# Waste Management

Author(s): William J. Pate, BS, MBA, MPH, DrPH, CIH, CSP, CHMM
Program Director, Radiation & Occupational Safety
University of Texas Medical Branch at Galveston
Galveston, TX

Jeremy Wilke, BS, CIH, CSP
Senior Environmental Protection Specialist
University of Texas Medical Branch at Galveston Galveston, TX

Published: March 18, 2022

## Abstract

Infection preventionists have varying levels of involvement with healthcare waste management and are often focused on regulated medical waste. The categories of regulated medical waste streams of particular interest to infection preventionists include infectious waste, pathological waste, and sharps waste. An effective waste management program is complex due to numerous regulations and guidelines, evolving technologies, expanding healthcare delivery settings, emerging infectious diseases, and the potential for bioterrorism. Although responsibility for the management of healthcare waste is typically outside the area of responsibility for most infection preventionists, they may still be affected or involved in a wide

range of issues related to regulated medical waste management. Safe management of medical waste continues to present a challenge in countries with developing economies. This chapter provides information and resources to assist the infection preventionist with successful participation in the safe management of regulated medical waste and associated healthcare waste streams.

## Key Concepts

- Definitions of medical waste can be confusing.
- Medical waste regulations and guidance should be based on scientific analysis.
- Waste management plans should include input from the infection prevention and control program.
- The infection preventionist should be aware of new technology and emerging issues related to regulated medical waste.
- A properly managed medical waste management program reduces regulatory risk, increases staff, patient, and public safety, and provides cost savings to the institution.
- Performance improvement may be used to measure effectiveness of waste management.
- Internationally, the personnel responsible for managing healthcare wastes can vary considerably based on country-specific regulatory requirements and definitions.

## Key Terms

See Waste Terminology subsection under Basic Principles.

## Background

In the late 1980s and early 1990s, medical waste caught the public's attention because of the potential for medical waste to contaminate the environment and transmit disease.[1] Media reports, some of which were sensationalistic and not based on scientific analysis, focused on beach wash-ups and dwindling landfill space, as well as fears regarding HIV transmission.[2, 3]

Today, despite years of effort and new regulations, the

mismanagement of medical waste continues to make headlines.[4, 5]

When asked to define the risks that healthcare wastes pose to the public and to communities, experts at the Centers for Disease Control and Prevention (CDC) stated in 1985:

"No epidemiologic evidence suggests that most of the solid- or liquid wastes from hospitals, other healthcare facilities, or clinical/research laboratories is any more infective than residential waste. […] Moreover, no epidemiologic evidence suggests that that traditional waste-disposal practices of health-care facilities (whereby clinical and microbiological wastes were decontaminated on site before leaving the facility) have caused disease in either the health-care setting or the general community."[6]

This statement remains in CDC guidelines to this day. Notably, although there is no documented evidence of transmission of disease to the public through healthcare waste streams, data limitations prevent firm conclusions on risk from being developed.[6]

Unfortunately, some confusion remains, compounded by inconsistent, specific, and occasionally conflicting definitions of "medical waste" or "infectious waste."[7, 8] This confusion is driven by input from individuals with little knowledge of infectious disease transmission or related microbiology.[9] Documents have been and continue to be drafted at local, state, federal, and international levels that lack scientific risk/benefit analysis or consistency in application.[2, 9, 10]

Hospitals, healthcare providers, regulators, and accrediting bodies have recognized the potential occupational risk of disease transmission from medical waste and therefore require caution when healthcare personnel and others handle and dispose of wastes.[6, 11, 12] Healthcare "infectious" wastes may include microbiological laboratory waste, hazardous waste, blood/body fluids, sharps, pathology wastes, pharmaceutical wastes, and certain wastes from patients who are placed in isolation.[13]

Careful handling, sorting, and transportation, as well as appropriate packaging and disposal of waste from these settings, may help to explain the absence of infection transmission from waste in the community.

This chapter discusses healthcare waste from a practical and scientific perspective, with most of the chapter focusing on traditional “infectious” waste. However, the infection preventionist (IP) may be involved in other aspects related to waste management in a variety of healthcare settings. Among other issues, IPs may be concerned with:

- purchasing;
- design of waste disposal areas;
- reuse and recycling of medical items (such as reusable sharps disposal containers);
- handling and disposal of special types of waste (emerging infectious and bioterrorism agents);
- waste disinfection and sterilization technologies;
- ecological considerations; and
- assessment of a waste management plan using performance improvement.

Accordingly, brief and pragmatic overviews of a range of waste topics are included in this chapter to assist the IP, and resources are provided for further consideration. Individual healthcare facilities and services must consider applicable codes, regulations, and guidelines prior to implementing or updating an effective waste management program.

# Basic Principles

## WASTE TERMINOLOGY

The primary constituent of healthcare waste that is traditionally of interest to IPs is waste capable of transmitting infectious agents. Articles on this topic offer inconsistent findings due to lack of a standardized definition of what constitutes waste capable of transmitting an infectious disease. Terms such as “biomedical waste,” “regulated waste,” “red bag waste,” “medical waste,” and “infectious waste” have been used interchangeably. The same term may have a different definition depending on the resource.

For example, the World Health Organization defined “infectious waste” as “waste suspected to contain pathogens and that poses a risk of disease transmission.”[13] In contrast, the Occupational Health and Safety Administration (OSHA) Bloodborne Pathogens Standard uses the term, “regulated waste,” which is defined as

"liquid or semi-liquid blood or other potentially infectious materials."[14]

Categories of waste that are included in these definitions vary from state to state and even from federal agency to federal agency. To reduce confusion, the term "infectious waste" is used in this chapter to refer to "waste that is capable of producing an infectious disease."

A common misconception is to assume that exposure to a pathogen in wastes will likely result in infection. Pathogenic organisms are found in many different day-to-day settings. Ordinary garbage, bed linens, soiled diapers, and unwashed hands are all examples of environments in which pathogens can routinely be found both within and outside the healthcare setting. Multiple studies have shown that although hospital wastes can have a greater variety of organisms than residential wastes, household wastes are more heavily contaminated.[2, 15, 16, 17, 18]

Even when generated from healthcare activities, most garbage, soiled bed linens, and diapers do not have any special handling requirements in most instances.

For a waste to be capable of causing infection, all five of the following specific factors are necessary:

- dose,
- host susceptibility,
- presence of a pathogen,
- virulence of a pathogen, and
- portal of entry.

## INFECTIOUS WASTE CATEGORIES

Many categories of infectious waste have been proposed by a variety of associations, individuals, and agencies in the past. However, if we strictly adhere to the preceding definition of infectious waste, classifying infectious waste is simple and should include the categories described in following sections (see also Table 1 for a summary of the various infectious waste categories).

**Table 115-1** Types of infectious waste

| Infectious Waste Category | Examples | Disposal/Management Comments |
|---|---|---|
| Contaminated sharps | Discarded needles, scalpels, broken glass (slides, Pasteur pipets) | • Place in an appropriate rigid, puncture-resistant, closeable, and leakproof container for immediate disposal. |
| Microbiological cultures and stocks of infectious agents | Bacterial and viral stocks used in research; cultures of infectious bacteria (*Staphylococcus aureus, Bordetella pertussis, Escherichia coli),* viruses (HIV, Hepatitis B, Hepatitis C), and other microorganisms | • Use chemical, thermal (autoclave), or radiological (irradiation) treatment/inactivation prior to disposal as nonhazardous waste.<br>• Ship off-site as regulated medical waste (possibly Category A) for final disposal if on-site treatment is not possible. |
| Animal waste | Tissues or blood from research animals infected with infectious agents | • Evaluate for potential zoonotic exposure risks.<br>• Treat on-site prior to disposal. |

| | | |
|---|---|---|
| Blood and blood products | Whole blood, serum, red blood cells, albumin, blood coagulation factors, immunoglobulins | • Small amounts (blood-tinged bandage or dressing) present minimal risk and are not considered regulated medical waste.<br>• Blood-saturated materials and bulk liquids are to be collected as regulated medical waste.<br>• Use chemical (bleach) or thermal treatment on-site<br>• Bulk blood should be solidified if being transported on- or off-site. |
| Category A infectious waste | Hemorrhagic fever viruses (e.g., Ebola), Hantavirus, smallpox, cultures of other agents such as Herpes simplex B virus | • Use on-site inactivation (autoclave or incineration)whenever possible.<br>• Off-site treatment requires shipment as a Category A infectious substance and compliance with Department of Transportation requirements |
| Pathology waste | Tissue samples or organs collected during autopsy; tissue specimens collected/removed as a result of surgery | • Formalin fixation reduces infectious hazard immensely.<br>• Incineration or grinding for sanitary sewer discharge is usually acceptable.<br>• Avoid release of recognizable human body parts into landfill waste stream. |

## Contaminated Sharps

All discarded sharps (e.g., needles, scalpels) and items that could potentially become sharps (e.g., glass Pasteur pipettes,

glass slides) should be considered and treated as potentially infectious waste due to their potential to cause cuts or puncture wounds.[13] This category of infectious waste poses the greatest risk for injuries. The risk of infection is related to contamination with a sufficient dose of pathogenic organisms (such as Hepatitis B virus, Hepatitis C virus, or HIV) and the provision of a portal of entry into a susceptible host via a puncture or cut.

These devices represent a significant occupational hazard to those handling and disposing of them.[19] However, once contaminated sharps are properly placed into appropriate rigid, puncture-resistant containers, the environmental risk they pose is negligible.[20] (Also see **107. Minimizing Exposure to Blood and Body Fluids** .)

## Microbiologic Cultures and Stocks of Infectious Agents )

Of all the possible categories of infectious waste, cultures, stocks, and amplified microbial populations that have not undergone predisposal treatment (autoclaving, bleach treatment, etc.) pose the greatest potential for infectious disease transmission because they contain high concentrations of potentially pathogenic organisms. Laboratory personnel should handle discarded cultures and stocks accordingly.

