April 2023

Alternative disposition services: Green burial, alkaline hydrolysis and human composting

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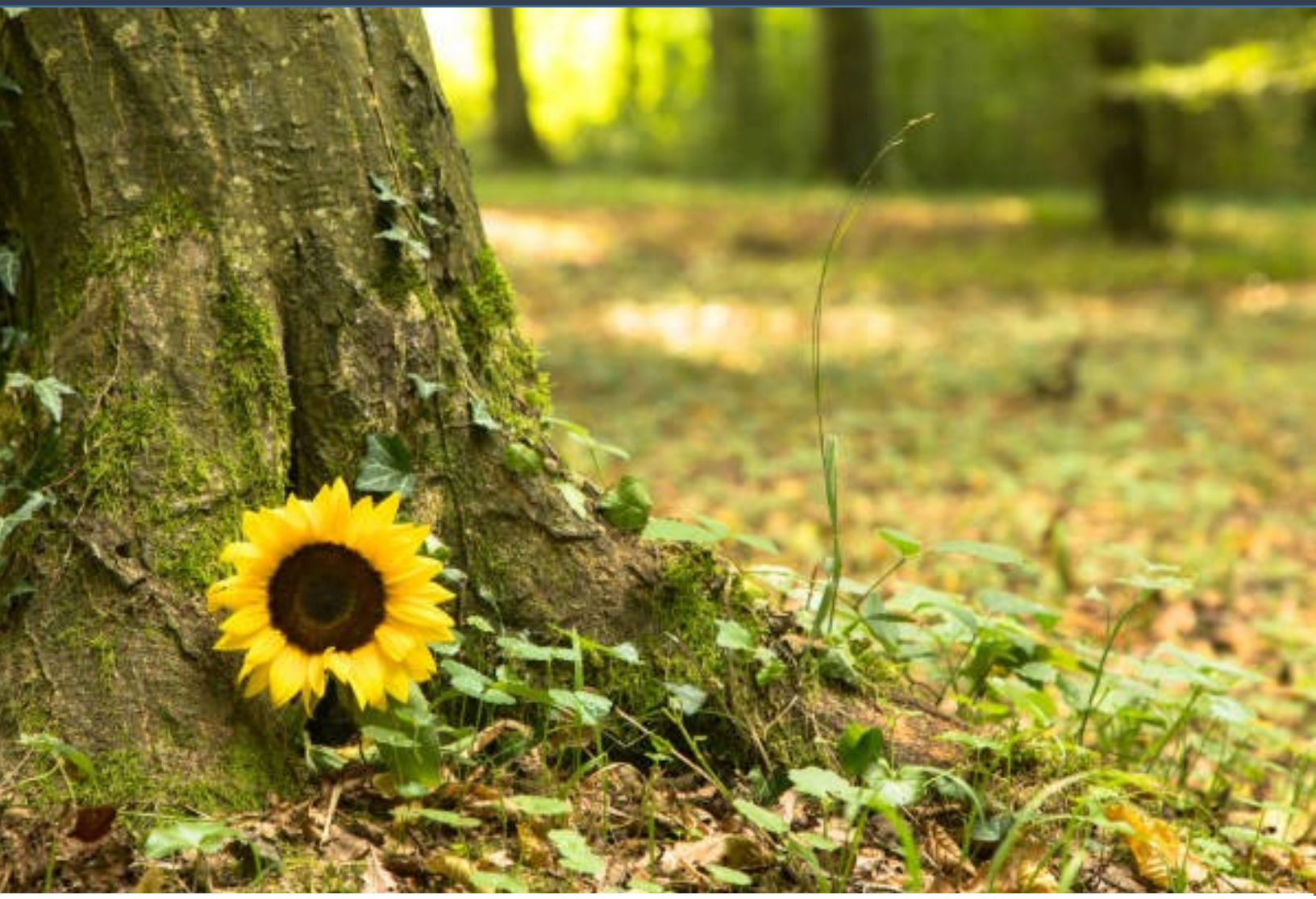

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Key Messages

- Public interest in new ways to dispose of human remains (alternative disposition services) is growing, driven in part by consumer demand for more sustainable funeral options.
- Alternatives include **green burial** (permitted in most Canadian provinces and territories), **alkaline hydrolysis** (only permitted in SK, ON, QU, NL, and NWT), and **human composting**, which is not currently permitted in any Canadian jurisdiction.
- The environmental benefits of these services are mostly derived from avoiding the use of chemicals, energy, and materials used in conventional methods.
- The environmental health concerns include the potential for nuisance (e.g., odour, aesthetic impacts, and traffic), water or soil pollution, and public or occupational exposure to biological, chemical, or radiological agents.
- There has been limited scientific investigation of the scope and scale of hazards; however, approaches to minimizing hazards could include:
    - Ensuring decomposition leachate from green burial sites does not contaminate environmental waters or drinking water sources;
    - Ensuring alkaline hydrolysis process conditions are safe for operators and sufficient to inactivate pathogens, and effluent is sufficiently treated to reduce impacts on wastewater systems.
    - Ensuring human composting operational parameters are sufficient to ensure the inactivation of pathogens and safety of operators, and that final compost material is managed in a way to reduce risk of operator or public exposure to biological, chemical, or radiological agents.
- Consideration should be given to whether any disposition method is appropriate for decedents with certain diseases or radiological implants where there is potential for occupational or public exposure to harmful agents during handling of the deceased or from release of decomposition leachate, effluent, or compost to the environment.
- Further study of the technical safety and the potential for nuisance or pollution could inform regulation and good practice guidance on selecting appropriate sites, designing operation controls, and ensuring appropriate oversight and monitoring.

Introduction

In Canada, human remains are typically cremated or interred in cemeteries, but there is growing consumer interest in alternatives to these conventional disposition services that offer more environmentally sustainable end-of-life options. In response to inquiries to the NCCEH about the possible environmental and health considerations associated with alternative disposition services, this document seeks to provide an overview of three such services: ***green burial***, ***alkaline hydrolysis***, and ***human composting.*** These services have been the subject of public interest, media attention, petitions, or planning inquiries in various Canadian jurisdictions. Other alternative disposition practices (e.g., ***promession***) and the handling of pet remains are outside the scope of this review.

This document addresses the following questions:

- What are the alternative disposition services under consideration and their proposed environmental benefits?
- What are the environmental health concerns associated with alternative disposition services?
- What approaches can be used to minimize possible environmental health hazards of alternative disposition?

Methodology

General approach

We used a multi-pronged approach that included consultation with individuals who have expertise on the subject of human disposition services, alongside a rapid literature search for academic and grey literature and public health guidance or resources relevant to the topic.

Consultation

Across Canada, oversight for human disposition is generally the responsibility of provincial or territorial agencies, ranging from consumer protection to environment, health, or public safety Ministries (see **Appendix 1**). At the local level, these oversight bodies and public health units are often called on to comment on planning applications, and provide advice and support to operators or municipalities. Industry bodies, while sitting outside of the regulatory regime, also provide education and support to operators, and may set internal criteria for member certification.

