DEPARTMENT OF HEALTH

Green Burial and Natural Organic Reduction Study

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The growing demand for environmentally sustainable end-of-life practices has led to the rise of green burials and natural organic reduction (NOR). While these methods offer environmental benefits, they also raise complex public health and regulatory challenges. This report examines the current regulatory landscape of green burials and NOR, with specific attention to Minnesota's unique context. This report further studies the environmental and health impacts that may be caused from these disposition methods. Recommendations focus on ensuring environmental protection and public health safety to these eco-friendly burial methods.

Current Minnesota legislative landscape

In Minnesota, green burials are primarily governed by local ordinances rather than state-level regulations. A key legislative development is the moratorium outlined in the 2023 Minnesota Session Laws, chapter 70, section 102, which places a temporary hold on establishing new green burial sites from July 2023 to July 2025. This moratorium allows for further study of the environmental impacts of green burials and potential public health risks. Nationally, 46 states permit green burials without specific regulations, while four states have set standards for burial depth and proximity to water sources. In parallel, the practice of NOR is gaining momentum. As of 2024, 12 states have legalized NOR, with Minnesota joining the list in 2024 by passing legislation in Minnesota Statutes, chapter 149A, section 149A.955.

Environmental and public health impacts

Although there are no specific studies conducted on the aftereffects of the processes of green burials and NOR specifically, based on current information, green burials and NOR may:

- Minimize environmental contamination when sited and managed properly.
- Enrich soils with nutrients from natural decomposition with minimal introduction to the environment of foreign materials, such as implants, which could have posed further environmental contamination.
- Mitigate risks to groundwater contamination through shallow burial depths and careful siting.
- Be safely conducted with proper Personal Protective Equipment (PPE) that is consistent with traditional burial methods.

However, these methods require safeguards to address potential risks, including infectious disease transmission and nutrient overloading in soil.

Recommendations

1. **Siting Standards:** Burial pits must maintain at least one meter (~3.28 feet) of clearance above the highest natural water table to prevent groundwater contamination.

2. **Water Source Safety Measures:** Establish minimum distances from water supply wells, springs, and field drains, including 50 feet from wells and borings and 30 meters (~98.42 feet) from watercourses.
3. **Flood-Prone Areas:** Prohibit burials within flood-prone zones to minimize environmental and safety risks.
4. **Burial Depth:** Adopt burial depth guidelines of 3.5 to 4 feet to optimize decomposition conditions while preventing contamination of deeper water tables.
5. **Burial Density:** Implement evidence-based burial density standards to ensure sustainable land use, such as a maximum of 300 burials per acre over a 100-year period.
6. **Environmental Monitoring:** Require green burial sites to perform regular groundwater and soil testing at burial sites to detect potential contamination and ensure compliance with environmental standards.
7. **Temporary Preservation Methods:** Promote eco-friendly alternatives to embalming, including refrigeration, polymer refrigerants, and dry ice, to temporarily inhibit decomposition while adhering to Minnesota state laws regarding these methods.
8. **Cemetery Regulations:** Explore policies that incentivize or require cemeteries to offer green burial options, ensuring broader access to sustainable burial practices.
9. **Reuse Intervals:** Conduct further research to establish appropriate time intervals before burial spaces can be reused, based on site-specific evidence and environmental data.

Legislative Study: Green Burials and Natural Organic Reduction (NOR)

This study was conducted in response to 2023 Minnesota Laws, chapter 70, section 102: *Moratorium on Green Burials; Study*.

Over the past decade, green burials have emerged as a prominent eco-friendly method of disposition. As demand for such practices increases, it is essential to conduct thorough research and propose appropriate recommendations for legislation to address this demand while prioritizing public health. This document will examine the background, benefits, and complications associated with green burials, review the current legislative landscape, and provide recommendations for implementing green burial and NOR practices. These recommendations will focus on safeguarding health impacts on involved parties and preventing environmental harm.

Introduction

Trends in burial methods over the years

A 2023 Pew Research Center report revealed that 54% of Americans view climate change as a major threat, and over two-thirds of United States adults support investing in alternative energy sources.[1] This strong commitment to environmental issues has led to 69% of Americans favoring initiatives aimed at achieving carbon neutrality by 2050.[1] As a result, consumers themselves are increasingly adopting eco-friendly practices to align with the green movement.

In response to this trend, the death care sector is also embracing sustainability. Funeral directors have noted a growing consumer interest in green funeral services. According to the National Funeral Directors Association (NFDA), interest in green funeral services rose from 55.7% in 2021 to 60% in 2023.[2]

Cemeteries nationwide have reported a 72% increase in demand for green burials.2 A 2015 survey by the Funeral and Memorial Information Council found that 64% of individuals aged 40 and older were open to considering a green burial, marking a 21% increase over five years.[3] Additionally, NFDA data indicates that 11.3% of respondents aged 40 and older prefer green burials over other disposition methods.[4]

The growing interest in green burials also intersects with equity considerations, particularly in relation to religious practices. Islam and Jewish burial traditions closely align with the principles and practices associated with green burials. In Minnesota, the increasing population of Muslim and Jewish communities has highlighted the need for equitable access to green burial sites. For instance, the Garden of Eden Cemetery, which facilitates nearly 90% of Muslim burials in the Twin Cities, is projected to reach full capacity within the next decade.[5] This trend underscores the urgency of addressing the availability of green burial options to meet the needs of these religious communities.

Given this rising interest and demand, a temporary moratorium on new cemeteries in Minnesota performing green burials has been implemented to facilitate a thorough evaluation of their environmental and health impacts. This pause allows for a detailed study to ensure that the

adoption of green burial practices meets public health and environmental standards, balancing consumer demand with necessary precautions.

Defining green burials

A green burial is a method of laying a body to rest which emphasizes environmental sustainability without interfering with natural decomposition. To qualify as a green burial, these criteria must be met:

1. The body is either not embalmed or is embalmed with only non-toxic substances.
2. A biodegradable casket or shroud is used.
3. No vault or outer burial container is employed for the casket or shroud.[6]

Green burials are designed to provide respectful care of the deceased while minimizing environmental impact through the conservation of natural resources, reduction of carbon emissions, protection of worker health, and preservation or restoration of habitats.