Cultures and stocks may be stored in glass containers (e.g., tubes) that, if broken, become contaminated sharps and therefore should be handled carefully. Microbiologic waste may be treated on site before it is discarded (e.g., by autoclaving) and subsequently disposed of as nonhazardous solid waste in accordance with related solid-waste disposal regulations.[21, 22]

## Animal Wastes

Discarded material originating from animals inoculated with infectious agents during research, production of biologicals, or pharmaceutical testing should be considered infectious waste. Like microbiologic cultures and stocks of infectious agents, animal waste materials may contain high concentrations of pathogenic organisms. Therefore, animal wastes that fit into this category are handled in the same manner as cultures and stocks.

Certain tissues and bodies from animal research areas may have special considerations for handling and disposal because of the

potential for zoonotic microbes; each should be addressed based on knowledge of the specific organism.[21, 22]

## Blood and Blood Products

Blood and blood products, as defined in the OSHA Bloodborne Pathogens Standard [14] (e.g., serum, plasma, and other components known or suspected to be contaminated with a transmissible agent), must be handled carefully. Small amounts of these materials dried on dressings or other disposable items represent an insignificant hazard once they are properly contained because of the absence of a portal of entry and a means of transmission.

Bulk blood, blood-tinged suctioned fluids, excretions, and secretions are considered infectious waste because they may be splashed onto mucous membranes or because the container may break and become a contaminated sharp.[14] These fluids may be carefully poured down a drain connected to a sanitary sewer that is designed for the disposal of human waste. Before disposing of these fluids in the sanitary sewer, it is important to verify that local regulations allow this practice, as there may be local prohibitions on the disposal of whole blood in the sanitary sewer.

Healthcare personnel (HCP) handling blood and blood products must follow Standard Precautions, including the use of personal protective equipment (PPE), due to splash and aerosolization potential. Alternative treatment methods for inactivation or handling before disposal such as solidification of liquid infectious waste are available.[3, 6]

## Selected Isolation Wastes

Discarded waste materials contaminated with excretions, exudates, and secretions from patients with highly communicable diseases such as Ebola (classification risk group 4 by the National Institutes of Health's Guidelines for Research Involving Recombinant or Synthetic Nucleic Acid Molecules) who are treated in isolation should be classified as infectious waste. [23]

Blood and sharps originating from these patients are already included in the preceding categories.

## Pathology Wastes

Pathology wastes include human tissues and body parts that are collected at autopsy or during surgery. Pathology wastes do not usually fit the definition of infectious waste outlined previously.

There is an absence of a portal of entry, and most of these materials have been soaked in alcohol or formaldehyde and thus seldom contain pathogens.[24, 25] Incineration or grinding and discharging into a sanitary sewer are the common acceptable methods of treating this waste.

## NONINCLUDED WASTES

HCP who are responsible for developing safe handling and disposal practices for materials that do not meet the definitions of infectious waste must keep in mind that the waste discharged from healthcare institutions differs little from that in normal households.[18, 26] Many people with infectious diseases are not hospitalized, and much of the volume of hospital created waste does not pose a higher risk than general solid waste streams. Thus, characterizing all waste as infectious increases healthcare costs and creates undue confusion and concern. These impacts of improperly classifying and managing wastes illustrate the importance of following the regulatory definitions of infectious waste.

## WASTE-RELATED REGULATION AND GUIDANCE

On the US federal level, several agencies have published regulations and guidance pertaining to “infectious,” “medical,” or “regulated” waste. OSHA and the US Department of Transportation (DOT) have such regulations.[27, 28] In addition, both the CDC and Environmental Protection Agency (EPA) have issued guidance documents pertaining to medical waste management.[3, 6] At the request of the US Congress, the Agency for Toxic Substances and Disease Registry prepared and published a comprehensive review of the public health implications of medical waste.[29]

The Joint Commission includes medical waste as hazardous within its Environment of Care Standards through several elements of performance (EP) within EC.02.01.01 and in EP 6 under Infection Prevention and Control in Standard IC.02.01.01.[11] DNV GL Healthcare also includes requirements to appropriately manage biomedical/medical wastes.[30]

The US Postal Service has laws related to sending hazardous and biological substances through the mail.[31] The Nuclear

Regulatory Commission and the Environmental Protection Agency have shared jurisdiction over waste that contains both biological and radiological hazards ("mixed waste").[32] The US Food and Drug Administration (FDA) Center for Devices and Radiological Health has regulatory authority over selected aspects of waste management, including the designation of sharps disposal boxes as class II medical devices.[33, 34] Table 2 describes the different classes of medical devices as defined by the FDA.[35]

**Table 115-2** US Food and Drug Administration medical device classifications

| Classification* | FDA Definition | Example |
|---|---|---|
| Class 1 | The device is not life-supporting or life-sustaining or for a use which is of substantial importance in preventing impairment of human health, and which does not present a potential unreasonable risk of illness of injury. | • Elastic bandages<br>• Enema kits |
| Class 2 | General controls alone are insufficient to provide reasonable assurance of the device's safety and effectiveness, and there is sufficient information to establish special controls. | • Surgical gloves<br>• Contact lenses<br>• Powered wheelchairs |
| Class 3 | Life-supporting or life-sustaining device, or device for a use which is of substantial importance in preventing impairment of human health, or the device presents a potential unreasonable risk of illness or injury. | • Implantable pacemaker<br>• Automated external defibrillators |

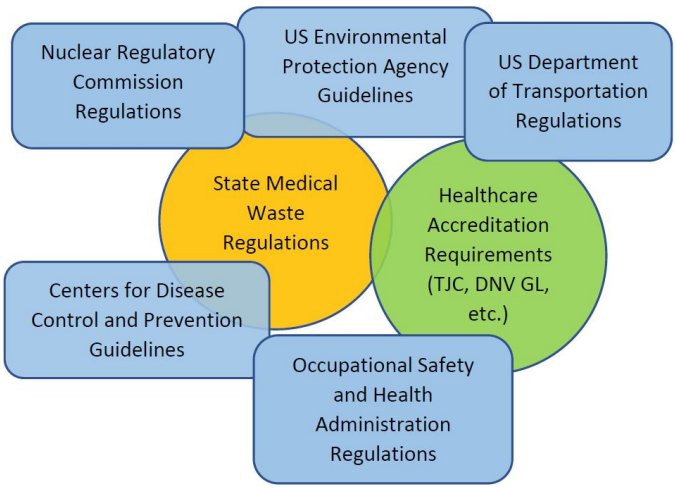
Source: Adapted from [35] **Ref 0-35 US Food and Drug Administration. Medical device classification procedures: definitions. 21 CFR 860.3 (2020). Accessed January 18, 2022. ht...**

*Class 1 medical devices require a low degree of control to ensure the devices are safe and effective whereas Class 3 medical devices require a high level of control to ensure the devices are safe and effective

Other agencies have regulations and guidelines related to wastes from healthcare settings; selected entities are identified where indicated in the chapter. (Also refer to **4. Accrediting and Regulatory Agencies**.)

In the United States, state and local governments also have a range of regulations related to these materials. Therefore, it is important that IPs recognize which regulations are applicable based on the authority having jurisdiction for their healthcare setting(s). IPs, in partnership with other institutional stakeholders such as Environmental Services and Environmental Health and Safety, should remain current with applicable local, state, and federal regulatory activity within the United States or with the authority having jurisdiction for regulatory oversight in the international community. Figure 1 illustrates the complex relationship between the various regulatory and accreditation requirements and guidelines.

**Figure 115-1.**




**The complex interplay of federal and state regulations and healthcare accreditation requirements for infectious waste management creates challenges for healthcare organizations.**

View Image

# Waste Management Plans

## PLAN BASICS

The efficient waste management plan includes definitions of “infectious” and “noninfectious” waste and addresses every step from acquiring materials that become waste to generation of waste, discarding, collection and containment, handling, accumulation and storage, transportation, treatment, and ultimate disposal. The key to success is a collaborative effort, including the IP’s involvement.

## INFECTIOUS WASTE

Once a facility has a working definition of “infectious waste,” the next step is to develop or update a plan for managing these materials. A management plan is addressed to some extent by regulatory, advisory, and licensing agencies such as OSHA and the CDC, various state agencies such as the Department of Natural Resources or Department of Health, as well as other bodies, such as the Joint Commission.[6, 11, 14, 30]

This written plan should include provisions for the assignment of responsibility and authority for overseeing the program to an individual who is knowledgeable regarding infectious disease transmission and who is familiar with applicable federal, state, and local regulations (e.g., the facility safety officer or environmental services director or, less commonly, an IP). This will ensure that these materials are handled as required and in a scientific manner.

Objectives for the plan include:

- rendering infectious waste safe for disposal;
- ensuring that there is minimal risk to patients, HCP, visitors, and the community from exposure to pathogenic organisms associated with waste generated in the healthcare facility;
- meeting or exceeding all federal, state, and local regulations; and
- educating HCP regarding the management plan and the real versus the perceived risk associated with “infectious waste.” Several studies have shown the importance of adequate

resources and staff education in the implementation of an effective medical waste management program.[36, 37, 38]

The other components of an infectious waste management plan include designation, segregation, packaging, storage, transport, treatment or disposal, contingency planning, and staff training. Each component is discussed further in the following sections.

## Designation

Once a facility has developed definitions for infectious and noninfectious wastes, its policies and procedures for sorting the discarded materials into the proper waste stream must be aligned with regulatory and safety requirements.. It is recommended that a list of infectious wastes generated in the facility be developed and that the generating areas be identified in the management plan. For example, blood/blood products known or suspected to be infected with transmissible agents are generated on patient floors and in surgery, the autopsy suite, clinics, emergency departments, and ancillary departments, whereas formalin-fixed pathology wastes may only be generated in the clinical laboratory.

