

Medical Waste in Maryland: Alternatives to Incineration

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Cover Photo: The Phoenix Medical Waste Incinerator, the world's largest, is located in Baltimore.

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Executive Summary

Maryland's hospitals and health care facilities annually classify over 35,000 tons of their waste as regulated medical waste that must be sterilized before disposal. Incineration of this waste creates pollution that imperils public health. Safer alternatives are readily available.

Burning medical waste in incinerators creates air pollution that harms the health of people in Baltimore and across the state. The two pollutants of greatest concern are mercury and dioxin.

- Mercury is a neurotoxin, particularly for developing fetuses. Children born to mothers exposed to mercury may learn to walk and talk later or have reduced neurological test scores.
- Maryland's nine medical waste incinerators, including the world's largest, released 280 pounds of mercury to the air in 2003, equal to nearly 10 percent of mercury air emissions in Maryland.
- Dioxin is a carcinogen and one of the most toxic chemicals known, even at trace levels. The U.S. Environmental Protection Agency estimates that one in 1,000 people in the U.S. will get cancer because of exposure to dioxin.
- Maryland's medical waste incinerators released 18,000 milligrams of dioxin in 2002. Nationally, medical waste incineration is the third largest source of dioxin emissions.

Maryland does not need to rely on incineration to disinfect regulated medical waste. Alternative disposal methods can sterilize waste without producing the dangerous emissions that come from incinerators.

- Autoclaves use steam and high pressure to kill microorganisms. Microwave disinfection heats the water present in waste to destroy pathogens.
- Neither method heats waste to high enough temperatures to create and release dioxin.

- Mercury emissions from autoclaves, microwaves, and incinerators depend on the amount of mercury present in the waste. Separating mercury waste beforehand reduces mercury emissions.

The state has the potential to offer adequate capacity to allow hospitals and health care facilities to autoclave or microwave all their regulated medical waste except for human anatomical remains.

- The amount of regulated medical waste generated in Maryland could be reduced by approximately 45 percent, to 19,000 tons annually, if more health care facilities separated non-infectious waste from their regulated medical waste stream. Due to perverse incentives in current waste-disposal contracts, relatively few Maryland hospitals separate their wastes.
- Stericycle, a disposal company that accepts regulated medical waste from multiple hospitals, is constructing an autoclave in Baltimore. This facility, which can handle 22,800 tons annually, can treat over 60 percent of Maryland's current regulated medical waste stream. However, Stericycle did not design the plant to treat anatomical remains and so intends to continue incinerating all pathological waste.
- Clarification of state regulations regarding disposal of human anatomical remains to allow the use of alternative technologies would smooth the way for hospitals and health care facilities to completely end their reliance on incineration.

Maryland has the tools available to safely dispose of regulated medical waste and to protect public health.

1. State and local decision makers should call for an end to medical waste incineration. Alternatives to incineration can render pathological waste noninfectious and unrecognizable.
 - Currently, Maryland regulations do not require incineration of any of the regulated medical waste stream but also do not clearly approve of alternative treatments for human anatomical remains. Mechanical destruction and steam disinfection is a feasible treatment for anatomical remains. However, state regulations do not explicitly permit this.
 - The regulations are not flexible enough to authorize the use of some of the newer alternative treatment methods, such as alkaline digestion. Adopting broader standards would enable hospitals to choose among all technologies to find the alternative treatment method that best suits their needs.
2. Maryland regulations governing the disposal of regulated medical waste should be made more supportive of alternative technologies.
 - The regulations are not flexible enough to authorize the use of some of the newer alternative treatment methods, such as alkaline digestion. Adopting broader standards would enable hospitals to choose among all technologies to find the alternative treatment method that best suits their needs.
3. The Maryland Department of the Environment (MDE) and the Department of Health and Mental Hygiene (DHMH) should help hospitals and health care facilities transition to safe disinfection methods.

- MDE and DHMH could help health care facilities end purchases of mercury-containing products by providing information on alternatives and helping to develop a plan for replacing mercury-based items. Information about what products contain mercury could help hospitals identify items that need to be included in shipments to mercury recycling programs.
- Hospitals and health care facilities can reduce the volume of waste that requires special handling by separating infectious materials from other waste. MDE and DHMH can help hospitals audit their current waste streams, create recycling and segregation programs, and design staff trainings to implement the plan.

Introduction

In the summer of 1988, medical waste washed ashore at beaches along the east coast and the Gulf of Mexico, prompting concern about possible exposure to the AIDS virus and hepatitis from hypodermic needles and blood vials mixed in the sand, and sparking a public outcry for stronger rules controlling the disposal of regulated medical waste.

Though the waste on beaches resulted from improper disposal of ordinary trash that contained materials from home health care and illegal drug use, public concern focused attention on the handling of regulated medical waste from health care facilities. Congress enacted the Medical Waste Tracking Act for five states, Washington, D.C. and Puerto Rico to track regulated medical waste from its point of generation to its final treatment or disposal.¹

Hospitals sought a reliable waste disposal method. Burning regulated medical waste—which destroys all pathogens in the waste and renders the waste unrecognizable—seemed to solve the problems associated with medical waste. Non-incineration technologies were rela-

tively new and untested, and so most hospitals either built an incinerator or signed a long-term contract with an independent incinerator. Hospitals could be absolutely certain they were eliminating the risk that someone could become sick from direct contact with the waste.

