Assessing Homeowner Perspectives and Barriers to Maintenance of On-Lot Septic Systems in Rural Pennsylvania

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Abstract: A survey of septic system users was conducted to characterize current maintenance practices and factors hindering proper septic system maintenance across Pennsylvania. The survey was completed by 656 people, with 53 and 47 percent of the respondents located in rural and urban counties, respectively. Sixty-five percent of septic systems are over 20 years old, raising concerns around the potential environmental impacts from the aging infrastructure. Over 75 percent of the respondents pump their septic tanks at a one- to five-year interval, while only about 30 percent keep up with routine system inspections. Less than 30 percent of respondents indicated that their municipalities require proof of septic system maintenance or pumping. While some municipalities have enforced routine septic system maintenance, others have published non-specific and vague ordinances. These varying local approaches do not help resolve inconsistent maintenance practices nor facilitate early detection and management of septic system issues. While survey data indicated moderate to high levels of awareness regarding certain best practices, identified challenges include repairing and replacing old failing systems (43 percent) and the cost of routine system maintenance (33 percent). One hundred twenty-five private water sources were tested, and 53, 10, and 3 percent of the samples failed to meet federal drinking water safety standards for coliform bacteria, *E. coli*, and nitrate, respectively. Identified outreach and educational needs include improving understanding of the purpose and benefits of routine, comprehensive septic system maintenance and continued monitoring of source water quality.

Keywords: Septic systems, System maintenance, Private water systems, Water quality

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Executive Summary

In 2024 and 2025, we surveyed septic system users across Pennsylvania to characterize current septic system maintenance practices, existing needs and barriers to maintenance, and the potential links between septic system maintenance practices and water quality in private water sources. Respondents were recruited using a short recruitment survey in phase one, and interested septic-system owners and users completed the follow-up survey in phase two. The follow-up survey was completed by 656 people across Pennsylvania, with at least one participant in all counties except Cambria, Mifflin, and Philadelphia. Fifty-three percent and 47 percent of the respondents were in rural and urban counties, respectively. From this group, 145 respondents were selected for private water testing based on their self-reported septic system maintenance practices, and 125 submitted their water samples.

Key Findings

- **Septic systems across the state are aging**: Only 26 percent of septic systems are less than 20 years old. Thirty-eight percent are between 21 and 40 years old, while about 27 percent are more than 40 years old. The average lifespan of septic systems is estimated to be 15 to 40 years (US EPA, 2025). Depending on site-specific conditions and overall maintenance practices, aging septic systems are more likely to pose environmental and human health concerns (Connelly et al., 2023). Therefore, users should prioritize complete septic system maintenance (routine inspections and pumping) to ensure timely identification and resolution of system malfunctions or failures.
- **Septic maintenance practices are inconsistent**: The U.S. EPA recommends professional septic system inspections every three years and tank pumping every three to five years, or sooner if sludge levels exceed 30 percent of tank capacity. Only 32 percent of users reported following the recommended inspection intervals. A significant share of septic systems older than 20 years (60 percent) have never been inspected, and many homeowners are uncertain if a septic inspection has ever been done. About 75 percent report pumping their tanks at a one- to five-year interval, while some have never done any maintenance despite having old systems. From an analysis of publicly available information on septic maintenance from municipalities with ordinances in 9 counties, pumping and inspections were typically required every 3 to 5 years and 3 to 6 years, respectively. However, in many cases, municipalities published discretionary enforcement or ambiguous maintenance triggers, such as health and safety complaints or signs of system malfunction. Twenty-five percent of survey respondents indicated that their municipalities require proof of pumping, and 20 percent require proof of inspections. Inconsistent maintenance practices are not surprising, given the variation in local approaches.

