



The Science Behind Green and Conventional Burial

In Lay Terms

Overview and Disclaimers

The Green Burial Council is frequently asked about the science of burial, specifically the environmental or health effects of burial without a vault, conventional hardwood or metal casket, or embalming. Questions range from repercussions to benefits of natural burial for both the living and the dead, but are about the future of the planet.

The majority of available research about burial to date relates to concerns about mass casualty, epidemic, and infectious disease disposal, primarily in livestock. Data regarding individual human burial

and its effects on public health is largely based on the supposition that historical mass events such as typhoid or cholera outbreaks in the 1800's were connected to cemeteries. These reports have very little to offer today in relation to direct earth burial.

This article is intended to act as a general collection of facts, observations, and commonly asked questions. It is not intended to take the place of scientific study. It is our hope that readers will find it informative and useful as a stepping stone to further research and inquiry.

Areas of Inquiry

Frequently asked questions around green burial fall into several distinct areas that will be addressed here:

- What happens during the average decomposition processes?
- What public health and safety risks exist?
- What role does embalming serve?
- How does burial density affect outcome?
- What is the potential for contamination of ground water, including aquifers?
- What is the role of soil in filtering potential contaminants?
- What are the pollution effects of conventional burial practices under typical circumstances?
- Are nuisance pests a problem, and if so, how they can be controlled?

Decomposition

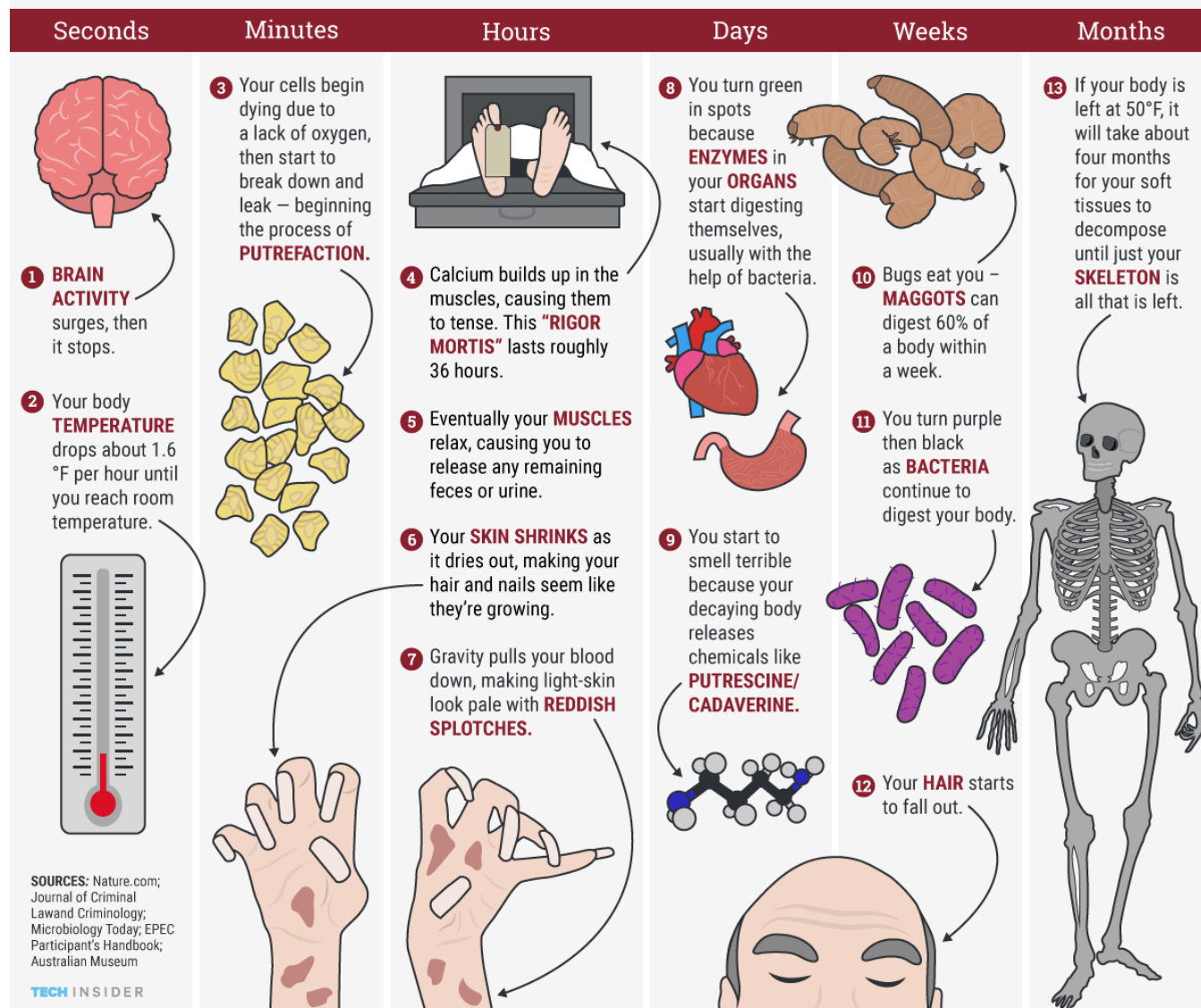
Decomposition of the body begins shortly after death, when cells die and begin the process of breaking down. It takes close to 72 hours for micro-organisms to begin putrefaction within the body. Keeping the body clean and cool helps to preserve the body in the short term (up to 8 days), and non-toxic embalming solutions are available.

