A LIFETIME OF WATER USE

Danna Revis[1]

INTRODUCTION

With the advent of alternative onsite sewage systems, much current literature is focused on the use of alternative systems comprised of a trash tank followed by a secondary treatment unit, often with nitrogen reduction, and followed by either pressurized or non-pressurized soil dispersal. While these systems are great, there are still millions of conventional systems in the United States alone, in various stages of their life cycles. Many homeowners are not aware that while these conventional systems can last for decades, they were never expected to last forever.

Anecdotally, in my 38 years working in the onsite sewage industry, I have observed many examples of how a conventional system lasts the life of a family. Mom and Dad (or Mom and Mom or Dad and Dad) marry, raise a few kids, the kids move out, and it's just Mom and Dad again. They've never reported a problem with the onsite sewage system except maybe once in 1995 when they "had" to have the tank pumped and it turned out someone had flushed a GI Joe down the drain.

After 40 years in the home, Mom and Dad decide to sell the house to move into a retirement community. The real estate inspection of the drainfield shows that water is ponding over the gravel in the absorption trenches, even in the summer. When questioned further, Mom says she could only do one load of laundry a week for the two of them and never right after it rained, and she took the bedding to the laundromat. She had stopped using the dishwasher because it made the shower drain slow. But it had never occurred to them that there was a problem with the drainfield.

We often run into this phenomenon with homeowners who have lived on septic a long time. The problems with the drainfield have developed very slowly, perhaps only seasonally at first. The family altered their water use in ways that allowed them to manage even though the system was displaying problems and limitations. The families that begin seeking solutions are the ones where the systems tend to back up into the house. If the sign of failure is a wet spot in the yard, many owners will just mow around the wet spot for many years and accept that drainfields "act like that".

For conventional systems, primary treatment occurs in the septic tank, but the remainder of the treatment occurs in the soil (Wilhelm, 1994) and treatment is sometimes incomplete before the septic tank effluent reaches the water table and causing a biomat to form at the gravel/soil interface. We can infer then, that the lifetime of the drainfield is determined by site and soil characteristics, water use, and biochemical loading. If the soil could provide enough oxygen to satisfy the BOD and COD, theoretically no biomat would form and the drainfield could continue to operate much longer than we currently see, clogging eventually only due to inorganic solids

[1] Danna Revis, MALT, MAOSE, MAOSSO, Old Dominion Onsite, Inc., Ashland, VA; danna.revis@olddominiononsite.com

suspended in the septic tank effluent (albeit discharging nitrates into the soil and possibly the water table).

For the purposes of this inquiry, we will consider the static model as the baseline – a family buys the home at the beginning of their life together, raises their kids to independence and then grows old together in the same home. Since this model was the norm for rural homeowners when indoor plumbing became popular and onsite sewage standards were initially developed, understanding this baseline for onsite sewage system performance will help us understand the basis upon which the standards were developed. Hopefully we can build on this model to better understand the lifetime performance of conventional onsite sewage systems for both non-transient and transient communities.

VIRGINIA DRAINFIELD DESIGN (CONVENTIONAL)

In northern, central, and eastern Virginia, if a soil has permeability suitable for a drainfield, the main issues are a suitable standoff to seasonal high water table (SHWT) or rock. Regulations prior to 1982 did not specify stand-off to SHWT or rock. The 1982 Sewage Handling and Disposal Regulations, 12 VAC 5-610, required a 12" standoff to rock and had a sliding scale for standoff to SHWT, from 2 inches in very fast, sandy soil horizons to 18" in slow, clayey soils, and seasonal high water table was determined by gray, defined as chroma 2 or less on the Munsell soil color chart . Primarily conventional systems were allows under these regulations. Low- pressure distribution systems were allowed at a smaller footprint under these regulations with the same vertical standoffs. Some engineered systems were permitted, but the primary strategy was to use a Wisconsin Mound or otherwise add sand to meet the standoff requirements in the Regulations. Pretreatment systems were used primarily for discharging systems under separate regulations. In 1993, GMP 20 allowed limited use of pre-treatment systems to reduce vertical standoffs for onsite sewage systems, and a few proprietary treatment products with smaller footprints were allowed under dedicated policies. Drip irrigation, both with pre-treatment and for STE was approved prior to the 2000 Regulations by policy as well.