Defining NOR

NOR is an emerging process of human disposition that transforms human remains into nutrient-rich soil through managed decomposition. The duration of the process generally ranges from 4 to 12 weeks, depending on the technology and practices employed by the NOR facility and the size of the individual. The process begins with placing the body in a vessel, where organic materials such as alfalfa, straw, and woodchips create an environment conducive to natural decomposition. During this phase, the decomposition environment is carefully controlled to maintain temperatures of 131°F or greater, ensuring the elimination of harmful pathogens such as *E. coli* and *Salmonella*.[7, 8] NOR providers comply with safety and environmental standards established by the state where the facility operates. These standards require that the resulting material meet acceptable thresholds for heavy metals, pharmaceuticals, and pathogens to prevent their release into the environment. Furthermore, NOR providers identify and remove non-organic materials, such as implants, from the final product, ensuring they are recycled or disposed of in an environmentally responsible manner.

Once the compost is deemed safe, the decedent's responsible party can then receive the resulting soil for use in a variety of environmentally meaningful ways, some examples include the planting of trees or dispersion in significant locations.

Understanding variations in the NOR process

NOR facilities employ a variety of technologies and methodologies, resulting in differences in how the process is conducted. For instance, the duration of the NOR process varies depending on the approach used by individual providers. Some systems utilize heat and pressure within controlled vessels, completing the process in approximately 45 days, while passive systems that rely solely on natural decomposition may take 60 to 90 days or longer, depending on factors such as the size of the individual. Additionally, there could potentially be other methods for NOR that have not been reviewed or discussed for this study.

Another key area of variation lies in how bones are processed during NOR. Many facilities use grinders or hammermills to break down remaining bones, producing small bone fragments in the

resulting soil. Variability is also evident in the selection of organic materials used to support decomposition; while some providers utilize straw and wood chips, others opt for alternative organic inputs. These differences highlight the need for regulatory frameworks that account for the diversity of practices within the NOR industry. Overly prescriptive standards risk excluding effective and environmentally sustainable methods, potentially disadvantaging providers and limiting consumer choice. Flexible and inclusive regulatory approaches are essential to support innovation and sustainability while maintaining robust safety, environmental, and quality standards.

Background

National-level overview of green burial regulations and practices

As of 2024, no state in the United States mandates the use of a burial vault, embalming if burial occurs in a timely manner, or a casket for burial.[9] Thus, conditions that allow for green burials are legally permissible in all 50 states, provided that a burial permit and death certificate are obtained prior to the burial.[10] While there are no state laws expressly prohibiting green burials, local regulations and cemetery policies may influence the feasibility and location of such burials.

Currently, 46 states allow green burials without specific regulations.[10] For example, Wisconsin permits burials on private property without a casket, contingent upon adherence to local regulations and zoning laws.[10] In Vermont, refrigeration can be utilized as an alternative to embalming if preservation of the body is required, such as for transportation across state lines.[10]

Four states — California, Georgia, Maryland, and Washington — have established specific regulations for green burials (Table 1).[10] These states differ in their requirements for minimum burial depth and the distance between burial sites and water sources, reflecting the diverse approaches to managing green burial practices across the country.

Table 1: Comparison of Green Burial Standards for the Four States that Regulate Green Burials

	CALIFORNIA	GEORGIA	MARYLAND	WASHINGTON
MINIMUM BURIAL DEPTH	3 Feet	3 Feet	3 Feet	3.5 Feet
MINIMUM DISTANCE BETWEEN BURIAL SITE & WATER SOURCE	≥ 100 Feet	≥ 200 Feet	≥ 100 Feet	≥ 50 Feet

Current green burial regulations and practices in Minnesota

Minnesota Department of Health does not regulate cemeteries. Instead, cemetery regulations are governed by Minnesota Statutes, chapters 306 and 307, which are enforced by local governments, along with any additional laws, ordinances, or zoning requirements they impose.

Many states do have broad laws regarding Green Burials. Regarding green burials specifically in Minnesota, the following laws apply:

1. An unembalmed body must be buried or cremated within 72 hours of release from the place of death or coroner or medical examiner. If the body is not embalmed, it must be refrigerated, with refrigeration limited to six calendar days and dry ice use limited to four calendar days. Disposition must occur within a reasonable time thereafter.[11]
2. A body must be buried in a legally recognized cemetery.[12]

A disposition permit, details regarding how the body will be disposed of, is required for all burials.[11] The Green Burial Council International (GBC) has identified three GBC-certified funeral homes in Minnesota:

1. Inspired Journeys LLC, St. Paul, Minnesota.
2. Interra Green Burial by Mueller Memorial (which operates two locations, St. Paul Minnesota and White Bear Lake, Minnesota).[13]

These funeral homes are associated with specific green burial sites. Currently, the GBC lists only two GBC-certified cemeteries in Minnesota that practice green burials:

1. Resurrection Cemetery of The Catholic Cemeteries in Mendota Heights.
2. Mound Cemetery in Brooklyn Center.[14]

However, it is possible that additional sites in Minnesota offer green burial options but are not listed on the GBC website. For instance, the Interra Green Burial website identifies Roselawn Cemetery and Fort Snelling National Cemetery as participating in green burials to varying extents.[15] Furthermore, Jewish and Islamic cemeteries, due to their specific religious practices and beliefs, should also be considered in the count of green burial-participating sites.

Enacted moratorium details

In response to rising concerns and the need for further study, the Minnesota Legislature passed a moratorium on the establishment of new green burial sites from July 1, 2023, through July 1, 2025.[6] During this period, no new cemeteries may begin performing green burials. However, cemeteries that were already conducting green burials prior to the moratorium and are in compliance with applicable ordinances or regulations are permitted to continue offering these services. This moratorium allows time to evaluate environmental and public health impacts, ensuring that future green burial practices are safely and responsibly regulated.