Incineration, however, harms public health by releasing mercury, dioxin, and other chemicals into the air. Mercury is a toxin that can cause neurological damage at very low doses, particularly in children. It also can affect the reproductive, cardiovascular, and immune systems. Dioxin is a known carcinogen and can also cause immune system, reproductive, and developmental problems.

Medical waste may release more pollution than other types of waste when incinerated. Many medical devices—including blood pressure cuffs and thermometers—contain mercury. If those items are sent to an incinerator instead of being treated separately, the mercury will be released to the atmosphere. Dioxin forms when combustion occurs in the presence of chlorine, an ingredient in many medical items. Polyvinyl chlo-

ride (PVC) is a chlorinated plastic used to make common medical products such as IV bags, tubing, and labware. Bleached paper also may contain chlorine.

Medical waste incineration is of particular concern in Maryland, home to numerous hospitals and medical institutions. The state has nine medical waste incinerators, including the world's largest (built in the late 1980s), that release mercury and dioxin to the state's environment.

Fortunately, non-incineration technologies for disposing of medical waste have improved dramatically over the past 20 years and have proven track records of performance comparable to incineration. Dangerous waste can be sterilized

with high pressure and temperatures (without combustion), an approach that does not release dioxin. Most waste generated by hospitals, though, is largely the same as that from hotels or a large office building and does not pose any disease risk. That waste can be recycled or sent directly to a landfill. These alternative technologies can safely dispose of regulated medical waste at a cost competitive with incineration.

But for many hospitals, the upfront cost of switching from incineration to another technology or of canceling a long-term incineration contract is daunting. By choosing an alternative technology, hospitals make a commitment to pollute less and to protect public health.

Air Pollution from Maryland's Medical Waste Incinerators

Hospitals generate waste. Most of it is no different than the paper, cardboard, and other trash that every office produces, but some of it is contaminated with infectious material and cannot be directly discarded into a landfill. Infectious waste, which includes cultures, human anatomical remains, bulk blood or other bodily fluids, and sharp items such as used needles or scalpel blades, accounts for approximately 15 to 17

percent all waste generated in hospitals.² Hospitals also produce a small amount of radioactive, chemotherapeutic, and hazardous waste. (See Figure 1 and Table 1.)

Maryland's health care facilities annually classify over 35,000 tons of hospital waste as regulated medical waste, though, as will be discussed later, much of this is likely non-infectious solid waste.⁵ Regulated medical waste cannot

Figure 1. Breakdown of Waste Generated at Hospitals³

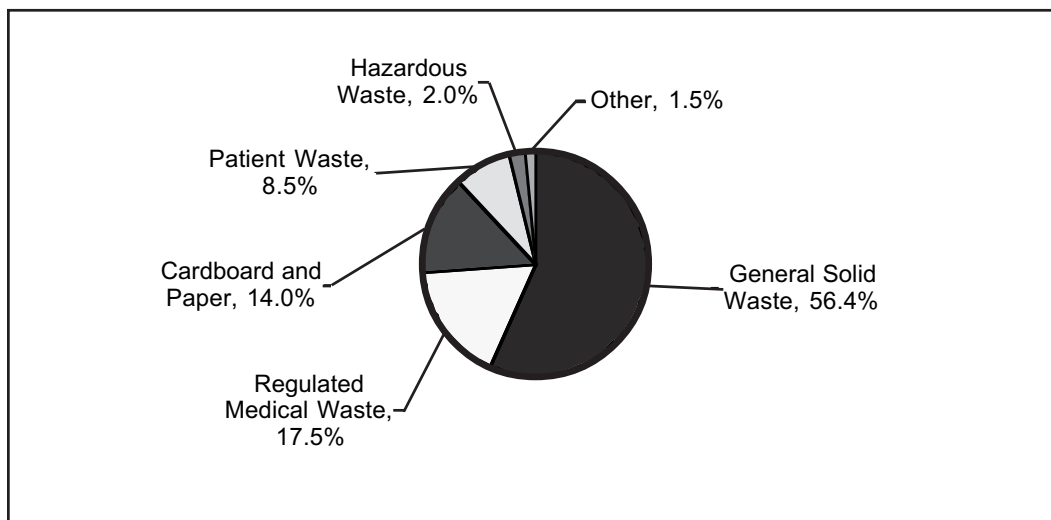


Table 1. Common Components of Regulated Medical Waste⁴

Cultures and stocks
Pathological wastes
Blood and other bodily fluids
Sharps
Animal wastes
Isolation wastes
Contaminated medical equipment
Surgery wastes
Laboratory wastes
Dialysis wastes

be thrown away with regular trash destined for a landfill but must be specially handled. Infectious and pathological waste must be disinfected. Waste from hospitals, clinics, doctors' and dentists' offices, long-term care facilities, and morgues can be disinfected by high temperatures (such as with steam in an autoclave or microwave), through chemical reactions (such as bleach), or with irradiation or biological agents. Waste can also be burned, a process that kills pathogens but releases hazardous pollution. Radioactive and chemotherapeutic wastes are handled separately from regulated medical waste and must be treated as hazardous waste.