The body is made up of 64% water, 20% protein, 10% fat, 5% mineral and 1% carbohydrate. If the body is not cooled or embalmed, the proteins begin releasing gasses such as putrescine, cadaverine, hydrogen sulfide, methane, ammonia, nitrate, sulfide (transformed to sulphurous acid) and

organic acids. Carbohydrates decompose to sugars, a process aided by bacteria and fungi. Decomposing fat produces adipocere, which is composed of saturated fatty acids. Micro-organisms naturally present in the intestine, such as *fecal*

coliform, *E. coli*, *fecal streptococci*, and *Pseudomonas aeruginosa*, break down the dead intestinal cells, and bacteria such as *coliforms* and *clostridia* begin traveling to other body parts.

What happens to your body after you die



Organs that house digestive enzymes such as the pancreas and liver, for instance, release those enzymes and begin to self-digest.

Depending on the cause of death, general condition of the body, body size, disease processes, medications, analgesic use, storage procedures, and many other environmental factors, decomposition may be accelerated or retarded.

Decomposition time after interment primarily depends on whether or not the body is confined in a coffin, whether or not there is water present and how much, the type of soil, and how the body was handled during burial.

Much of the available data regarding decomposition timing is based on above ground observation studies, not scientific assessments of bodies buried

underground. A best guess is that open-air decomposition happens twice as fast as underwater decomposition, and four times faster than with full body burial underground.

Five Elements that Affect Decomposition

1. An increase of 10° C doubles the rate of decomposition
2. Humidity slows decomposition
3. Alkalinity speeds decomposition
4. Exposure to oxygen speeds decomposition
5. Soil type/moisture can change the relationships of the above factors

Four Stages of Uninterred Decomposition

- Fresh 1-6 days
Cellular autolysis begins, rigor mortis peaks in 24 hours, blood pooling (livor mortis), skin slippage
- Bloat 7-23 days
Liquefaction, gas releases freons, benzene, sulfur, carbon tetrachloride
- Active Decay 24-50 days
Tissue decomposition complete, anaerobic saponification
- Dry 51-64 days
Skeletal, odor free

Public Health & Safety

Here's what some experts say about the risk of infection from dead bodies:

- *"...concern that dead bodies are infectious can be considered a 'natural' reaction by persons wanting to protect themselves from disease" although "the risk that bodies (that died in a natural disaster) pose for the public is extremely small." —Pan American Health Organization (PAHO)*
- *"Transmission of infection requires the presence of an infectious agent, exposure to that agent, and a susceptible host... The human body is host to many organisms, only some of which are pathogenic. When the body dies, the environment in which pathogens live can no longer sustain them. Microorganisms involved in the decay process (putrefaction) are not pathogenic..." —PAHO*
- *"... transmission of infectious agents from a cadaver to a living person may occur. Infectious hazards for individuals who routinely handle cadavers include tuberculosis, group A streptococcal infection, gastroenteritis, transmissible spongiform encephalopathies (such as Creutzfeldt-Jakob disease), hepatitis B, hepatitis C, HIV infection, and possibly meningitis and septicemia (especially meningococcal)." —PAHO*
- *"Historically, epidemics resulting in mass casualties have only occurred from a few diseases, including plague, cholera, typhoid, tuberculosis, anthrax, and smallpox...such infections are no more likely to be present in disaster victims than in the general population. Furthermore, although some of these diseases are highly contagious, their causative agents are unable to survive long in the human body following death... It is therefore unlikely that such epidemics will result from contact with a cadaver. Indeed, survivors present a much more important reservoir for disease..." —World Health Organization (WHO)*
- *"Dead or decayed human bodies do not generally create a serious health hazard, unless they are polluting sources of drinking water with fecal matter, or are infected with plague or typhus, in which case they may be infested with the fleas or lice that spread these diseases. In most smaller or less acute emergency situations therefore, families may carry out all the necessary activities following a death..." —WHO, regarding mass burials in emergencies*