- **Awareness gaps and challenges exist.** While many participants (81 percent) value the fact that they do not pay sewer bills, the obligation of system care and maintenance was a burden to some homeowners. Some of the challenges reported were repair and replacement in aging systems (43 percent) and costs for routine maintenance (33 percent). Although cost is a challenge for many, only 35 percent strongly agreed to a statement on budgeting for septic system expenditures. Furthermore, less than 1 percent of the respondents have used any of the septic financial support funding programs through the Pennsylvania Housing Finance Agency (PHFA). Although many users regularly pump their tanks, few conduct system inspections. There is a mistaken belief that septic tank pumping alone is sufficient maintenance or that inspections are only necessary when septic system issues arise.
- **Water contamination is measurable**. In the tested private water systems, contaminants linked to septic system sources, such as nitrate, coliform bacteria, and *E. coli*, were present in 69, 53, and 8 percent of tested samples, respectively. Notably, violations of health-based drinking water standards were noted in 3 percent (nitrate), 53 percent (coliform bacteria), and 8 percent (*E. coli*) of samples. Less than 15 percent of the samples also failed to meet health-based standards for arsenic, barium, and lead. Still, for lead and arsenic, 10 and 2 percent of samples, respectively, were above the 0.01 mg/L MCLs in drinking water. Some samples (less than 30 percent) failed to meet the aesthetic or sensory guidelines for substances that can negatively affect the taste, smell, or color of water, such as manganese, aluminum, pH, and total dissolved solids (TDS).
- **Water contamination, septic systems, and wells**. Based on comparisons of water quality across septic system maintenance categories and age, water samples from properties with only partial septic system maintenance on average exhibited total coliform concentrations approximately 30 percent higher than those from properties with complete maintenance. Similarly, samples from systems that are irregularly maintained showed nearly double the coliform levels. Water samples collected from properties with older, irregularly maintained septic systems exhibited elevated concentrations of total coliform and *E. coli*. Lower *E. coli* concentrations were observed in deeper wells (more than 300 feet) and drinking water sources with longer isolation distances from septic system components.

Policy Implications

Survey results point to inadequate septic system maintenance and monitoring practices, likely related to limited local oversight and community education. First, municipalities should consider the importance of maintenance inspections as a tool for early detection of existing septic system issues. This would be of benefit to septic system users, given that the majority of septic systems are aging, and the leading challenge for most is system repairs and replacements. Second, regulatory bodies should adopt uniform language for system care and maintenance recommendations and mandates that can provide clarity and consistency on system maintenance while recognizing that there may be slight variations based on local site characteristics. Third, septic system repair and maintenance costs are a challenge for many. Thus, it is important to increase awareness of existing financial support programs and create other avenues to support local communities. Fourth, source water characteristics varied across study participants, pointing towards the need for standardized statewide construction guidelines for private wells. It is simpler and potentially cost-effective when best practices are implemented during the initial well drilling and construction process. Finally, there is a need to expand homeowner education programs on septic systems and water quality.

General septic system maintenance recommendations include having professional system inspections every three years and septic tanks being pumped every three to five years or when an inspection indicates that the accumulated sludge in septic tanks exceeds 30 percent of their volume capacity. Based on the survey in this study, while many users (77 percent) report taking essential steps to pump their tanks every one to five years, only 32 percent keep up with system inspections. Some municipalities in Pennsylvania have mandated complete system maintenance (routine inspections and pumping), some only require routine pumping, while others have no guidelines. Given that most septic users are not keeping up with inspections, municipalities should consider the importance of encouraging maintenance inspections. Septic system inspections are a diagnostic procedure used to assess the structural integrity, hydraulic performance, and measurement of sludge and scum layer thickness to determine the need for pumping (i.e., if sludge is more than 30 percent of tank volume), and signs of system failure such as leaks, backups, standing water in the drainfield, etc. (US EPA, 2025). This would benefit septic system users, given that the majority of systems are old (more than 20 years old) and repair and replacement needs are a leading system challenge for residents (43 percent).

Regulatory bodies in the state could adopt uniform language for system care and maintenance recommendations and mandates that can provide clarity and consistency on system maintenance. For example, Pennsylvania's Standard for On Lot Sewage Facilities does not specify system inspection or pumping frequencies. PA DEP recommends that septic systems be pumped out at least every three to five years but does not offer guidance on inspections. Such variability in recommendations can be a significant source of confusion for users, regardless of whether they are in a region with mandated system care practices. Furthermore, because PA DEP registers septage haulers in the state and also trains SEOs, a public-facing list of registered service providers at the state or regional scale could also be of benefit.