The 2000 Sewage Handling and Disposal Regulations increased the standoff to SHWT and rock to 18" in all soils for conventional systems and allowed reduced standoffs to SHWT and rock for secondary treatment. The 2000 Regs also allowed dispersal depths less than 18" with pre-treatment and with timed dosing required in some cases. A number of proprietary systems were approved following the 2000 Regulations until finally the Emergency Regulations for Alternative Systems were issued in 2009 and extended until the final Regulations for Alternative Onsite Sewage Systems were approved in 2011. The regulation requiring nitrogen reduction within the Chesapeake Bay watershed had a delayed implementation and ENT into effect December 2013.

In practice, prior to 1982, local health departments in Virginia used soil criteria to assist in drainfield design based on local or regional practices. The 1971 Regulations Governing Sewage Disposal (Virginia Department of Health, 1971) contains the following soil criteria for drainfields:

7. Soil Evaluation-Soil evaluation for a drainfield system shall follow a systematic approach including consideration of physiographic province, position of landscape, degree of slope and soil profile (thickness of horizon, color, texture). Such evaluation shall indicate whether or not the soil has problems relative to the position in the landscape, seasonal water table, shallow depths, rate of absorption, or a combination of any of the above. .If absorption rate problems are suspected and there is no indication of a water table, percolation tests should be made but their result shall not be presumptive, prima facie or conclusive evidence as to the suitability for effluent absorption. Such percolation tests may be considered and analyzed as one of many criteria in determining soil suitability for absorption of effluent.

Combined with a knowledge of local soil characteristics, these general guidelines provided some guidance for septic system design. The sizing chart provided in these regulations was a step up from previous sizing guidance and has been refined in subsequent regulations.

WATER USE

Design flow is another important factor in drainfield design and ongoing water use impacts the lifetime of the drainfield. In Virginia, onsite sewage systems are currently designed based on 75 gppd.

Table 5.1.
Sewage Flows.

Discharge Facility	Design Unit	Flow (gpd)	BOD (#/day)	S.S. (#/day)	Flow Duration (Hour)
Dwelling[1]	per person total	75	0.2	0.2	24
Food preparation	--	15	--	--	--
Toilet facilities	--	20	--	--	--
Bathing facilities	--	20	--	--	--
Handwashing facilities	--	5	--	--	--
Laundering	--	15	--	--	--

Fig. 1. Sewage Flow from Virginia Regulations *(Virginia Department of Health, 2000)*

The design flow standard was slightly different in previous regulations, but not significantly different for the purposes of this inquiry.

Design flow includes a consideration of peak flow as well as average flow. Traditionally, average daily flow estimates fall between 48 gppd and 60 gppd. In this 2011 study by DeOreo (DeOreo, 2011), water use per capita is as low as 35.6 gppd for high efficiency new homes built after 2001.

For the purposes of this inquiry, we are using the figure of 62.18 gppd from a 1999 study by Mayer et.al. (Mayer, 1999) which is also presented in DeOreo's newer analysis.

Table 4-33: Indoor water use comparisons between four study groups

Parameter	REUWS (gphd)	Standard (post-2001) study group	EPA post-retrofit group	High-efficiency new homes
N	1188	302	96	25
Mean ± 95% C.I. (gphd)	177 ± 5.5	140 ± 10.0	107 ± 10.3	105 ± 28
Median (gphd)	160	125	100	90
Percapita relationship (gphd=)	$87.41x^{0.69}$	$66.30x^{0.63}$	$50.21x^{0.77}$	$59.58x^{0.53}$
Household use for family of 3 (gphd)	187	132	117	107
Projected Percapita use for family of 3 persons (gpcd)	62.18	44.15	39.0	35.6

Fig. 2. Indoor water use comparisons among four study groups *(DeOreo, 2011)*

Based on DeOreo's study, the relationship between indoor water use and the number of residents is non-linear (DeOreo, 2011). The "Percapita relationship" equation in the table above provides the basis for extrapolating water use based on the number of residents.