- “...the mere presence of a dead body without regard to its embalmed status and one that is not leaking blood from an open wound or perforation, does not pose an increased [health] risk of infectious disease transmission for the person who might handle that body or review it in a private setting. Once a human dies, infectious agents that would be of any concern, including those on the individual’s skin or internal organs, is greatly diminished...there simply is no measurable risk of that body transmitting an infectious disease agent...” —Dr. Michael Osterholm, Center for Infectious Disease Policy and Research (CID)

	Definition	Caused by	Examples of disease transmission patterns
Infectious	Infection that results when bacteria, viruses or fungi are transmitted with or without actual contact; caused by a microorganism; some are contagious or communicable, others spread by germs carried in air, water, food, soil, animals or vectors	<ul style="list-style-type: none"> Bacteria Viruses Fungi Parasites Person to person contact Animal to person Mother to unborn child Bites Ingesting contaminated food or water Exposure to organisms in the environment 	<p>Blood borne:</p> <p>Hepatitis B virus Hepatitis C virus HIV/AIDS HTLV</p> <p>Bacterial:</p> <p>Cholera Diphtheria E-coli Plague Salmonella Yellow fever</p> <p>Airborne:</p> <p>Anthrax Influenza Tuberculosis</p>
Communicable	Disease that is able to be transmitted (from person to person) by direct contact with an affected individual or the individual’s discharges or by indirect means		<p>Viral:</p> <p>Ebola Hepatitis A Norovirus Rabies Rotavirus Smallpox</p> <p>Parasitic:</p> <p>Giardia Cryptosporidium Typhus Louse-borne relapsing fever</p>
Contagious	Disease that is transmissible by direct or indirect contact with one who has an infectious disease, with a bodily discharge of such a patient, or with an object touched by such a patient		<p>Meningitis can be viral, bacterial, or fungal</p> <p>Creutzfeldt-Jakob is only transmitted through direct contact with prion proteins in brain matter (low risk)</p>

The average dead body has been proven to be without risk to public health when cared for properly and in a reasonable amount of time. The fear of health risks associated with dead bodies under extreme conditions is not without merit, but undisturbed burial is usually the most desirable and effective method of disposition.

Embalming

“The use of embalming is of no consequence in reducing the risk...” —Dr. Osterholm, when asked about the protective quality of embalming bodies with infectious disease.

Embalming is a practice endemic to the US and Canada that is employed to give a body a more “life-like” appearance for public viewing in a funeral

establishment, to meet requirements for long distance travel by common carrier, or in preparation for body donation. The preservative effect of embalming is intended to get the body through a service and funeral period and usually lasts about two weeks before dissipating.

The body preparation process that includes embalming is as follows:

- Rigor mortis (stiffness) is relieved by massage. Rarely, tendons or muscles must be cut for a more natural pose if limbs are distorted by disease, e.g., arthritis.
- Massage cream is used on the face and hands to keep the skin soft and pliable.
- Facial features are set by putting cotton in the nose, eye caps below the eyelids, and a mouth-former in the mouth, with cotton or gauze in the throat to absorb purging fluids. The mouth is then tied shut with wire or sutures. Glue may be used on the eyelids or lips to keep them closed in an appropriate pose.
- Facial hair is shaved if necessary.
- Arterial embalming is begun by injecting embalming fluid into an artery while blood is drained from a nearby vein or from the heart. The two gallons or so needed is usually a mixture of formaldehyde or other chemicals and water. In the case of certain cancers, some diabetic conditions, or because of the drugs used prior to death (where body deterioration has already begun), a stronger or “waterless” solution is likely to be used for better body preservation. Chemicals are also injected by syringe into other areas of the body.
- The second part of the embalming process is called cavity embalming. A trocar—a long, pointed, metal tube attached to a suction hose—is inserted close to the navel. The embalmer uses it to puncture the stomach, bladder, large intestines, and lungs. Gas and body fluids are withdrawn before “cavity

fluid,” a stronger mix, is injected into the torso.

- The anus and vagina may be packed with cotton or gauze to prevent seepage if necessary. A close-fitting plastic garment may also be used.
- Incisions and holes made in the body are sewn closed or filled with trocar “buttons.” The body is washed again and dried.
- Nails are manicured, any missing facial features are molded from wax, makeup is used on the face and hands, and head hair is styled. The body is dressed and placed in the casket, and fingers are glued together if necessary.