In addition to state regulations, there are also variations and sometimes vagueness, in municipal ordinances. Therefore, we suggest that there is a need to provide clearer and standardized guidelines across jurisdictions and targeted education on routine comprehensive septic system maintenance and why it matters. To support maintenance needs, government entities should also provide residents with lists of qualified service providers. After reviewing municipalities in several selected counties, this study found that many recommend or require tanks to be pumped every three to five years, with flexible enforcement in some cases, or the discretion of the SEO. While some require inspections every three to six years, the majority offer vague guidance such as inspections may be done "*at any reasonable time*", "*as needed*", "*when there is a complaint*", or if "*the system is malfunctioning*". Some municipalities do not offer any descriptions on what their septic system inspections entail, while others only conduct surface and visual checks of components. System inspections for some municipalities are more detailed and constitute checking for structural integrity of septic components and leaks, effluent and water sample collection, tracer studies to assess flow, and other important details. Almost 70 percent of respondents indicated that knowing when to inspect and pump these systems and finding a service provider (38 percent) were the top factors they consider when thinking about maintenance. Some municipalities provide a list of service providers to support maintenance needs, while others do not.

Our results also underscore the need for policy interventions and user education on financial support programs, such as loan and grant programs available through the Pennsylvania Housing Finance Agency, US Department of Agriculture (USDA) Rural Development, and the Pennsylvania Department of Community and Economic Development. The cost of repairs and routine maintenance was cited as a challenge by many respondents. However, many users do not include septic system care and maintenance in household financial planning, and only 1 percent were aware of existing state financial support programs. The potential for regional management of on-lot septic system maintenance and repair was assessed by Noss and Billa, (1988). They found that such arrangements would not only ensure timely maintenance and rehabilitation of failing systems but would also lower individual user costs (Noss and Billa, 1988). There is still a need to explore whether users at a regional scale would embrace some of these services, and whether it would result in improved system maintenance practices and reduced environmental impacts.

In addition to financial considerations for septic systems, other identified educational needs from this study include how septic systems are designed and how they treat wastewater, the maintenance of septic systems, proper landscaping around septic systems, and the impact of septic systems on water resources. Some of these topics were covered in the 2024 and 2025 Penn State Extension septic system webinar series (Appendix 9).

There is a need for statewide construction standards for private wells in Pennsylvania to provide clarity for both homeowners and drillers. Sanitary well construction features such as casing to the bedrock, grout seals, above-ground well casing, sanitary well cap, and well-head protection areas have been documented in previous monitoring to be associated with water quality benefits (Swistock et al., 2009). Participants in the study had drilled wells, while one had a pounded well. Reported depths ranged from 40 to 750 feet. Isolation distances from septic system components were estimated to be from 20 to 2000 feet. Water tests showed that average concentrations for nitrates were typically below the safety standard of 10 mg/L for all groups, but higher levels were observed at the shortest isolation distances (20 to 100 feet). Depending on the underlying geology, soil properties, density of septic systems in a region, and private water system construction features, larger setback distances may be needed to protect drinking water sources (Blaschke et al., 2016). While a majority of the respondents had at least two sanitary well construction features (above-ground casing and a sanitary well cap), only two indicated they had wells that were grouted to the bedrock. While some of these safety features, such as a sanitary well cap, could be easily installed by a well owner, isolation distances are costly to change. It is estimated that 20,000 new wells are drilled in Pennsylvania each year (Penn State Extension, 2022). Establishing uniform statewide standards would align Pennsylvania with management practices adopted by other states and provide clear requirements for new well constructions.

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Introduction

Approximately 25 percent of homes in the rural and suburban areas of Pennsylvania rely on on-lot septic systems to treat and dispose of domestic wastewater (Day et al., 2008). When those same homes are located outside centralized water supply service areas, residents tend to also use private water sources such as wells, springs, or cisterns for domestic drinking water supply. About 3.5 million residents in Pennsylvania rely on private water systems for their domestic water supply (Maupin et al., 2014). When these private water system users in Pennsylvania were surveyed, Swistock et al. (2009) found that almost 90 percent had some type of on-lot septic system.

