Ohio's Professional Soil Scientists

2024 Winter Newsletter
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Journal Articles etc. of note

A story from Duane Wood, https://www.morningagclips.com/dirt-powered-fuel-cell-runs-forever/

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Dirt-Powered Fuel Cell Runs Forever

New tech harvests energy from microbes in soil to power sensors, communications

PUBLISHED ON **JANUARY 17, 2024**

The fuel cell's 3D printed cap peeks above the ground. The cap keeps debris out of the device while enabling air flow. (Photo: Bill Yen/Northwestern University)

EVANSTON, Ill. — A Northwestern University-led team of researchers has developed a new fuel cell that harvests energy from microbes living in dirt.

About the size of a standard paperback book, the completely soil-powered technology could fuel underground sensors used in precision agriculture and green infrastructure. This potentially could offer a sustainable, renewable alternative to batteries, which hold toxic, flammable chemicals that leach into the ground, are fraught with conflict-filled supply chains and contribute to the ever-growing problem of electronic waste.

To test the new fuel cell, the researchers used it to power sensors measuring soil moisture and detecting touch, a capability that could be valuable for tracking passing animals. To enable wireless communications, the researchers also equipped the soil-powered sensor with a tiny antenna to transmit data to a neighboring base station by reflecting existing radio frequency signals.

Not only did the fuel cell work in both wet and dry conditions, but its power also outlasted similar technologies by 120%.

The research will be published today (Jan. 12) in the Proceedings of the Association for Computing Machinery on Interactive, Mobile, Wearable and Ubiquitous Technologies. The study authors also are releasing all designs, tutorials and simulation tools to the public, so others may use and build upon the research.

“The number of devices in the Internet of Things (IoT) is constantly growing,” said Northwestern alumnus Bill Yen, who led the work. “If we imagine a future with trillions of these devices, we cannot build every one of them out of lithium, heavy metals and toxins that are dangerous to the environment. We need to find alternatives that can provide low amounts of energy to power a decentralized network of devices. In a search for solutions, we looked to soil microbial fuel cells, which use special microbes to break down soil and use that low amount of energy to power sensors. As long as there is organic carbon in the soil for the microbes to break down, the fuel cell can potentially last forever.”

“These microbes are ubiquitous; they already live in soil everywhere,” said Northwestern’s George Wells, a senior author on the study. “We can use very simple engineered systems to capture their electricity. We’re not going to power entire cities with this energy. But we can capture minute amounts of energy to fuel practical, low-power applications.”

Wells is an associate professor of civil and environmental engineering at Northwestern’s McCormick School of Engineering. Now a Ph.D. student at Stanford University, Yen started this project when he was an undergraduate researcher in Wells’ laboratory.

Solutions for a dirty job

In recent years, farmers worldwide increasingly have adopted precision agriculture as a strategy to improve crop yields. The tech-driven approach relies on measuring precise levels of moisture, nutrients and contaminants in soil to make decisions that enhance crop health. This requires a widespread, dispersed network of electronic devices to continuously collect environmental data.

"If you want to put a sensor out in the wild, in a farm or in a wetland, you are constrained to putting a battery in it or harvesting solar energy," Yen said. "Solar panels don't work well in dirty environments because they get covered with dirt, do not work when the sun isn't out and take up a lot of space. Batteries also are challenging because they run out of power. Farmers are not going to go around a 100-acre farm to regularly swap out batteries or dust off solar panels."

To overcome these challenges, Wells, Yen and their collaborators wondered if they could instead harvest energy from the existing environment. "We could harvest energy from the soil that farmers are monitoring anyway," Yen said.

'Stymied efforts'

Making their first appearance in 1911, soil-based microbial fuel cells (MFCs) operate like a battery — with an anode, cathode and electrolyte. But instead of using chemicals to generate electricity, MFCs harvest electricity from bacteria that naturally donate electrons to nearby conductors. When these electrons flow from the anode to the cathode, it creates an electric circuit.

But in order for microbial fuel cells to operate without disruption, they need to stay hydrated and oxygenated — which is tricky when buried underground within dry dirt.

"Although MFCs have existed as a concept for more than a century, their unreliable performance and low output power have stymied efforts to make practical use of them, especially in low-moisture conditions," Yen said.