Individuals representing provincial regulators, public health units, and industry with in-depth knowledge of disposition services currently in use or proposed were consulted. Consultees were asked for information on the types of services being considered, key resources, regulations, or best practice documents relevant to Canada, and the key environmental health issues that should be considered in regulation or oversight of these services. Several consultees also assisted in providing external review of this document prior to publication.

Literature search

A rapid literature search was performed to identify evidence of environmental public health hazards associated with disposal of human remains, with a focus on emerging and alternative "green" disposition methods. EBSCOhost databases (includes Medline, GreenFILE, CINAHL, Academic Search Complete), Google Scholar, and Google were scanned for results with no date limit, no jurisdictional limit, and English language documents. Variants and Boolean operator combination of key search terms were used (a full list of search terms is available upon request). Examination of bibliographies and citations of key articles was used to retrieve more extensive information via forward and backward chaining, along with supplemental searches as necessary. Additional grey literature and government websites (Canadian and international) were also scanned for relevant legislation, regulations, and guidance information. Retrieved papers were assessed by a single reviewer for inclusion and synthesized narratively. The synthesis was subjected to internal and external review.

Results

Background

Human disposition practices refer to the final treatment of deceased persons (decedents) and have been established over time based on traditional, cultural, or religious norms, to provide dignified treatment of decedents. Disposition practices are also intended to provide safe disposal of the deceased to ensure the living are protected from environmental health hazards, including exposure to harmful agents or nuisance. In Canada, cremation and cemetery burial are the most common disposition methods, with preference for cremation over burial increasing since the 1950s. The Cremation Association of North America (CANA) estimated that in 2021 approximately 75% of human remains in Canada were cremated, and predicts this to rise to > 80% by 2025.[1]

Common disposition methods are often associated with some potentially negative impacts, including the following[2-9]:

- Embalming of bodies can result in release of biological or chemical contaminants to sanitary drains (e.g., pathogens, nutrients, formaldehyde, pharmaceuticals),[4] and health risks from occupational exposure of embalmers and others who handle embalming chemicals.[5,10,11]
- Caskets made of hardwoods and metals with paints, varnishes, and preservatives, have a high environmental footprint based on raw materials and energy used in their production, as do imported headstones.[2,6,8,12]
- Conventional burial can result in:
    - Possible soil and water contamination with leachate from decomposition of bodies, caskets, and burial materials,[3,5,9,13-15] which could be exacerbated at sites where risks of flooding or permafrost melting is increasing due to climate change.[16-18]
    - Challenges of competing land use, especially in urban spaces, possible aesthetic and nuisance impacts (e.g., visual, odour, traffic),[5,9,19] and ongoing environmental costs of maintenance and landscaping (e.g., energy and pesticides).
- Flame cremation can result in:
    - Consumption of electricity and gas, contributing to climate change.[2,8,12]
    - Concerns about air pollutants from the combustion of bodies, caskets, and funeral items, and aesthetic and nuisance impacts (e.g., visual, odour, traffic), contributing to challenges of competing land use and public opposition to new crematoria.[2,5,14,20]
    - Possible soil contamination from spreading of ashes (e.g., heavy metals).[3,21]

These factors are driving interest in alternative disposition services that avoid or reduce some of the impacts listed above. Other drivers include commercial motivations of funerary service providers and consumer-related motivation such as greater choice and lower costs.[22-24] Access to alternative disposition services in Canada is currently limited due to a lack of providers for some services, or services not being permitted in part or all of Canada. Many consumers are also unaware of alternatives, or may have cultural or religious preferences that preclude them from using alternatives.

What are the alternative disposition services under consideration and their proposed environmental benefits?

Green burial: Description and environmental benefits

Also known as organic, natural, woodland, conservation, or forest burial, bodies or ashes are buried in ground that is intended to remain or become "natural."[3,22,25-29] Burial may be on land used as a woodland, meadow, parkland, or wildlife conservation reserve that preserves or enhances existing habitats. This can include either rural or urban/suburban locations. Green burial sites may be standalone locations or part of existing municipal or private cemeteries (hybrid sites), where designated areas are set aside for green burial and intended to become more naturalized over time by discontinuing regular grass

cutting and landscaping, and pesticide use, and prohibiting the use of conventional headstones. Operators may also plant trees or other native vegetation on the site.

Green burial is permitted in most Canadian jurisdictions but burials outside of established cemeteries may be prohibited, with land use and zoning regulations prescribing where alternative disposition services can be provided.[28] There are currently around 15 green burial or hybrid sites in Canada that are certified by industry bodies such as the Green Burial Society of Canada (GBSC), or the North American Green Burial Council (GBC), which set industry standards that may be separate from local regulatory requirements. The practice of green burial is more common in other countries, such as the UK and the US, each of which have several hundred green burial sites.[28]

Common criteria for many industry-certified green burial sites include prohibition of embalmed bodies, hardwood or metal caskets, headstones, or memorial items. In most sites, grave markers are not permitted, although practice varies by site, with some allowing mourners to place bird or bat boxes or small plaques on trees or stones.[30] Burial must be in a cloth shroud or biodegradable casket (e.g., cardboard, wicker, or sustainable timber). Some companies are developing biodegradable burial clothing or vessels to serve the green burial market. These may include unbleached and undyed natural fibres such as jute,[8] water soluble fabrics, mycelial coffins, or mushroom burial suits impregnated with fungal spores.[31] Some burial products incorporating fungi claim to aid decomposition and neutralization of toxins ("mycoremediation"); however, no peer-reviewed studies could be found to verify this process in the literature. Some of the proposed environmental benefits of green burial are listed in Box 1.[3,22,25-29]

Box 1: Proposed environmental benefits of green burial

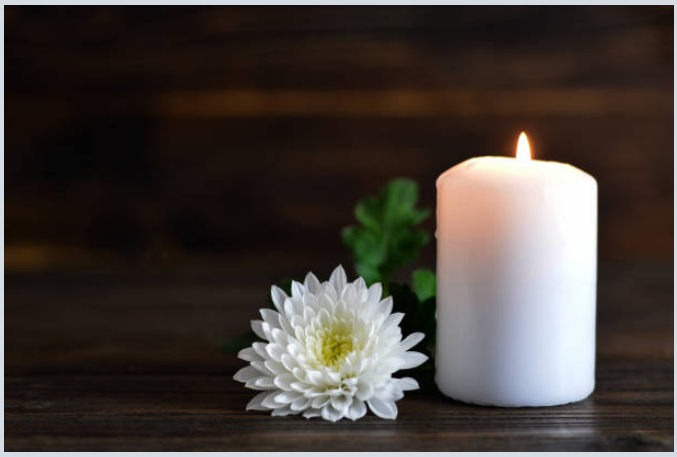
- Avoidance of landscaping practices that require machinery (e.g., lawnmowers) and chemicals (e.g., pesticides or fertilizers) to maintain cemeteries.
- Avoidance of chemical leachate from burial materials (e.g., metals) and bodies (e.g., embalming chemicals).
- Avoidance of embodied environmental cost of burial materials, coffins, and head stones.
- Reduced impermeable surfaces, contributing to natural drainage and flood alleviation.
- Protection of wild land as a natural or public asset, contributing to enhanced biodiversity or public green spaces.