On-lot septic systems can be primarily categorized as conventional or alternative systems. Conventional septic systems consist of three main components: (i) a two-compartment septic tank, (ii) a distribution box and pipes, and (iii) a soil treatment area, also commonly known as the absorption area, drainfield, or leachfield. The septic tank is an underground and watertight tank that acts as a settling chamber for solids and allows for anaerobic digestion of complex organic matter in wastewater and retained solids. Partially treated wastewater from the septic tank, herein referred to as "septic effluent," is dispersed to soil absorption areas (e.g., sand mound, inground trench, or bed) by a series of perforated distribution pipes. The soil treatment area absorbs discharged effluent and further removes contaminants via physical, chemical, and biological processes in the subsurface as effluent percolates to recharge underlying groundwater supplies (US EPA, 2002). Alternative septic systems employ the same fundamental treatment processes and components as conventional systems. However, they are typically used in environmentally sensitive areas where conventional systems cannot be reliably used to treat wastewater due to site-specific limitations such as a high-water table, unsuitable soil properties, small lot sizes, or the presence of sensitive surface water sources nearby. Alternative systems can include add-on treatment units to a conventional septic tank, aerobic treatment units, and engineered porous media biofilters (e.g., peat moss, coco husk, etc.), with the goal of improving the quality of effluent discharged to soil treatment areas or producing effluent of high enough quality for beneficial reuse such as landscape irrigation (Rudman et al., 2023; Siegrist et al., 2000).

Apart from conventional and alternative septic systems that treat and dispose of domestic wastewater, some landowners may have holding tanks and cesspools that offer no treatment of wastewater. Holding tanks are used as temporary wastewater storage on a property before pumping to an approved facility for treatment and disposal. In Pennsylvania, holding tanks are permitted as a short-term measure during construction or repairs of failed on-lot septic systems (PA DEP, 2016). While not permitted in new installations, some landowners may have outdated sewage disposal systems that offer no wastewater treatment, known as cesspools. Traditionally, cesspools were constructed as underground systems with perforated bottoms or walls to allow wastewater to discharge into the environment. Currently, cesspools in

Pennsylvania may be used as a wastewater disposal system with sufficient pre-treatment of wastewater in a septic tank and may be subject to mandatory inspections and pumping guidelines depending on the municipality.

Septic effluent can contain pathogens (e.g., bacteria, viruses, and protozoa); nutrients (i.e., nitrogen (N) and phosphorus (P)); heavy metals; and organic contaminants of emerging concern such as pharmaceuticals and personal care products (PPCPs), hormones, and per- and polyfluoroalkyl substances (PFAS). Some of these contaminants can negatively impact human health and result in undesirable ecosystem changes if effluent reaches receiving groundwater and surface water sources. Due to incomplete treatment in septic tanks and drainfields, as well as leaks from old or poorly maintained septic systems, these contaminants have been detected in adjacent groundwater and surface water sources (Digaletos et al., 2023; Kibuye et al., 2019; Lusk et al., 2017; Murphy et al., 2020; Richards et al., 2016; Schaider et al., 2016a). Pathogens can result in human health concerns, creating household or communal concerns such as waterborne illnesses if drinking water sources are affected (Borchardt et al., 2011; Murphy et al., 2016). Additionally, nitrates above safe drinking water limits (10 mg/L) can be fatal to children by limiting oxygen transfer in the body, and heavy metals, such as arsenic, barium, and lead, pose additional risks, including carcinogenic effects (US EPA, 2024). Although more research is still ongoing on different classes of emerging contaminants, some PFAS compounds are currently subjected to drinking water regulations due to their associated negative human health impacts, such as cancer, immune suppression, and developmental issues (US EPA, 2024). Beyond the direct human health implications through drinking water contamination, septic systems are non-point pollution sources for nitrogen, phosphorus, and other contaminants to downstream surface water sources. For example, it is estimated that in Maryland alone, septic systems can contribute up to 3.6 million pounds of nitrogen to the Chesapeake Bay (Harrison et al., 2012). Excessive nutrient pollution degrades surface water quality, resulting in harmful algal blooms that are detrimental to water sources used for recreation and drinking water production (Moore et al., 2003; Rakhimbekova et al., 2021).