Another important issue is cost control. Infectious waste disposal is significantly more expensive than noninfectious solid waste disposal. It may be possible to engage the regulated medical waste transport/treatment company to have them evaluate the hospital's medical waste program and identify cost-reduction opportunities.

## Segregation

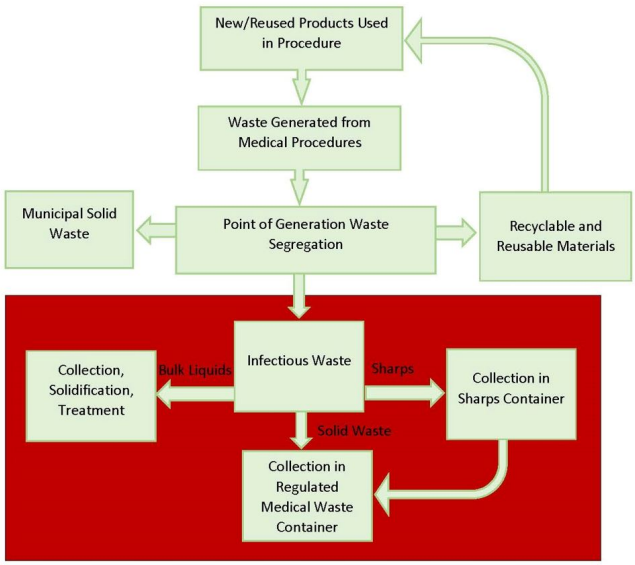
Individuals who are knowledgeable about the waste's origin and its hazard potential must segregate infectious waste at the point of origin. The waste should then be placed into appropriate designated leakproof containers. Needles must never be recapped, bent, or broken by hand before being discarded. Infectious waste with multiple hazards (e.g., used sharps from patient receiving chemotherapy) must be segregated as necessary for the management and treatment of the waste characteristic with the most stringent handling requirements.

For example, in the surgical suite, the engagement of perioperative personnel in the separation of infectious and noninfectious waste at the point of use can limit the volume of waste that must be handled and disposed of as infectious waste.[39] Examples of successful segregation in this setting have also

offered benefits of environmental sustainability and have facilitated recycling of the large quantity of materials and packaging generated during perioperative care.[40, 41]

Figure 2 demonstrates a process for appropriate waste segregation to minimize the volume of infectious waste generated.

**Figure 115-2.**




**Waste minimization efforts can help reduce infection exposure risk, control waste disposal costs, and improve regulatory compliance. Reducing the volume of waste in the red region drastically reduces costs, environmental impact, and liability.**

View Image

## Packaging

Infectious waste must be packaged properly to protect patients, HCP, visitors, and the public from potential exposure to infectious materials and to facilitate the proper handling, storage, treatment, or disposal of the waste. Selection of the packaging must be appropriate for the type of waste being contained to maintain the integrity of the packaging during collection, transport, storage, and disposal.[27]

States generally specify packaging requirements in their infectious waste regulations. In addition, OSHA and the CDC

specify that sharps be placed in rigid puncture-proof containers.[6, 14]

Infectious waste must be properly identified as a biohazard. Infectious waste containers should be labeled with a biohazard label or color-coded red to identify the contents. OSHA requires either red color-coding or use of the universal biohazard symbol and term “biohazard.”[14] State regulations may require additional information on the packaging, such as the name of the generating facility, date, bilingual terminology, and so forth. Packaging used for shipment will often contain additional markings and be labeled to comply with applicable shipping regulations (e.g., orientation arrows on sharps containers).[27]

Sharps containers must be impervious, rigid, puncture resistant, leakproof on the sides and bottom, and closable.[14]

Plastic bags are appropriate for bulk solid or semisolid infectious wastes or for disposables containing residual liquids. Plastic bags should be impervious and tear resistant.

Potentially infectious liquid wastes can be carefully poured down a designated sanitary sewer by personnel using appropriate engineering controls (such as equipment that is connected to and automatically discharges liquid wastes to the sanitary sewer system) and PPE.

When disposal via a sanitary sewer is not desirable or possible, liquid wastes should be placed in leakproof containers, such as a flask or bottle, that can be tightly capped or stoppered. Absorbent material sufficient to absorb the entire contents of the containers must be added to the outer container. Free-flowing liquids should not be poured directly into a waste container. Suction canisters must be tightly closed and placed in plastic bags. Bags may need to then be placed in a secondary container, such as a cardboard box, to preserve the integrity of the packaging during transport and storage. Semirigid or rigid secondary containers usually are required for off-site transport of infectious waste.

## Storage

Infectious waste should be treated and disposed of as soon as possible after generation. Although there is no published national standard for how long infectious waste may be stored, some states may have limits on storage time at the generating facility.

The proper packaging outlined here will ensure containment and exclusion of rodents and vermin. Storage areas should have limited access, and a biohazard symbol should be posted so it is readily visible to anyone with access to the area.[14]

Many states have specifications for the type of enclosure required for storage of infectious waste, and they often specify the duration of storage that is permissible. Some states have very elaborate requirements for storage areas that require the room to have floors that slope to a drain that is connected to a sanitary sewer. This provides for a safe method of cleaning up liquid spills. In any case, a system for immediate spill containment and cleanup should be available in the storage area (e.g., hose connected to steam line).

## Transport

The internal and external systems used for the transportation of infectious waste must maintain the integrity of the packaging and protect handlers. Mechanical waste collection devices and gravity or pneumatic-chute transport of infectious waste are discouraged due to potential damage to packaging. Leakproof carts that are readily cleanable or that can be lined with plastic are generally used for transportation of infectious waste from the generating areas to the storage area where it will be picked up for treatment.

Commercial or private vehicles that are employed in the transport of infectious waste should be leakproof and identified in accordance with municipal, state, and federal regulations. IPs should be aware of regulatory requirements and provide input into relevant key operational services. For example, a facility's clinical laboratory couriers, who often pick up not only specimens but also infectious waste from affiliated physician practices and other ambulatory care facilities, commonly provide transport of infectious waste. In general, states require the registration of vehicles used in the transportation of infectious waste.

Some facilities transport and treat their own infectious waste. Another option is to contract with appropriately licensed commercial companies to transport and treat healthcare wastes.

A waste manifest documenting the shipment information must accompany transported waste.[27] A waste manifest serves as a document that tracks the waste from the generating facility until its final disposition, and it acts as a record of the waste's movement. The waste manifest also acts as a legal document

whereby the generator certifies that the waste has been correctly classified, packed, marked, and labeled according to applicable shipping regulations. Because of this, it is important that the waste manifest be reviewed and signed by a trained individual before the waste is transported off-site. DOT considers the individual signing the waste manifest to be a hazardous materials employee, and thus the employer is required under Title 49 of the *Code of Federal Regulations* (CFR) to train that individual. Having the waste manifest signed by an untrained employee can result in significant penalties.

Copies of waste manifests must be retained for a minimum of 3 years under DOT regulations, and states may require longer retention times.[27] Staff such as clinical laboratory couriers involved in the handling of potentially infectious materials should receive specialized training as required by the OSHA Bloodborne Pathogens Standard (see the Training section, later in this chapter).[14]

## Treatment

Many options are available for the proper treatment of infectious waste.[3, 13, 26] The method selected will be determined by the amount of infectious waste generated, the capabilities of the facility, and the cost effectiveness of on-site treatment versus contracting the service to a licensed commercial vendor.

The type of treatment selected will depend on municipal, state, and federal regulations. Hospitals traditionally selected incineration as the primary method for treating infectious waste, but its use has declined due to EPA regulations related to the Clean Air Act and control of emissions.[3] Depending on the type of infectious waste, acceptable methods for rendering these materials innocuous include steam sterilization, chemical disinfection, gas/vapor sterilization, and irradiation decontamination. Modern alternative technologies have broadened the scope of available treatment options. Microwave, infrared, thermal plasma, and hyperchlorination, are only a few of the new technologies being used to render infectious waste innocuous.[42, 43, 44, 45]

The treatment selected should be based on the type of waste generated and the suitability of available options. States generally require that the efficacy of the treatment methods selected be monitored. The monitoring system selected will depend on the treatment method. For example, steam

sterilization treatment would be monitored using a biological indicator that includes *Geobacillus stearothermophilus* spores.[46]

## Disposal

The direct disposal of infectious waste at a properly sited landfill does not present a threat to public health and safety, according to many experts, and is still acceptable in many areas.[17]

However, perceived risk concerns and the nationwide movement away from land disposal have resulted in widespread landfill prohibitions on the disposal of untreated infectious waste in landfills.[15, 17] After treatment, medical wastes are usually disposed of in a sanitary landfill that is specifically designed to protect the environment from releases. Untreated liquid medical waste such as bulk blood or the contents of suction containers can be disposed of by carefully pouring them into the sanitary sewer when allowed by local regulations.

When designing an infectious waste management plan, it may be helpful to communicate with the waste hauler contractor and local landfill representatives during the planning process. This will help ensure that the healthcare facility follows regulatory codes, and, most importantly, it facilitates education and training for those who handle and haul these materials.

Municipal waste sites (landfills) will often evaluate waste to ensure it is acceptable for disposal. If medical waste is inappropriately disposed of in a municipal waste site, the generator of the waste can be fined for regulatory noncompliance.

## Contingency Planning

Healthcare organizations need to have systems in place to address unforeseen events that may disrupt the normal treatment, transportation, and disposal of infectious waste materials. Both on-site and off-site contingencies should be available, and alternate strategies should be available in case on-site treatment systems fail or there is an unanticipated power shortage. A backup disposal contractor should be designated in case there is a disruption of the ability of the primary outside contractor to serve the facility. Emergency spill procedures should also be in place for on-site and off-site emergencies.

The ability or willingness of your medical waste transporter or disposal to facility to manage all potential waste streams,

including possibly highly infectious or emergency disease waste, should be assessed and alternatives identified when needed.