National-level overview of NOR regulations and practices

In 2019, Washington became the first state to enact legislation legalizing NOR as a method for human body disposition.[16] This was followed by Colorado and Oregon, which passed similar laws in 2021 and California, Vermont, and New York joining the movement in 2022.[8, 17, 18, 19, 20] In 2024,

the momentum for NOR legalization has grown, with the number of states adopting NOR legislation doubling from six to twelve. As of July 2024, the states of Arizona, Delaware, Maine, Maryland, Minnesota (effective July 1, 2025), and Nevada enacted laws permitting this environmentally sustainable process.[21, 22, 23, 24, 25, 26, 27]

While the legalization of NOR has expanded, the specific legislative language and regulatory frameworks vary by state, reflecting regional considerations and differing approaches to public health, environmental sustainability, and worker protection protocols.

For the states in the U.S. that have NOR laws, please see below for a breakdown of different topics identified in the respective state's laws. Of note, not all states address each topic. In 2024, Minnesota passed NOR statutes in certain topic areas, which are reflected below. As of the date of the publication of this study, rulemaking is currently underway to support Minnesota's NOR statutes.

Health restrictions on NOR eligibility

- **Delaware**: Persons who had or are suspected of having a viral or other health risk that the Delaware Division of Public Health determines may not be eliminated during the human composting process. In addition, if a person dies due to a radiological incident or if their body contains radioactive implants, they cannot undergo NOR. An individual may be excluded from undergoing NOR if they have, or are suspected of having, a prion disease, Mycobacterium tuberculosis infection, or Ebola virus disease.
- **Maryland**: Remains cannot undergo NOR if there is reasonable suspicion that they have been embalmed or carry an infection, disease, or biological condition that could render the NOR process or resulting soil unsafe such as Creutzfeldt-Jakob disease or other prion disease, Mycobacterium tuberculosis infection, Ebola virus infection, the presence of diagnostic or therapeutic radioisotopes, or any other infection, disease, or biological condition identified by the Director of the Office of Cemetery Oversight based on the reasonable recommendation of a federal, State, or local health authority.
- **New York**: Remains cannot undergo NOR that have been embalmed, contain a battery, battery pack, power cell, or radioactive implant, a person whose cause of death, including the immediate cause or as a consequence of, was active tuberculosis, Ebola, or a prion disease such as Creutzfeldt-Jakob Disease, or are known or suspected to have been at the time of their death infected with any contagious disease rendered by New York Department of Health as unsuitable for NOR, or a person who passed as a result of a radiologic incident or accident unless deemed by the New York State or local Department of Health.

NOR equipment requirements

- **Delaware**: The NOR vessel, where the human body will be transferred to, must maintain an internal minimum temperature of 131 degrees Fahrenheit for a minimum of 72 hours during the NOR process.

- **Minnesota**:
  - The NOR vessel must promote aerobic reduction and minimize odors.
  - The room where the human body will be prepared for NOR must be ventilated with exhaust fans, properly lit, have a functional sink with hot and cold water, nonporous flooring, the door, walls, ceiling, and windows must be constructed in a manner that prevents odors from spreading to other rooms of the NOR facility, and have walls and the ceiling of the room be covered in appropriate material such as tile, plaster, or sheetrock with washable paint.
  - The area containing the vessels must be ventilated with exhaust fans and contain windows that maintain privacy. The door, walls, ceiling, and windows must be constructed in a manner that prevents odors from spreading to other rooms of the NOR facility, have nonporous flooring, and have walls and the ceiling of the room be covered in appropriate material such as tile, plaster, or sheetrock with washable paint.
  - The NOR facility must have a functional emergency eye wash and quick drench shower.
  - The vessel must naturally reach and maintain a minimum of 131 degrees Fahrenheit for a minimum of 72 hours during the NOR process.
- **New York:**
  - The NOR facility must be clean, orderly, and sanitary with proper ventilation and a temporary storage facility to store human remains awaiting to undergo NOR while maintaining privacy.
  - The temporary storage facility should be properly ventilated, comply with all applicable public health laws pertaining to proper handling and storage of human remains and body fluids, operated and maintained to protect the health of employees, and limit access to only authorized individuals.
  - Additions to the NOR vessel that are permitted are: water, oxygen, or air, and bulking agents (e.g. tree and shrub parts, straw, alfalfa), a non-compostable identifier, other items permitted by the NOR facility and authorizer of the disposition that does not violate these previous conditions, inhibit the NOR process, or risk safety or health.
  - Additions to the NOR vessel that are not permitted include: wood or organic material that has been painted, glued, or chemically or pressure treated, construction and demolition debris, acids, alkaline agents or other solvents, insects, worms, or other animals, dimensional lumber, materials that will not compost, materials that pose a threat to health and safety if present in the vessel, any other material that is inappropriate to use as a bulking agent.
  - The vessel should: provide accurate measurements of the internal temperature and other data required by the NOR process, prevent vectors from entering the vessel, be leak-proof and able to withstand heating to the required temperature for the necessary time period, and control odors and emit air in accordance with New York Codes, Rules and Regulations.

- The NOR facility must be located at least 200 feet from the nearest surface water body (e.g. lakes, rivers, streams), potable water wells, residence, state-regulated wetland, or place of business not including the cemetery itself. This distance may be reduced if means are accessible to reduce odor transmission and accidental leachate run-off.
- The NOR facility must be constructed in a manner that prevents any ponding or discharge, prevent waste and leachate from being discharged into sewers, surface waters or groundwater; and must be operated in a manner that minimizes the generation of leachate and that does not drain, dump or discharge leachate.
- For pathogen reduction, NOR facilities must use one of these methods before the NOR remains leave the facility: maintain the temperature of the remains at 55 degrees Celsius or higher for a minimum of 72 consecutive hours, or other methods or operating conditions that are approved by the division.
- For vector attraction control, the remains must be treated by an aerobic process for a minimum of 14 days while the remains simultaneously maintaining a temperature higher than 40 degrees Celsius and the average temperature of the remains must be higher than 45 degrees Celsius, or other methods or operating conditions that are approved by the division. This process must be conducted either simultaneously with the pathogen reduction method or before the remains leave the facility.