Incineration is the most common method for treating medical waste in Maryland, even though it creates health-threatening air pollution. Medical waste is burned in dedicated incinerators that heat the waste to temperatures of 1400° to 1800° F.⁶ Exhaust gas is released to the atmosphere and though it undergoes some pollution control, it still contains mercury, dioxin, and other harmful pollutants such as arsenic, lead, benzene, toluene, and xylene.⁷ Leftover ash, which contains concentrated amounts of the same pollutants, is sent to landfills where rainwater seeping through the debris can carry pollution into groundwater.

Compounding the dangers of incinerating medical waste, health care facilities often burn far more waste than is necessary—in part as a result of long-term waste-disposal contracts that create no incentive for waste reduction—sending uncontaminated paper, cardboard, plastic, thermometers, laboratory supplies, and other material to the incinerator. Paper bleached in a chlorine-based process and polyvinyl chloride (PVC), a common plastic, release dioxin when burned.

Medical waste incinerators release over 25 dangerous air pollutants, including particulate matter, carbon monoxide, lead, and other heavy metals.⁸ The two contaminants of greatest concern are mercury and dioxin.

Mercury

Mercury is a highly toxic, bioaccumulative metal. It is used in many medical products including dental fillings and thermometers, though it is less common today than it once was. The incineration of products that contain mercury vaporizes the metal and sends it into the atmosphere, where it is dispersed by the wind before being deposited onto soil or water hours or months later. Mercury that settles out of the air and finds its way into water presents the greatest threat to human health because it becomes concentrated in fish.

Mercury can have a variety of health effects but its most potent effect—and the effect most likely to occur at the lowest doses—is neurotoxicity, causing damage to the nervous system, particularly for developing fetuses. Methylmercury, an organic form of mercury that is easily absorbed by animals, is readily transported across the placental barrier, meaning that a pregnant woman's lifetime exposure to mercury exposes her fetus as well. Mercury has also been found in breast milk, presenting another route of

exposure for infants. Similar effects are possible for small children exposed to mercury in fish.

The health impacts of fetal exposure to mercury are well-documented. Children born to mothers exposed to mercury during pregnancy can exhibit a wide variety of neurological problems, including delayed onset of walking and talking, impaired motor function, decreased attention spans, and reduced neurological test scores.⁹ Other health effects of mercury exposure may include damage to the immune, cardiovascular, and reproductive systems.

Mercury exposure represents a major potential health threat to tens of thousands of Americans. A 2004 study by U.S. Environmental Protection Agency (EPA) scientists found that one in six American women of reproductive age has levels of mercury that exceed levels that could damage a developing fetus.¹⁰

Fish consumption is the most important pathway for mercury exposure in humans. Mercury from the atmosphere is deposited into waterways, where it is converted by aquatic organisms into its organic form, methylmercury. The aquatic food chain is typically made up of many levels—ranging from tiny plankton through small fish and up to the larger fish that humans typically consume. At each step of the food chain, methylmercury becomes increasingly concentrated in animal tissue, such that large fish can accumulate significant amounts within their bodies—enough to cause health problems for the birds and mammals (including people) that consume the fish.

The bioaccumulation of mercury through the food chain means that very small releases of mercury are dangerous to humans.¹¹ For fish to be safe enough for the average American woman to eat two six-ounce meals of fish per week, mercury concentrations must be no greater than 0.13 parts per million.¹²

Maryland has significant mercury pollution, which is reflected in the number of fish species that are unsafe for human consumption. The state's Department of the Environment warns residents to limit their consumption of striped bass caught in the Chesapeake Bay and its tributaries, and bluegill and small and largemouth bass from locations across the state due to mercury contamination.¹³

Releases of mercury within the state contribute to Maryland's problem. Industrial sources released approximately 3,000 pounds of mercury to Maryland's air in 2003.¹⁴ Medical waste incinerators were responsible for nearly 10 percent of that amount, or 280 pounds.¹⁵ However, mercury emissions from medical waste incineration may have a disproportionate impact in Maryland because the type of mercury released by incinerators—reactive mercury—remains airborne for only a few hours, or at most several days, and is easily cleared out of the air by precipitation, posing a significant risk for nearby communities.¹⁶

Dioxin

Dioxin refers to a group of persistent toxic chemicals that are released into the air by manufacturing and industrial processes that use or burn chlorine. Nationally, the U.S. EPA estimates that medical waste incineration is the third largest source of dioxin air emissions.¹⁷

Humans are exposed to dioxin primarily by eating contaminated food, especially meat and dairy products. Airborne dioxin settles onto soil and plants. Animals that eat those plants accumulate dioxin in their bodies; people are exposed to dioxin when they eat meat, eggs, and dairy products.