### Training

Training of all personnel involved in the generation, handling, transporting, treatment, or disposal of infectious waste is imperative for the infectious waste management plan to be effective.[36, 37, 38, 47, 48, 49] Training should include:

- the definition of infectious waste,
- handling procedures,
- appropriate PPE,
- hand hygiene,
- labeling or coding that designates an item as infectious waste, and
- postexposure management.

Regulatory agencies such as OSHA and DOT require specific training for some personnel.[14, 27] For example, individuals

involved in the infectious waste shipping process (which includes signing of waste manifests), must meet DOT training requirements that includes at a minimum general awareness training, function-specific training, safety training, and security awareness training. As part of this training, the employee must be tested, and the employer must certify in writing that the employee has met the training requirements. Training must be completed within 90 days of hire, with refresher training completed every 3 years. The employer must maintain records associated with worker training.

## INFECTION PREVENTION AND CONTROL IMPLICATIONS

The IP may be involved in developing and coordinating the infectious waste management plan. The plan should be based on sound scientific information and be consistent with local, state, and federal regulations and guidelines.

When developing or revising a healthcare waste management plan, IPs and their colleagues should consider the following noteworthy points:

- The items used in the care of hospitalized patients can generate up to 25 pounds of hospital waste per day, which

averages to almost 7,000 tons of daily waste by hospitals.[50]

- About 10%-15% of the total hospital waste by weight is considered infectious waste (~1,000 tons/day).[50]
- The cost of disposing of infectious waste is up to 10 times greater than that for disposal of noninfectious hospital wastes, and up to 30 times more than recycling, adding $10 billion in annual disposal costs to health care.[50]
- With the exception of sharps such as needles, which have caused disease only in an occupational setting, there is no scientific evidence that medical waste has caused disease in hospital or community settings.[6]
- Household waste contains, on average, 100 times as many human pathogens as medical waste.[7]
- The beach wash-ups of syringe-related materials that created nationwide concern were found to come from improper landfill disposal, illegal drug use, and home healthcare; hospitals were not implicated as a cause of this problem.[5, 51, 52, 53]

# Other Waste Management Concerns

## PURCHASING

Products brought into healthcare settings and the development of policies and procedures related to their use should be part of an effective infection prevention and control program. HCP responsible for product selection should consider published recommendations and guidelines and comply with regulatory agency standards (e.g., standards for sharps, disposal containers, or chemotherapy waste boxes).

Studies have shown that relatively minor changes in the design, size, or location of sharps containers can result in a significant reduction in employee needlestick injuries.[54, 55] Workers involved with handling of waste, such as used needles, should be included in an evaluation process. (Also see **107. Minimizing Exposure to Blood and Body Fluids**.)

Waste minimization efforts, as part of a waste management plan, can be achieved by purchasing products that generate less waste or are substituted for existing items.

## WASTE DISPOSAL AREAS

Healthcare wastes of all types should be sorted at the point of creation to ensure appropriate handling and disposal. For example, used sharps should be immediately discarded into sharps disposal containers.

The design and construction of renovated or new healthcare facilities should be based on the Guidelines for Design and Construction of Hospitals published by the Facility Guidelines Institute (FGI), and an IP should be included in the process from conception through commissioning.[56] Waste handling and areas for storage and disposal should be designed and located as appropriate for the types of wastes generated by the facility. (Also see **118. Construction and Renovation** and **109. Environmental Services**)

## WASTE REDUCTION, INCLUDING REUSE AND RECYCLING

IPs may be asked to help evaluate reusable items to replace single-use, disposable items to reduce waste volume. (Also see **32. Reprocessing Single-Use Devices**.)

Reusable containers for regulated medical waste and sharps disposal boxes are one such effort that has gained popularity with the increased emphasis on environmental stewardship. Some have raised concerns over safety of reusable sharps disposal containers in terms of adequate removal of potential contaminants after they are emptied, cleaned/disinfected, and returned to a facility:

- Pogorzelska-Maziarz published a study comparing rates of *Clostridioides difficile* infections between hospitals that had single-use sharps containers versus those using recyclable sharps containers. In that study, hospitals using single-use sharps containers had a significantly lower rate of *C. difficile* infection compared to those that used reusable sharps containers.[57] Additional studies are required to further investigate what role these reusable sharps containers might be playing in pathogen transmission.
- Neely and associates compared single-use sharps containers with reusable sharps containers to determine levels of contamination for various microbes. This study found that there was less contamination on single-use containers, and that those microbes identified on containers have the potential

to cause harm among patients who may be immunocompromised.[58]

- Runner cultured surfaces of reusable containers for bacteria and certain viruses delivered to a community hospital.[59]

  Quantitative levels of microbes recovered were not provided in the study and, as in the study by Neely et al., most of the bacteria were common skin commensals. In Runner's study, polymerase chain reaction (PCR) testing identified a proportion positive for certain bloodborne viruses; however, PCR testing is very sensitive and does not always correlate with presence of viable infectious virus.[59]

IPs need to keep the findings of these studies in perspective relative to principles of disease transmission outlined in the Waste Terminology section of this chapter. If visible soil is found on or inside reusable containers, the container manufacturer should be promptly notified and the soiled containers should not be placed into use.

Surface contaminants, even with bloodborne infectious agents, do not represent an appreciable risk to HCP given routine use of gloves, hand hygiene, and the environment typical of the hospital setting. Extensive studies of risk of occupational exposure to bloodborne infectious agents have indicated that the risk strata is highest for hollow-bore devices introduced through the skin, much lower for percutaneous introduction of blood/other potentially infectious material, and likely negligible for intact skin that is in contact with a contaminated surface.[60]

By contrast, there is evidence that reusable sharps containers can dramatically lower the incidence of sharps injuries to healthcare personnel during disposal of contaminated sharps, although it is possible that the reduction was observed due to the reusable sharps containers having larger openings or being installed near the point of sharp use.[54, 61]

As described previously, the IP must be involved in the evaluation, selection, and implementation of a sharps disposal system, regardless of the container design that is chosen. A careful risk assessment should be completed to ensure that reprocessing of containers is effective and in compliance with regulations for the safety of patients and staff. The Joint Commission has provided some recommendations related to things to include as part of the risk assessment process.[62]

# Selected Special Types of Waste

## GENE THERAPY

As of October 2021, the FDA listed 22 approved cellular and gene therapy products [63] , and thousands of clinical trials were underway worldwide. Although human gene transfer and treatment had originally focused on genetic deficiency diseases, most trials and activities since gene therapy products were first approved have been aimed at cancer.[64]

The vectors used in gene therapy pose a potential infectious risk. Most protocols involve the use of adenovirus and retrovirus vectors, but lipofection and other noninfectious methods have also been evaluated. Other vectors that have been proposed or used include Epstein-Barr, baculovirus, canarypox, fowlpox, herpes simplex, vesicular stomatitis, and HIV viruses.[64]

Information related to the safety of gene therapy in healthcare settings was introduced to most IPs in two articles by Evans and Lesnaw.[65], [66]The authors recommended appropriate Transmission-based Precautions to protect HCP and other patients. For example, they suggested that waste resulting from gene therapy be handled as biohazardous material and that disposal treatment should follow medical regulated waste protocols (i.e., incineration). In some localities, regulations may require on-site inactivation of gene therapy waste before disposal.

The FDA Center for Biologics Evaluation and Research regulates gene therapy research and trials with the objective to ensure safety.[67] The NIH Novel and Exceptional Technology and Research Advisory Committee (NExTRAC) provides advice on safety and ethical issues related to emerging biotechnologies, including gene therapy.[68] At the local level, biotechnology research is supervised by Institutional Review Boards and Institutional Biosafety Committees, with optional input from Infection Control Committees.

Given the perceived theoretical nature of infection risk, the CDC has not yet developed formal clinical infection prevention guidelines for gene therapy. However, the CDC did participate in a multidisciplinary conference in 1999 that resulted in several infection prevention recommendations.[69], [70]

At least one study has indicated that the risk of adeno-associated virus vector mobilization may be a real safety concern that deserves attention.[71] The major goal for IPs is to prevent transmission of the vector or any recombinant vector between persons, including those handling and preparing the vectors (i.e., pharmacy). Therefore, the existing system recommended by the NIH and CDC for biosafety levels and disinfectants should be referenced.

Another concern is vector shedding, which may occur inside and outside an isolation room from the treated patient, those caring for the patient, and others entering the patient's area, including housekeeping personnel. Protocols for safe transport of the vector product and items for disposal should be established, and HCP involved in the protocols should receive training based on the vector and current knowledge of the vector.[72] Coordination with the waste disposal company may be required.

If a healthcare facility is involved in gene therapy, the IP should be consulted and involved in policy and procedure development as well as education and training. Gene therapy and vectors are evolving, and the IP should follow current guidelines as appropriate to minimize potential risks related to handling and disposal.

Some suggest that a biological safety officer be included as a key member of any gene therapy trial team. This role includes ensuring appropriate handling of waste materials.[73]

## PIPED SYSTEMS WASTE

Vacuum and suction systems are part of medical gas systems and should not be overlooked in a waste management program. The installers, inspectors, and verifiers should be certified based on codes and regulations.

Piped suction/vacuum systems and disposal of associated liquids are considered biohazardous. Such systems may be used for suction of body fluids in surgical and procedure areas, dentistry, laboratories, and research settings. The waste holding tank, part of the piped vacuum system, should be installed per manufacturer's recommendations, with the waste tank contents discarded through a drain into the sanitary sewer system. At higher biocontainment levels, liquid waste must be appropriately processed through an effluent treatment system before it is released into the sanitary sewer.[21, 22]

Laser plume and surgical smoke may be evacuated into the wall suction system in some locations. Analysis of surgical smoke and aerosols has found the presence of viable organisms, including bacteria and viruses, in addition to numerous potentially hazardous chemicals. Patient-to-patient and patient-to-provider transmission of human papillomavirus has been reported during a laser procedure.[74, 75] More recently, laser plume has been shown to be of potential concern for infection with SARS-CoV-2.[76]

Use of wall suction, even with in-line filtration, is only suitable for minimal amounts of plume; a smoke evacuator system with appropriate filtration system is preferred. In both situations, the in-line filters from wall suction and plume capture equipment should be treated and discarded as potentially infectious waste.