Alkaline hydrolysis: Description and environmental benefits

Also known as aquamation, resomation, water cremation, or bio-cremation, alkaline hydrolysis involves placing the body in a stainless steel vessel that is filled with a mixture of water and strong alkali solution, usually potassium hydroxide (KOH), and heated. The strong alkali solution, heat, and pressure help to dissolve the body into a liquid. The liquid that remains in the vessel after the hydrolysis process is a mixture of the high alkali solution and the breakdown products of the human remains, which can include amino acids, basic sugars, and minerals. This liquid, referred to as **hydrolysate,** is usually neutralized or diluted to lower the pH, after which it can then be discharged to sanitary drains. Bone fragments remain in the hydrolysis vessel and are then recovered, crushed, and returned to next of kin in a similar manner to conventional cremation remains. Metal implants and mercury bound to teeth can also be recovered and recycled. Alkaline hydrolysis is permitted for human disposition in Saskatchewan, Ontario, Quebec, Newfoundland and Labrador, and the Northwest Territories. Across these jurisdictions there are currently only a few licensed providers. It is permitted or pending approval in approximately half of the US states, but there is limited uptake outside of North America.[32] In many jurisdictions, (e.g., Saskatchewan, Quebec, NWT) the definition of "cremation" in legislation includes alkaline hydrolysis, but elsewhere (e.g., Ontario), it is defined separately.[33-36]

Most human alkaline hydrolysis processes use a high-temperature system; however, low-temperature systems are also available. High-temperature systems are operated under pressure to maintain temperatures above 100°C (typically around 150°C), and take about 3–6 hours. Low-temperature systems also use a strong alkali solution, but operate just below 100°C, and do not use a pressurized vessel. Low-temperature systems require a longer processing time to ensure complete hydrolysis of biological material, which can take up to 18 hours.[37] Some of the proposed environmental benefits of alkaline hydrolysis are listed in Box 2.[33-36]

Box 2: Proposed environmental benefits of alkaline hydrolysis



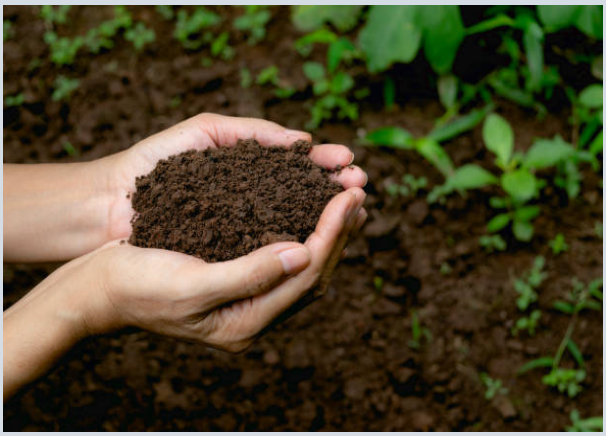
- Avoidance of embalming chemicals leaching into the environment.
- Avoidance of burial items (e.g., coffins) and memorial headstones.
- Less energy consumption than flame cremation (estimates of 1/7th to 1/8th the consumption of flame cremation).[33,34]
- No emissions to air of mercury, particulate, smoke, odours, dioxins, etc.
- Mercury fillings and metal implants can be recovered, and metals recycled.
- Pathogen reduction has been observed for alkaline hydrolysis of animals (e.g., 7–9 log reduction), including inactivation of viruses, bacteria, spores, and prions due to high pH and sustained elevated pressure and temperature.[35,36,38]
- Process may also destroy some aldehydes (formaldehyde) and some chemotherapeutic agents.[38]

Human composting: Description and environmental benefits

Also known as natural organic reduction (NOR), terramation, or recomposition, human composting is not currently permitted in any Canadian jurisdiction. Canadians can access the service in US states such as Washington, the first North American jurisdiction to make it legal. The process involves placing the body into a specialized vessel containing organic materials (e.g., woodchip, straw, alfalfa), which is turned and aerated over about 30 days. The process mimics conventional aerobic composting processes that promote microbial decomposition of organic material. Some mechanical action may be used to break down more resistant material such as bones. Heat is naturally generated during the process but can also be added to ensure pasteurization temperatures are achieved (e.g., 55°C for 72 hours to reduce bacteria such as fecal coliforms and salmonella). The decomposed mixture of human remains and organic matter is removed from the composting vessel and aerated for several months. The soil-like material is sieved and metals or implants are recovered and recycled if possible. The final compost material can be returned to next of kin, donated to a reclamation site to be used as top soil, or deposited on a designated site, but the permitted uses may vary by jurisdiction (see **Appendix 2** on permitted uses in US jurisdictions). Some of the proposed environmental benefits of human composting are listed in Box 3.

Box 3. Proposed environmental benefits of human composting

- Avoidance of embalming chemicals leaching into the environment.
- Avoidance of burial items (e.g., coffins) and memorial head stones.
- Avoidance of cemetery burial impacts (e.g., energy and chemical use in landscaping).
- Lower energy consumption compared with flame cremation and no combustion emissions to air.
- Production of a soil material that can be reused for soil reclamation.



Evaluating the proposed environmental benefits

Few studies have evaluated the magnitude of environmental benefits that may be accrued from alternative disposition services. A few life cycle assessments (LCA) pertaining to human disposition processes have compared the environmental impacts (pollution, embodied energy, and materials) of conventional disposition practices[8,39] and alternative services (alkaline hydrolysis and promession).[12] These LCA find that pre-funeral processes and raw material consumption for cremation and burial (embalming, coffin use) contribute significantly to life cycle impacts. These pre-funeral processes are avoided for alternative services where no embalming or coffin is used. Alternative services also avoid the embodied energy and materials of headstones, or the release of combustion emissions to air. Most of the benefits are thus gained from avoidance of material use or emissions, rather than added benefits from recycling of materials. No studies were identified that evaluated the benefits of human composting in comparison to conventional disposition services.

What are the environmental health concerns associated with alternative disposition services?

The literature review was used to search for evidence of whether alternative human disposition services present a risk of physical, chemical, or biological exposures that could affect the health of persons living and/or working in or near those sites, resulting in acute or chronic injury or illness. Literature on the subject was found to be limited. No studies have assessed the direct or indirect environmental health impacts of these processes, either as standalone studies or in comparison with conventional processes. In addition, there are no data available regarding the association between alternative human disposition and adverse public or occupational health outcomes. This is not surprising given that these processes are

relatively new, and that the literature on conventional disposition practices is also limited.[19,20] Additional information was sought from multiple other sources including consultees, grey literature, and public agencies to further characterize the possible environmental or health concerns that may arise from alternative human disposition processes. This included literature and reports on the use of burial, alkaline hydrolysis, or composting for the disposition of health-care waste or animal carcasses. Issues surrounding public perception and societal acceptable of alternative processes were also considered.