Current average levels of dioxin in humans are at or near the levels that have been demonstrated to cause problems in animals. Because of how dioxin accumu-

lates through the food chain, breast-feeding infants may receive a dose 35 to 65 times higher than “safe” levels.¹⁸ The EPA estimates that the cancer risk from dioxin in levels already present in the general public is approximately one case per 1,000 people, far higher than EPA’s acceptable risk level of one in one million.¹⁹

The International Agency for Research on Cancer, an arm of the World Health Organization, has determined that one type of dioxin (the type present in the pesticide Agent Orange sprayed on foliage in Vietnam) is a known human carcinogen.²⁰ Unlike many chemicals which have a negative effect only in doses above a certain level, dioxin does not have a threshold below which it is known to be safe.²¹ Any exposure to dioxin, even a dose as low as one thousandth of one millionth of a gram, can be hazardous.²²

Dioxin has been linked to numerous other problems in addition to cancer, including reproductive and developmental problems, increased heart disease and diabetes, and a weakened immune system.²³ Animal studies have shown that dioxin can lower sperm counts and delay testicular descent in males and increase the risk of endometriosis and failed pregnancies in females.²⁴ Children exposed to dioxin may suffer from delayed development,

learning disabilities, and IQ deficits.²⁵ The impacts of dioxin exposure are particularly severe when exposure occurs *in utero* or during childhood.²⁶

Dioxin can form when chlorine is present during a combustion process. Many health care products, such as polyvinyl chloride (PVC) IV bags and tubing, contain chlorine, enabling the creation of dioxin when these items are burned.²⁷

The Risk to Maryland’s Residents

Most of Maryland’s medical waste is treated through incineration. There are nine medical waste incinerators in the state, four of which are located in Baltimore. (See Table 2.) The largest incinerator in Maryland belongs to Phoenix Services, a company that consolidates regulated medical waste from many facilities, including some from out of state. Several Maryland hospitals operate their own incinerators.

Phoenix Services operates the world’s largest dedicated medical waste incinerator in the Curtis Bay neighborhood of Baltimore. The plant burns approximately 80 tons of medical waste every day, though it is permitted to burn up to 150 tons and has a capacity to handle 170

Table 2. Current Maryland Incinerators³¹

Facility Name	Location	Tons of Medical Waste Burned Annually
Phoenix Services	Baltimore City	29,604
Fort Detrick	Frederick County	1,001
Franklin Square Hospital Center	Baltimore County	812
Northwest Hospital Center	Randallstown	730
Mercy Medical Center	Baltimore City	676
Washington County Hospital	Hagerstown	395
Johns Hopkins Univ. School of Medicine	Baltimore City	299
Howard County General Hospital	Columbia	155
University of Maryland Hospital	Baltimore City	19

tons per day.²⁸ The incinerator opened in 1991 to treat waste from Maryland hospitals located in central Maryland. Phoenix now imports waste from hospitals and medical waste handlers in other states, including New York, Pennsylvania, Virginia, and Washington, D.C.²⁹ Burning 30,000 tons of waste in 2003 at the plant created 10,700 tons of ash that was landfilled. (See Table 3.)

Mercy Medical Center, the Johns Hopkins University School of Medicine, and the University of Maryland at Balti-

more also operate incinerators in Baltimore. Elsewhere in the state, four other hospitals and one Army base have incinerators.³⁰

Burning medical waste releases significant amounts of pollution to Maryland's environment. In 2003, medical waste incinerators in Maryland released 280 pounds of mercury, nearly 10 percent of statewide mercury air emissions.³³ Annual emissions of dioxin were over 18,000 milligrams. (See Table 4.)

Table 3. Out-of-State Waste Treated at Maryland Incinerators (tons)³²

Facility	Location	Total Medical Waste Accepted	Medical Waste from Maryland	Medical Waste from Other States	What States	Ash Generated
Phoenix Services	Baltimore City	29,604	23,962	5,642	VA, DC, PA, NY	10,709
Fort Detrick	Fort Detrick	1,001	837	164	DC	446

Note: Ash generated at Fort Detrick includes ash from municipal waste incineration.

Table 4. Emissions from Maryland Incinerators in 2003³⁴

Incinerator Name	Location	Mercury (pounds)	Dioxin/Furan (milligrams)
Phoenix Services	Baltimore City	198	31
Stericycle [^]	Baltimore City	30	1
Mercy Medical Center	Baltimore City	28	2,994
Fort Detrick [*]	Frederick County	14	4,354
Washington County Hospital	Hagerstown	11	1
University of Maryland Hospital	Baltimore City	2	91
Johns Hopkins University School of Medicine	Baltimore City	1	71
Northwest Hospital Center	Randallstown	0	11
Franklin Square Hospital Center	Baltimore County	0	10,886
Howard County General Hospital	Columbia	0	12
Total		283	18,143

[^]Stericycle has closed its incinerator and is constructing an alternative treatment facility.
^{*}Fort Detrick burns solid waste in addition to medical waste. These emissions figures are for all incineration.
 Note: These emissions figures are based on data reported by each facility to the state. Reported emissions have not necessarily been measured, but are the result of modeling conducted by the facility, using model inputs such as the results of selected stack tests and the amount of waste burned.