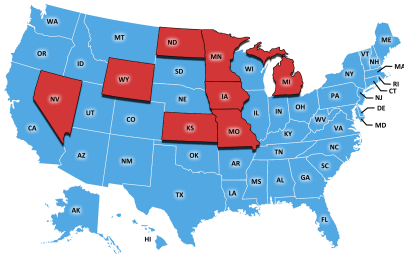
—from *Embalming: What You Should Know*,
Funeral Consumers Alliance (www.funerals.org)

The medical community is of one opinion that embalming is a cosmetic procedure and is not in any way a public health safeguard. Bodies prepared for green burial are not embalmed with chemicals. Natural and chemical-free refrigeration techniques, such as use of dry ice, Techni-Ice, cooling blankets, air conditioning, fans, and open windows in cool weather are all effective methods of slowing down the decomposition process until burial.

The more pressing medical issue related to embalming is the risk to embalmers and funeral directors from inhaling the vapors of embalming fluid, which contains formaldehyde, benzene, ethanol, ethylene glycol (an ingredient in antifreeze) and other toxic chemicals, causing:

- 13% higher death rate for embalmers (CDC)
- 8 times higher risk of contracting leukemia (11.24.09 Journal of National Cancer Institute)
- 3 times higher risk of contracting ALS and other auto-immune and neurological diseases (7.13.15 Journal of Neurology, Neurosurgery & Psychiatry)

Despite this data, eight states require or permit by law that infectious bodies (defined as likely to be transmitted to people, organisms, etc., through the environment) be embalmed:



The environmental impact of embalming is difficult to quantify as it includes the 4.3 million gallons of embalming fluid buried every year, and unidentifiable amounts of nonrenewable resources involved in the manufacture, shipping, and disposal of embalming products. Embalming facilities are required to have dedicated lines for the disposal of the blood and other fluids removed from bodies; however, they all end up in the public wastewater treatment plant or backyard septic system. Some embalmers indicate that they routinely include disinfectants in the displacement process so that bloodborne pathogens will likely be ameliorated before reaching the public system.

Temperature

The generally accepted temperature required to keep a body from visibly decaying above ground prior to burial for up to three days is 65°. After burial, a body's decomposition is affected by the soil condition and the air temperature above ground. The deeper a body is buried, the slower the rate of decomposition due to lack of oxygen and microbe community. That rate will be affected by the temperature which is specific to the depth. Higher outdoor temperatures will increase the decomposition rate depending on how close to the surface the body is buried.

Burial Density and Depth

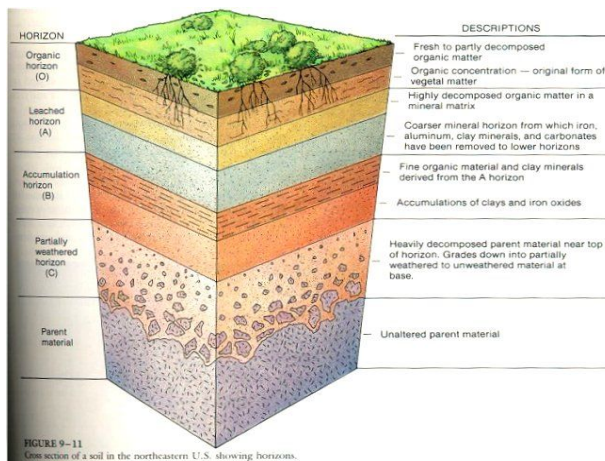
The basic premise of green burial is that the body is buried at the optimum depth in soil capable of binding organic material while promoting rapid, uninhibited, aerobic decomposition, resulting in the decay that creates the basis for fertile soil. Burial at 3-4 feet rather than 5-6 feet places the body at a depth that allows greater oxygen flow, which in turn feeds bacteria, resulting in more rapid, efficient decomposition. In addition, at a depth of 3-4 feet, beneficial carrion beetles burrow in to aid the process.

Staphylinidae (rove beetles) and *Silphidae* (also known specifically as carrion beetles) or *Nicrophorinae* (sexton beetles), plus insect species such as *Conicera tibialia* (the coffin fly) and *Phoridae* (humpbacked or scuttle flies) colonize decomposing remains underground, often for long periods of time, reproducing to complete their work over several generations.

By burying at shallower depths, land areas such as forests and wooded areas previously untenable for use by conventional cemeteries can be utilized. Green burial graves are less densely situated, allowing more space around each body to lessen competition of decay agents. The expectation is that with more efficient use of space, the land will remain intact with less disturbance, keeping nature in balance. An added possibility is that these spaces may be used for future burials as necessary.

Soil

The two greatest concerns regarding green burial are around soil and water contamination. The two are intrinsically intertwined, both in their ability to encourage natural decomposition and to inhibit it. Site selection is almost entirely dependent upon both the presence of optimum soil and the location of water sources. This section is devoted to exploring how soil affects the location and operation of green burial cemeteries, not the other way around.