Winning geometry

With these challenges in mind, Yen and his team embarked on a two-year journey to develop a practical, reliable soil-based MFC. His expedition included creating — and comparing — four different versions. First, the researchers collected a combined nine months of data on the performance of each design. Then, they tested their final version in an outdoor garden.

The best-performing prototype worked well in dry conditions as well as within a water-logged environment. The secret behind its success: Its geometry. Instead of using a traditional design, in which the anode and cathode are parallel to one another, the winning fuel cell leveraged a perpendicular design.

Made of carbon felt (an inexpensive, abundant conductor to capture the microbes' electrons), the anode is horizontal to the ground's surface. Made of an inert, conductive metal, the cathode sits vertically atop the anode.

Although the entire device is buried, the vertical design ensures that the top end is flush with the ground's surface. A 3D-printed cap rests on top of the device to prevent debris from falling inside. And a hole on top and an empty air chamber running alongside the cathode enable consistent airflow.

The lower end of the cathode remains nestled deep beneath the surface, ensuring that it stays hydrated from the moist, surrounding soil — even when the surface soil dries out in the sunlight. The researchers also coated part of the cathode with waterproofing material to allow it to breathe during a flood. And, after a potential flood, the vertical design enables the cathode to dry out gradually rather than all at once.

On average, the resulting fuel cell generated 68 times more power than needed to operate its sensors. It also was robust enough to withstand large changes in soil moisture — from somewhat dry (41% water by volume) to completely underwater.

Making computing accessible

The researchers say all components for their soil-based MFC can be purchased at a local hardware store. Next, they plan to develop a soil-based MFC made from fully biodegradable materials. Both designs bypass complicated supply chains and avoid using conflict minerals.

"With the COVID-19 pandemic, we all became familiar with how a crisis can disrupt the global supply chain for electronics," said study co-author Josiah Hester, a former Northwestern faculty member who is now at the Georgia Institute of Technology. "We want to build devices that use local supply chains and low-cost materials so that computing is accessible for all communities."

The study, "Soil-powered computing: The engineer's guide to practical soil microbial fuel cell design," was supported by the National Science Foundation (award number CNS-2038853), the Agricultural and Food Research Initiative (award number 2023-67021-40628) from the USDA National Institute of Food and Agriculture, the Alfred P. Sloan Foundation, VMware Research and 3M.

–Northwestern University
via EurekAlert!

Jim Bauder sends along this story about forest recovery and the ability to sequester CO2 after reforestation. My son, Adam Rice, also saw the report and sent the information on. Here is the link, https://www.msn.com/en-us/lifestyle/lifestyle-buzz/study-reveals-unexpected-recovery-times-when-forests-are-left-alone-to-regrow-after-destruction/ar-AA1hQBkF?ocid=socialshare&pc=DCTS&cvid=1eeeb071df4d49cd86c95004cd1111aa&ei=14

Study reveals unexpected recovery times when forests are left alone to regrow after destruction

Story by Leo Collis • 1mo

"If there's no source for seeds, heavily degraded soils, and no way for animals to get there, that's going to be a problem."© Provided by The Cool Down

Deforestation has an immense impact on global heating, as the destruction of trees and plant life stops the absorption of harmful gases such as carbon dioxide, which otherwise remain in the atmosphere and contribute to rising temperatures.

According to the World Wildlife Fund, up to 15 billion trees are cut down every year to help meet global demand for meat, soy, and palm oil.

But a 2021 study has found that forest regeneration can occur with unexpectedly fast recovery times if forests are simply left alone to grow and thrive.

Research published in the journal Science and summarized by Anthropocene sought to see how former forests that have been turned to pasture and farmland could recover and how quickly the process could be achieved.

A total of 77 different sites at different stages of growth were examined at the same time, including wet and dry forests in Central and South America, as well as coastal West Africa.

Incredibly, after one to nine years, the sites were able to achieve 90% of the carbon, nitrogen, and soil density levels found in untouched forests.

Further, the size of tree leaves, tree wood density, and the number of nitrogen-fixing trees took between three to 27 years to return to old growth conditions.

Clemson University ecologist Sara DeWalt noted that natural regeneration of forests is the most efficient way to do things, both ecologically and economically. “Nature will take care of it if we let it,” she said.