Because of the potential for raw (untreated) wastewater and partially treated wastewater to leach into adjacent ground and surface water sources, the design and installation of on-lot septic systems follow specific regional guidelines. The Pennsylvania Sewage Facilities Act (Act 537) outlines provisions for all municipalities to develop a sewage facilities plan and, through their trained Sewage Enforcement Officer (SEO), to manage the permitting and installation for the construction of individual and communal septic systems (PA DEP, 1966). The Pennsylvania code for on-lot septic systems (PA DEP, 2025) requires that private water supply sources have isolation or setback distances of at least 50 and 100 feet from septic tanks and drainfields, respectively. In contrast, surface water sources should have a minimum of 25 feet of isolation from septic tanks and 50 feet from drainfields. Additionally, current regulations require a minimum of 4 feet of vertical setback distance of suitable, unsaturated soil between the bottom of the drainfield and any limiting zone of impervious bedrock or seasonal high-water table. Both vertical and horizontal setback distances allow for soil to act as a natural filter for contaminants in wastewater before effluent can reach groundwater and surface water sources. However, depending on the underlying geology, soil properties, density of septic systems in a region, and private water system construction features, larger setback distances may be needed to protect drinking water sources (Blaschke et al., 2016).

In addition to design and installation, regular maintenance and monitoring can be key factors that influence the performance of septic systems and the associated impacts on surrounding water resources (Withers et al., 2012). As septic systems are used, solids accumulated in the tanks form a layer of sludge at the bottom and scum at the top. This separation leaves a zone of clear wastewater in the middle that is eventually dispersed in the drainfields for further treatment. The amount of sludge accumulated in the septic tanks increases over time and can be higher if the household size increases (Mancl, 1984). As sludge continues to build up in the tanks, the minimum clearance required to allow for effective separation of solids and scum decreases; hence, solids and scum do not have sufficient space to separate as designed. Inadequate separation results in solids passing through the tank and being dispersed into the drainfields. The septic system drainfield should only receive effluent, as solids and scum can clog the soil pores, reduce effluent treatment efficiency, and even result in system failure (Cotteral et al., 1969). Therefore, routine septic system maintenance practices include inspections to check the level of sludge and scum in the septic tanks, pumping of accumulated sludge, checking for signs of leakage, and overall performance of system components (US EPA, 2025). The US EPA recommends that septic systems be professionally inspected every three years and that septic tanks be pumped every three to five years or when an inspection indicates that the accumulated sludge in septic tanks exceeds 30 percent of their volume capacity. These guidelines have been adopted by state regulatory bodies such as the Pennsylvania Department of Environmental Protection (PA DEP) but are not enforced at the state or federal level. Unlike public sewer systems that are monitored and maintained by local municipalities, sanitation districts, or utilities, on-lot septic systems are typically maintained by individual homeowners after they are installed. While some municipalities in Pennsylvania have Sewage Management Programs (SMPs) that require homeowners to show proof of periodic on-site inspections and septic tank pumping, others do not. Therefore, in many parts of the state, septic system owners or users are voluntarily responsible for all maintenance, inspections, and monitoring needs.

The lack of policies and effective oversight on septic system maintenance, monitoring, and inspections can result in undocumented septic system failures and chronic pollution discharges to water resources (Withers et al., 2014). Septic system users/owners may choose not to follow recommended maintenance schedules unless there are obvious signs of septic failure, such as ponding of septic effluent in the yard, backflow of sewage into the home, sewer odors, etc. Unlike municipal water supplies, private water system owners and users are solely responsible for their own water supply testing, treatment, and maintenance to ensure drinking water safety. Because estimates are that most private water system users/owners (74 percent) do not frequently test their drinking water sources (Swistock et al., 2009), chronic septic system failures that are not noticeable can contaminate drinking water sources.

Environmental issues from poorly maintained or malfunctioning septic systems negatively impact individual homes and their communities at large (Mohamed, 2009). However, there is limited research on user practices and barriers towards effectively operating and maintaining septic systems. Some studies have identified gaps in user knowledge regarding septic system function and maintenance requirements as a major driver for the lack of proper system care (Devitt et al., 2016; Schwartz et al., 1998). A study in Wake County, North Carolina, found that poor understanding of the links between septic maintenance and risks of private well water contamination was a primary factor hindering septic maintenance (Fizer et al., 2018). To design effective risk intervention and septic system management education programs in Pennsylvania, there is a need to characterize homeowner practices, perspectives, needs, and factors influencing decision-making regarding septic system maintenance.

Goals and Objectives

This study surveyed septic system users in Pennsylvania in 2024 and 2025 to:

- Assess whether residents follow current septic system maintenance guidelines.
- Characterize barriers and needs for proper septic system maintenance.
- Evaluate the occurrence of septic system-related water contaminants in private water sources and how they relate to reported septic system maintenance practices.