Specific characteristics of soil affect its ability to act as a filter for natural body waste or any product buried within it. These include biodegradable materials in green cemeteries as well as heavy metals and wood finishes that may leach from coffins and urns, and chemicals and byproducts from concrete vaults in conventional cemeteries.

Optimum soil conditions include sandy, loamy soils, with permeability coefficients of more than 10^{-3} m/s. Soils that are waterlogged and impervious, such as clay, impede decomposition and redirect water in ways that may not be conducive to cemetery health or efficient decomposition. Additionally, clay and organic matter may bind decomposition byproducts, slowing decay and creating an anaerobic situation.

Decomposition of organic matter in soils is accomplished largely by microorganisms. The rate and course of decomposition is influenced by climate, organic matter composition, and nutrient availability from the environment. Over 90% of the microbial activity in soil is in the upper foot; most plant roots are also quite shallow. Shallow burial is aerobic, accommodating rapid decomposition due to warmer temperatures in the summer.

Rather than being an inert material, soil contains a dynamic living ecosystem. This organic soil is thought to actually have the most bio-diverse ecosystems; only about 1% of the organisms have been identified. One cup of undisturbed native organic soil may contain:

Organism	Number
Bacteria	200 billion
Protozoa	20 million
Fungi	100,000 meters
Nematodes	100,000
Arthropods	50,000

Humus, or the top organic soil layer improves soil structure by binding particles together into larger aggregates, creating pore space and improving air and water filtration. It also slowly releases nitrogen, phosphorus, and sulfur which over time is used by plants for growth and development. Humus buffers soil pH and can bind metals in soil, preventing heavy metal toxicities.

These unique and important qualities on the top organic soil layer highlight the importance of carefully removing soil strata when digging the grave and replacing it in the order it was removed.

Due diligence in choosing a site with appropriate soil is key. Soils maps ensure that a site is viable. Town or city engineers are resource personnel who can provide and help interpret local and US government soil overlay maps. Digging test pits and having them professionally analyzed prior to initiating cemetery status is advised.

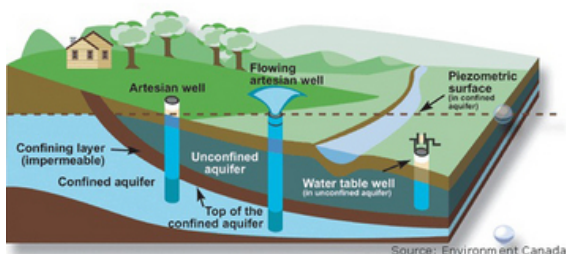
It should also be noted that certain infectious agents survive in the soil such as hepatitis C survive in the soil, but are less infectious than when carried by a live person. Anthrax and botulism are endemic in most soils. There is no evidence for travel of these biologic agents in soils.

Other considerations are equally important criteria for ideal soil for green burial, including amount of organic matter present, alkalinity, salt levels, texture of the soil (large and loose to dense and impermeable), depth to bedrock, slope, presence of fractured or cavernous bedrock, and more.

Water

“There is little evidence of microbiological contamination of groundwater from burial...Microorganisms involved in the decay process (putrefaction) are not pathogenic.” —PAHO

The potential for contamination of drinking water due to body decomposition, though possible and frankly expected if best management practices are not followed, is not definitively substantiated by studies at this time. Areas adjacent to conventional cemeteries, especially historical cemeteries, have been reported to have elevated results when core soil and water specimens were tested for contaminants in a handful of cases.



But there is no evidence that these findings are attributable to body decomposition processes. Due to the types of contaminants found, it is highly likely that the problems were caused by leachate from casket, vault, or embalming fluid or other incidental materials. No contamination has been reported from or near any green cemeteries in the US, Canada, Great Britain or Australia since their inception in 2003.

In areas near cemeteries where ground water has been found to have elevated organic compounds such as dissolved organic carbon concentrations,

there has been discoloration, unpleasant odor, and changes in taste when chlorinated, but these compounds are not harmful in and of themselves.

Arsenic is still being found in water near cemeteries where Civil War soldiers who were embalmed and transported were buried. This finding, unfortunately, does not help us understand the contaminant properties of bodies on water sources below the grave separate from the casket, vault, and embalming leachate, either then or now.

In 1998, the World Health Organization published recommended guidelines for burying disaster victims in relation to water sources, suggesting that humans and animals be buried at least 250 meters from any well, borehole, or spring from which potable water supply is drawn, 30 meters away from any other spring or water source, and at least 10 meters from any field drain. While helpful in a disaster scenario, these figures are not particularly useful for determining water safety in a variety of potential green burial sites in the US.

Many states provide setback parameters for water, buildings and roads for home burial that may give some guidance for best practices in green cemeteries. Each region has unique conditions that must be taken into account.