Infectious disease risks

An area of interest among consultees was whether the potential for exposure to infectious diseases from alternative disposition processes differs from exposures in conventional processes.[40] Some infectious agents can persist in tissues or fluids of diseased persons for extended periods, such as anthrax spores or **prions**, both of which can be difficult to destroy via conventional disinfection techniques. Prions diseases, or transmissible spongiform encephalopathies (TSE), include rare brain diseases in humans such as Creutzfeldt-Jakob Disease (CJD). Infection can occur via direct contact with contaminated fluids or tissues of a decedent, particularly the brain, due to accidental ingestion or inoculation. Fewer than 90 deaths per year are reported of persons with a definite or probably diagnosis of CJD in Canada.[41] Other diseases that may be of concern could include cholera, typhoid, smallpox, and viral hemorrhagic fevers (VHF), although the occurrence of these in Canada is either low or non-existent in recent years.[42]

The broad infection hazard for persons involved in handling of the deceased is already well known and standard precautions, when applied for any disposition service, can reduce exposure to pathogens, whether an infectious disease is known, or undiagnosed, at the time of death.[43-45] There are also biosafety measures recommended for those handling infected tissues, designed to prevent accidental inoculation or ingestion of materials,[46] including the safe management of biological material or embalming waste from persons affected by a TSE.[47] When following these recommendations, which include personal protective measures, the risk of transmission of infectious diseases from decedents is low. The release of infectious agents to the environment following green burial, alkaline hydrolysis, or human composting, however, has not been well studied. This hazard, and other environmental concerns, are discussed below for each of these practices.

Green burial: Environmental health hazards

Decomposition of the body in a burial site results in the release of liquid leachate into the soil, which can be further mobilized by rainwater drainage. This leachate has the potential to contaminate nearby soil and groundwater with nutrients, organic matter, microbial, and chemical contaminants, affecting environmental and drinking water quality.[3,16,19,22,25,26] Green burial leachates may spread more readily than in conventional burials, due to the absence of a coffin. These leachates are unlikely to include embalming fluids or other chemicals (e.g., preservatives or varnishes in coffins) used in conventional burial processes,[14] but they can contain other chemical contaminants such as residual personal care

products, pharmaceuticals, or drugs contained in the body. Antibiotic resistant bacteria or resistance genes could also persist.[48] The risk of water contamination from burial leachate depends on the size and topography of the burial site, the number and frequency of burials, the soil type, pH, and temperature, and the proximity to local surface water or groundwater sources. Pathogens are often retained in the upper soil surface, or adsorbed to soil particles,[40] and detection decreases with distance from the burial site. Even prions, which can remain viable in the soil, have a strong binding affinity for soil particles, suggesting low mobility in the environment.[49-51] Burial, however, is not generally recommended for animal carcasses with a TSE, suggesting green burial may also be unsuitable for human decedents with a TSE.[35,36]

A review of microbial contamination of groundwater from conventional cemeteries found a relatively low level of contamination in moderate climates;[16] however, greater contamination was found in warm, moist climates, with extended periods of rainfall contributing to mobilization of contaminants over 100 m.[16] A review of natural burial sites in the UK for risk of groundwater contamination found that green burial sites were generally smaller and less dense than conventional cemeteries, and none were identified as high-risk; however, a site assessment prior to operating such sites could identify water sources at risk of contamination.[14]

Other concerns related to green burial could include general nuisance concerns, such as traffic, the potential for decomposition odours, or littering in natural settings with memorial items placed on burial sites.[27] Some of these concerns may be similar to those raised for conventional sites. In a study that surveyed green burial locations in the UK, public objections were raised at about one third of the sites based primarily on concerns about local water contamination, hygiene, and traffic.[26] In Macon-Bibb County in the US state of Georgia, public concerns about green burial sites included the risks of decomposition leachate entering water supplies, or animals digging up remains that were not contained in a casket. This resulted in green burial sites being banned in the county, and a requirement for leak-proof casket or vaults being implemented.[52] No evidence was found that human remains at green burial sites present a greater risk of being dug up by animals than in conventional burial sites, where this is known to occasionally occur.[53-55] Burial depth may be an important consideration in limiting odours and animal access to human remains at both conventional and green burial sites.

Alkaline hydrolysis: Environmental health hazards

The risk of infectious pathogens surviving alkaline hydrolysis processes is low. Heat, in combination with strong alkaline solution, as applied in alkaline hydrolysis, has proven effective for disinfection of bodily fluids and tissues from CJD patients,[47,56,57] and is recognized by the World Health Organization (WHO) for the destruction of prions in human tissues and cadavers.[58] A United Nations Environment Programme (UNEP) report on technologies for the treatment/destruction of health-care waste also found alkaline hydrolysis to be suitable for prion destruction at a combination of elevated temperature (e.g., 150°C), pressure, and a minimum exposure time of six hours.[38] Alkaline hydrolysis has also been found to be

suitable for disposal of TSE-contaminated animal material in reports by the European Commission (EC)[59] and the US Environmental Protection Agency.[35] Effluent from high-temperature alkaline hydrolysis is unlikely to retain viable pathogens, if operated at the specified alkali concentration, temperature, and time conditions. The Health Council of the Netherlands developed a framework for assessing new disposition techniques based on "guaranteed technical safety" and "no emission of high-risk agents."[60] In applying this framework to alkaline hydrolysis, the Health Council Committee determined it met the proposed conditions with respect to technical safety, when operated by trained personnel in accordance with manufacturer's instructions, and appears to result in no emission of high-risk agents, although some technical specifications could require further assessment.

Concerns were raised in Ontario about whether low-temperature systems are sufficient to degrade prions, or whether there are risks of occupational exposure to prions for persons that handle hydrolysate, or risks of environmental contamination with prions from effluent released to the environment.[61] Alkali concentration and temperature can affect the speed at which prions are degraded, and previous study has indicated that systems using low pressure and low temperature (e.g., 95°C) require a longer process time to enable prion destruction (e.g., up to 18 hours).[38] The potential for human exposure to infectious agents in the hydrolysis effluent can depend on the operational controls, the probability of an infected decedent being present, the effectiveness of workplace controls, and the environmental protection measures in place.[59] The combination of high pH, heat, adequate process time, and subsequent dilution of hydrolysate prior to disposal reduces the likelihood of high concentrations of prions being present in effluent. The low prevalence of TSE infections in the Canadian population also suggests a low likelihood of exposure to infected decedents. Previous study of prions in wastewater matrices has indicated that prions that persist will bind strongly to particles, and if present in diluted effluent, would likely be retained in solids rather than be released in treated effluent to the environment.[51]

A separate environmental health concern often raised for alkaline hydrolysis is the potential impact of the hydrolysate on sewage infrastructure. Effluent released to municipal wastewater infrastructure can have elevated pH, organic content, nutrients, ammonia, or solids if not pretreated.[35,36] This could affect downstream pipework or wastewater treatment processes, depending on the volume released and the capacity of the system to accommodate high-strength effluent.[33-36] For example, septic tanks would be less able to accommodate large inputs of concentrated effluent compared with large wastewater treatment plants. Depending on the quantity released to wastewater drains, concentrated effluent could introduce some system challenges. Hydrolysate could solidify if large quantities are released as warm, high pH effluent, without dilution.[36,59] A study undertaken by the water utility, Yorkshire Water in the UK to analyse the effluents from five alkaline hydrolyses, found that the effluent did not pose any significant concern for the wastewater infrastructure, treatment works, or receiving water quality.[34] There is limited published literature elsewhere reporting on the quality of hydrolysate and its impact on sewage infrastructure.