How the remains arrive to the NOR facility

- **California**: NOR facilities cannot make or enforce rules that require the human remains to be placed in a casket. However, NOR facilities can require some form of container or disposal unit.
- **Delaware**: The body must arrive in a leak-resistant container that maintains a secure closure.
- **Maine**: The body must arrive in a suitable container for natural decomposition. If not, an alternative container must be used.
- **Maryland**: The body must arrive in a cot and pouch or receptacle.
- **Minnesota**:
  - The body must arrive to the facility in a container that is impermeable or leak-resistant with the disposition permit and NOR authorization.
  - The body cannot be accepted if there is a known dispute regarding NOR of the body, there is reasonable basis for questioning the written authorization, or for any other lawful reason.
  - If the container or pouch containing the body shows evidence of leaking bodily fluid, the container or pouch with the body must be returned to the contracting funeral establishment or the body must be transferred to a new container or pouch by a licensed mortician.
  - If the body arrives to the NOR facility in a container or pouch that will not fully decompose during NOR, a licensed mortician must transfer the body to the NOR vessel.

- **Nevada**: NOR operators cannot require that human remains arrive at the facility with a casket nor refuse to accept the human body because it is not in a casket. Specific instructions on how the container that arrives at the NOR facility are: cover the human remains completely when closed, resist leaking or spilling, be rigid enough for easy handling, be able to be reduced, and protect the health and safety of employees of the operator. Additionally, the operator is not required to accept a container that shows any signs of leaking bodily fluids.
- **New York**:
  - The body must arrive in an alternative container or wrappings that contain the remains and can fully decompose during NOR.
  - If the remains arrive to the NOR facility in a container (e.g. casket) that cannot be fully reduced with the body, the NOR facility should be given timely notice that the remains must be transferred to a fully decomposable container or wrapping.
- **Washington**: The individual responsible for transport of human remains shall use effective hygiene measures consistent with handling potentially infectious material and is responsible for ensuring that the human remains are in a leak-resistant container placed inside another leak-resistant container to prevent the leakage of body fluids.

Timeline for facilities to perform NOR

- **California**: NOR should occur within 24 hours of delivery to the facility unless the remains have been preserved interim by refrigeration. Within two hours of the remains being delivered, the body must be refrigerated at a temperature not greater than 50 degrees Fahrenheit, unless the NOR process will begin within 24 hours of the time the delivery occurred.
- **Colorado**: For individuals who have a religious custom or rite, NOR can begin within seven days after death.
- **Maine**:
  - NOR must be conducted within a reasonable time after death unless the body is to be buried outside of Maine.
  - NOR cannot be performed within 48 hours of death unless the cause of death was contagious or infectious disease.
  - The medical examiner must provide a certificate confirming the investigation into the cause of death and that no further inquiry is needed.
- **Maryland**: NOR must be conducted at least 12 hours after death. If the unembalmed remains are stored for more than 48 hours before NOR takes place, the NOR facility must maintain the body with refrigeration and a temperature determined by regulation.
- **Minnesota**: NOR must be conducted within 24 hours of the NOR facility receiving the remains.
- **Nevada**: Unembalmed remains cannot be held for more than 24 hours unless the facility is refrigerated.

- **New York**: NOR must be conducted within 24 hours of receiving remains. If NOR is not done for more than 48 hours after receiving the body, good faith (e.g., identifying remains) must be demonstrated. If there is an objectionable odor from the remains, NOR must commence as soon as possible either after the remains have been delivered to the NOR facility or when the odor is first detected.
- **Vermont**: NOR process cannot start until at least 24 hours have passed since the person's death, as stated on the death certificate. However, if the person died from a highly contagious disease, health regulations may require that the body be NOR-ed before the 24-hour period is up. Attorney General or State's Attorney can request an NOR delay upon reasonable belief that the cause of death might have been due to other than accidental or natural causes. The NOR delay can last a sufficient time to permit an investigation.
- **Washington**: NOR is to be performed within three business days of receiving the remains with a permit.

Precautions when handling remains

- **Minnesota**: NOR employees must use universal precautions and otherwise exercise all reasonable precautions to minimize the risk of transmitting any communicable disease from the body.
- **New York**: If the container or wrappings of a deceased person's remains are opened after delivery to a NOR facility, only a licensed funeral director or registered resident can do so. The opening must occur in front of the witness and adhere to all health and safety regulations for the protection of facility personnel.
- **Washington**: NOR facility employees handling or touching the remains must: wash hands and other exposed skin areas with soap and water after touching human remains, blood, or body fluids, use barrier precautions if a procedure involves potential contact with blood, body fluids, or internal tissues of the deceased or hazardous chemicals, dust, or other potentially hazardous material.

Disposing of foreign materials inside the remains

- **Maine**: The next of kin/authorized person must confirm that the body does not contain hazardous materials such as batteries or radioactive devices. A magnet/sieve/etc. is used after NOR is complete.
- **Nevada**: Must remove artificial devices from the body before arriving at the NOR facility.
- **New York**: If the body contains a battery, battery pack, power cell, radioactive implant, or radioactive device, these materials must be removed before the start of NOR and the body's arrival to the NOR facility. The incidental and foreign material of the NOR process shall be disposed of in a safe manner in compliance with all sanitary rules and regulations as by-products.
- **Oregon**: Diagnostic or therapeutic radioisotopes inside an unreduced body may be buried, entombed, or otherwise disposed of in a lawful burial site, even if the body contains low-level radioactive waste, by-product material, or special nuclear material exempted by the United States Nuclear Regulatory Commission.