Due to the lack of specific data regarding single body burial at 3-4 feet in a certified cemetery without use of a vault, casket or embalming, we should proceed with caution and common sense, follow established parameters regarding distance from known water sources, pay attention to seasonal high water tables, and recognize that aquifers are often located several hundreds of feet below ground. Ground water would have to filter through at least 80 to 100 types of soil to reach an aquifer, naturally making it potable.

When attempting to determine cemetery impact on water, it is important to acknowledge the

differences between acceptable levels of nutrients and minerals in aquifers, lakes, streams, and rivers, and the levels that are considered polluting, contaminating, or toxic in each specific context.

Aquifers — natural underground geological formations of soil and rock that serve as storage water areas

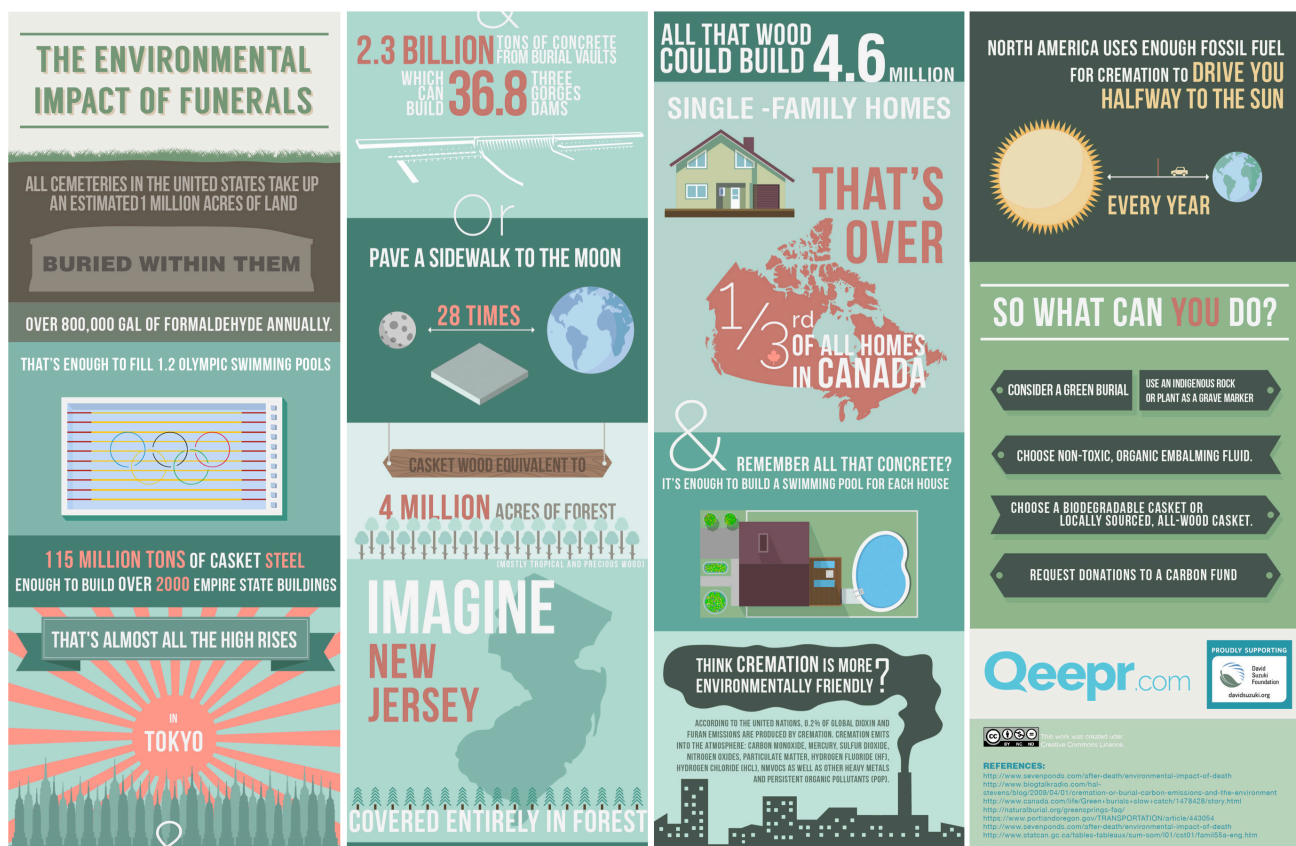
Ground water — water that moves through the soil and aquifers and supplies wells, springs, and surface water bodies

Surface water — lakes, streams, rivers

Water table — the upper limit of the portion of the ground wholly saturated with water

Sources of Pollution

More Americans are asking cemeteries to stop burying toxic chemicals, metal and exotic wood caskets, and concrete or plastic vaults in the ground. They are opting instead for a burial in an eco-friendly casket or shroud in a green cemetery that promotes environmentally responsible land management.