Reducing the Impact on Public Health of Treating Medical Waste

Given the high cost to human health, incineration is not a suitable technology for treating regulated medical waste.

Concerns that might have prevented public decision makers from calling for an end to incineration five or ten years ago to protect public health are not obstacles today. Alternative non-incineration technologies are available that can render waste noninfectious and unrecognizable. Capacity should not be a significant concern either. Maryland soon will have the ability to treat most types of regulated medical waste without using incineration; the state still needs to identify and develop options for disinfecting human anatomical remains.

Non-Incineration Sterilization Technologies

When medical waste washed onto beaches in the summer of 1988, there were relatively few alternatives to incineration for disinfecting regulated medical waste and making it unrecognizable. Today, a number of non-incineration technologies are well established.

Though ending waste incineration virtually eliminates the creation of dioxin during medical waste treatment, mercury pollution from waste sterilization is a problem as long as there is mercury in waste to begin with. Thus the first step to protect public health from mercury pollution released during the disposal of regulated medical waste is to help health care facilities eliminate the use of mercury-containing medical devices. Only then can non-incineration treatment methods such as autoclaves and microwaves deliver on their potential for disinfecting regulated medical waste without producing dangerous pollution.

Eliminating Mercury from the Waste Stream

Treating a mercury-containing product in an autoclave, which sterilizes waste using heat and pressure, will simply mix mercury with everything else in the autoclave. Some of the mercury will be volatilized and will be released into the atmosphere when air from the autoclave is vented. Some will be mixed with the waste that will go to the landfill. The rest

will taint the condensed steam that is drained from the autoclave into the sewer.³⁵

The first step to eliminating mercury releases during treatment of regulated medical waste is to help hospitals and health care facilities stop using products with mercury. Currently, many medical products contain mercury, including thermometers, blood pressure cuffs, and weighted esophageal dilators.³⁶ Cost-effective mercury-free alternatives are available for almost every health care need. For example, electronic thermometers, aneroid blood pressure devices, and tungsten-weighted esophageal dilators perform as well as their mercury-containing counterparts. In addition, the lifetime cost of these products may be lower because hospitals do not have to deal with cleaning up costly mercury spills when equipment breaks.

Many hospitals have largely eliminated the use of mercury through mercury-free purchasing policies. Kaiser Permanente, a large national health care provider, began phasing out mercury products in the late 1990s. In Maryland, the Johns Hopkins Hospital has not used mercury-based blood pressure cuffs for several years.³⁷

Until health care facilities cease purchasing new mercury-filled equipment and get rid of all old mercury-based items, they need to make sure they are properly handling mercury-tainted waste and keeping it separate from the rest of the regulated medical waste stream. The best way to dispose of mercury is to recycle it.³⁸

Like mercury, radioactive materials and chemotherapeutic wastes should never be mixed with regulated medical waste. They should be handled separately. Chemotherapeutic waste should be disposed of as hazardous waste or can be treated with an alternative technology such as alkaline hydrolysis. Short-lived radioactive waste can be stored until the

radionuclides have decayed to background levels and then can be disinfected or disposed. In this discussion, we assume that radioactive and chemotherapeutic wastes have been kept segregated from regulated medical waste and thus are not a factor in emissions from treatment technologies.

The Technologies

After mercury has been separated from other medical wastes, infectious waste can be sterilized through non-incineration methods without producing health-threatening pollution. Non-incineration methods fall into four general categories: thermal, chemical, irradiative, and biological. Chemical, irradiative and biological methods are relatively uncommon. Thus the following discussion will focus on thermal methods, which use heat to kill microorganisms.³⁹ Temperatures remain low enough that no combustion occurs and therefore no dioxin is created.

Autoclave

Autoclaves disinfect waste by using steam and high pressure. The equipment consists of a metal canister into which regulated medical waste is loaded. Once the door to the canister is closed and sealed, air is removed to create a vacuum. Steam is forced into the container to heat the material to a target temperature. After 30 minutes or some other programmed duration, pressure and temperature are lowered by releasing steam through a condenser. Water waste is sent to the sewer. Solid waste is then removed and sent to a landfill.

Almost all regulated medical wastes can be treated in an autoclave. Acceptable waste includes sharps, cultures, blood, surgery waste, laboratory materials (except chemical waste), bandages, and gowns. As discussed in the next section, human anatomical remains can also be

disinfected in an autoclave, though mechanical destruction of the waste inside the autoclave is needed to ensure even disinfection and to make the waste unrecognizable. Large, bulky items such as excessive bedding material that the steam heat cannot fully penetrate cannot be successfully treated in an autoclave.

Provided that mercury wastes are separated, autoclaves have zero to low emissions.⁴⁰ Plastics can be treated safely in autoclaves without creating dioxins because dioxin formation occurs at temperatures over 480° F, much higher than the operating temperature of autoclaves.

Hospitals routinely disinfect equipment using steam and the treatment has a solid track record of killing microorganisms.