However, the researcher also noted there will be times when intervention is required.

“If there’s no source for seeds, heavily degraded soils, and no way for animals to get there, that’s going to be a problem,” she said. “There will be times when planting will be necessary.”

While this is mostly encouraging research, it still brought up a couple of worrying findings. For example, it took 12 decades for species found in old-growth tropical forests to return to the new growth areas.

But, still, the fact that once-vital forests can return more quickly than anticipated is welcome news for biodiversity and carbon capture.

There is a video at the web site well worth watching.

A NOVA Special that links to Kathy’s President’s letter.

Reading Kathy’s letter reminded me of a fascinating NOVA special I watched on PBS not that long ago. It was a repeat, I had seen it before, but I did not make the connection originally, I think it is well worth mentioning now. The episode is titled Artic Sinkholes, https://www.youtube.com/watch?v=HvKpnaXYUPU. If you have the hour, watch this.

Mound Systems in Ohio

There at two OSU Extension bulletins that addresses the design, construction and use of septic mound systems in Ohio. These two bulletin publications PDF and in hard copy can be purchased from Extension, but I also found them online. They are OSU Bulletin 813 (guidance) and Bulletin 829 (pressure distribution).

Link to OSU Fact sheet, https://ohioline.osu.edu/factsheet/aex-744

Ohioline

Ohio State University Extension

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Septic Tank: Mound System

Karen Mancl, Professor, Food, Agricultural and Biological Engineering
Brian Slater, Associate Professor, Environment and Natural Resources
Peg Cashell, On-site Educator, Logan, Utah

Ohio has large areas of soils that are too shallow for typical septic tank-leach field systems, which require 36 inches of suitable soil before hitting a limiting layer. Limiting layers are bedrock, sand, and gravel, dense and compacted layers, and water tables. About 53 percent of soils in Ohio have limiting layers at shallow depths that do not provide the 36 inches of suitable soil, as shown in Figure 1. In these areas, mound systems are often used to remove pollutants from wastewater to protect the public health and the environment. These systems can be used in soils that have a limiting layer within 12 to 36 inches from the soil surface.

Figure 2 shows a typical mound system. In these systems, specially selected sand is placed on top of natural soil to help treat septic tank effluent. Effluent discharging from a septic tank accumulates in a dosing tank where a pump discharges a predetermined volume of wastewater into the mound.

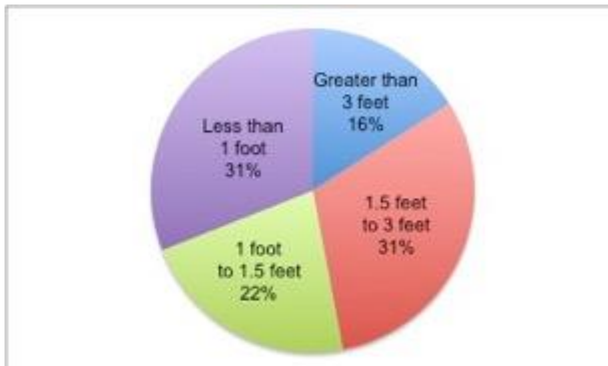


Figure 1. Percentage of the land area of Ohio with various depths to a limiting condition.

Mound systems are long and narrow, and must be constructed along the lot contour. For a three-bedroom home, a mound system can be as long as 200 feet, depending on soil and site conditions. For larger homes, up to 30 feet in length per bedroom is added to a mound system.

A mound is constructed in layers of predetermined depths (Figure 3). First, the natural soil depth above the limiting layer is determined (minimum of 12 inches). A layer of specially sized sand is placed on top of the natural soil. Together, the natural soil depth and the added sand equal the minimum depth required to treat wastewater effluent. A layer of gravel or a chamber surrounding the distribution pipes is then placed on top of the sand. Finally, after a final covering with construction fabric, a layer of soil fill is placed over the entire mound to protect the pipes from freezing. A layer of topsoil is also needed to grow grass or other nonwoody plants that control erosion.