Regulatory requirements for NOR-processed remains

- **Delaware**: Reduced remains must not exceed the following limits:
  - Fecal coliform: 1,000 (most probable number per gram of total solids, dry weight).
  - Salmonella: 3 (most probable number per 4 grams of total solids, dry weight).
  - Arsenic: 20 ppm (mg/kg dry weight).
  - Cadmium: 10 ppm (mg/kg dry weight).
  - Lead: 150 ppm (mg/kg dry weight).
  - Mercury: 8 ppm (mg/kg dry weight).
  - Selenium: 18 ppm (mg/kg dry weight).
- **Maryland**: The reduced soil remains must contain less than 0.01 mg/kg dry weight of specific physical contaminants. A third-party laboratory must test the soil remains to identify the presence of heavy metals or microbial pathogens according to the appropriate contamination parameters for biosolids specified by the EPA under Title 40 C.F.R., part 503, chapter I, subchapter O.
- **Minnesota**: The reduced soil remains must contain less than 0.01 mg/kg dry weight of any physical contaminants. Reduced remains must not exceed the following limits:
  - Fecal coliform: 1,000 (most probable number per gram of total solids, dry weight).
  - Salmonella: 3 (most probable number per 4 grams of total solids, dry weight).
  - Arsenic: 11 ppm (mg/kg dry weight).
  - Cadmium: 7.1 ppm (mg/kg dry weight).
  - Lead: 150 ppm (mg/kg dry weight).
  - Mercury: 5 ppm (mg/kg dry weight).
  - Selenium: 18 ppm (mg/kg dry weight).
- **New York**: Before the soil remains are removed from the NOR facility, either the fecal coliform density must be less than 1,000 most probable number (MPN) per gram of total solids (dry weight), or the salmonella bacteria density must be below 3 MPN per 4 grams of total solids (dry weight). Before the soil remains are removed from the NOR facility, the soul remains must not contain pollutants that exceed the following standards, per maximum concentration mg/kg, dry weight.
  - Fecal coliform: 1,000 (most probable number per gram of total solids, dry weight).
  - Salmonella: 3 (most probable number per 4 grams of total solids, dry weight).
  - Arsenic: 41 (mg/kg dry weight).
  - Cadmium: 10 (mg/kg dry weight).
  - Chromium: 1,000 (mg/kg dry weight).
  - Lead: 300 (mg/kg dry weight).

  - Mercury: 10 ppm (mg/kg dry weight).
  - Molybdenum: 40 (mg/kg dry weight).
  - Nickel: 200 (mg/kg dry weight).
  - Selenium: 100 (mg/kg dry weight).
  - Zinc: 2,500 (mg/kg dry weight).
- **Washington**: Reduced remains must not exceed the following limits:
  - Fecal coliform: 1,000 (most probable number per gram of total solids, dry weight)
  - Salmonella: 3 (most probable number per 4 grams of total solids, dry weight).
  - Arsenic: 20 ppm (mg/kg dry weight).
  - Cadmium: 10 ppm (mg/kg dry weight).
  - Lead: 150 ppm (mg/kg dry weight).
  - Mercury: 8 ppm (mg/kg dry weight).
  - Selenium: 18 ppm (mg/kg dry weight).

NOR regulatory entity

- **Arizona**: Arizona Department of Health Services.
- **California**: Cemetery and Funeral Bureau within the Department of Consumer Affairs, California State Department of Public Health.
- **Delaware**: Delaware Department of Public Health. For testing requirements, it can be established by either Delaware Department of Public Health or local health departments for additional parameters.
- **Maryland**: Director of Office of Cemetery Operations, State Board of Morticians and Funeral Directors.
- **Minnesota**: Minnesota Department of Health (licensure effective July 1, 2025).

Use of NOR remains

- **California**: A permit will be issued for final disposition, specifying: the cemetery where remains will be interred, burial at sea, the address or description of where the remains will be buried or scattered, or location where the remains will be stored. If the death was caused by a contagious disease, special conditions apply, and permits will be issued that adhere to public health requirements.
- **Colorado**: Soil remains cannot be sold or offered to be sold, comingled with another individual's soil remains without consent, used to grow food for human consumption.
- **Delaware**: The individual receiving the soil remains can transport and dispose of them in any manner they choose, in compliance with state laws.

- **Maryland**:
  - Soil remains may only be buried in family plots, approved cemeteries, crematories, reduction facilities, or following other legal methods.
  - Soil remains cannot be sold or resold, mixed with compost intended for sale, used to grow food for human or livestock consumption, be placed on public or private land without consent of the property owner or relevant parties.
- **Nevada**:
  - Soil remains can be scattered, provided they do not mix with other remains.
  - Scattering is allowed at sea, over public waterways, or in designated cemetery areas, or on private property with property owner consent.
- **New York**: Soil remains can be scattered in a designated scattering garden, area in a cemetery, or placed in a grave, crypt, or niche.
- **Vermont**: Soil remains can be placed in a columbarium, crypts, or buried. For soil remains, the strict requirements for durable, sealed, and weather-resistant burial structures do not apply.
- **Washington**: A burial-transit permit outlines how the disposition of soil remains must comply with Washington state laws and regulations.

Current national NOR practices

As of October 2024, there are no organizations in Minnesota that offer NOR as a method of disposition. NOR licensure was passed by the legislature in 2024, to be effective July 1, 2025. Nationally, four companies provide NOR services, and all are willing to accept transported remains across state lines, allowing individuals from any part of the country to access their services:

1. The Natural Funeral – Operates in Colorado.
2. Recompose – Operates in Washington.
3. Earth – Operates in Washington and Nevada.
4. Return Home – Operates in Washington.

As more states legalize NOR and establish regulatory frameworks governing its practice, the availability of NOR services are expected to increase across the United States.

The Minnesota Department of Health is currently engaged in a rulemaking process to review regulatory areas that may need further refinement. This ongoing process will consider the findings of this study to help inform further discussions.

The research behind NOR

In 2018, Recompose, one of the nation's current NOR facilities, collaborated with Washington State University's Soil Science Department to evaluate the safety and effectiveness of NOR as a method for human disposition. The study involved six human subjects and utilized a closed vessel system that was modeled after livestock mortality composting.[28] Over four to seven weeks, the process achieved key safety benchmarks.