Autoclaves can be installed to handle a range of loads, from a few pounds to several tons per cycle. This means that hospitals can purchase an autoclave for use on-site and that companies that handle waste from multiple hospitals also can use autoclaves. They have relatively low capital costs.⁴¹

Stericycle, the largest medical waste hauler in the nation, is now constructing an autoclave in Baltimore that is permitted to accept 1,900 tons of waste per month.⁴² While this is larger than the incinerator Stericycle recently operated, the autoclave does not have shredders and therefore Stericycle will continue incinerating pathological waste at another facility it owns.⁴³ Were Stericycle to install an *internal* shredder in its autoclave to ensure even disinfection of waste and render it unrecognizable, all regulated medical waste, including all human anatomical remains, could safely be treated in the company's autoclave. A *post-disinfection* shredder would allow Stericycle to treat sharps, but not anatomical waste. However, Stericycle is unlikely to add either type of shredder.

Advanced Autoclave

Autoclaves that mechanically process the waste through shredding or compaction in addition to disinfecting it are referred to as advanced autoclaves or rotoclaves. Waste is shredded before, during, or after disinfection and may be compacted afterward. These mechanical treatments offer several benefits, including uniform disinfection of waste, dramatically reduced waste volume, and the ability to treat human anatomical remains.

An advanced autoclave with an *internal* shredder—preventing the spread of infectious material but also rendering the waste a uniform size before disinfection to allow the steam to fully disinfect the material—can treat all types of waste, including human anatomical remains. It is not clear, however, that current Maryland regulations allow this disposal method for anatomical remains, though the waste is fully disinfected and unrecognizable.

Sinai Hospital ceased incinerating its waste three years ago and, in addition to segregating its wastes, began using a San-I-Pak advanced autoclave. The autoclave can treat 460 pounds of waste per hour, and has been operated for 14 hours per day for three years with relatively few problems.⁴⁴ After sterilization, the waste is shredded twice and then compacted. Treated waste then joins the municipal waste stream.⁴⁵ Bon Secours Hospital also uses a San-I-Pak autoclave.

Microwave

Regulated medical waste can be disinfected using microwave technology that heats water already within the waste or water that has been applied to the waste. The heat kills infectious material.

Microwave devices produce rapidly cycling waves that cause water molecules to vibrate. The friction from vibration creates heat, destroying microorganisms.

Because the microwaves have little impact if there is no water in the waste, microwave disinfection systems typically add water before treating the waste.⁴⁶ After treatment, water can be drained into the sewer and waste sent to a landfill.

Unlike home microwaves, large microwaves for treating regulated medical waste can safely handle items containing metal and thus can treat the same range of items as autoclaves.⁴⁷

Microwaves produce few emissions. During the microwave process, temperatures do not reach levels high enough to produce dioxin. And as with autoclaves, if toxic materials such as mercury and formaldehyde are kept out of the waste stream, the emissions are minimal. One common microwave disinfection unit involves feeding waste into a shredder before it is disinfected, a process that could release some untreated vapors. However, shredding is conducted once the system is closed and steam is added to the hopper; during shredding a vacuum system sends that air through a filter and greatly reduces potentially hazardous emissions.

Provided the waste placed in the unit is moist enough, microwaves can disinfect all regulated medical waste. Tests of waste treated in microwaves show that the efficacy varies some from one kind of organism to another but that overall performance is satisfactory. However, because microwaves do not heat waste to the same temperatures as autoclaves, periodic testing is recommended to confirm that the system is killing bacteria.⁴⁸

The model of microwave disinfection equipment that has been commercially available the longest has a capacity ranging from 220 to 900 pounds per hour. The equipment is relatively expensive to purchase, with capital costs of \$500,000 to \$600,000.⁴⁹ It is also possible to lease a microwave disinfection unit, thereby avoiding the need for this large capital investment.

The Peninsula Regional Medical Center in Salisbury has used a Sanitec microwave processing system since the mid-1990s. Peninsula treats 85,000 to 100,000 pounds of regulated medical waste per month from the main hospital and its satellite facilities.⁵⁰ The hospital's microwave unit can process 500 pounds of waste an hour and has had relatively little downtime.⁵¹ The cost of microwaving regulated medical waste is estimated at \$0.08 per pound, compared to \$0.35 per pound for incineration.⁵² Peninsula sends anatomical remains to be incinerated.

Non-Incineration Capacity in Maryland

Though non-incineration treatment technologies are capable of disinfecting medical waste, a possible concern about ending medical waste incineration may be that Maryland does not have adequate capacity to treat all regulated medical waste without relying on incineration. This should not be a significant concern. Maryland can reduce the volume of waste that must be disinfected by segregating regulated medical waste from other wastes. Further, new non-incineration facilities—both Stericycle's newly constructed autoclave and future facilities constructed on-site by hospitals—will increase Maryland's capacity to treat regulated medical waste without relying on incineration.

Reducing the Amount of Regulated Medical Waste

Maryland hospitals often send more waste to be incinerated than is actually necessary. Many Maryland hospitals have entered long-term contracts with Phoenix Services to haul and burn their waste. Commonly, the hospitals pay the same amount regardless of the volume of trash.

Financial Costs of Incineration

Not only is incineration bad for the environment, but it can also be bad for the bottom line.