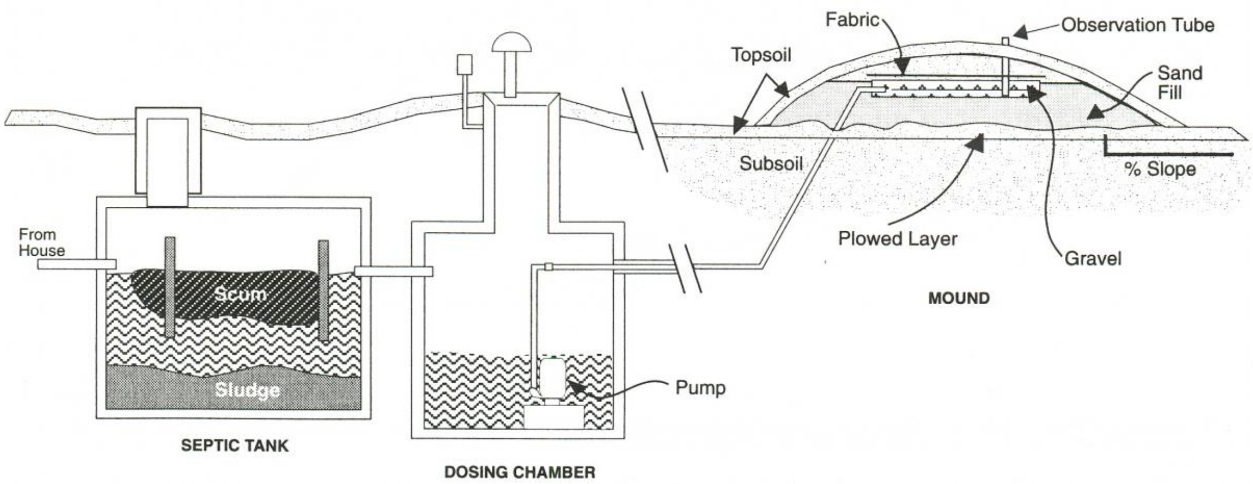


Figure 2. Components of a mound system.

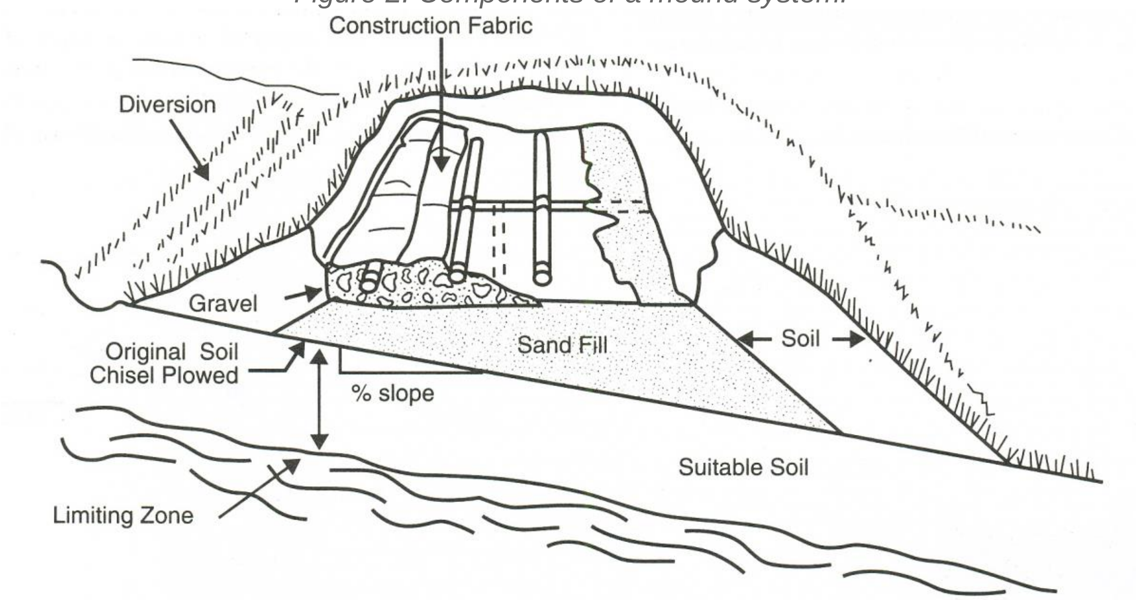


Figure 3. Details of a mound.