Methods

Septic System Survey

This project was approved by the Penn State University Institutional Review Board (IRB) as an 'exempt' research study. Participant recruitment was conducted in phase one using a short survey (Appendix 1) that was used to gauge interest and assess if respondents met eligibility criteria, including residence within the Commonwealth of Pennsylvania and the presence of a septic system and private water source. The participant recruitment survey was distributed across the Commonwealth through print and online newspaper publications; statewide exhibits such as Keystone Farm Show and Penn State's Ag Progress Days; County Extension offices; printed distribution at in-person Extension events and workshops; postings on Penn State Extension and County Conservation Districts' social media platforms; email blasts on Penn State Extension newsletter subscription lists; and Extension volunteer groups including Master Well

Owner Network (MWON), Master Watershed Stewards (MWS), and Pennsylvania Forest Stewards (PAFS).

In the second phase, eligible participants who expressed interest in completing a follow-up survey were provided with the survey's Qualtrics link, a QR code, or a mailed printed paper survey, depending on their preferences documented during the recruitment phase. The follow-up survey (Appendix 2) was a 34-item questionnaire divided into four sections: (i) household characteristics that included questions on household size and location in the state; (ii) septic system characteristics that evaluated respondent knowledge about the features of their domestic wastewater systems; (iii) management where the focus was on current maintenance practices and issues users faced; and (iv) drinking water that focused on their household water supply characteristics and maintenance. Socio-demographic questions were not included to keep the survey completion time within approximately 30 minutes.

Selecting Respondents for Water Testing

Eighty-three percent of the participants (*n*=493) were interested in private water supply testing through this study. While giving priority to residents in rural counties, all interested participants were classified into four main groups describing their septic system maintenance practices, including: (i) complete, (ii) partial, (iii) irregular, and (iv) poor. Complete maintenance corresponded with systems routinely inspected and pumped within the recommended frequencies of between 1 and 5 years. On the other hand, partial maintenance consists of systems that are either inspected or pumped routinely, but not both. These include systems that are pumped between 1 and 5 years without inspection, inspected at intervals greater than 5 years, or systems that are inspected routinely but are not pumped at recommended frequencies. "Irregular maintenance" refers to systems inspected and pumped outside the recommended schedules or cases where respondents only conducted one type of maintenance with poor records. Finally, poor maintenance schedules include systems that are not maintained or have unknown maintenance schedules; this can include those that have never been inspected or pumped or those that have unidentified maintenance schedules. From these four groups, and among those who indicated interest in free water testing, a total of 145 respondents were selected to receive free water-testing kits. Of those who had their water tested, 85 percent were in rural counties, while 15 percent were in urban counties.

Water Sample Collection and Analysis

Respondents selected for free water testing were divided into groups of 10 to 20 people. Each group was sent a sample collection kit between March and September of 2025 as well as an electronic or phone notification of kit shipment. The kits included sample collection containers, handling instructions (Appendix 3), a pre-paid overnight return shipping label, Ziplock bags for ice, and a sample submission form that collected supplementary data on source water characteristics, including construction features, well depth, and any household water treatment devices (Appendix 4). To support timely completion, participants also received periodic reminders during a collection window of two weeks from the date of kit delivery. To assess the potential influence of septic systems on source water quality, participants were instructed to collect their raw (untreated) source water samples from an outside spigot or from another location that best represented the source water quality prior to any in-home water treatment systems.

All samples were tested for general water quality indicators such as pH and total dissolved solids (TDS); bacteria, including total coliform and *E. coli*; trace elements, including arsenic (As), aluminum (Al), barium (Ba), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), manganese (Mn), nickel (Ni), and phosphorous (P); and dissolved salts such as nitrate (NO_3-N), chloride (Cl), and sulfate (SO_4). These contaminants or substances were selected because they have been detected in septic effluent (Lusk et al., 2017; Richards et al., 2016) and are contaminants that have US EPA health-based primary or aesthetic-based secondary drinking water standards. Health-based primary standards provide maximum contaminant levels (MCLs) in drinking water for substances that can negatively affect human health. Public water systems are legally obligated to ensure that these substances are at levels below the MCLs in water distributed to customers. In contrast, aesthetic-based secondary standards have MCLs that are not legally binding but are used as guidelines that address contaminants that can negatively affect the aesthetic or sensory properties of water, such as taste, odor, color, and appearance. Table 1 below summarizes the tested analytes, their corresponding primary or secondary MCLs in drinking water, and their negative health or sensory impacts to drinking water when present above the US EPA MCLs. Although private water sources are not regulated and are not required to meet the MCLs, users are encouraged to ensure their drinking water sources meet these minimum safety recommendations.