Operating an on-site incinerator incurs costs for labor, power, maintenance, upgrades, ash disposal (hauling and landfilling), and other support activities. Maintaining the emissions control equipment on a 550 lb/hour incinerator costs \$138,000 annually, in addition to capital costs of installing the equipment and the basic costs of operating the incinerator.⁶¹ Sinai Hospital estimates that, had it chosen to continue operating its incinerator, complying with federal Title V air pollution regulations would have cost \$1.7 million.⁶²

Waste burned offsite is no less costly. Disposal contracts for hauling waste, on-site storage of waste, and liability costs make commercial incinerators expensive.

Though alternative treatment methods often involve high capital costs—which can be a significant barrier for hospitals wishing to switch from incineration to a cleaner technology—ongoing expenses tend to be lower. Safe disposal methods incur many of the same costs as incinerators—labor to operate the equipment, utilities, maintenance, treated waste disposal—but unlike on-site incinerators, autoclaves and microwaves do not require emission-control equipment which can be expensive to purchase and operate.

A decade ago, when hospitals had few options other than incineration for safely disposing of regulated medical waste, these put-or-pay contracts made sense by guaranteeing the incinerator would have adequate revenues to stay in business and provide service to hospitals. Today, however, fixed put-or-pay contracts mean that many of Maryland's hospitals have no financial incentive to reduce or segregate their waste to reduce dioxin and mercury emissions.

Waste reduction strategies include changing purchasing practices, reusing and recycling some items, and segregating the waste stream. Specifically, hospitals can stop purchasing products that contain polyvinyl chloride (PVC) and mercury, eliminate unnecessary materi-

als such as packaging material, and pare down what products are included in standardized kits. Disinfecting and reusing items from gowns to bedpans further reduces waste. Printer cartridges, cardboard, x-ray film, fluorescent bulbs, and solvents can be recycled rather than thrown away.

Separating regulated medical waste from general waste is a critical step to reducing the volume of waste that must be disinfected. When paper, food waste, and other trash is mixed with infectious waste, an unnecessarily large amount of material must be disinfected.

A waste audit can help a facility identify the components of the waste stream, including the makeup of both regulated medical waste and general trash. With

Table 5. Maryland Medical Waste Volume (tons)

Amount of in-state medical waste	36,000
Incinerated annually	34,000
Treated through other methods	2,000
Reduction potential through waste separation	17,000
In-state waste needing treatment after separation	19,000

this information, it is possible to find recycling opportunities, alter purchasing strategies, and establish waste segregation practices.

Waste separation programs can dramatically reduce the amount of regulated medical waste that hospitals must disinfect. Sinai Hospital in Baltimore began a waste segregation program three years ago that has reduced its volume of regulated medical waste by 70 percent.⁵³ Such significant reductions in waste are possible at most hospitals. For example, Wisconsin requires all hospitals and health care facilities to separate their regulated waste from regular waste. Waste reporting forms submitted by facilities across the state show that waste segregation has reduced the regulated medical waste stream by an average of 25 to 50 percent since 1995. A few facilities have achieved even greater reductions.⁵⁴

For hospitals that do not have put-or-pay contracts with an off-site treatment facility, waste segregation saves money. Proper treatment of regulated medical waste is generally considered to be five times as expensive as disposal of regular waste, which can simply be sent to a landfill.⁵⁵ The California Department of Health Services estimates that regulated medical waste can be 19 times more expensive.⁵⁶ By separating waste according to type, hospitals can reduce the amount of waste that must be disinfected before it can be thrown away.

The Beth Israel Medical Center in New York estimates that its waste separation program saves the hospital \$600,000 annually on regulated medical waste disposal and \$900,000 on regular waste disposal, a 60 percent savings.⁵⁷

Because of the put-or-pay incineration contracts common in Maryland, relatively few hospitals have waste separation programs. Thus, the potential gains of beginning segregation efforts are great.

Maryland hospitals currently generate approximately 36,000 tons of waste annually that they identify as regulated medical waste. Of that, 34,000 tons are incinerated. Assuming that Maryland hospitals and health care facilities that use incineration do not have any waste segregation programs in place, the total volume of regulated medical waste could be significantly reduced through the implementation of separation and recycling programs. Even with percentage savings less than those achieved at Sinai Hospital, the amount of regulated medical waste needing treatment could be reduced by 17,000 tons to 19,000 tons annually. (See Table 5.)

Alternative Treatment Capacity

Maryland could soon develop adequate capacity to disinfect all regulated medical waste without using incineration. The recently constructed autoclave owned by Stericycle boosts the volume

of waste that can be treated safely and it is likely that several hospitals will soon begin operating their own autoclave or microwave units. If non-incineration capacity for treating human anatomical remains is developed, Maryland would be able to treat all regulated medical waste without incinerators.

Stericycle will soon open an autoclave in Baltimore that is permitted to accept 22,800 tons of waste annually.⁵⁸ With the new facility, Stericycle will be able to handle more waste than it had burned at its incinerator. Stericycle had burned only 4,200 tons per year in its own incinerator and had sent the rest of its waste to Phoenix Services for incineration.⁵⁹ The autoclave will allow Stericycle to treat an additional 18,600 tons per year. It is likely that some of this capacity will be dedicated to out of state facilities that Stericycle already serves, limiting somewhat the amount of waste Maryland hospitals can send to be autoclaved by Stericycle.

