Introduction

The 2014–16 West Africa Ebola epidemic and treatment of 11 patients in the United States presented unique logistical challenges to federal, state, and local entities not encountered routinely. Handling of infectious wastes from the patients was no exception. The waste generated by the patients, both solid and liquid, was not the only aspect requiring attention. The proper disposal of personal protective equipment (PPE) worn by health care providers, bed linens, items used to decontaminate medical equipment and surfaces in the room, and any other objects that came into contact with the patients during transport and treatment needed to be disposed of properly as a critical step of infection control due to potential or actual pathogen contamination. Even materials that infected individuals came into contact with in their homes or in public spaces had to be managed appropriately.

Waste contaminated with—or suspected to be contaminated with—Ebola virus and other pathogens capable of causing highly hazardous communicable diseases (HHCDs) can be inactivated effectively utilizing existing decontamination or sterilization methods, including incineration.

* This work was written in the author’s personal capacity and does not necessarily represent the views of the US Department of Labor/Occupational Safety and Health Administration.
tion and autoclaving. Once infectious waste has been appropriately incinerated, autoclaved, or otherwise inactivated by a validated process in order to eliminate the specific pathogen, it is no longer considered a hazardous material under federal law. Ideally, such waste should be properly inactivated at the site where it was generated; however, over the past several decades, many health care facilities have decommissioned their on-site incinerators, and few have sufficient autoclave capacity to support treating the large volume of waste associated with HHCD patient care. The alternative, transporting infectious waste for treatment at off-site facilities, is potentially more hazardous to workers, more complex from a compliance perspective, and tends to draw greater public scrutiny. Any US medical facility providing care for patients with HHCDs but lacking the ability to inactivate the waste on-site needs to ensure that its personnel are trained to properly and safely package the waste, procure proper packaging materials for transport, and work with a medical waste transporter that has the appropriate qualifications, including all potentially applicable state permits, a US Department of Transportation (DOT) special permit, proper insurance, and so on. Facilities need to ensure that the waste they are releasing will be disposed of at a properly permitted treatment facility. This chapter details the complexities of managing HHCD or Category A infectious wastes throughout the waste life cycle, from generation through on-site treatment, packaging, transportation, and off-site treatment to ultimate disposal. It also examines associated risks, as well as considerations and suggestions for both solid and liquid waste management.

**Waste Regulations**

Management of waste associated with isolation and quarantine must be done in a manner that complies with a complex framework of requirements at the federal, state or territorial, and, in some cases, local levels. Laws, regulations, and local ordinances (if applicable) may apply differently to solid and liquid waste, as well as to different categories of potentially hazardous or infectious waste. This section discusses some of the most important examples.
Several federal agencies regulate potentially infectious waste at various stages of its life cycle. Perhaps most pertinent for solid waste are the Hazardous Materials Regulations (HMR; 49 Code of Federal Regulations [CFR] Parts 171–180) of the DOT. The HMR cover the transportation of all hazardous materials, including those contaminated with or otherwise containing material designated as Category A and Category B infectious substances. The most virulent organisms, including Ebola viruses, which are present in a form capable of causing permanent disability or life-threatening disease in otherwise healthy humans or animals, comprise Category A, while those that are not life-threatening, fatal, or disability-inducing, including those found in waste generated through routine patient care, make up Category B. Importantly, specimens potentially containing certain organisms, such as Ebola and some other hemorrhagic fever viruses, are always considered Category A, while others, such as *Bacillus anthracis*, are considered Category A only when they are intentionally propagated (i.e., cultured). Regulated medical wastes, which include waste or reusable material derived from the medical treatment of an animal or human, that contain an infectious substance must be classified as either Category A or Category B, depending on the substance(s) known or suspected to be in the waste and the form that these substances are in (e.g., cultures versus patient waste only). Category A waste, which is assigned United Nations (UN) identification numbers 2814 (infectious substances, affecting humans) or 2900 (infectious substances, affecting animals), must be managed according to the HMR’s packaging, marking, and shipping requirements for Category A infectious substances when transported in commerce (i.e., by commercial waste haulers) via air, highway, rail, or water. When Category B materials (designated UN 3373) become waste, they are then assigned identification number UN 3291 and have their own specific set of packaging requirements.