Bodies

Bodies themselves are potential contaminants in any burial situation, as decomposition naturally releases nutrients such as nitrogen and nitrates. With proper soil and appropriate water setbacks, contaminants from decomposing bodies are not a likely source of contamination of known water sources. Micro-organisms present in cemetery soils, referred to as “decay plumes,” could present

potential health concerns if allowed to reach drinking water sources. Due diligence in establishing the cemetery site after investigating aquifer and known water sources is recommended.

As an alternate perspective: One body will decompose over a period of 4 to 6 weeks, releasing about 12 gallons of moisture. The average family of four flushes 250 gallons of water every day with

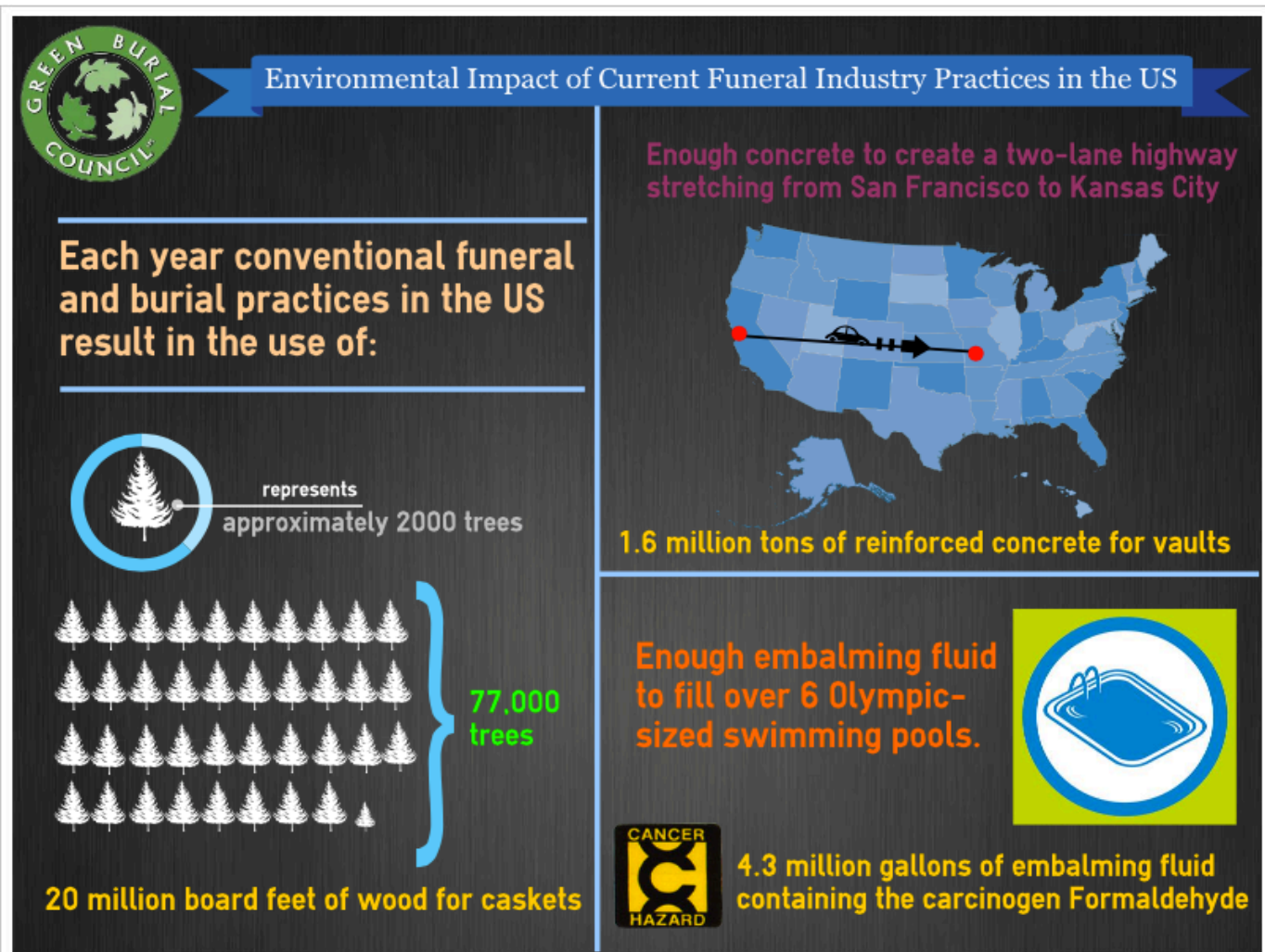
“infectious” waste that possibly contains drugs such as chemotherapy or birth control.

