K, CO2, BUN, Creat, Gln,</td>
</tr>
<tr>
<td>Pregnancy test (all females): neg/pos</td>
</tr>
<tr>
<td>Thyroid: TSH, T3, free T4</td>
</tr>
<tr>
<td>Cytogenetics (green-top tube; keep at room temp; send ASAP if exposure potentially &gt; 0.5 Gray)</td>
</tr>
<tr>
<td>HLA typing (green-top tube; hold if potential for requiring bone marrow transplant)</td>
</tr>
</tbody>
</table>

#### 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:

#### Diagnosis:

1)  
2)  
3)  

#### Decomporating agent considered: Yes ☐ No ☐

#### Disposition:
- home ☐, transfer to: ☐, admit ☐
- Follow-up: RTED if: FP/ED in days (pt aware)
- outpt label: ☐ days (pt aware)

#### Prescriptions:

#### Signature:

---

**Place ID STICKER HERE**

---

**METER Course, v2.4 (5/09)**
### BODY MAPPING Form

#### 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>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Contamination

Initial survey done by [Name] at [Time] on [Date].

Final survey done by [Name] at [Time] on [Date].

Circle location of contamination, then number consecutively. List details below. Be sure to survey nose, mouth, hands & feet. Readings should be in ‘counts per minute’ (CPM).

<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>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Radiation Casualty Assessment Tool

<table>
<thead>
<tr>
<th>Name</th>
<th>Age</th>
<th>M/F</th>
<th>Date</th>
<th>Time of Arrival</th>
<th>Time of Assessment</th>
</tr>
</thead>
</table>

**Place ID**

**STICKER HERE**

**METER Course, v.2.4 (5/09)**

## Severity Scoring Form

- **Time of Exposure**
- **Time of Symptom Onset**
- **Time of Assessment**

### 1. Neurological

<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>Nausea</td>
<td>Mild</td>
<td>Moderate</td>
<td>Severe</td>
<td>Unbearable</td>
</tr>
<tr>
<td>Vomiting</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>Anorexia</td>
<td>Mildly decreased appetite</td>
<td>Moderate decreased appetite</td>
<td>Severely decreased appetite</td>
<td>Unable to eat</td>
</tr>
<tr>
<td>Fatigue Syndrome</td>
<td>No functional impairment</td>
<td>Moderate functional impairment</td>
<td>Severe functional impairment</td>
<td>Unable to function</td>
</tr>
<tr>
<td>Fever</td>
<td>37.5–38 °C</td>
<td>38.1–40 °C</td>
<td>&gt; 40 °C for &lt; 24h</td>
<td>&gt; 40 °C for &gt; 24h</td>
</tr>
<tr>
<td>Headache</td>
<td>Mild</td>
<td>Moderate</td>
<td>Severe</td>
<td>Unbearable</td>
</tr>
<tr>
<td>Hypotension</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>Neurological deficits</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>Cognitive deficits</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

<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>Abs Lymphocyte</td>
<td>≥ 1.5 × 10^9/l</td>
<td>1.0–1.5 × 10^9/l</td>
<td>0.5–1.0 × 10^9/l</td>
<td>&lt; 0.5 × 10^9/l</td>
</tr>
<tr>
<td>Abs Granulocyte</td>
<td>≥ 2.0 × 10^9/l</td>
<td>1.0–2.0 × 10^9/l</td>
<td>0.5–1.0 × 10^9/l</td>
<td>&lt; 0.5 × 10^9/l</td>
</tr>
<tr>
<td>Abs Platelet count</td>
<td>≥ 100 × 10^9/l</td>
<td>50–100 × 10^9/l</td>
<td>20–50 × 10^9/l</td>
<td>&lt; 20 × 10^9/l</td>
</tr>
<tr>
<td>Infection</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>Bleeding</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 Gy, 2–3 Gy, 3–6 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
RADIATION CASUALTY ASSESSMENT TOOL

Name ____________________  Age _____ M/F
Date __________ Time of Arrival ______ h
Physician:__________ Time seen ______ h

3. CUTANEOUS (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>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, &gt;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>

4. GASTROINTESTINAL (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>Stool frequency</td>
<td>2-3 stools per day</td>
<td>4-6 stools per day</td>
<td>≥ 7 stools per day</td>
<td>&gt; 10 stools per day; intractable diarrhea</td>
</tr>
<tr>
<td>Mucosal loss with diarrhea</td>
<td>Rare</td>
<td>Intermittent, with moderate patches</td>
<td>Persistent, with larger patches</td>
<td>Continuous, with large patches</td>
</tr>
<tr>
<td>Bleeding with diarrhea</td>
<td>Occult</td>
<td>Intermittent</td>
<td>Persistent</td>
<td>Gross hemorrhage</td>
</tr>
<tr>
<td>Abdominal cramping &amp; pain</td>
<td>Minimal</td>
<td>Tolerable</td>
<td>Intense</td>
<td>Excruciating</td>
</tr>
</tbody>
</table>

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-gluconate (10mL of 20% solution bid)
- Strontium → Barium sulphate (300g po single dose), Ca gluconate
- Other decorporating agents: Diferoxamine, Dimercaprol (BAL), and Penicillamine

- Dec and other decorporating agents: refer to REMM; for local availability refer to Disaster Plan

---

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

---

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