## EMERGING INFECTIOUS AGENTS AND POTENTIAL BIOTERRORISM AGENTS

Certain agents, including microbes and biologicals, have been identified based on their risk to national security or public health and are known as Select Agents and Toxins. Each facility not registered with the Federal Select Agent Program with diagnostic or clinical laboratories that could receive these specimens must have the capacity to destroy discarded cultures and stocks on-site or transfer them to a registered facility within 7 days after diagnosis or verification.[77]

Hospitals that could potentially treat patients infected with these agents should have plans in place for government notification and safe handling/disposal of generated medical waste. (See the next section of this chapter, Category A Regulated Infectious Substances.)

The emergence of new infectious agents may present new challenges in waste disposal, especially when knowledge about a causative agent is limited and information about transmission or infectious nature is incomplete, such as was seen recently with SARS-CoV-2. In these cases, stringent recommendations for waste handling and disposal are often implemented.

As of September 2021, CDC guidance on COVID-19 does not require any special handling or precautions other than those normally used for other types of waste generated from non-COVID-19 patients.[78] However, the COVID-19 pandemic, which

began in early 2020, has had a significant impact on medical waste management. When the nature of disease transmission was unknown, hospitals produced more waste than usual as PPE use increased and more materials than usual were being treated as potentially infectious. Items that previously would have been recycled or reused were instead being redirected into the more traditional medical waste streams to minimize risk of disease transmission.[49, 79] This increase in waste volume, combined with the commercial shutdowns and other supply chain issues, resulted in fewer recycling and treatment options than would be normally available.[80]

Tissues and certain wastes from prion diseases such as Creutzfeldt-Jakob disease and the variant strain causing bovine spongiform encephalopathy (commonly called mad cow disease) require special handling and disposal. (Also see **75. Creutzfeldt-Jakob Disease and Other Prion Diseases**) Incineration with a minimum secondary temperature of 1,000°C or alkaline hydrolysis using pressurized 1 N NaOH or 20,000 ppm sodium hypochlorite at 121°C are two possible disposal methods for animal carcasses and other tissues suspected of containing prions.[81]

Potential bioterrorism agents, such as smallpox and Ebola virus, have prompted guidance that includes waste handling and disposal. For example, even though the smallpox vaccine does not contain the smallpox virus, smallpox vaccination plans should still address the handling and disposal of bifurcated needles, vaccination site dressings, and discarded unused vaccine. (Also see **122. Infectious Disease Disasters: Bioterrorism, Emerging Infections, and Pandemics** and **98. Viral Hemorrhagic Fevers**.)

## CATEGORY A REGULATED INFECTIOUS AGENTS

Infectious substances can be categorized based on their ability to cause permanent disability, life-threatening, or fatal diseases. Category A infectious agents such as Ebola virus can cause permanent disability, life-threatening, or fatal diseases upon human or animal exposure, whereas Category B infectious agents cannot.[82]

Waste contaminated with Category A agents is deemed regulated medical waste, and its disposal must be managed in one of two

ways—it is either inactivated on-site or transported to a facility for disposal.[83] The most common waste disposal method is on-site inactivation. There are several ways a facility can inactivate Category A waste, including the use of an autoclave or incineration. These procedures should be outlined in a facility's waste management plan. Once inactivated, the waste is no longer considered Category A or regulated medical waste and can be handled as general waste, as long as it is not considered hazardous under the Resource Conservation and Recovery Act.[83]

If a facility cannot properly inactivate the Category A waste itself, it can elect to transport the waste to a facility that has disposal capability. However, Category A waste is held to more stringent DOT regulations than general regulated medical waste.[82]

Transportation of Category A waste must comply with DOT's Hazardous Materials Regulations.[84] These regulations require that hazardous waste is properly packaged and labeled and the proper shipping documentation is completed. Category A waste can also be transported by entities that have obtained a special permit from DOT. A special permit allows special, often larger, packaging for Category A wastes to be used when available packaging is not adequate. Traditional Category A packaging is designed to transport low volumes of waste normally seen in research settings.

The 2014-2016 Ebola outbreak in West Africa was the first to result in Ebola transmission in the United States, and the treatment of Ebola patients resulted in significant waste management challenges for the US hospitals that provided care.[85] (See 98. Old - Viral Hemorrhagic Fevers - You do not have permission to view this object. for details on the 2014-2016 outbreak and the US Ebola cases.) Medical treatment of patients infected with Category A infectious agents produce a larger volume of waste; a single Ebola patient generates about 440 gallons of waste each day.[86] To accommodate increased transportation volumes of Ebola waste, DOT issued special permits to allow the use of alternative packaging. This practice eased waste management limitations and aided in timely waste destruction.[83]

The Ebola crisis illustrated the need for effective plans to manage Category A waste and identify facilities willing to accept such waste. Healthcare workers handling waste generated during the 2014 Ebola outbreak experienced perceptions of lack of

preparedness/training and fear of disease transmission when handling these infected patients and their waste.[87] After the planned incinerator in Louisiana refused to accept Ebola waste generated from a Dallas, Texas, hospital patient in 2014, the University of Texas Medical Branch agreed to accept the waste and destroy it in their medical waste incinerator.[88, 89] Healthcare organizations should proactively address preparedness planning, training, and PPE for HCP and confirm the willingness of their medical waste processors to accept these types of waste and identify suitable alternatives if necessary.

## Selecting Technologies for Waste Treatment

Many technologies are available or under development to treat or decontaminate regulated medical wastes.[90] Methods reduce microbial load, and the final waste product does not need to be sterile prior to disposal. Processes include autoclaving, incineration, internment (anatomic wastes), chemical disinfection, grinding/shredding/disinfection methods, energy-based technology (microwave or radio waves), disinfection/encapsulation, and disposal into a sanitary sewer.[90, 91]

Incineration is an effective method for treating most medical wastes and is appropriate for antineoplastics; however, it should not be used for radionuclides. Regulation at federal and state levels, due to environmental impact, has limited the availability of incinerators, so alternative methodologies—both on-site and off-site—are being used.

Criteria for choosing a treatment method include the following:[45, 90, 92]

- Suitability for types of waste
- Risks related to handling
- Effectiveness of treatment
- Uniformity or quality of process
- Costs (capital, operating, startup, labor, materials)
- Success of process (experience of others using same method)
- Occupational and environmental risks
- Reduction in waste volume and weight

- Community acceptance
- Applicable regulatory requirements

## Performance Improvement

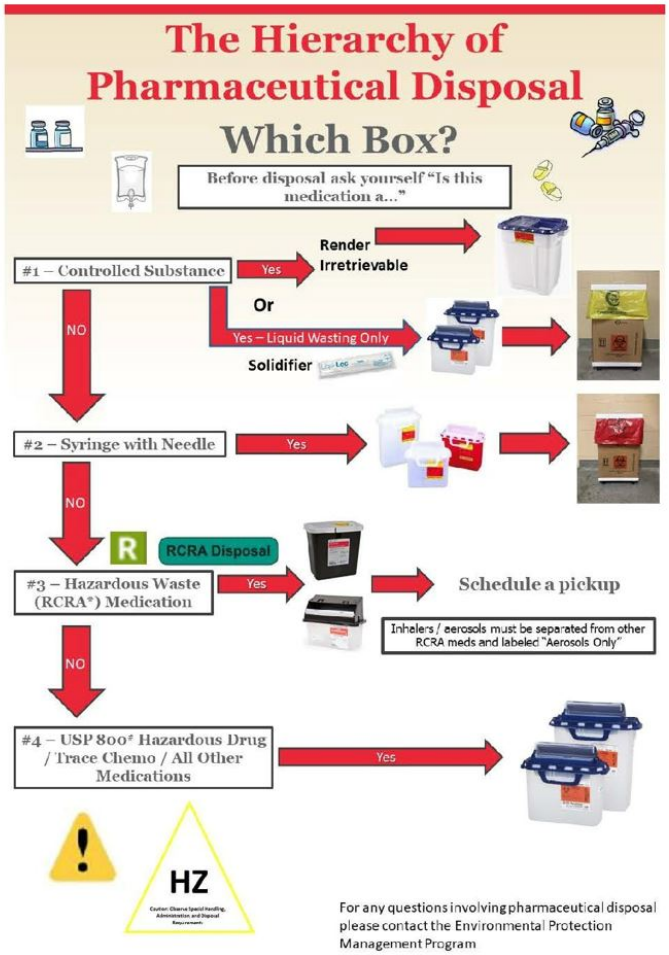
To help assess the effectiveness of the waste management plan, performance improvement measurements can be used. For example, standards from the Joint Commission may be referenced when identifying and documenting a performance improvement activity. Examples of performance improvement related to waste include:

- monitoring exposures to body fluids and sharps injuries related to disposals of contaminated needles;
- monitoring the “fullness” of sharps disposal containers to determine whether the containers are changed at proper intervals; and
- evaluating whether waste is sorted appropriately by conducting a visual audit or assessing the contents in waste containers (appropriate precautions are required if the latter approach is used).

Periodic audits of waste generation areas and accumulation points, including questioning of staff on appropriate waste management procedures, can help an organization identify opportunities for training and process improvements. Focused training aimed at improving the knowledge of HCP and medical waste handlers can also improve management of medical waste and reduce injury rates.[36]

Regardless of the performance improvement monitors selected, the data should be used to ensure the program is working. Data analysis and reports of performance improvement measures provide objective measures to verify the effectiveness of any corrective actions taken and identify opportunities for improvement. Cost-reduction strategies may follow the same strategy outlined in a report by Windfeld and Brooks describing several interventions and related improvement measurements that can be used to reduce the volume and cost of disposing of infectious waste.[10] Figure 3 provides an example of a poster than can be provided to help frontline staff appropriately differentiate and segregate various types of waste streams.