The NOR process successfully met EPA standards for pathogen reduction, including passing the *Process to Further Reduce Pathogens* defined by EPA 40CFR Part 503 App B.[28, 29] This standard requires maintaining a minimum temperature of 131°F (55°C) for three consecutive days, a benchmark that was met at least twice for all six trials.[28, 29]

In addition to pathogen reduction, the resulting NOR compost passed the Washington Administrative Code (WAC) 173-350-220 standards for composting facilities.[28, 30] The NOR process stabilized heavy metals, with test results for arsenic, cadmium, copper, zinc, lead, and mercury measuring at below EPA limits.[28] Additionally, the initial water-soluble content of the pharmaceutical drug Diazepam was reduced by 95%, ensuring the safety of the resulting material.[28]

Recompose asserts that the resulting NOR compost "was unrecognizable visually, chemically, or microbiologically as human remains," further supporting the conclusion that NOR represents a safe and environmentally sustainable method of human disposition.[28]

Analysis of environmental and health impacts

The decomposition stages of the human body

After death, the human body undergoes five distinct stages of post-mortem decomposition. The rate at which these changes occur is influenced by several variables, including bacterial presence, body composition, pre-existing medical conditions (such as sepsis), injuries, environmental temperature, and the geographical location in which the remains are found.[31] For example, warm and humid climates, along with open injuries or infections, tend to accelerate the decomposition process, while cooler environments can slow it down.

1. **Stage I — Fresh.** This stage begins immediately after death, where the body's temperature matches its ambient surroundings, intestinal bacteria begin to ingest the intestinal walls, and body enzymes begin to break down cells and tissues. Microbes consume remaining bodily reserves and insects are initially attracted to the body.
2. **Stage II — Bloat.** Microbial activity increases due to the abundance of bodily materials. Methane, carbon dioxide, nitrogen, and hydrogen sulfide gases are released as a byproduct and cause the body to bloat and contribute to the greatest amount of odor emitted during the decomposition process. Simultaneously, insects contribute to the digestion of the cadaver.
3. **Stage III — Active Decay.** The body loses most of its mass due to microbial and insect activity. Fluids associated with decomposition are released into the surrounding environment. The most insects are present at this stage.
4. **Stage IV — Advanced Decay.** As decomposition progresses, insects with chewing mouthparts process bones, cartilage, and other remnants, while most soft tissue has been consumed.
5. **Stage V — Dry Remains.** Only skeletal remains persist at this stage, which will eventually break down and reintegrate into the environment.

The effect of soil composition on the rate of decomposition of the human body

The decomposition rate of a human body is influenced by various soil characteristics, including temperature, pH, porosity, texture, and moisture. For example, a 68-kilogram human body can fully decompose within a period ranging from 20 to 200 days in the absence of a burial vault.[32] During the Active Decay phase, decomposition by-products create a nutrient-rich hotspot, potentially enhancing soil biodiversity and contributing to terrestrial biogeochemical cycling.[33] However, the use of protective burial coverings, such as vaults, can slow the release of these by-products, depending on the porosity of the covering material.[32] The greater the separation between the body and the soil, the longer it takes for the body to decompose.

Sandy soils, due to their higher permeability and capacity for gaseous diffusion, facilitate faster decomposition and greater interaction with native aerobic microorganisms compared to clay soils.[34] However, sandy soils are typically avoided in burial practices to mitigate the risk of leaching decomposition by-products into groundwater. On the other hand, low-permeability soils, while effective at preventing nutrient leaching, tend to become waterlogged, creating anaerobic conditions that can significantly slow decomposition, extending the process over decades. In a comparative study of soil types — including loamy, sandy, clay, and organic soils — decomposition occurred most rapidly in loamy and organic soils.[34] This is attributed to the unique interactions between soil microorganisms and the physical and chemical properties of these soils.

Human decomposition and its effect on soil characteristics

The human body is composed predominantly of 11 elements, accounting for approximately 99% of its total mass.[33] These include calcium, carbon, chloride (ionized chlorine), hydrogen, potassium, magnesium, nitrogen, oxygen, phosphorus, sodium, and sulfur. In a standard 70-kilogram (~154.3 pounds) individual, between 1 and 38.6 kilograms (2.2 pounds and 85.1 pounds) of carbon, hydrogen, nitrogen, and oxygen are present, while the remaining elements are found in quantities of less than 1 kilogram (≥2.2 pounds) each.[33] Upon decomposition, these elements are deposited into the soil, provided there are no significant losses due to atmospheric release, insect activity, or scavenging. Notably, carbon, phosphorus, and nitrogen are of particular environmental concern, as they can cause harm if released in excess.

Studies examining the effects of decomposing human cadavers on soil are limited, with most research focusing on other vertebrates such as swine and beavers. These studies indicate significant impacts on the soil microbiome and properties directly beneath and adjacent to the cadaver, with minimal effects observed at greater distances.[35, 36] The influence of decomposition byproducts is generally confined to a lateral distance of less than one meter, consistent with findings from human cadaver studies.[35, 36] This localized impact corresponds to the cadaver decomposition island (CDI), a nutrient-rich zone formed directly beneath and around a decomposing body.

Nutrient absorption from decomposition is largely confined to the CDI, shaping soil chemistry and microbial communities such as reduced soil pH.[33] The soil microbiome beneath the cadaver differs significantly from that at distances of one meter (~ 3.28 feet) or five meters (~ 16.4 feet), though no significant differences are observed between the one meter and five meter marks.[37]

Role of carbon

Carbon constitutes a significant proportion of the human body and is released into the soil during decomposition, primarily as organic matter. This organic carbon enhances soil structure and microbial activity, serving as an energy source for microorganisms.[38] These processes drive decomposition and nutrient cycling. However, not all carbon remains in the soil; some is released into the atmosphere as carbon dioxide or methane under anoxic conditions.[38] Research shows that microbial biomass carbon, the amount of carbon contained within living microorganisms in a soil sample, remains elevated for up to 430 days after pig cadavers are buried, and bacterial colony-forming units, the number of viable bacteria in a sample, increase in the soil beneath the carcasses for up to 42 months post-burial.[39, 40] These findings underscore the potential for decomposition to contribute to localized carbon fluxes, which vary based on environmental factors such as soil type, moisture, and temperature.