When building a mound, the site must first be carefully prepared. The grass is mowed and leaves raked away. Trees and shrubs are cut off at ground level, with the roots left in place. The installer will use a chisel-plow to break up the grass and roughen the surface in preparation for the sand layer. The installer will be careful not to compact the soil in the mound area and just downslope of the mound. After construction, the lot will be carefully graded to divert any runoff water around the mound.

For specific information on how to design and construct a mound system, see Ohio State University Extension Bulletin 813, *Mound Systems for Onsite Wastewater Treatment* and OSU

Extension Bulletin 829, *Mound Systems: Pressure Distribution of Wastewater*. Learn more at setll.osu.edu. Both publications are available online at extensionpubs.osu.edu.
As with all household sewage systems, the homeowner must maintain the system to ensure trouble-free operation. The homeowner should:

pump the septic and dosing tanks every one to five years.

use water wisely and install water-saving devices in the home.

- never compact the soil downslope of the mound by paving, constructing a building, or parking cars.
- avoid clogging pipes with roots by not planting trees or shrubs on the mound.

Topics:
Energy and Environment
Tags:
wastewater
septic system
sewage treatment system
sewage
sewage treatment
mound system
septic tank
Program Area(s):
Food, Agricultural and Biological Engineering
Originally posted Jul 26, 2019.

The links to the two extension bulletins are available on line for free from Brown Township Franklin County, Ohio but they are labeled in reverse. This address is actually for Bulletin 819, https://www.browntwp.org/site/assets/files/1090/e813_2_-1.pdf. This link is for Bulletin 829, https://www.browntwp.org/site/assets/files/1090/e829_1_-2.pdf. Not sure why they are backwards. Here is the link to the ODH requirements for mound systems, https://odh.ohio.gov/wps/wcm/connect/gov/07f910a7-d98a-4c1f-a71c-9dbdebfd9084/SDA-thin-soils-mounds.pdf?MOD=AJPERES&CONVERT_TO=url&CACHEID=ROOTWORKSPACE.Z18_M1HGGIK0N0JO00QO9DDDDM3000-07f910a7-d98a-4c1f-a71c-9dbdebfd9084-nvkqW8s.

Bulletin 813 is copyright 2016, by T.V. Nimesha Madhavi Gunarathne, M.Ph and Dr. Karen Mancl, OSU FABE

Bulletin 829 is copyright 2005, by Young Woon Kang (Eun Young Kim of the mud pie fame's husband), Dr. Karen Mansl, FABE, and Dr. Robert Gustafson, former Chair FABE but by this point, Associate Dean Engineering.

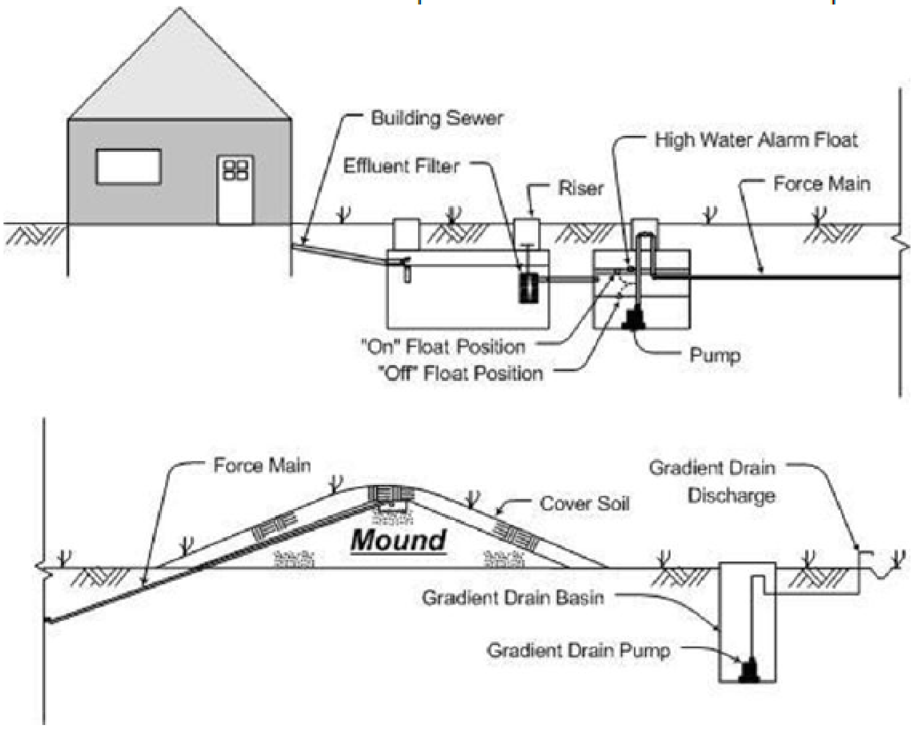
The folks at Clermont County Public Health are supposed to have a different manual that the septic installers like better but I cannot find it on line. I did find a link to "Care and Maintenance of Your Sewage Treatment system that looked useful, https://ccphohio.org/wp-content/uploads/sites/21/2017/02/maintainmound.pdf.