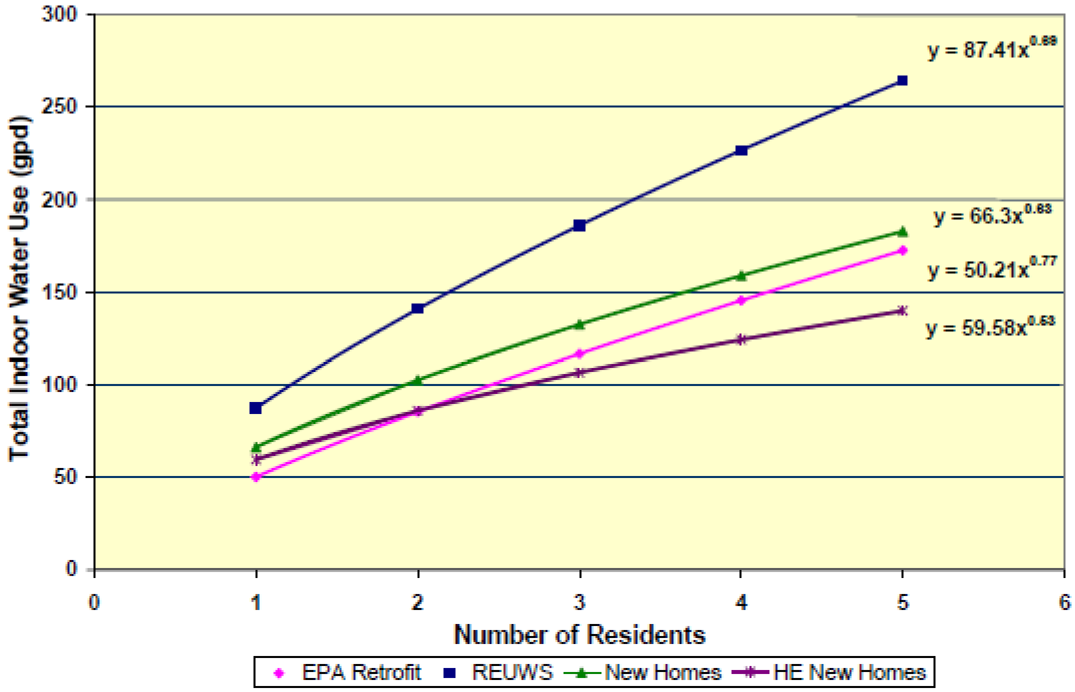

Figure 4-30: Comparison of indoor use versus residents

Fig. 3. Comparison of indoor use versus residents *(DeOreo, 2011)*

This calculation makes sense intuitively: while toilet use and basic hygiene such as handwashing and bathing are individual uses in a household, other water uses such as laundry and food preparation are usually communal.

ORGANIC LOADING

A conventional onsite sewage system is comprised of zones within zones of treatment processes. The main treatment zones can be classified as the anaerobic treatment zone which is the septic tank followed by the primarily aerobic treatment zone in the drainfield (Wilhelm, 1994).

The septic tank provides physical treatment by allowing sufficient retention time for larger particles to settle to the bottom of the tank (Wilhelm, 1994). Sanitary tees or baffles in the tank provide a quiescent surface where particles less dense than water such as fats, oils, and grease can rise to the surface and accumulate. Microorganisms within the tank create energy through fermentation and other anaerobic processes. Sludge and scum layers form that must periodically be pumped out of the tank and disposed at a wastewater treatment plant.