Occupational health and safety concerns associated with alkaline hydrolysis may arise from manual handling of decedents, exposure to caustic chemicals, exposure to high-temperature liquids or vessels, or mechanical failure of pressurized vessels potentially causing injury. Low-temperature systems present lower risks of operator injury due to the lower processing temperature and absence of pressurized vessels. The Canadian Nuclear Safety Commission now includes alkaline hydrolysis in the Radiation Protection Guidelines for Safe Handling of Decedents.[62] The guidance states that alkaline hydrolysis is not suitable for a decedent who underwent a therapeutic nuclear medicine procedure or manual brachytherapy, reducing the possibility of occupational exposure or environmental release of radioactive agents.

Public concerns related to alkaline hydrolysis sites can include perceived nuisance from traffic or reduced property prices.[63,64] Public opposition to alkaline hydrolysis, however, is most often based on cultural or religious beliefs, and the perceived indignity of disposal of hydrolysed remains to sanitary drains.[33,65,66] In contrast, some groups have signaled support for alkaline hydrolysis as a more culturally acceptable practice. In Hawaii, Indigenous groups petitioned for alkaline hydrolysis to be made available as a means of recovering the bones of their deceased, allowing for funeral rituals more in line with cultural norms.[67]

Human composting: Environmental health hazards

Environmental health concerns for human composting include risks to persons involved with manual handling of the deceased, equipment operators, or those handling compost (e.g., operators and next of kin), especially from decedents who died with certain infections (e.g., anthrax, smallpox, VHF, TSE, tuberculosis). For disposal of animal waste, composting is generally found to be unsuitable for infected carcasses, as composting conditions and temperatures may be insufficient to guarantee inactivation of some high-risk pathogens such as prions. Prions may remain bound to particles of organic matter and retain infectivity in soils where compost is spread.[51] Accidental ingestion or inoculation could occur via direct contact with potentially infectious material (e.g., skin contact, on edible plant surfaces, or taken up by plants in home gardens).[68]

Risks to the environment or wider public from land-spreading of human compost have not been assessed, including the risks of exposure to biological, chemical, or radiological contaminants in compost applied to domestic gardens or land used for growing of food. In addition to possible exposure to infectious material, compost material from persons who have received radiation seed implants, or have undergone radiotherapy prior to death, could present a radiation exposure risk. Decedents may also have chemicals within their tissues (e.g., drugs or pharmaceuticals) that are not degraded by the composting process and could remain in the compost material. The quality of the compost material may depend upon the condition of the decedent at the time of death. There is currently no Canadian legislation on where and how human-derived compost can be disposed, and requirements vary in US states. (See Appendix 2.) No regulation or guidance was identified on the practice of bringing human-derived

compost from licenced US human composting providers back to Canada for use on private gardens by next of kin.

Public opposition may arise based on possible nuisance impacts such as odour. The odour and air quality impacts of conventional composting facilities can sometimes reach several hundred metres downwind of compost facilities,[69] and result in inflammatory and immune effects, or eye, nose, or throat irritation.[70,71] Human composting facilities are likely to be much smaller than commercial composting facilities, but the release of bioaerosols, particulate, or volatile organic compounds (VOCs), and the possible nuisance or health effects have not been widely assessed, and could be an area for further study.

Public opposition to human composting based on cultural or religious beliefs has also been raised by some groups,[72] based on perceived indignity of handling human remains by this process. In jurisdictions that have considered, but rejected, or have yet to permit human composting, concerns have included uncertainty and disagreement as to the appropriate regulatory and oversight requirements needed to ensure public safety, and cultural and societal sensitivity over handling of the deceased. The Health Council of the Netherlands' framework for new disposition techniques[60] concluded that insufficient information was available on human composting to fully assess if the process guaranteed technical safety and no emission of high-risk agents.

What approaches can be used to minimize possible environmental health hazards of alternative disposition?

The oversight of human disposition processes aims to reduce the spread of disease and exposure to nuisance by implementing laws and procedures for safe handling of the deceased. This protects workers and the public from exposure to pathogens and harmful agents. This includes the requirement for burial and cremation facilities to be licenced disposition sites and to comply with zoning laws and operational requirements to prevent release of contaminants that could cause a public health hazard or nuisance.[19,20] These general requirements apply to alternative disposition services where they are currently permitted.

Within existing regulatory frameworks, provisions to control environmental health hazards vary widely between provinces and territories, and among municipalities. Variation in regulatory approaches and local practices will thus affect who may have access to alternative disposition services across the country, or how these services are delivered. For example, some jurisdictions (e.g., AB, SK, MB, ON, NS, QU, YK) require leak-proof metal or hermetically sealed caskets for persons who have died with certain infectious diseases, which would bar some decedents from green burial, alkaline hydrolysis, or human composting, since the caskets cannot be degraded. The types of diseases specified for sealed caskets are not the same across these jurisdictions. Most include smallpox or plague in the requirement for a sealed casket, but others may require one for additional diseases (e.g., VHF, TSE, cholera, typhus). Other jurisdictions (e.g.,

BC, NB, PEI, NL, Nun, NT) may not require a sealed casket for these diseases, or may only require one on a case-by-case basis.

Another example of regional differences in disposition regulations is burial depth, which may not be specified, or may vary by province, territory, municipality, or individual burial site. Requirements can also vary based on whether a casket or burial liner is used, which affects green burial sites differently in some jurisdictions, but not all.[73-75] For alkaline hydrolysis, Ontario stands alone in having detailed requirements for alkaline hydrolysis operators, which were developed by the Bereavement Authority of Ontario (BAO);[76] whereas, in other Canadian jurisdictions where alkaline hydrolysis is permitted, requirements simply align with those required for crematoria operators and may be non-specific to the technology.

Overall, a consistent regulatory approach for disposition services is hampered by the lack of a strong evidence base on which to design control measures, and oversight sometimes falls short of considering and ensuring environmental health protection.[77] While the scope and scale of oversight varies widely across Canada, based on this review, some general approaches to minimizing the environmental health hazards could be considered for alternative disposition services as described in Table 1.