The categorical designations applied to potentially infectious solid waste under the HMR are independent of the classification of waste as hazardous under Environmental Protection Agency (EPA) requirements and the authority of the Resource Conservation and Recovery Act
(RCRA). Generally, the HMR govern the methods by which hazardous materials or hazardous waste is moved between locations, while RCRA regulations set requirements as to how hazardous waste must be managed at landfills and other hazardous waste treatment facilities. RCRA requirements specify measures for protecting the environment from hazardous materials that could leach out of landfills if they are not properly contained, especially those that may persist in the environment, bio-accumulate, or otherwise have a lasting negative environmental impact.

Many activities that generate potentially infectious waste or involve workers managing such waste also trigger worker protection requirements enforced by the Occupational Safety and Health Administration (OSHA), such as the agency’s Bloodborne Pathogens (29 CFR 1910.1030) and PPE (29 CFR 1910 Subpart I) standards. Some states that operate their own OSHA-approved safety and health programs also have similar, if not more stringent, worker health and safety requirements. Generally, these requirements obligate employers to assess hazards that could lead to worker exposures, identify ways to reduce or eliminate those hazards in order to protect workers, and train workers to perform their jobs safely. Depending on the circumstances, state and federal occupational safety and health requirements apply throughout much of the typical waste life cycle.

**STATE REQUIREMENTS**

Most states set their own requirements for the management and treatment of infectious medical wastes. This state-by-state approach leads to significant variability among states. Some states regulate medical waste as part of a broad set of requirements for all solid waste, often under the authority of their environmental protection agencies. Other states use a combination of solid waste regulations and health department requirements—and these regulatory measures may not always fully align, especially when it comes to managing highly infectious waste. Some states also require various types of regulated medical waste to be managed in a specific way, while others allow some or all regulated medical waste to be put directly into specialized or appropriately permitted landfills. In many cases, states that require treatment allow for either incineration through a permitted hospital medical infectious waste
incinerator (HMIWI) or autoclaving with a properly validated process. Alternative treatment technologies may be permitted but must often go through additional validation processes.

These state-by-state differences, as well as intrastate differences among various environmental and health departments, created considerable challenges during the management of Ebola-contaminated Category A waste. Few, if any, states were prepared to deal with Category A waste (other than routine research laboratory specimens) and the potential hazards, both real and perceived, associated with managing this type of waste stream. Some states took extreme measures, prohibiting waste haulers from moving such materials through their state or requiring a police escort to do so. More measured approaches required waste treatment facilities accepting material from health care institutions to validate microbial inactivation protocols ahead of waste acceptance.

**Management of Solid Waste**

Waste contaminated with—or suspected to be contaminated with—pathogens capable of causing HHCDs, including Ebola virus, can be managed safely and effectively. However, doing so requires careful planning, in advance of patient admission, which considers the complete waste life cycle and applicable federal, state or territorial, and local requirements. Facilities that might accept patients with HHCDs, whether to triage, stabilize, and transfer them to better-equipped hospitals, or to treat them as patients in their own specialized biocontainment units, should work with local and state health and environmental departments to understand their requirements. Additionally, facilities should discuss capabilities and options with their contracted waste management companies to ensure all involved are aware of and in agreement with a waste management plan in advance of accepting a patient or a potential outbreak.

Several considerations related to waste generation in quarantine and isolation settings can simplify downstream waste management steps. Minimizing the total amount of waste generated by taking only necessary supplies into patient care or other contaminated areas is a best practice. When waste is generated, it should be segregated into Category A
regulated medical waste, Category B regulated medical waste, or waste that may be disposed of in standard municipal trash streams. This can potentially reduce the amount of bona fide Category A waste and alleviate challenges associated with on- and off-site storage, treatment, and disposal of unnecessarily large amounts of materials.