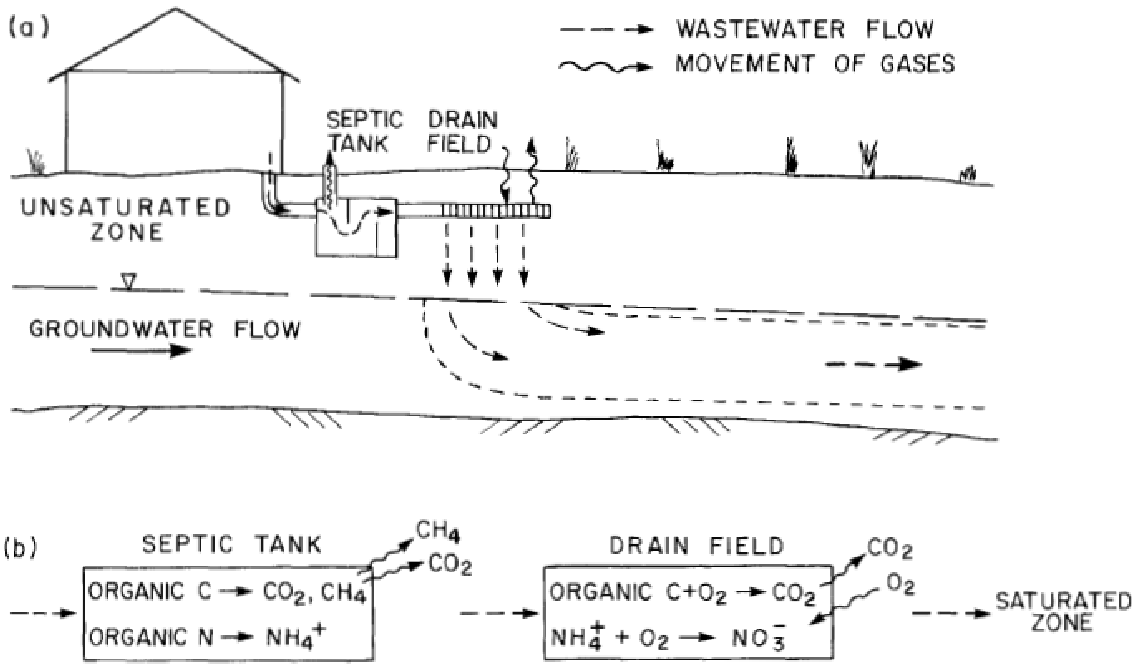

Fig. 1. (a) Schematic cross section of a conventional septic system, including septic tank, distribution pipe, and ground-water plume. (b) Sequence of simplified redox reactions in the two major zones of a conventional septic system: the septic tank and the drain field.

Fig. 4. Schematic cross section of a conventional septic system *(Wilhelm, 1994)*

In the drainfield a biomat forms at the bottom of the trench (Wilhelm, 1994). Introduction of the effluent through the biomat creates zones of microbial and chemical processes causing patterns for treatment of microbes and chemical compounds of oxygen, carbon, nitrogen, and sulfur, as well as pH and alkalinity within the trenches. Insoluble FeS compounds often form within the biomat, giving it the characteristically black appearance and limiting flow through the biomat. Eventually, the biomat can become the controlling factor for downward movement of water in the drainfield.

The formation and location of treatment zones within the drainfield varies based on site conditions and the characteristics of the septic tank effluent entering the drainfield (Wilhelm, 1994). Some drainfields provide more complete treatment than others.