**Figure 115-3.**




**Poster to help frontline staff manage pharmaceutical waste.**

Source: Graphic developed and used with permission by Dean Leathers, UTMB

*RCRA = Resources Conservation and Recovery Act, the law that authorizes the US Environmental Protection Agency (EPA) to regulate hazardous waste. RCRA is also used to refer to the EPA's policies to regulate hazardous waste (**https//www.epa.gov/rcra/resource-conservation-and-recovery-act-rcra-overview**).

*USP800 = United States Pharmacopeial Convention. USP General Chapter <800>: Hazardous drugs—handling in healthcare settings. 2017. Accessed December 15 2021. **http://www.org/sites/default/files/usp/document/our-work/healthcare-quality-safety/general-chapter-800.pdf**

View Image

## Conclusions

This chapter provides a brief overview of practical information necessary for the appropriate management of wastes generated in healthcare settings that may present an infectious risk. As the CDC explains, “The most practical approach to medical waste management is to identify waste that represent[s] a sufficient potential risk of causing infection during handling and disposal and for which some precautions likely are prudent.”[6]

## Future Trends

Costs for packaging, segregation, treatment, and disposal of infectious waste will likely increase in the future. The use of incineration as a waste disposal method will likely continue to decline as other treatment technologies develop and regulations on incinerators become more stringent.

Scientific studies to characterize the risks associated with healthcare wastes will assist lawmakers in updating regulations. Recycling of some items currently categorized as infectious waste is under consideration; with plastic making up about 35% of medical waste, it presents a possible opportunity for recycling.[49] Environmental stewardship will also prompt continued interest in interventions to minimize waste volume, such as reusable disposal containers. As resources become more limited and environmental concerns intensify, innovative approaches to managing healthcare wastes will continue to evolve.

## International Perspective

A review of the permutations and combinations of waste management systems in use throughout the international community is beyond the scope of this chapter. However, the literature suggests that waste management systems outside of the United States vary drastically, from none at all to highly regulated functioning systems.[37,47,48,93,94,95]

Many countries have considered the regulations and guidelines promulgated in the United States to help establish their own standards. Some countries have encountered “growing pains” like those the US healthcare community went through in the 1980s and 1990s.

For example, according to Udofia and coauthors, 89% of households in Southern Ghana disposed of unwanted medicines and sharps in regular trash without any type of container.[96]

Nigeria has seen recent improvements in healthcare facility waste segregation and management through the adoption of a national policy for healthcare waste management.[97]

Problems associated with infectious waste disposal practices are compounded in underdeveloped countries where trash may be dumped anywhere. Trash "pickers" commonly rummage through discarded trash to find usable or salable items. Children are often involved, and this practice represents another source of infectious disease exposure beyond those caused by poor sanitation, lack of safe food and water, and poor medical care.

Unfortunately, the mismanagement of healthcare waste has caused some institutions in developing countries to give up single-use syringes in favor of reusable glass syringes. While this eliminates the waste management issues, reusable syringes are an infection risk if they are not properly sterilized.

The following are examples of general infectious waste issues that have been cited in the international literature:[37, 47, 48, 93, 94, 95, 96, 97, 98]

- Professional training in how to handle infectious wastes is lacking.
- The proliferation of other medical concerns means that waste management, in general, is ignored.
- Licensing standards are unclear, conflicting, or confusing.
- Healthcare facilities do not have waste collection and storage plans or lack the finances and resources to successfully implement them.
- Even when waste management laws and regulations are enacted, they are not always enforced.
- Needles and syringes are commonly thrown in the regular trash.
- Necessary technologies such as incineration or sterilization are unavailable or inadequate.

IPs and others in the international community looking to implement a practical, scientific, infectious waste management program can refer to the body of this chapter in addition to references cited and the supplemental resources provided.

# Supplemental Resources

Agency for Toxic Substances and Disease Registry. **https://www.atsdr.cdc.gov**

American Society of Gene and Cell Therapy. **https://www.asgct.org**

Association for Professionals in Infection Control and Epidemiology. **https://www.apic.org**

Canadian Standards Association. *CSA Z317.10:21 Standard: Handling of Waste Materials in Health Care Facilities and Veterinary Health Care Facilities*. Toronto, ON: CSA Group; 2021.

Centers for Disease Control and Prevention. Workbook for designing, implementing, and evaluating a sharps injury prevention program. Page last reviewed February 11, 2015. **https://www.cdc.gov/sharpssafety/resources.html**

Centers for Disease Control and Prevention. Primary containment of biohazards. selection, installation and use of biological safety cabinets. Appendix A. In *Biosafety in Microbiological and Biomedical Laboratories (BMBL).* 6th ed. Page last reviewed November 17, 2020. **https://www.cdc.gov/labs/BMBL.html**

Clinical and Laboratory Standards Institute. **https://clsi.org**

Friedman C, Petersen KH. *Infection Control in Ambulatory Care*. Sudbury, MA: Jones and Bartlett Publishers; 2004.

Healthcare Environmental Resource Center. **https://www.hercenter.org**

National Institutes of Health. **https://www.nih.gov**

National Institutes of Health Office of Research Facilities. Waste management services.**https://orf.od.nih.gov/EnvironmentalProtection/WasteDisposal/Pages/default.aspx**

Physicians for Social Responsibility. **https://www.psr.org**

US Department of Transportation. **https://www.transportation.gov**

US Environmental Protection Agency. **https://www.epa.gov**

US Occupational Safety and Health Administration. **https://www.osha.gov**

World Health Organization. Laboratory biosafety manual, 4th ed. Revised December 21, 2020. **https://www.who.int/publications/i/item/9789240011311**

World Health Organization. Health-care waste (fact sheet). February 8, 2018. **https://www.who.int/news-room/fact-sheets/detail/health-care-waste**

World Health Organization. Policy paper: safe health-care waste management. 2004. **https://www.who.int/water_sanitation_health/medicalwaste/en/hcwmpolicye.pdf**

## References

[1] New Jersey Department of Environmental Protection. DEP snapshot: it's 1988, legislation passed on ocean dumping to keep beaches cleaner. Published May 19, 2020. Accessed October 23, 2021. **https://www.nj.gov/dep/dep50/snapshots/20_S019.html**

[2] Keene JH. Medical waste: a minimal hazard. Infect Control Hosp Epidemiol. 1991;12(11):682-685. doi:**10.1086/646266**

[3] Environmental Protection Agency. Medical waste. Updated March 29, 2021. Accessed January 18, 2022. **https://www.epa.gov/rcra/medical-waste**

[4] Suter L. Needles, medical waste wash up on shore at Venice Beach. ABC7 Los Angeles. Published November 10, 2019. Accessed January 18, 2022. **https://abc7.com/5688531**

[5] Warren MS, Napoliello A; NJ Advance Media for NJ.com. More syringes are washing up on Jersey beaches. It's a problem that starts miles away. Published August 7, 2018; updated May 14, 2019. Accessed January 18, 2022. **https://www.nj.com/news/2018/08/more_syringes_are_showing_up_on_jersey_beaches_her.html**

[6] Centers for Disease Control and Prevention. Environmental infection control guidelines. Last reviewed July 23, 2019. Accessed January 18, 2022. **https://www.cdc.gov/infectioncontrol/guidelines/environmental/index.html**

[7] Rutala WA, Mayhall CG, Society for Hospital Epidemiology of America. SHEA position paper: medical waste. Infect Control Hosp Epidemiol. 1992;13(1):38-48. doi:**10.2307/30146966**

[8] Komilis D, Fouki A, Papadopoulos D. Hazardous medical waste generation rates of different categories of health-care facilities. Waste

Manag. 2012;32(7):1434-1441. doi:**10.1016/j.wasman.2012.02.015**

[9] Hedrick ER. Infectious waste management—will science prevail? Infect Control Hosp Epidemiol. 1988;9(11):488-490. doi:**10.1086/645757**

[10] Windfeld ES, Brooks MS-L. Medical waste management -- a review. J Environ Manage. 2015;163:98-108. doi:**10.1016/j.jenvman.2015.08.013**

[11] The Joint Commission. Comprehensive Accreditation Manual for Hospitals. Oakbrook, IL: Joint Commission Resources; 2021.

[12] Padmanabhan KK, Barik D. Health hazards of medical waste and its disposal. In Barik E, ed. Energy from Toxic Organic Waste for Heat and Power Generation. Cambridge, MA: Elsevier;2019:99-118. doi:**10.1016/B978-0-08-102528-4.00008-0**

[13] Chartier Y, Emmanuel J, Pieper U, et al., eds. Safe Management of Wastes from Health-Care Activities. 2nd ed. Geneva, Switzerland: World Health Organization; 2014. Accessed January 18, 2022. **https://www.euro.who.int/__data/assets/pdf_file/0012/268779/Safe-management-of-wastes-from-health-care-activities-Eng.pdf**

[14] Occupational Safety and Health Administration. Standard 1910.1030 -- Bloodborne pathogens. Published May 14, 2019. Accessed January 18, 2022. **https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.1030**

[15] Xiang R, Xu Y, Liu Y-Q, Lei G-Y, Liu J-C, Huang Q-F. Isolation distance between municipal solid waste landfills and drinking water wells for bacteria attenuation and safe drinking. Sci Rep. 2019;9(1):17881. doi:**10.1038/s41598-019-54506-2**

[16] Li L, Wang Q, Bi W, et al. Municipal solid waste treatment system increases ambient airborne bacteria and antibiotic resistance genes. ACS Environ Sci Technol. 2020;54(7):3900-3908. doi:**10.1021/acs.est.9b07641**

[17] Gerba CP, Tamimi AH, Pettigrew C, Weisbrod AV, Rajagopalan V. Sources of microbial pathogens in municipal solid waste landfills in the United States of America. Waste Manag Res. 2011;29(8):781-790. doi:**10.1177/0734242X10397968**