When waste is generated, it should be stored in a secure area accessible only to appropriately trained and protected essential personnel. Facilities should consider the rate of anticipated waste generation, as well as their capacity to treat that waste or the frequency with which a waste hauler will collect it, when determining where and how to store the waste. Care of patients with severe disease, especially those with viral hemorrhagic fevers who produce copious amounts of feces and vomitus, as well as items contaminated with blood and other body fluids, may generate eight to ten 55-gallon drums of used PPE, medical supplies, linens, and other material waste per day. Although it may vary based on the duration an ill patient is hospitalized, along with other factors, total waste from a single Ebola patient over the course of hospitalization has been shown to exceed sixty (60) 55-gallon drums.

Some health care facilities may plan to treat solid waste on-site through a variety of means. One such method is autoclaving, a steam sterilization process in which heat is applied to the waste in a highly pressurized chamber for a specified time and at a specified temperature and pressure in order to render pathogens nonviable. Most pathogens can be inactivated using a facility’s on-site autoclave capabilities, but waste management contracts may also augment this capability with portable autoclaves. In either case, treating waste with a validated autoclave cycle, typically heating for a minimum of 30 minutes at 250°F, ensures it is no longer infectious. Standard procedure involves the use of spores as biological indicators of the autoclave’s ability to inactivate organisms. Autoclaving processes are typically validated to reduce viable organisms by $10^{-4}$ or $10^{-6}$—for example, a reduction of 1 million organisms to either 100 or 1, respectively. This validation should be done with sample waste or dunnage similar to the wastes the facility anticipates accepting for treatment, prior to using the autoclave for actual infectious waste. This is important to ensure that treatment protocols effectively inactivate waste with viable pathogens. After validation and during the course of
treating waste, spore testing and parametric monitoring can ensure that autoclave cycles achieve appropriate time and temperature to inactivate pathogens in the waste.

Incinerating waste, especially bulkier items such as mattresses and draperies, can achieve similar results by reducing the material to ashes. Once Ebola-associated waste has been appropriately incinerated, autoclaved, or inactivated by another validated means, it is no longer deemed hazardous material under federal law since pathogens in the material have been inactivated. However, as previously noted, the chief stipulation at the time of the 2014–16 outbreak was that, in the United States, the Ebola-associated waste needed to be properly inactivated on-site.

Without on-site autoclave or incineration capabilities, facilities generating infectious waste need to plan to transport the waste for off-site treatment. This waste material must be packaged according to applicable DOT HMR requirements, which are more stringent for Category A waste than for Category B or regular regulated medical waste. For all waste to which the HMR apply, containers must be leak-proof, properly marked, and accompanied by hazardous materials shipping papers. Category A infectious substances require more complex and protective packaging to ensure that waste materials are safe for transport.

Prior to the 2014–16 Ebola outbreak, there were no standard packaging options for waste larger than typical laboratory samples. DOT had to issue a special permit and instructions to allow for packaging accommodations so that waste haulers could transport waste materials from health care facilities to a treatment facility.

When infectious waste is packaged appropriately, it is usually not necessary to pretreat the waste with a disinfectant prior to moving it off-site for treatment. Disinfectant added to waste is usually unable to penetrate porous materials, so the waste remains potentially infectious. However, moving waste that has not yet been autoclaved or incinerated likely means that downstream treatment and disposal workers will need additional protections compared to workers managing only autoclave residuals. This is also why it is critical for health care staff packaging the waste be properly trained on all packaging and closure protocols.

Although this chapter is not intended to address off-site treatment and disposal, note that these stages of the waste life cycle should be con-
sidered as part of any waste management plan. Entities that anticipate generating waste themselves or managing waste generated elsewhere, including in infected individuals’ homes, should consider the ultimate destination of such waste if it is not fully inactivated on site, how it will get there, and where the final product—including autoclave residual or incinerator ash—will be sent.