Impact of nitrogen

Decomposition introduces an abundance of bio-elements, including nitrogen, which can significantly alter soil chemistry. Research on non-human carcasses reveals that nitrogen release affects the surrounding environment for approximately one year post-mortem. [42] Most cadaver-derived nitrogen is incorporated into microbial biomass, aiding nitrogen stabilization and cycling, particularly in nitrogen-limited soils. [39] However, if plants and microbes fail to utilize the nitrogen, it may transform into nitrate, which is mobile and leachable, or ammonium, which can release gaseous ammonia in alkaline conditions. [39] Anoxic conditions beneath cadavers may convert nitrate into nitrogen gas or nitrous oxide, contributing to atmospheric emissions. [39] Despite these potential impacts, soil nitrogen levels typically return to baseline within three years if growing vegetation is present. [42]

Challenges of phosphorus management

Phosphorus, an essential nutrient for plants, presents unique challenges during decomposition. Unlike nitrogen, phosphorus is immobile in most soil types and is not prone to leaching.[38] It does not form gaseous species, making it less likely to contribute to atmospheric emissions. However, excess phosphorus can still disrupt soil ecosystems.[38] Planting deep-rooted trees or ensuring that green burials occur in areas with such vegetation are effective strategies to manage excess phosphorus.[42] These trees can absorb the phosphorus and integrate it into the broader nutrient cycle.

Recommendations

Research on human decomposition shows that the nutrients found in the human body are released at different stages and persist for varying lengths of time.[33] These variations in nutrient release highlight the importance of thoughtful management practices to balance ecological impacts. Considering the distinct behaviors of carbon, nitrogen, and phosphorus during decomposition — carbon's release into the atmosphere and soil, nitrogen's potential for leaching or transformation into gases, and phosphorus's immobility but possible accumulation — managing these nutrients becomes essential to prevent soil degradation. A legislative recommendation of 300 burials per unimpeded acre over a 100-year period helps ensure

environmental preservation. Additionally, strategies such as planting appropriate vegetation or selecting burial sites with existing vegetation can aid in mitigating localized nutrient imbalances.

Potential groundwater source of pollution with green burials

In a study of 49 green burial sites, the average burial depth was measured at 1.45 meters (~4.76 feet), compared to traditional burial depths, which typically range from 1.8 to 4.6 meters (~5.91 – 15.09 feet).[43] This reduced burial depth in green burials, compared to standard practices, not only promotes greater gaseous exchange and interaction with surface soil elements — accelerating the decomposition process — but may also reduce potential contamination of groundwater and underlying soil layers.[44] By limiting the downward migration of harmful by-products, green burials may mitigate the risk of environmental pollution.

Minnesota Department of Health (MDH)'s Environment Health Division, states that the depth of green burials poses minimal risk to groundwater resources at this time. Site specific considerations such as depth to groundwater, distance to surface water bodies, potential for flooding, density of burials, and other potential factors would still need to be evaluated. Additionally, variations in Minnesota's weather, including humidity, rainfall, and frost, are not expected to increase the risk to groundwater resources.

This conclusion is further supported by a New York study that found significantly higher nitrate concentrations in cemetery groundwater compared to residential groundwater.[45] However, this discrepancy is most likely attributed to the presence of a stream running through the cemetery and leading to the watershed, as well as the cemetery's location in an area subject to frequent flooding events.[45] These findings highlight the critical importance of carefully considering the siting of cemeteries to prevent potential environmental impacts.

Further research observing groundwater samples near burial sites where bodies were interred with arsenic-treated wood and formaldehyde-based embalming fluids found concentrations of these chemicals below detectable limits.[46] These sites, located downhill on slopes with gradients ranging from 12 to 20 percent and in close proximity to water sources, demonstrate a minimal likelihood of harmful byproducts contaminating groundwater, even under conditions that could theoretically increase risk.[46]

This finding is particularly significant as it highlights that even when traditional burial practices introduce chemicals and materials absent from green burials or NOR, the risk of groundwater contamination remains minimal. By comparison, the absence of such materials in green burials further reduces the potential for harmful environmental impacts, reinforcing the safety and sustainability of these practices.

Additionally, a study evaluating the impact of decomposing bodies over an 11-year period on groundwater pollution within wells located in cemetery areas found that physicochemical parameters (including phosphorus, manganese, chromium, ammonia, nitrate, lead, mercury, silver, and cadmium) were all below detectable limits.[47] Two major microbiological indicators of water quality — total coliforms and Escherichia coli — were also absent in these wells.[47] Researchers attributed this to the favorable topographic and hydromechanical properties of the unsaturated soil above aquifers, particularly its highly porous, laterite composition.[47]

Together, these findings indicate that decomposition byproducts, even under traditional burial conditions, pose minimal risk to groundwater contamination. When combined with the site-specific safeguards typical of green burial practices, such as shallow burial depths and careful siting, the potential for environmental pollution is further mitigated.

Based on the studies outlined above, as well as the recommendations from the United Kingdom Environment Agency and the World Health Organization (WHO), the following measures are recommended to further mitigate potential groundwater contamination:[48, 49]

- Cemeteries should be situated on gentle slopes, as steep gradients increase the risk of surface water runoff, grave flooding, and the leaching or migration of decomposition byproducts.
- Cemeteries should be located on bedrock with the following conditions:
  - Clay mineral content should be between 20% and 40%.
  - The grave's bottom must be at least 1.5 meters (~ 4.92 feet) above the highest groundwater level. If the substrate has a permeability between 10^{-5} and 10^{-7} cm/s (or greater), this distance must be increased.
- Cemeteries should be avoided in areas with:
  - Shallow groundwater levels.
  - Seasonal or temporary flooding.
  - Highly permeable substrates, such as sands, gravels, fractured rocks, or karst formations.
  - Low-permeability substrates like clays and loams, where anaerobic conditions promote the formation of adipocere, a waxy substance formed when body fat decomposes in an anaerobic environment.
- Stormwater drainage systems should be installed within cemeteries and their surrounding areas.
- Cemeteries should be bordered by buffer zones with trees that have deep root systems.
- Groundwater in cemeteries should be regularly monitored for biological contamination and changes in the water table level.