Table 1. Environmental health hazards and risk-reducing measures for alternative disposition services

Hazard	Measures
Green burial	

Contamination of drinking or environmental water with decomposition leachate	• Conduct site surveys (desktop and onsite) and/or local consultation to:
	  ○ Identify water bodies or drinking water wells at risk of contamination[14,16]
	  ○ Assess the site suitability for retaining leachate (e.g., avoiding highly permeable soils, proximity to seasonal high-water table, geological faults, steep slopes, and areas at risk of flooding or permafrost melting).[14,50]
	  ○ Establish safe separation distance from burial site to water sources based on local conditions.[19,40]
	• Consider control measures for managing site drainage such as leachate collection systems, liners, or barriers to restrict the movement of leachate,[5] vegetation,[40] or the use of natural sorbents (e.g., silage, cornstalks, wood chips, or rice hulks) to reduce leachate flow.[35]

Release of odour or animal access	• Set burial depths to minimize release of odours and animal access, while maintaining an adequate distance between the grave bottom and water table. This may need to be determined by site and jurisdictional requirements. ○ Industry norms often recommend 1–2 m (3–6 ft) depth; however, the scientific basis for this is limited. The WHO recommends a minimum of 1 m soil cover, whereas local requirements may differ.[40] • Consider odour control measures such as the addition of natural organic sorbents (e.g., silage, cornstalks, wood chips, or rice hulks) in the grave.[35]
Alkaline hydrolysis	
Risks to operator, or next of kin, health and safety	• Ensure equipment is operated by trained personnel in accordance with manufacturer's instructions, and following general occupational health and safety guidance available for safe handling of decedents and chemicals.[60] • Some jurisdictions may require the removal of pacemakers prior to hydrolysis to prevent explosion at high temperature. • Consider the appropriateness of alkaline hydrolysis for decedents with some infectious diseases, and additional safety measures required for safe handling of these decedents.
Risks of inadequate inactivation of infectious pathogens	• Ensure process conditions are appropriate for the equipment used. Higher-temperature and longer-duration systems are more effective than low-temperature, short-duration processes. ○ For high-temperature systems, a minimum of 150°C, and minimum three hours treatment is commonly recommended. For low-temperature systems, manufacturer specifications should be followed, but previous literature suggests process durations in excess of six hours, and up to 18.
Risk of exposure to radiological agents in the hydrolysis process, or in effluent	• Exclude decedents who underwent a therapeutic nuclear medicine procedure or underwent manual brachytherapy based on the Canadian Nuclear Safety Commission's Radiation Protection Guidelines for Safe Handling of Decedents.[62] Removal of radioactive implants may be required. • Consider whether other exclusions are needed (e.g., persons who have died as a results of a radiologic incident or accident).[78]

Damage to sanitary drains or wastewater infrastructure	• Ensure the capacity and configuration of the downstream treatment is suitable for accepting the hydrolysate, and pre-treatment is applied where needed.[36,38] Pre-treatment could include pH adjustment using neutralizing agents or CO_2 bubbling, dilution, or slow release to drainage.[38]
Human composting	
Risks to operator, or next of kin, health and safety	• Ensure equipment is operated by trained personnel in accordance with manufacturer's instructions, and following general occupational health and safety guidance available for safe handling of decedents and chemicals. • Removal of pacemakers may be required prior to composting to prevent explosion from mechanical damage. • Consider the appropriateness of composting decedents with some infectious diseases, and additional safety measures required for safe handling of these decedents.
Risks of exposure to pathogens in compost	• Ensure process requirements are sufficient to ensure inactivation of pathogens like fecal bacteria, salmonella, and others. • Consider whether end uses of compost material pose a risk of public exposure to pathogens, and whether any microbiological testing of the final product, or restrictions on use, are needed.
Risk of exposure to chemical hazards in compost	• Consider whether end uses of compost material pose a risk of public exposure to chemicals that are not degraded by the composting processes (heavy metals, drugs, or medications), and whether any chemical testing of the final product, or restrictions on use, are needed.
Risk of exposure to radiological agents in the composting process, or in handling of compost	• Given the exclusion of certain decedents from alkaline hydrolysis under the Radiation Protection Guidelines for Safe Handling of Decedents,[62] these decedents could be excluded from human composting, should the process be approved in Canada. Removal of radioactive implants may be required. • Consider whether other exclusions are needed (e.g., persons who have died as a results of a radiologic incident or accident),[78]
Release of odours	• There is limited observational data to inform the possible nuisance impacts, but odours, which may be most intense in the early decomposition stages, can be contained by the use of closed-vessel systems. • Additional controls could be considered such as the use of such as biofilters, and appropriate siting of facilities, with sufficient setback distances from residences, businesses, and public facilities.
Canadians accessing human composting abroad	• Consider whether inspection or restrictions on the end use of compost transported across borders is required, from jurisdictions where the process is currently permitted, to jurisdictions where it is not.

For all disposition methods, additional considerations may include the available land supply and the needs of the community for different social or economic purposes, the acceptability of new services and sites to residents, the potential for nuisance, and the types of sites to be used (greenfield or brownfield), which can be informed by public consultation.[14,22,26-28] The public, however, may have limited knowledge

of the environmental benefits and risks of alternative disposition services, which may require the guidance of public health professionals to convey. Cultural and social considerations have been found to significantly influence public perception of alternative disposition processes in many jurisdictions; therefore, there may be a need to accommodate different beliefs, religions, and cultural practices in future legislation.[79]

Summary

Consumer demand for more sustainable and lower cost end-of-life disposition options, alongside commercial motivations of service providers, are driving interest in new funerary services. This has raised questions about both the environmental benefits and the environmental health hazards that may be associated with new services. Opposition to practices based on cultural or religious factors may cause some groups to avoid using certain services; however, other groups may perceive alternative services to serve the needs of their communities better than existing ones.

The benefits of alternative human disposition methods are most commonly framed in terms of avoidance of the undesirable environmental impacts of conventional disposition services such as embalming, the use of caskets and headstones for conventional burial, and emissions to air and energy consumption from flame cremation. Proponents of these alternative disposition services also cite benefits such as positive impacts on nature and biodiversity, recycling of nutrients or metals, and increasing consumer choice, including more culturally appropriate disposition methods. Life cycle assessments (LCA) provide some indication of the scope and scale of environmental benefits of alternative services compared with conventional services, but only a few studies have been conducted, and none that evaluate human composting.

This review identified limited scientific evidence of direct harms of alternative disposition services, including occupational and public health risks. Potential hazards could include exposure to biological, chemical, or radiological agents; however, many knowledge gaps remain. Some of the potential exposures described above are novel (e.g., handling of materials derived from human composting), warranting precaution until more research has been conducted. Further study on the persistence and mobility of decomposition leachates from green burial sites, as well as likelihood of odour release, or animal access based on appropriate burial depths, could better inform operational controls at these sites. For alkaline hydrolysis, additional study on the persistence of pathogens in low-temperature systems could assist in specifying operational controls, such as process duration. For human composting, further study of the release of odours and the possible nuisance or health effects is needed, which may require observation of new sites and monitoring of complaints in jurisdictions where the service is newly being offered. Improved understanding these issues among those with regulatory and oversight authority will

help to inform guidance on designating appropriate sites, designing appropriate controls, and ensuring adequate oversight of new sites or services.