All testing was conducted through the Agricultural Analytical Services Laboratory (AASL) at Penn State University. The AASL is certified by the PA DEP for potable water analysis. All testing and sample preservation were in accordance with current standard methods. Bacteria and dissolved salts (NO_3-N, SO_4, Cl) were processed and analyzed following Standard Method (SM) 9223-B and SM 4110 B, respectively (APHA et al., 2017), while trace elements followed US EPA Methods 200.5 (USEPA, 2002) and 200.7 (USEPA, 1994). TDS was estimated by multiplying electrical conductivity measurements (mS/m) by a proportionality constant of 0.64 (Walton, 1989). The limits of quantification (LOQ), which are the lowest levels of a chemical that the laboratory can accurately measure and report, are shown in Appendix 5.

A total of 125 study participants submitted their samples and received a water quality report within two weeks. Reports also compared their test results with current drinking water standards and flagged analytes that failed to meet health-based and aesthetic guidelines for contaminants that can affect the taste, smell, and color of water.

Additionally, contact information for the local Extension Educators was included to help with test result interpretation and identifying actions users can take to solve existing water quality issues.

Survey and Water Quality Data Processing

To maintain the confidentiality of study participants, all personal identifying information from survey responses and water test reports was eliminated during data analysis, and aggregate descriptive statistics were used to summarize and explore survey and water quality data. Frequencies and percentages were used for categorical variables such as septic system types, maintenance practices, costs, and contaminant detections. Since participants only responded to questions applicable to their systems, not all survey sections and questions were fully answered by all participants. Therefore, some analyses were conducted with smaller sample sizes (*n*). Similarly, some questions presented multiple answer selections, and respondents may have selected more than one response. Percentages presented herein were calculated using the corresponding *n* for each question. Survey responses on location and triggers for septic maintenance (i.e., pumping and inspection) were analyzed to identify potential municipal mandates. This information is self-reported and reflects respondents' understanding of local septic ordinances. For water quality data, concentrations below the limits of quantification (LOQ) were reported as 'not detected' and were excluded from all statistical analyses.

Table 1: List of Tested Contaminants That Have U.S. EPA Primary and Secondary Maximum Contaminant Levels (MCLs)

Analyte Category	Analyte	Maximum Contaminant Levels (MCLs)	Potential human health effects[1] and aesthetic impacts on water quality[2]
Contaminants With Primary (Health-Based) Drinking Water Standards	Total coliform	Zero	Not a health threat in itself; it is used to indicate whether other potentially harmful bacteria may be present
	Escherichia coli (*E. coli*)	Zero	A type of coliform bacteria that only occurs in animal or human waste. Some strains can cause gastrointestinal illness
	Arsenic	0.01 mg/L	Skin damage or problems with the circulatory system and a higher risk of getting cancer
	Barium	2 mg/L	Increase in blood pressure
	Cadmium	0.05 mg/L	Kidney damage
	Chromium	0.1 mg/L	Allergic dermatitis
	Copper	1.3 mg/L Action Level	Gastrointestinal distress and liver or kidney damage
	Lead	0.010 mg/L Acton Level	Delays in physical or mental development; children could show slight deficits in attention span and learning abilities. Kidney problems; high blood pressure in adults
	Nitrate	10 mg/L	Serious illness or death in infants. Symptoms include shortness of breath and blue-baby syndrome
Analytes With Secondary (Aesthetic) Drinking Water Standards	Aluminum	0.05-0.2 mg/L	Colored water
	Chloride	250 mg/L	Salty taste
	Copper	1 mg/L	Metallic taste; blue-green staining
	Manganese	0.05 mg/L	Black to brown color; black staining; bitter metallic taste
	pH	6.5-8.5	Low pH: bitter metallic taste; corrosion high pH: slippery feel; soda taste; deposits
	Sulfate	250 mg/L	Salty taste
	Total dissolved solids (TDS)	500 mg/L	Hardness; deposits; colored water; staining; salty taste