A significant problem is that Stericycle has not included any shredding capability at its new plant and thus will not accept some types of waste. Human anatomical remains can be treated in an autoclave with an internal shredder that allows full disinfection of the waste. Without an internal shredder, Stericycle will not be able to treat this portion of the waste stream at its autoclave and instead will burn it at a different facility it owns.

Several Maryland hospitals and waste treatment facilities have already begun using alternative treatment methods such as autoclaves and microwaves for their regulated medical waste other than human anatomical remains. Other hospitals could do the same.

To stop incinerating all regulated medical waste, Maryland may not need to increase its alternative treatment ca-

capacity for most waste but will need to ensure that there is a non-incineration option for treating human anatomical remains. Such remains do not have to be incinerated. They can be disinfected in an autoclave or microwave with an internal shredder or they can be treated in a chemical process such as alkaline digestion which dissolves and disinfects the waste. Maryland hospitals continue to incinerate anatomical remains because there currently are few alternative facilities equipped with internal shredders available in Maryland and because state regulations are unclear about how anatomical remains may be treated.

Developing the capacity to treat human anatomical remains should not be difficult. Pathological waste, of which human anatomical remains are a subset, comprises only two percent of all hospital waste or 13 percent of regulated medical waste.⁶⁰ Hospitals that want to cease relying on incineration could install a relatively small alternative treatment unit specifically designed to handle anatomical remains and send all other regulated medical waste to an off-site treatment facility or to an autoclave or microwave unit that they might already own.

State lawmakers and regulators could ease hospitals' transition to alternative treatment of anatomical remains by clarifying state regulations regarding disposal. It is unclear in current regulations if human anatomical remains may be treated in an autoclave or microwave even if the unit has a shredder. Hospitals will be reluctant to invest in alternative treatment capacity for anatomical remains without reassurance that the process is fully legal.

Maryland is within reach of having the ability to treat all regulated medical waste without relying on incineration. Waste segregation techniques in hospitals and health care facilities can reduce

Table 6. Maryland Medical Waste Volume and Non-Incineration Treatment Capacity (tons)

Amount of in-state medical waste currently treated	36,000
Reduction potential through waste separation	17,000
In-state waste needing treatment after separation	19,000
Non-incineration treatment capacity (by end of 2004)	
Total	24,800
Commercial	22,800
On-site (hospital)	2,000
Note: The state remains limited by a lack of options for treating human anatomical remains.	

the volume of waste requiring treatment. The opening of Stericycle's autoclave units will significantly increase non-incineration capacity for disinfecting many components of regulated medical waste. With clarification from state regulators, hospitals could install alternative technologies for treating human anatomical remains and Maryland could treat all of its regulated medical waste without using incinerators. (See Table 6.)

Policy Recommendations

Maryland can protect public health and end the practice of incinerating medical waste.

Phase Out Incineration

State and local decision makers should call for an end to medical waste incineration. Mercury and dioxin from Maryland's nine waste incinerators affect the health both of people who live in the same neighborhood as an incinerator and of people who live miles away. Children are particularly vulnerable to the toxic impacts of pollution from incinerators. Ending medical waste incineration will protect public health.

Alternative methods for disinfecting medical waste are currently available to hospitals and health care facilities. Autoclaves and microwaves thoroughly disinfect regulated medical waste and can treat even anatomical remains if the equipment is fitted with an internal shredder. Provided that mercury-containing products are removed from the regulated medical waste stream, autoclaves and microwaves have virtually no mercury or dioxin emissions.

Update and Clarify Waste Treatment Regulations

Maryland's regulations governing the treatment of regulated medical waste should be updated to ensure that they allow the use of current and future alternative treatment technologies. Methods that satisfy disinfection and unrecognizability requirements should be permitted. By offering as broad a list of alternative technologies as possible, the regulations will enable hospitals and health care facilities to select the treatment approach that best meets their needs without relying on incineration.

Maryland regulators should ensure that existing incinerators are not emitting mercury, dioxin, and other pollutants in excess of their permitted amounts.

Help Hospitals Switch Technologies

For hospitals that have incinerated their waste for decades and that do not have waste segregation programs in place, the prospect of using another disinfection technology may seem daunting.

However, many hospitals have successfully closed their incinerators and begun segregating wastes, offering models for how to transition from reliance on incineration. Further, the Maryland Department of the Environment (MDE) and the Department of Health and Mental Hygiene (DHMH) can offer assistance to hospitals and health care facilities to make these changes easier.

- MDE and DHMH can help hospitals audit their current waste streams, create recycling and segregation programs, and design staff trainings to implement the plan.
- MDE and DHMH can help health care facilities end purchases of mercury-containing products by providing information on alternatives. Information about mercury recycling programs could help hospitals separate and recycle existing items with mercury.
- A thorough review of autoclave and microwave units available on the market could help health care facilities select the appropriate unit.

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