Acknowledgements

We acknowledge the valued input of consultees for sharing their expertise and knowledge in production of this document, and for those who assisted in review of this document including: Dr. Angela Eykelbosh, Environmental Health and Knowledge Translation Scientist, Ms. Michele Wiens, Librarian, and Dr. Lydia Ma, Manager of the National Collaborating Centre for Environmental Health (NCCEH); Karah Harvey, Public Health Inspector-Coordinator, Healthy Physical Environments, Safe Healthy Environments, Alberta Health Services; Jin Hee Kim, Alvin Ching Wai Leung, and Vince Spilchuk of Public Health Ontario; and Consultees from Consumer Protection BC and the BC Ministry of Public Safety and the Solicitor General.

Appendix 1: Oversight bodies and relevant legislation by Province/Territory*

Jurisdiction	Oversight body for this sector and relevant legislation
British Columbia	The Ministry of Public Safety and Solicitor General is responsible for the legislation. Consumer Protection BC administers and enforces the Act and is responsible for licensing. • Cremation, Interment and Funeral Services Act and Regulations
Alberta	Alberta Funeral Services Regulatory Board • Funeral Services Act and Regulations • Bodies of Deceased Persons Regulation (AR 135/2008)
Saskatchewan	Funeral and Cremation Services Council of Saskatchewan • Funeral and Cremation Services Regulations • The Disease Control Regulations (Chapter P-37.1 Reg 11)
Manitoba	The Funeral Board of Manitoba • The Cemeteries Act and Regulations • The Funeral Directors and Embalmers Act and Regulations • Dead Bodies Regulation (CCSM c. P210)
Ontario	Bereavement Authority Ontario (BAO) • Funeral, Burial and Cremation Services Act and Regulations and Consultation on changes • Requirements for an alternative disposition operator - hydrolysis • Communicable Diseases- General (R.R.O. 1990, Regulation 557)
Quebec	Ministry of Health of Québec/ Ministère de la Santé et des Services sociaux • Regulation respecting the application of the Act respecting medical laboratories, organ and tissue conservation and the disposal of human bodies • Act respecting prearranged funeral services and sepultures of 1987 • Minister's Regulation under the Public Health Act (chapter S-2.2, r.2) • Regulation respecting the application of the Act respecting medical laboratories and organ and tissue conservation
New Brunswick	Financial and Consumer Services Commission • Pre-arranged Funerals Act • Embalmers, Funeral Directors and Funeral Providers Act and Regulations • Reporting and Diseases Regulation (New Brunswick Regulation 2009-136)
Nova Scotia	Nova Scotia Board of Registration of Embalmers and Funeral Directors • Cemetery and Funeral Services Act and Regulations • Communicable Diseases Regulations • Embalmers and Funeral Directors Act and Regulations • Operators of Crematoria Regulations • Transportation of the Dead Regulations (NS Reg 44/42) Under the health protection act

Prince Edward Island	Prince Edward Island Funeral Services and Professions Board • Funeral Service and Professions Act
Newfoundland and Labrador	The Embalmers and Funeral Directors Board • Funeral Directors Act • Public Health Protection and Promotion Act (SNL 2018 Chapter P-37.3)
Yukon	Government of Yukon • Funeral Directors Act and Regulations • Public Health Regulations Respecting Embalmers and Embalming of Corpses (OIC 1980/102)
Northwest Territories	Consumer Affairs Office • Crematorium Regulations • Reportable Disease Control Regulations (R-128-2009) • Northwest Territories Infection Control Policy and Procedures on: Care of the Deceased with an Infectious Disease
Nunavut	Department of Community and Government Services • Public Health Act, Consolidation of SNu 2016, c 13 • Reporting and Disease Control Regulations (R-051-2019)

*Information current as of Mar 15, 2023

Appendix 2: **Examples** of regulatory requirements from Canadian and US jurisdictions for alkaline hydrolysis and human composting*

Jurisdiction	Relevant legislation and examples of various requirements related to environmental public health matters
Canadian jurisdictions: Alkaline hydrolysis	
Ontario	• Bereavement Authority of Ontario (BAO) requirements for an alternative disposition operator – hydrolysis. o Requirements on hydrolysate disposal, equipment inspection, maintenance, and use; o Safety and emergency protocols, including minimum operating condition (temperature, pressure, pH, time), provisions to address mechanical failures, leaks or spills, and waste; o Design requirements in compliance with all jurisdictional legislation and by-laws (workplace safety, handling of dangerous goods, environmental protection, etc.).
Quebec	• Regulation respecting the application of the Funeral Operations Act, CQLR c A-5.02, r 1

	○ Excludes bodies with a probable CJD diagnosis or any other prion disease, active tuberculosis, plus several additional diseases (e.g., cholera, MERS-CoV, VHF, anthrax, plague, smallpox). ○ Electromagnetic stimulators must be removed prior to disposition.
Saskatchewan	• The Funeral & Cremation Services Bylaws ○ Alkaline hydrolysis is included in the definition of cremation. ○ Requires removal or pacemakers or radioactive implants, or other non-combustible objects or hazardous materials that may pose a danger during or after the cremation process.
Newfoundland and Labrador	• No specific requirements were identified in current regulation for alkaline hydrolysis operators.
Northwest Territories	• No specific requirements were identified in current regulation for alkaline hydrolysis operators
National level requirements	• The Canadian Nuclear Safety Commission includes alkaline hydrolysis in the Radiation Protection Guidelines for Safe Handling of Decedents. The guidance states that alkaline hydrolysis is not suitable for a decedent who underwent a therapeutic nuclear medicine procedure or underwent manual brachytherapy.
US jurisdictions: Alkaline hydrolysis	
California	• Department of Consumer Affairs - Cemetery and Funeral Bureau Under Licensure and Regulations of Alkaline Hydrolysis ○ Requirement that **facilities that discharge** hydrolysates to sewer to submit the current California Department of Public Health (CDPH) evaluation with the annual renewal application. The CDPH only evaluate the hydrolysis chamber every five years, but will evaluate the technical specification of any hydrolysis models that are marketed in California for the treatment of human remains to ensure systems can efficaciously destroy pathogens. Only facilities using CDPH-approved equipment will be granted a licence.
Minnesota	• Minnesota statues on alkaline hydrolysis ○ Requirements for a **purpose built** human alkaline hydrolysis system, a holding facility for bodies awaiting alkaline hydrolysis, a system for drying and a system for processing hydrolyzed remains, all approved by the commissioner of health. ○ Requirements for **the hydrolysis container** (e.g., hydrolysable or biodegradable leak proof container or pouch).
Nevada	• Nevada Revised Statutes: Chapter 451 – Dead bodies ○ Requirement of operators of **facilities that discharge** hydrolysates to sewer to advise State environmental regulators and sewer operators on intent to use alkaline hydrolysis in a crematoria, to ensure compliance with laws pertaining to water pollution. ○ Requirement of **sewer operators** to ensure the equipment complies with provisions (NRS 445A.300 to 445A.730) and other relevant laws, ordinance or regulations. ○ Requirements specific to **the container** used (readily dissolvable by alkaline hydrolysis). ○ Requirements specific to **devices** (removal of artificial devices that would be dangerous if incinerated or subjected to alkaline hydrolysis).