[18] Collins CH, Kennedy DA. The microbiological hazards of municipal and clinical wastes. J Appl Bacteriol. 1992;73(1):1-6. doi:**10.1111/j.1365-2672.1992.tb04961.x**

[19] Centers for Disease Control and Prevention. National Occupational Research Agenda. Stop sticks campaign: sharps injuries. Page last reviewed February 26, 2019. Accessed January 18, 2022. **https://www.cdc.gov/nora/councils/hcsa/stopsticks/sharpsinjuries.html**

[20] National Institute for Occupational Safety and Health. *Selecting, Evaluating, and Using Sharps Disposal Containers.* Atlanta, GA: National Institute for Occupational Safety and Health; 1998. Accessed January 18, 2022. **https://www.cdc.gov/niosh/docs/97-111/default.html**

[21] Centers for Disease Control and Prevention. Biosafety in microbiological and biomedical laboratories (BMBL). 6th ed. Published June 2020. Accessed January 18, 2022. **https://www.cdc.gov/labs/BMBL.html**

[22] World Health Organization. Laboratory biosafety manual. 4th ed. Published December 21, 2020. Accessed January 18, 2022. **https://www.who.int/publications/i/item/9789240011311**

[23] National Institutes of Health Office of Science Policy. NIH Guidelines for research involving recombinant or synthetic nucleic acid molecules (NIH guidelines). Published April 2019. Accessed January 18, 2022. **https://osp.od.nih.gov/biotechnology/nih-guidelines**

[24] Lester SC. Safety precautions. In Manual of Surgical Pathology. 3rd ed. Philadelphia, PA: Saunders; 2010:196-203. doi:**10.1016/B978-0-323-06516-0.10008-6**

[25] Ramesh G, Katiyar A, Sujatha R, Raj A, Gupta B, Kumar A. Detection of microorganisms on formalin-fixed and stored pathology tissues: a microbiological study. J Oral Maxillofac Pathol. 2017;21(1):64-69. doi:**10.4103/0973-029X.203788**

[26] International Committee of the Red Cross. Medical waste management. Published 2011. Accessed January 18, 2022. **https://www.icrc.org/en/publication/4032-medical-waste-management**

[27] Environmental Protection Agency. Regulated medical waste. 49 CFR 173.197 (2011). Accessed January 18, 2022. **https://www.govinfo.gov/app/details/CFR-2011-title49-vol2/CFR-2011-title49-vol2-sec173-197**

[28] Occupational Safety and Health Administration. Occupational exposure to bloodborne pathogens; needlestick and other sharps injuries; final rule. Fed Regist. 2001;66:5317-5325. Codified at 29 CFR 1910. Accessed January 18, 2022. **https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_id=16265&p_table=FEDERAL_REGISTER**

[29] Agency for Toxic Substances and Disease Registry. Perspectives in disease prevention and health promotion summary of the Agency for Toxic Substances and Disease Registry report to Congress: The public health implications of medical waste. MMWR Wkly.

1990;39(45);822-824. Accessed January 18, 2022. **https://www.cdc.gov/mmwr/preview/mmwrhtml/00001835.htm**

[30] DNV GL Healthcare USA. National Integrated Accreditation for Healthcare Organizations (NIAHO) accreditation requirements, interpretive guidelines, and surveyor guidance for hospitals -- revision 20-1. Published September 21, 2020. Accessed January 18, 2022. **https://www.dnv.us/assurance/healthcare/standards/niaho-ac-dl.html**

[31] US Postal Service. Publication 52: Hazardous, restricted, and perishable mail. Published May 20, 2021. Accessed January 18, 2022. **https://pe.usps.com/text/pub52/welcome.htm**

[32] US Environmental Protection Agency. How is mixed waste regulated? Updated October 19, 2021. Accessed January 18, 2022. **https://www.epa.gov/radiation/how-mixed-waste-regulated**

[33] US Food and Drug Administration. Container, sharps. FDA product classification. Published January 17, 2022. Accessed January 18, 2022. **https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfPCD/classification.cfm?id=2772**

[34] US Food and Drug Administration. Regulatory controls: general controls for medical devices. Published March 2018. Accessed January 18, 2022. **https://www.fda.gov/medical-devices/overview-device-regulation/regulatory-controls**

[35] US Food and Drug Administration. Medical device classification procedures: definitions. 21 CFR 860.3 (2020). Accessed January 18, 2022. **https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/cfrsearch.cfm?fr=860.3**

[36] Hosny G, Samir S, El-Sharkawy R. An intervention significantly improve medical waste handling and management: a consequence of raising knowledge and practical skills of health care workers. Int J Health Sci. 2018;12(4):56-66.

[37] Karki S, Niraula SR, Karki S. Perceived risk and associated factors of healthcare waste in selected hospitals of Kathmandu, Nepal. PLOS ONE. 2020;15(7):e0235982. doi:**10.1371/journal.pone.0235982**

[38] Kumar R, Shaikh BT, Somrongthong R, Chapman RS. Practices and challenges of infectious waste management: a qualitative descriptive study from tertiary care hospitals in Pakistan. Pak J Med Sci. 2015;31(4):795-798. doi:**10.12669/pjms.314.7988**

[39] Shinn HK, Hwang Y, Kim B-G, et al. Segregation for reduction of regulated medical waste in the operating room: a case report. Korean J Anesthesiol. 2017;70(1):100-104. doi:**10.4097/kjae.2017.70.1.100**

[40] Wyssusek KH, Foong WM, Steel C, Gillespie BM. The gold in garbage: implementing a waste segregation and recycling initiative. AORN J. 2016;103(3):316.e1-8. doi:**10.1016/j.aorn.2016.01.014**

[41] Martin DM, Yanez ND, Treggiari MM. An initiative to optimize waste streams in the operating room: RECycling in the Operating Room (RECOR) project. AANA J. 2017;85(2):108-112.

[42] Zimmermann K. Microwave as an emerging technology for the treatment of biohazardous waste: a mini-review. Waste Manag Res. 2017;35(5):471-479. doi:**10.1177/0734242X16684385**

[43] Waldenmaier EW, Waldenmaier HEW, Green MW. System and method for disinfecting medical waste. US patent 10,399,086. Document i.d. 20160228590A1. Published August 11, 2016. Accessed January 18, 2022. **https://patents.google.com/patent/US20160228590A1/en**

[44] ai X, Du C. Thermal plasma treatment of medical waste. Plasma Chem Plasma Process. 2021;41:1-46. doi:**10.1007/s11090-020-10119-6**

[45] Healthcare Environmental Resource Center. Treatment and disposal of regulated medical waste. Published 2015. Accessed January 18, 2022. **https://www.hercenter.org/rmw/treatment.php**

[46] US Food and Drug Administration. Guidance for industry and FDA staff: biological indicator (BI) premarket notification [510(k)] submissions. Issued October 4, 2007. Accessed January 18, 2022. **https://www.fda.gov/media/71134/download**

[47] Oroei M, Momeni M, Palenik CJ, Danaei M, Askarian M. A qualitative study of the causes of improper segregation of infectious waste at Nemazee Hospital, Shiraz, Iran. J Infect Public Health. 2014;7(3):192-198. doi:**10.1016/j.jiph.2014.01.005**

[48] Dehghani MH, Ahrami HD, Nabizadeh R, Heidarinejad Z, Zarei A. Medical waste generation and management in medical clinics in South of Iran. MethodsX. 2019;6:727-733. doi:**10.1016/j.mex.2019.03.029**

[49] Singh N, Ogunseitan OA, Tang Y. Medical waste: current challenges and future opportunities for sustainable management. Crit Rev Environ Sci Technol. Published February 10, 2021. doi:**10.1080/10643389.2021.1885325**

[50] American Society for Health Care Engineering, Association for the Health Care Environment, Association for Health Care Resources & Materials Management, American Hospital Association. Sustainability roadmap for hospitals: waste. Published 2015. Accessed January 18, 2022. **http://www.sustainabilityroadmap.org/topics/waste.shtml#.YGDYqT9OmUk**

[51] Goduci J. Managing biohazardous waste: the syringe tide [blog post]. Enviromerica. Published July 31, 2018. Accessed January 18, 2022. **https://enviromerica.com/managing-biohazardous-waste-the-syringe-tide**

[52] Homer A. A history of healthcare waste. Pennsylvania State Nurses Association. Published May 2, 2016. Accessed January 18, 2022. **https://www.psna.org/a-history-of-healthcare-waste**

[53] Gross J. Beach debris still a mystery; 77 syringes wash up on S.I. The New York Times. Published July 12, 1988. Accessed January 18, 2022. **https://www.nytimes.com/1988/07/12/nyregion/beach-debris-still-a-mystery-77-syringes-wash-up-on-si.html**

[54] Grimmond T, Naisoro W. Sharps injury reduction: a six-year, three-phase study comparing use of a small patient-room sharps disposal container with a larger engineered container. J Infect Prev. 2014;15(5):170-174. doi:**10.1177/1757177414543088**

[55] Denny J. Reducing the risk of needlestick injuries in hospital. BMJ Qual Improv Rep. 2013;2(2). doi:**10.1136/bmjquality.u586.w511**

[56] Facilities Guidelines Institute. Guidelines for Design and Construction of Hospitals. 2018 ed. New York: Facility Guidelines Institute; 2018.