Infectious disease risk associated with green burials

To mitigate potential health risks arising from gaseous emissions during the decomposition process, human remains should be either buried or refrigerated as expeditiously as possible post-mortem. [49, 50] Importantly, standard PPE and universal precautions should be employed when handling deceased human remains, irrespective of the burial method utilized, to safeguard against any potential infectious disease transmission.[49, 50]

Green burial sites are defined as natural areas where lawns are unmanicured, and native flora can flourish, incorporating ecological safeguards. WHO states that plant root systems act as a natural barrier, limiting the spread of bacterial and viral pathogens through the soil.[49] This mechanism helps to prevent contamination of surrounding water sources. [49] By leveraging these natural processes, green burial practices offer a sustainable and environmentally responsible alternative while maintaining public health protections.

Recommendations

As part of the legislature's directive to MDH, MDH has identified the following topic areas that are not in current law. Statutory language changes may be needed in Minnesota Statutes, chapter 306 and/or 307, to implement these recommendations.

Siting of green burial locations:

The recommended siting of green burial locations is as follows:

- Burial pits must maintain at least **one meter** (~3.28 feet) clearance above the highest natural water table.
- No burials in standing water.
- No burials within **zone 1 groundwater source protection zones** around a spring, well, or borehole.
- No burials within flood prone areas.

Minimum distance from water sources

It is recommended that the minimum standards for burials of human bodies from water sources include the following: [46], [50], [51]

Table 2: Minimum Distance from Water Sources

WATER SOURCE SAFETY MEASURES	MINIMUM DISTANCE
Distance From Water Supply Wells and Borings	50 feet
Distance From Other Springs or Watercourses	30 meters (~ 98.42 feet)
Distance From Field Drains	10 meters (~ 32.80 feet)

Burial depth requirements

According to the GBC, optimal conditions for decomposition conditions occur at a depth of 3.5 to 4 feet from the base of the grave to the soil horizon.[51] Additionally, positioning the displaced soil in a mound over the grave effectively doubles the depth until natural settling occurs. Importantly, burials at a depth of 3.5 feet do not pose a risk of contaminating potable water located 75 feet below the surface.[51] WHO suggests that graves for natural burials should have least 1 meter (~ 3.28 feet) of cover.[49]

Maximum density of interments

Burial density is influenced by the type of cemetery, available space, and the suitability of the land. Wetlands, steep slopes, wildlife habitats, and other factors identified in a Natural Resources

Inventory can significantly reduce the area available for burial. While an initial guideline of 20' x 20' per gravesite was deemed reasonable, the GBC has found that a smaller plot size — approximately 8 to 9 feet by 4 feet — is more practical.[51] GBC recommends that over a 100-year period, burial density may reach a maximum of 300 burials per unimpeded acre; however, site-specific conditions are likely to reduce this estimate, depending on the land's unique characteristics.[51] This was further confirmed by MDH's Environment Health Division.

Methods to temporarily inhibit decomposition of an unembalmed body awaiting green burial

In cases where a body is not embalmed, state guidelines specify time-sensitive requirement for burial, cremation, or alternative disposition. These include strict limitations on refrigeration and dry ice use, emphasizing the need for timely handling after release from the place of death, coroner, or medical examiner. If refrigeration is used, it is limited to 6 calendar days, while dry ice use is capped at 4 calendar days, ensuring disposition occurs within a reasonable timeframe thereafter.[11]

Natural and chemical-free refrigeration techniques, such as the use of dry ice, polymer refrigerants, cooling blankets, air conditioning, fans, and open windows during cool weather, are effective methods for slowing the decomposition process prior to burial. These types of methods are considered the most eco-friendly as it minimizes environmental impact, poses the least risk to funeral home workers, and does not introduce chemicals into the soil upon burial. Three main methods are available as alternatives to traditional embalming, each serving to delay decomposition in varying capacities:

1. **Refrigeration:** The body is kept at a temperature below 40 degrees Fahrenheit, with humidity maintained at 85% to prevent dehydration. When properly maintained, refrigeration can temporarily delay the process of decomposition remains for up to three to four weeks, making it a viable long-term solution.[52, 54]
2. **Polymer refrigerants:** This is a short-term solution utilizing reusable gel packs, which are easy to use and safe to handle. Although not as cold as dry ice, gel packs require more frequent replacement. For the initial 24 hours following death, six frozen gel packs are applied, and they must be replaced every 3-4 hours.[54, 55] After the first 24 hours, replacements are needed every 8-10 hours as required. [54, 55]
3. **Dry ice:** Another short-term solution, often used during transport or between death and burial, dry ice is applied to various parts of the body. Approximately fifteen pounds of dry ice are required per day for an adult body, with replacements needed every 24 hours.[55] Safe handling and proper ventilation are essential to prevent hazards associated with dry ice. [55] Additionally, precautions must be taken to avoid freezing the body by using an insulating material, such as a foam pad, to separate the ice from direct contact with the remains.

Potential for discussing the regulation of cemeteries

While local authorities may permit the practice of green burials, cemeteries retain the authority to choose which burial methods they offer. This discretion, however, can result in a limited number of designated areas for green burials, potentially hindering access to this environmentally sustainable option. Furthermore, recent developments, such as Minnesota's

legislation on NOR, suggest a growing momentum toward alternative burial methods. Future discussions may consider whether it is appropriate for regulations to be implemented that require cemeteries to offer green burials as an option, establish designated sites for NOR remains, or introduce incentives to encourage the inclusion of such options. Such discussions could help address concerns regarding the availability of green burial sites, ensure equitable access, and further support the integration of sustainable burial practices into broader land use and environmental policies. These considerations are vital for developing a balanced approach that respects both the autonomy of cemeteries and the growing demand for environmentally sustainable burial options.

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