North Carolina	• North Carolina Legislature. Statues – Chapter 90 o Requirement for the **removal of** pacemakers, defibrillators, or any other implanted devices or material prior to hydrolysis. o Requirement **not to hydrolyze**, any decedent who is known or suspected to have been infected with the plague, smallpox, COVID-19, or severe acute respiratory syndrome (SARS), without first obtaining the written consent of the local health director.
Oregon	• Oregon Secretary of State Mortuary and Cemetery Board statutes - Chapter 830 o Requirement that **facilities** applying alkaline hydrolysis (dissolution) comply with requirements also applicable to crematory authorities and cremated remains. o Requirements for **dissolution vessels** to meet industry and commercial standards and achieve requirement for heat, time and circulation parameters necessary to achieve the complete reduction of all human remains, and if operated above atmospheric pressure to be an American Society of Mechanical Engineers' (ASME) certified pressure vessel. o Requirement that **liquid discharges** to sewer from dissolution processes meet sewage collection and treatment facility requirements for temperature and pH.
Utah	• Utah Code under the Funeral Services Licensing Act. Section 58-9-616 Procedures for alkaline hydrolysis. o **Disposal of liquid** remains should be in accordance with state and local requirements. o **Recoverable residues** should be removed and separated to the extent possible, from remaining bone fragments, which should be reduced to unidentifiable particles. o Section 58-9-617 includes additional language on final **disposition on land** of remains from the alkaline hydrolysis process.
Washington	• Washington state legislature – Chapter 308-47 Cremation, alkaline hydrolysis and natural organic reduction o Requirements on the **containers** used for receipt of human remains (e.g., leakage or spillage resistant). o Requirements on the **removal of implants or devices** prior to delivery to the facility. o Requirements for **dissolution chamber** (meets industry standards, used by a licenced operator, complies with local, state and federal laws). o Subject to **inspection** at least once per year by the inspector of inspector of funeral establishments, etc. to ensure compliance with Washington state laws and regulations related to health or the handling or disposition of human remains.
Wyoming	• Wyoming Board of Funeral Service Practitioners Statues Chapter 16 – Embalmers, Funeral Directors, Undertakers and Crematories o Requirements for **licensing and permitting** as a chemical disposition facility including the premises and structure. o Requirements to meet **minimum standards** of sanitation, fire protection, and environmental protection for the protection of the public. o Requirements for **containers** to be leakage and spillage resistant, rigid enough for handling, and provide protection for the health safety and integrity of personnel and the facility. o Requirements for the **equipment** (under Chapter 6 Crematory or chemical disposition facility) to be a purpose built vessel, certified by ASME if used above atmospheric pressure,

	and able to achieve parameters of heat, time, and circulation sufficient to achieve complete dissolution of all tissue remains. ○ Requirements to ensure **discharge liquid** meets the facility's sewage collection and treatment facility requirements regarding acceptable temperature and pH level.
US jurisdictions: Human composting	
California	• State of California AB-351 Reduction of human remains and the disposition of reduced human remains ○ Requirement for the **reduction chamber** to meet or exceed State Department of Public Health and federal Centers for Disease Control and Prevention requirements for **destruction of human pathogens**. ○ Manufacturers shall apply to the state DPH for **approval of a reduction chamber** for sale and use in the state. Licenses will only be granted to facilities using approved chambers. ○ Remains may be **integrated into soil** where no local prohibition exists, as long as remains are indistinguishable from soil, not in container, and written permission from the property owner or governing agency has been obtained. State or local agencies may authorize or prohibit integration of reduced remains into soils or lands under their jurisdiction. ○ May be restrictions on reduction of persons who died from infectious, contagious, or communicable **diseases** and dangerous to the public health, as determined by state or local health officers. ○ Prohibits **commingling of remains** in a reduction chambers or in the soil, or in a conservation area without consent.
Colorado	• State of Colorado Human Remains Natural Reduction Soil SB21-006 ○ Prohibits **selling or offering** to sell the soil. ○ Prohibits **commingling soil** of more than one person without consent. ○ Prohibits the use of **soil to grow food** for human consumption.
New York	• New York State Senate Assembly Bill A382 and Senate Bill S5535 ○ Requirement to **maintain facilities** in clean, orderly, and sanitary manner, with adequate ventilation, and inaccessible to the general public, with additional prescribed measures to maintain privacy. ○ Requirement for **removal of** battery, battery pack, power cell, radioactive implants or device prior to the process. ○ Prohibits the **commingling of remains** in a reduction chamber. ○ Provides details on **retrieval and disposal of incidental and foreign materials** (e.g., metals). ○ Requirement for **disposal of remains in designated locations** (e.g., a designated scattering garden or area of a cemetery).
Oregon	• Oregon Secretary of State Mortuary and Cemetery Board statutes - Chapter 830, Div 30 ○ Requirement that **facilities** must comply with requirements also applicable to crematory authorities and cremated remains. ○ Requirement for **vessels** to meet industry and commercial standards for heat, time and circulation necessary to achieve the complete reduction of all human remains.

Vermont	• Vermont General Assembly H.244 (Act 169) An act relating to authorizing the natural organic reduction of human remains o Aligned with the rights and responsibilities of crematory operators for minimum standards for permits and documentation, body handling, containers, infectious diseases, pacemakers, body storage, sanitation, equipment and maintenance, and other measures necessary to protect the public.
Washington	• Washington state legislature – Chapter 308-47 Cremation, alkaline hydrolysis and natural organic reduction o Requirements on the **containers** used for receipt of human remains (e.g., leakage or spillage resistant). o Requirements on the **removal of implants or devices** prior to delivery to the facility. o Requirements for **reduction vessels** (designed to promote aerobic reduction, minimizes odours and vectors, operated by a licensed person, and complies with local, state and federal laws). o Requirements for **process** - must reach a minimum temperature of 131 F (55°C) for 72 consecutive hours during the reduction process. o Subject to **inspection** at least once per year by the inspector of inspector of funeral establishments, etc. to ensure compliance with Washington state laws and regulations related to health or the handling or disposition of human remains. o Medical devices and implants do not need to be removed prior but may be recovered for recycling at the conclusion of the chemical disposition process.

* This table provides a selection of the types of approaches used in some jurisdictions but does not constitute a complete list of all legislative requirements. Information current as of Mar 15, 2023.

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How to cite this document

ISBN: 978-1-988234-83-0

This document can be cited as: O'Keeffe J. Alternative disposition services: Green burial, alkaline hydrolysis and human composting. Vancouver, BC: National Collaborating Centre for Environmental Health. 2023 Apr.

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