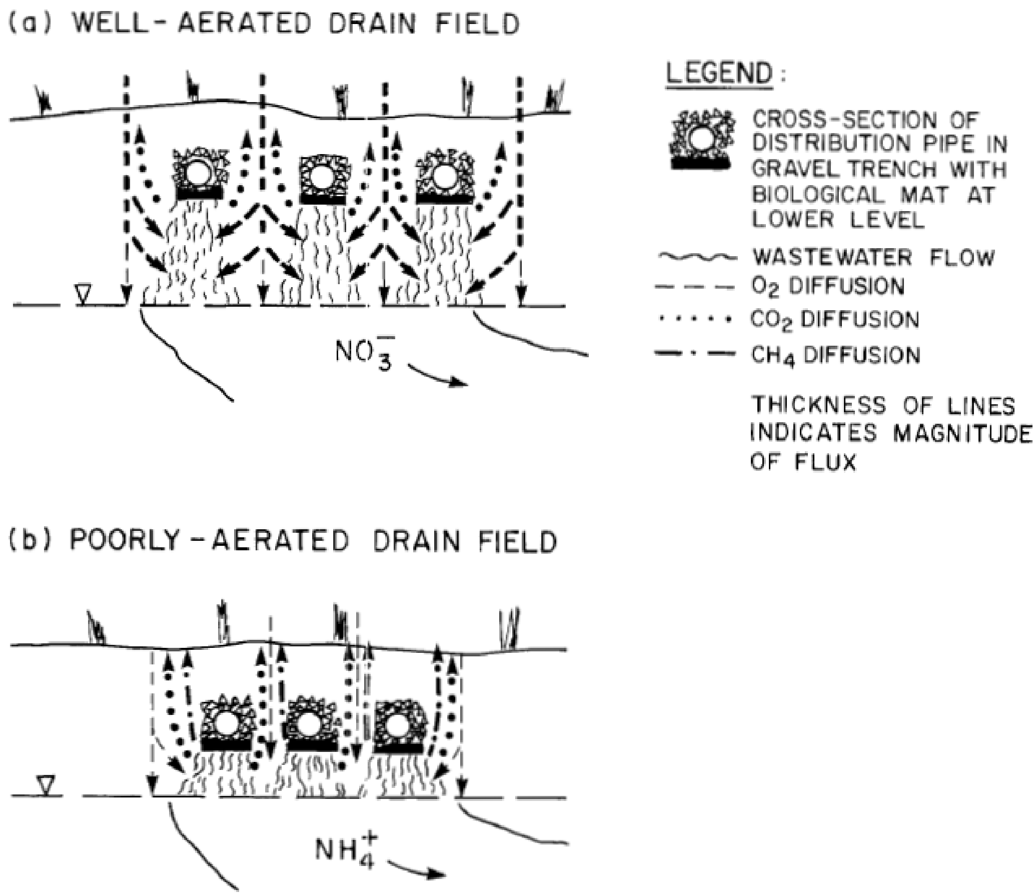

Fig. 2. Gas and water movement in the drain field of septic systems. (a) Well-aerated system, in which adequate O_2 enters the drain field and CO_2 and NO_3^- are produced. (b) Poorly aerated system, in which adequate O_2 does not enter drain field and CO_2 and CH_4 are produced.

Fig. 5. Gas and water movement in the drainfield *(Wilhelm, 1994)*

A LIFETIME OF WATER USE

To show the daily, annual, and cumulative amounts of water and BOD introduced into a drainfield, please visit [this spreadsheet (https://docs.google.com/spreadsheets/d/1b3MV5RHpofBwBHfLmv67YX06riodhROC8F9_SRdbvf8/edit?usp=sharing)](https://docs.google.com/spreadsheets/d/1b3MV5RHpofBwBHfLmv67YX06riodhROC8F9_SRdbvf8/edit?usp=sharing). This table shows water use based on the DeOreo study (DeOreo, 2011) and BOD accumulation based on Table 5.1 of the Virginia regulations (Virginia Department of Health, 2000). The amount of water added for additional family members is based on the "Percapita relationship" from DeOreo for pre 2001 homes.