**Management of Liquid Waste and Effluents**

There remains limited scientific information regarding the survivability and health hazards within wastewater associated with organisms that cause HHCDs. Emerging studies demonstrate that the Ebola virus can survive in US wastewater for days, posing a potential health hazard to wastewater workers, but that the Ebola virus in wastewater is susceptible to sodium hypochlorite—a commonly used disinfectant.

Multiple federal laws and regulations focus on overall water quality and source water protection, but they do not provide definitive advice regarding liquid waste and effluents from suspected or confirmed HHCD patients in isolation and quarantine. CDC guidance allowing for the untreated release of liquid waste from confirmed patients with Ebola virus disease would also apply to those under quarantine or isolation for unconfirmed Ebola and certain other HHCDs. However, it is important to consult state and local laws and regulations when planning for the management of liquid waste and effluents from those within isolation and quarantine. If no state and local laws and regulations governing the discharge of these types of wastes can be found, it is recommended that discussion of these scenarios and procedures with state and local officials be conducted, including those from the local municipal wastewater treatment plant (WWTP) or publicly owned treatment works (POTW).

Biosafety level 3 and 4 (BSL-3 and 4) laboratories, under the Federal Select Agent Program, are required to pretreat their liquid waste prior to discharge into the WWTP, and the US Army Medical Research Institute of Infectious Diseases (USAMRIID) chemically pretreats its liquid waste and also steam-sterilizes it prior to discharge. Existing biocontainment units in the United States that have treated patients known or suspected to have Ebola virus disease also opted to chemically pretreat liquid waste prior to discharge. Given the many unanswered questions, and the cur-
rent precedence set by BSL-3 and 4 laboratories, as well as biocontainment units, isolation and quarantine facilities should develop their own standard operating procedure (SOP) for the pretreatment of liquid waste and effluent prior to WWTP/POTW discharge.

Protecting Workers during Waste Management Activities

A critical consideration in planning for both solid and liquid waste management is protecting worker health and safety. There are numerous opportunities for worker exposure to potentially infectious waste or contaminated materials. These may occur at various points throughout the waste life cycle, including, but not limited to, situations wherein workers are collecting, packaging, moving, opening, or otherwise coming in contact with waste or waste containers. In solid waste streams in particular, sharp objects, such as needles, scalpels, and broken glass, can cause puncture wounds, cuts, and other percutaneous injuries that can lead to worker infections. Workers may also be exposed to chemicals when pretreating solid or liquid waste.

As in the case of other occupational health hazards, it is necessary for health care, waste management, and other employers to perform a thorough hazard assessment to identify if, how, when, and where their workers may be at risk of exposure to potentially infectious materials, dangerous chemicals, or other hazards. Following the hierarchy of controls (see chapter 8) consistently applied to workplace health and safety hazards, employers can then determine what types of engineering controls, administrative controls, safe work practices, and PPE should be used to protect workers. Existing OSHA standards for bloodborne pathogens (29 CFR 1910.1030) and PPE (29 CFR 1910 Subpart I) may require employers to provide certain types of controls, as well as worker training, medical exams, and other measures that, together, are part of a comprehensive protection program for waste workers or others with waste management duties.

Conclusion

The 2014–16 West Africa Ebola outbreak and the subsequent treatment of patients in the United States required health care and affiliated sec-
tors to work through the logistics of Category A waste management and transport on a large scale, for the first time. The handling of waste is a challenging and critical component of isolation and quarantine care. As such, the importance of planning for, and coordination of, such handling prior to patient acceptance cannot be overstated.

Ongoing work aims to create standards and guidance for the next HHCD event. Nevertheless, effective HHCD waste management that ensures the safety of all workers involved requires clearly delineated SOPs that take into account contingencies, appropriate acquisition of permits and packaging materials—or at least a relationship with a supplier from which those materials could be readily obtained—and coordination, partnership, and trust with affiliated federal, state, and local stakeholders will be pivotal in future scenarios. Especially in a world of emerging and reemerging HHCDs, it is only a matter of time before health care facilities and related organizations face the complexities of managing highly infectious waste again—ideally with better preparation the next time.