Clermont County Public Health

Prevent. Promote. Protect.

Care and Maintenance of your Mound Sewage Treatment System

This system uses sand placed on top of the natural soil to treat wastewater. As shown below, the wastewater is pumped to the mound from a lift station. Pipes in a gravel layer above the sand distribute the wastewater under pressure. After the wastewater passes through the sand, the natural soil absorbs the wastewater and provides further treatment and disposal.



Tank Care: Live bacteria in the septic tank provide biological treatment. Keep products harmful to bacteria out of the tank. Antibacterial soaps and disinfectant cleaners, excessive bleach, antibiotics, pesticides and poisons, drain cleaners, solvents, and automobile fluids are examples of harmful products. Chemotherapy and radiation therapy products may also kill bacteria in the tank. Dead tank bacteria provide no treatment, resulting in little settling of suspended solids, rapid accumulation of sludge, and higher maintenance costs. A dead tank will cause the system to clog and fail if the condition is not corrected in time. An in-sink garbage disposal is not recommended and, if used, will require more frequent septic tank pumping. Dispose of fats, oils and grease with your solid trash. **Avoid additives and products that claim to dissolve tank solids.** Keep non-soluble wastes, such as plastics and cigarette butts, pet wastes, cat litter, paint, construction and cleaning wastes out of your septic system. Also avoid disposing of paper products, (except toilet paper approved for septic tanks). **The General Rule is: Don't put anything into your septic system that has not gone through your body first.**

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Maintenance Tips

Have your tank pumped out by a registered septage hauler every 3 to 5 years, or as needed (see attached guidance for tank maintenance and pumping schedules). Septic tank risers (properly located and sealed to the tank) and lids simplify access to the tank for inspection and service. If your tank doesn't have an access riser, installing one is recommended. A riser should extend high enough above the ground surface to allow soil to be placed around it and sloped away, to keep surface water from ponding. Any riser must have a child proof lid installed. Keep a record of pumping and other maintenance.

Your mound system has electrical components for the pump in the dosing tank and, in most cases, for a gradient/curtain drain sump pump. Check the circuit breaker for your system, the condition of the wiring and connections, as well as the pump(s), on a regular basis. Underground electric service should be checked by a qualified person for proper grounding. Any electrical repairs should be completed by a qualified person and may require an inspection from the Clermont County Building Department.

DO NOT OVERLOAD YOUR MOUND SYSTEM beyond its capacity to absorb the wastewater from your home. **WATER CONSERVATION is a must**. Repair any leaking faucets or toilets. Use water saving appliances and devices, such as faucets, shower heads, and toilets. Take short showers and spread doing laundry throughout the week.

Divert all surface water away from your mound system. This includes roof drains, footer drains, and sump pump discharges. Eliminate any standing water around the mound by filling in low spots with good quality topsoil when the ground is dry.