[57] Pogorzelska-Maziarz M. Relationship between sharps disposal containers and Clostridium difficile infections in acute care hospitals. Am J Infect Control. 2015;43(10):1081-1085. doi:**10.1016/j.ajic.2015.06.007**

[58] Neely AN, Maley MP, Taylor GL. Investigation of single-use versus reusable infectious waste containers as potential sources of microbial contamination. Am J Infect Control. 2003;31(1):13-17. doi:**10.1067/mic.2003.17**

[59] Runner JC. Bacterial and viral contamination of reusable sharps containers in a community hospital setting. Am J Infect Control. 2007;35(8):527-530. doi:**10.1016/j.ajic.2006.09.017**

[60] Centers for Disease Control and Prevention. Exposure to blood: what healthcare personnel need to know. Published July 2003. Accessed January 18, 2022. **https://www.cdc.gov/hai/pdfs/bbp/exp_to_blood.pdf**

[61] Bylund S, Fink R, Grimmond TR, et al. Reduction of sharps injuries with a reusable sharps containment safety device—a 28 hospital study. Am J Infect Control. 2009;37(5):E141-E142. doi:**10.1016/j.ajic.2009.04.192**

[62] The Joint Commission. Medical equipment—sharps/needle boxes risk assessment. What are the specific requirements for the deployment of sharps containers? Updated October 21, 2021. Accessed January 18,

2022. **https://www.jointcommission.org/standards/Standard-FAQs/Home_Care/Environment_of_Care_EC/000001226**

[63] US Food and Drug Administration. Approved Cellular and Gene Therapy Products. Content current as of October 26, 2021. Accessed January 18, 2022. **https://www.fda.gov/vaccines-blood-biologics/cellular-gene-therapy-products/approved-cellular-and-gene-therapy-products**

[64] Shahryari A, Saghaeian Jazi M, Mohammadi S, et al. Development and clinical translation of approved gene therapy products for genetic disorders. Front Genet. 2019;10:868. doi:**10.3389/fgene.2019.00868**

[65] Evans ME, Lesnaw JA. Infection control in gene therapy. Infect Control Hosp Epidemiol. 1999;20(8):568-576. doi:**10.1086/501674**

[66] Evans ME, Lesnaw JA. Infection control for gene therapy: a busy physician's primer. Clin Infect Dis. 2002;35(5):597-605. doi:**10.1086/342194**

[67] US Food and Drug Administration Center for Biologics Evaluation and Research. Cellular & gene therapy products. Published July 9, 2021. Accessed January 18, 2022. **https://www.fda.gov/vaccines-blood-biologics/cellular-gene-therapy-products**

[68] National Institutes of Health Office of Science Policy. Novel and Exceptional Technology and Research Advisory Committee. Published April 8, 2019. Accessed January 18, 2022. **https://osp.od.nih.gov/biotechnology/main-nextrac**

[69] Centers for Disease Control and Prevention. Guideline for Isolation Precautions: preventing transmission of infectious agents in healthcare settings (2007). Last reviewed July 22, 2019. Accessed January 18, 2022. **https://www.cdc.gov/infectioncontrol/guidelines/isolation/scientific-review.html**

[70] Evans ME, Jordan CT, Chang SM, et al. Clinical infection control in gene therapy: a multidisciplinary conference. Infect Control Hosp Epidemiol. 2000;21(10):659-673. doi:**10.1086/501711**

[71] Song L, Samulski RJ, Hirsch ML. Adeno-associated virus vector mobilization, risk versus reality. Hum Gene Ther. 2020;31(19-20):1054-1067. doi:**10.1089/hum.2020.118**

[72] Brown AM, Blind J, Campbell K, Ghosh S. Safeguards for using viral vector systems in human gene therapy: a resource for biosafety professionals mitigating risks in health care settings. Appl Biosaf. 2020;25(4):184-193. doi:**10.1177/1535676020934917**

[73] Petrich J, Marchese D, Jenkins C, Storey M, Blind J. Gene replacement therapy: a primer for the health-system pharmacist. J

Pharm Pract. 2020;33(6):846-855. doi:**10.1177/0897190019854962**

[74] Katoch S, Mysore V. Surgical smoke in dermatology: its hazards and management. J Cutan Aesthetic Surg. 2019;12(1):1-7. doi:**10.4103/JCAS.JCAS_177_18**

[75] Cox SV, Dobry AS, Zachary CB, Cohen JL. Laser plume from human papillomavirus–infected tissue: a systematic review. Dermatol Surg. 2020;46(12):1676-1682. doi:**10.1097/DSS.0000000000002757**

[76] Sullivan JR, Rademaker M, Goodman G, Bekhor P, Al-Niaimi F. Guidance on infection control and plume management with laser and energy-based devices taking into consideration COVID-19. Australas J Dermatol. Published online August 19, 2020. doi:**10.1111/ajd.13425**

[77] Centers for Disease Control and Prevention/US Department of Agriculture Federal Select Agent Program. FAQ: report of identification of select agent or toxin. Last reviewed January 20, 2021. Accessed January 18, 2022. **https://www.selectagents.gov/compliance/faq/reporting.htm**

[78] Centers for Disease Control and Prevention (CDC). Interim Infection prevention and control recommendations for healthcare personnel during the coronavirus disease 2019 (COVID-19) pandemic. Updated September 10, 2021. Accessed January 18, 2022. **https://www.cdc.gov/coronavirus/2019-ncov/hcp/infection-control-recommendations.html**

[79] Sarkodie SA, Owusu PA. Impact of COVID-19 pandemic on waste management. Environ Dev Sustain. Published online August 26, 2020:1-10. doi:**10.1007/s10668-020-00956-y**

[80] You S, Sonne C, Ok YS. COVID-19's unsustainable waste management. Science. 2020;368(6498):1438-1438. doi:**10.1126/science.abc7778**

[81] World Health Organization. WHO infection control guidelines for transmissible spongiform encephalopathies: report of a WHO consultation, Geneva, Switzerland, 23-26 March 1999. Published 2000. Accessed January 18, 2022. **https://apps.who.int/iris/handle/10665/66707**

[82] US Department of Transportation. Transporting infectious substances overview. Updated April 2, 2020. Accessed January 18, 2022. **https://www.phmsa.dot.gov/transporting-infectious-substances/transporting-infectious-substances-overview**

[83] US Department of Transportation. Planning guidance for handling category a solid waste. Published August 2019. Accessed January 18, 2022. **https://www.phmsa.dot.gov/transporting-infectious-substances/planning-guidance-handling-category-solid-waste**

[84] US Department of Transportation. Category A infectious substances.49 CFR 173.196 (2002). Accessed January 18, 2022. **https://www.govinfo.gov/app/details/CFR-2011-title49-vol2/CFR-2011-title49-vol2-sec173-196**

[85] World Health Organization, Pan American Health Organization. First imported Ebola case is reported in the Americas. Published September 30, 2014. Accessed January 18, 2022. **https://www.paho.org/hq/index.php?option=com_content&view=article&id=10039:2014-first-imported-ebola-case-is-reported-in-the-americas&Itemid=135&lang=en**

[86] CBS News. New challenge for hospitals dealing with Ebola. Published October 21, 2014. Accessed January 18, 2022. **https://www.cbsnews.com/news/ebola-outbreak-hospitals-struggle-to-dispose-of-patient-generated-waste**

[87] Speroni KG, Seibert DJ, Mallinson RK. Nurses' perceptions on Ebola care in the United States, part 2: a qualitative analysis. J Nurs Adm. 2015;45(11):544-550. doi:**10.1097/NNA.0000000000000261**

[88] Associated Press. UTMB to destroy Ebola waste from Dallas hospital. Published October 17, 2014. Accessed January 18, 2022. **https://www.khou.com/article/news/health/ebola/utmb-to-destroy-ebola-waste-from-dallas-hospital/285-412266871**

[89] Catalanello R. Ebola waste will not be accepted at Louisiana hazardous waste facility. Times-Picayune/NOLA.com. Published October 13, 2014. Accessed January 18, 2022. **https://www.nola.com/entertainment_life/health_fitness/article_dc984fce-6c66-57ce-88be-1ec7398a7314.html**

[90] Health Care Without Harm. Non-incineration medical waste treatment technologies. Published August 2001. Accessed January 18, 2022. **https://noharm-uscanada.org/sites/default/files/documents-files/2062/Non-Incineration_Technologies.pdf**

[91] Voudrias EA. Technology selection for infectious medical waste treatment using the analytic hierarchy process. J Air Waste Manag Assoc. 2016;66(7):663-672. doi:**10.1080/10962247.2016.1162226**

[92] World Health Organization. Overview of technologies for the treatment of infectious and sharp waste from health care facilities. Published 2019. Accessed January 18, 2022. **https://apps.who.int/iris/handle/10665/328146**

[93] Sahiledengle B. Self-reported healthcare waste segregation practice and its correlate among healthcare workers in hospitals of Southeast Ethiopia. BMC Health Serv Res. 2019;19(1):591. doi:**10.1186/s12913-019-4439-9**

[94] Kuchibanda K, Mayo AW. Public health risks from mismanagement of healthcare wastes in Shinyanga municipality health facilities, Tanzania. Sci World J. 2015;2015. doi:**10.1155/2015/981756**

[95] Awodele O, Adewoye AA, Oparah AC. Assessment of medical waste management in seven hospitals in Lagos, Nigeria. BMC Public Health. 2016;16(1):269. doi:**10.1186/s12889-016-2916-1**

[96] Udofia EA, Gulis G, Fobil J. Solid medical waste: a cross sectional study of household disposal practices and reported harm in Southern Ghana. BMC Public Health. 2017;17(1):464. doi:**10.1186/s12889-017-4366-9**

[97] Ezirim I, Agbo F. Role of national policy in improving health care waste management in Nigeria. J Health Pollut. 2018;8(19). doi:**10.5696/2156-9614-8.19.180913**

[98] Nwachukwu NC, Orji FA, Ugbogu OC. Health care waste management—public health benefits, and the need for effective environmental regulatory surveillance in Federal Republic of Nigeria. Curr Top Public Health. Published online May 15, 2013. doi:**10.5772/53196**

## Feedback form

If you have questions or concerns about the contents of this chapter, please let us know. You can enter your comments for the editor in the form below or email us at **products@apic.org**.

**Comment** *(Required)*

**Name** *(Required)* Name

**Email** *(Required)* Email

SEND YOUR FEEDBACK

1400 Crystal Drive, Suite 900
Arlington, VA 22202

202-789-1890 / info@apic.org