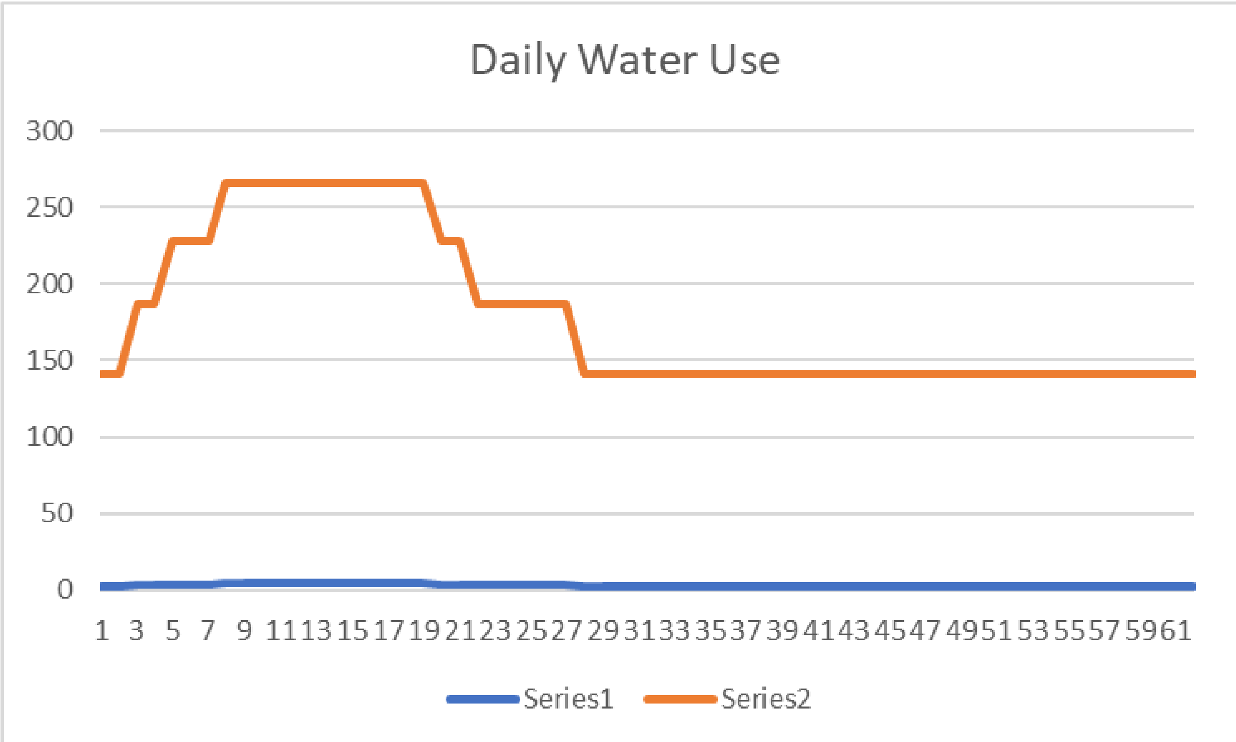

Fig. 6. Daily water use over the lifetime of a drainfield.

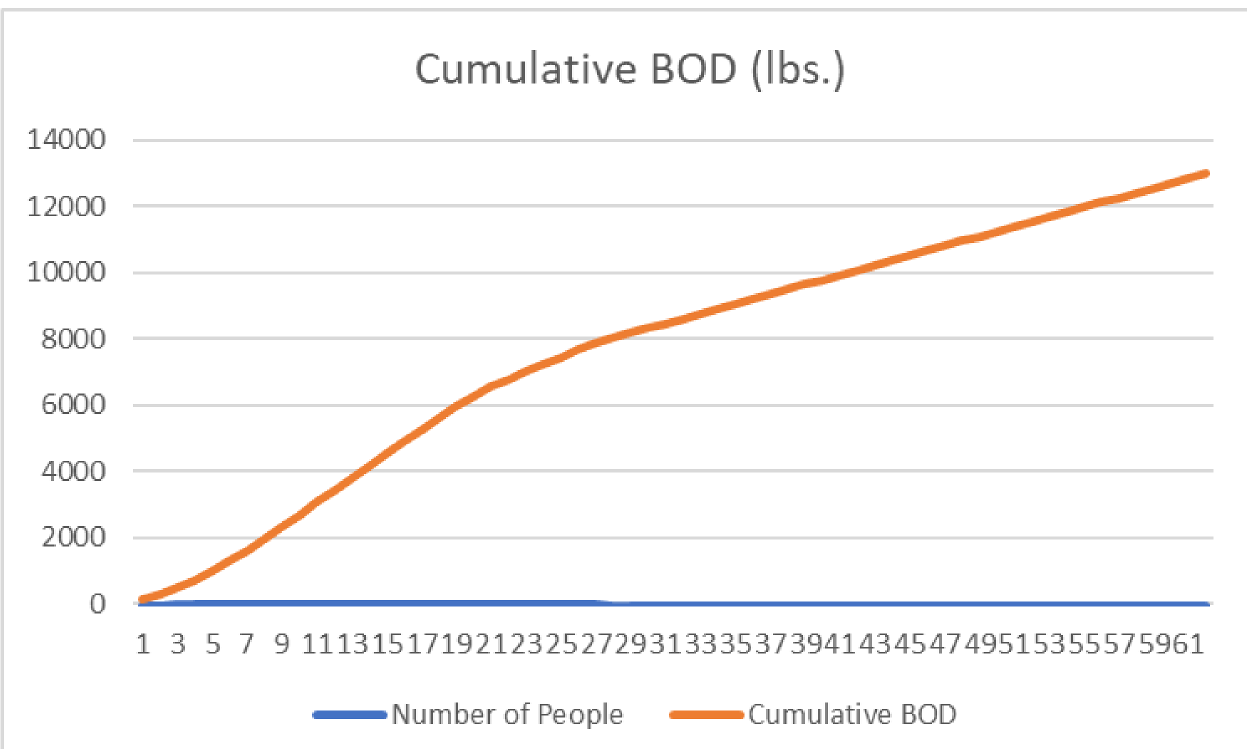

Fig. 7. Cumulative BOD over the lifetime of a drainfield.