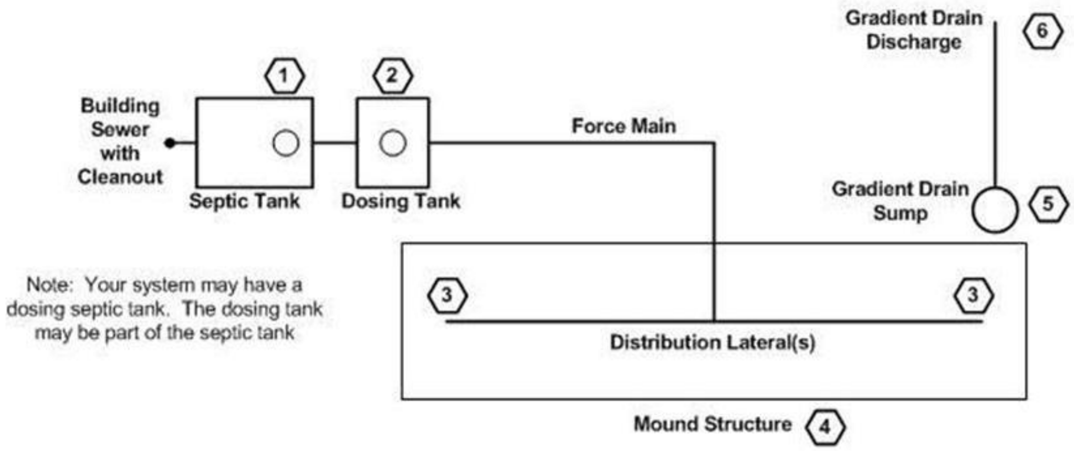
Keep a good stand of grass or vegetation on and around the mound. The mound should have vegetation mowed a minimum of twice per year. Trees and shrubs should not be planted directly on the mound. Landscaping near the mound, to blend the mound into the surrounding area, should be done with special care to avoid damage to the system (buried electric and piping exist).

Protect your system from damage. Do not allow anyone to park or drive over any portion of the system. Do not construct driveways or structures within 10 feet of the mound or in its replacement area. Livestock should not be allowed to graze on or near the mound, nor should pets be allowed to dig in the area. Do not excavate around your system, such as for an in-ground swimming pool or room addition, without first applying at the Health District for an inspection in advance.

If you experience slow draining toilets or drains, sewage backup into the house or smell strong sewage odors, your system may be malfunctioning. Call a bonded and registered service provider.

PROTECT YOUR INVESTMENT by providing routine maintenance to your mound sewage treatment system. A properly maintained mound system can effectively treat wastewater for years.

Wisconsin Mound (Type H Structure) Annual Maintenance



(1) Effluent Filter (if applicable) - Remove lids from septic tank. Remove filter from its housing. Using a garden hose, rinse filter over the first compartment of the septic tank-all drainage should fall into the septic tank. After all solids on filter have been removed, return filter into housing. Replace all lids.

(2) Disable pump by shutting off its electric service. Remove dosing tank lid. Note water level in the tank and look for any signs of water or root infiltration. Inspect all visible electrical connections. Any connections having questionable integrity should be replaced by a qualified individual (inspection by Building Department may be required). If flushing laterals at this time, ensure there is an adequate water supply in dosing tank. The visual and audible high water alarm operation needs to be verified by lifting the high water alarm float.

(3) Lateral Cleanout Connections - Remove access port lids. Gently grab and twist the exposed PVC wye to check integrity of glued joint. If loose, repair connection. For each lateral cleanout: 1) remove horizontal screw-on cleanout cap; 2) engage pump; 3) run pump until water exiting lateral is free of solids; 4) replace screw-on cap; and 5) repeat for all laterals.

(4) Mound Structure - Visually inspect mound for animal burrows, lack of vegetative cover (reseed if necessary), saplings/other large shrub-like plants, wet spots, areas that can pond water and any missing/damaged observation port/cleanout port lids. Correct deficiency as noted.

(5) Gradient Drain Sump - (May not be present on all mound systems) Remove basin lid. Disable pump by turning off its electrical service. Inspect all visible electrical connections, correcting any deficiencies (inspection by Building Department may be required). Restore power to pump. Start pump by lifting the float until pump activates.

(6) Gradient Drain Discharge Point - Check for free flowing discharge from this pipe. Inspect for any adverse erosion conditions, add splash guard as necessary. Verify that water is moving away from the discharge point.

That's the best information I could find. If anyone else has had experiences with these systems and anything better to share, please send it my way and I'll put it in the next newsletter.

This completes Part 2 of the Winter 2024 AOP Newsletter. Hope it is useful. Don't forget to log your hours for CEU credits if you read the documents or watch the NOVA episode.