Artifact Contaminants Used in Conventional Burial

The chemical leachate of materials buried with the body in a conventional burial pose a larger threat to water sources than bodies themselves. Metal caskets are a particular concern in acidic soils, potentially leaching heavy metals such as iron, copper, lead and zinc. Wood caskets prepared with preservatives, varnishes, or sealants may contain arsenic and other harmful chemicals. Vaults made of concrete, plastic, fiberglass, or asphalt, a semi-solid form of petroleum, not only off-gas or leach pollutants, they themselves are the pollutants. The harvesting, processing, manufacture and transport of casket and vault materials represent additional energy use and other environmental impacts.

Furthermore, encasing a body in a metal or hardwood box inside a concrete or other structure significantly slows decomposition. Synthetic or inorganic materials used in the manufacture of clothing or casket lining, and dyes, plastics and metals (such as zippers and buttons) further contribute to soil contamination. Artificial joints and silicone implants are also a concern.

Current estimates (Woodsen, 2014) regarding permanent installation of cemetery goods in the ground in US cemeteries each year are: 20 million board feet of wood, 4.3 million gallons of embalming fluids, 1.6 million tons of reinforced concrete, 17,000 tons of copper and bronze and 64,500 tons of steel. Green cemetery use of these materials is zero.



Runoff of Herbicides, Pesticides, Fertilizers

Conventional cemeteries routinely spread herbicides and pesticides, resulting in a high incidence of Chronic Obstructive Pulmonary Disease (COPD) and other respiratory and neurological illnesses in groundskeepers. These chemicals have the potential for making their way into surrounding water sources through run off or saturation.

Atrazine, banned in Europe, is one of the most widely used herbicides in the US on golf courses and in cemeteries to kill broadleaf weeds. It is the most commonly detected pesticide found in surface and drinking water and is a danger to humans and wildlife alike. Emissions from fossil fuels that power groundskeeping and gravedigging equipment are also pollutants. In contrast, many green burial cemeteries hand-dig graves, and avoid the use of herbicides or pesticides altogether.

Fertilizers used to improve lawn quality also endanger ground and surface water ecosystems, causing overproduction of phytoplankton and macrophytes (such as algae blooms). This may lead to an imbalance of what is otherwise an enrichment of surface waters with plant nutrients, causing eutrophication that can lead to habitat displacement, deoxygenation of water resulting in fish kills, weed infestation, noxious odors and tastes, and loss of public and recreational use.

Nuisance Pests

Burial depth at 3-4 feet in green cemeteries gives rise to concerns by the public regarding pest control. The general rule is to measure from the tip of the nose or hipbone to the surface to be sure to achieve an 18 - 24 inch smell barrier. This depth of soil is more than sufficient to remove any smell that animals, much less humans, can detect. To date, there have been no reports from any US green burial cemeteries of animals trying to dig up graves. Common pest problems, including bugs such as emerald ash borer, deer and rodents affect vegetation. While aggressive pests such as the

winter moth that attacks beech trees must be treated with minimal levels of pesticide, others, such as the wooly algeid, may be treated with horticultural oil on the hemlock it calls home. Integrated pest management plans in green burial cemeteries are helpful, but more appropriate in many cases are nuisance management plans. Deer overgrazing and rodent damage, though unpleasant, might best be treated with fencing and selective planting to divert attention to other, less sensitive areas.

Surface Vegetation

Digging graves creates disturbance to the soil and plant life in the immediate vicinity, affecting plant growth, soil microbial structure, and root strength. Oxygenation caused by aerating the soil, coupled with the nutrients released through decomposition, leads to increased plant growth above the grave. Rich humus surface horizons in forested areas may be removed by intact sections and later replaced, reducing damage to roots and microbial colonies and encouraging healthy surface plant life quickly after burial. Invasive plant management may be required to restore balance in areas overcome with nonnative species.

Density of vegetation is a factor not only in how well the area soil drains but in how much air will be allowed to circulate. Since efficient decomposition requires oxygen exchange, too much water being held in place by excessive moisture at the surface level can impede progress.

The most efficient method of mitigating the potential uptake of decomposition materials in cemeteries is to plant trees and shrubs, particularly at the edges. Tree roots incorporate viruses, bacteria, and heavy metals from the soil that are stored in the woody plant tissue without harm to the tree or the surrounding soil. Tree roots also have the added benefit of drawing water up from the soil, with the positive result of lowering the water table.

Conclusion

Lacking studies specifically related to green burial, we can only conclude from the basic science, eons of history, and the absence of any reports in over

twenty years in hundreds of practicing green burial cemeteries throughout the world, that green burial represents a natural, efficient, and safe disposition option when best practices are followed.

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