The spreadsheet shows 62 years of water use. Anecdotally, conventional drainfields fail between 30 and 50 years of use, although I have seen drainfields fail for no specific reason as early as 20 years and just recently I worked on a repair of a drainfield that was installed in 1965, 56 years ago at the time of writing in 2021.

FAILURE OF THE DRAINFIELD

As the drainfield ages, several factors can converge to cause problems. If the drainfield is undersized for wastewater flow, water mounding can occur under the trenches, causing saturated conditions. A similar problem can occur if the drainfield did not have sufficient standoff to the seasonal or static water table in the first place. Excess flow due to leaky fixtures, water treatment backwash, sump pumps, condensate drains or other non-sewage flows can cause the same type of saturated conditions, as can infiltration of surface water into the septic tank can overload the drainfield as well.

Additionally, for drainfields with parallel flow splitting into the absorption trenches, degradation of the distribution box can cause uneven flow that causes a portion of the drainfield to be hydraulically overloaded.

Some drainfields may experience seasonal failures due to seasonally high water table and work fine in the summer months, but struggle throughout the cold season. Eventually the drainfield will cease to recover through the summer months and fail altogether, but it can take many years.

Excess organic loading can cause the drainfield to fail by increasing the formation of the biomat, especially when the biomat increases to the point of becoming a restriction to the downward movement of effluent.

Root infiltration of trenches is another problem that can cause failure in a conventional drainfield. Roots in the distribution box can block flow to some or all of the trenches, causing overloading of the trenches not blocked, and root infiltration of the gravel can cause the trench or trenches to fail.

In Virginia, there is no requirement to periodically inspect functioning conventional systems, so often the only time we see an older drainfield prior to failure is when a client requests a real estate inspection. Occasionally we can replace a component, seal a tank, or otherwise intervene to extend the life of a drainfield.

Occasionally, we have a request to expand an existing system. Often in our area these requests are for lake homes with limited lots that are used only seasonally, and the best option is to add pre-treatment to the system to allow a higher loading rate in the existing drainfield. Often the existing drainfield appears unused altogether. In fact, in one case, someone had trenched through the conveyance line when running electric to the boat dock so we believe the drainfield WAS entirely un-used.

CONCLUSION

So what does a lifetime of water use look like and how does it factor into today's more transient communities? Could we study the "remaining use" of a drainfield and how? And if we could find out that the "remaining use" is limited, could we take steps to increase it?

At this point, I have more questions than answers. My understanding and intuition is that rather than total water use, it's more a question of oxygen exchange in the soil, although excessive water use can exacerbate the problem. At this point I almost believe that I can tell when a drainfield has gone too far to save, but it's all intuitive, based on experience, and we rarely see drainfields that are in the middle of the change. We don't usually see them until it's gone too far.

When we do see drainfields in transition to failure is during a real estate evaluation. With both seller and buyer charging ahead with the sale, it's tough to get anyone to listen to any recommendations unless the drainfield is actively failing.

While we can cite many cases of a drainfield lasting the lifetime of a family, many homes change hands well before the lifetime of the family has run out these days. By uncovering the tank and distribution box and augering into an existing trench, we can get some reading on the status of the drainfield, even with experience, we can often only judge if the drainfield is failing or not. We may be able to identify components in need of repair or replacement, but we can't quantify the "remaining use" of the drainfield.

While pre-treatment systems are great, they are also expensive and we have millions of conventional systems currently operating in the United States. Much of the research on conventional systems was done pre-1980. What have we learned from treatment systems that would apply to conventional drainfields? What can we do with a conventional system that is making the transition to failure? We understand redoximorphic features in the soil much better now. Will our current identification of seasonal high water table improve the lifespan of conventional systems we design today? How much do the unsaturated flow conditions created by using a demand-dose or time-dosed pump system help?

What are your observations?

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