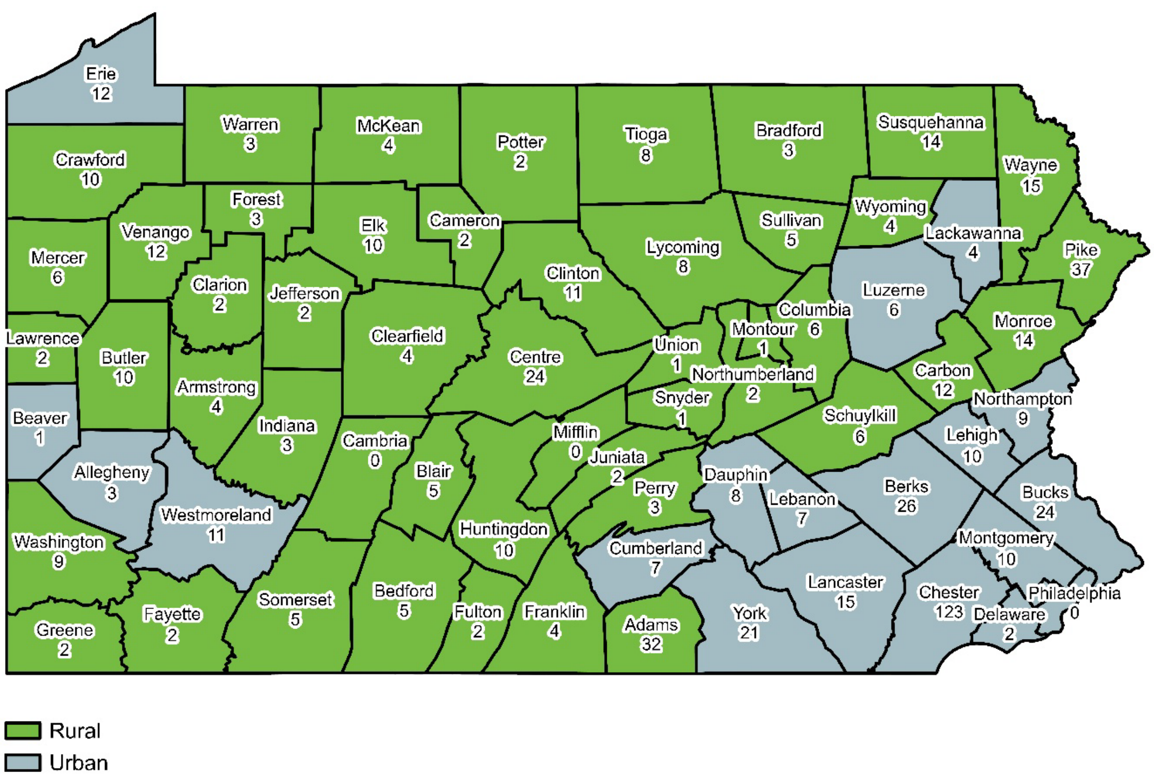
1) https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations; 2) https://www.epa.gov/sdwa/secondary-drinking-water-standards-guidance-nuisance-chemicals.

Results and Discussion

A statewide survey was conducted in 2024 and 2025 to assess how Pennsylvania residents maintain septic systems and if there are challenges or barriers to routine maintenance. Survey instruments were administered online through Qualtrics and through mailed paper versions, depending on respondents' preferences. Respondents selected to participate in the study by completing a recruitment survey where they indicated their follow-up survey completion method of choice and contact information. Both the recruitment survey and the follow-up survey were distributed on a rolling basis. Participants were allowed to choose which questions to answer, and as a result, some survey questions were skipped. Total sample sizes (*n*) reported here represent the total number of respondents for the corresponding question.

The follow-up survey was completed by 656 respondents across Pennsylvania, and 98 percent live in residences dependent on septic systems. A majority (53 percent) of the respondents were located in rural counties, while 47 percent were in urban counties. The total number of respondents for each county is shown in Figure 1 below. Ninety percent of the septic systems were used in primary residences, while 7 percent were installed in vacation or seasonal homes and cabins.

Figure 1: Distribution of Statewide Survey Respondents (*n*=631)



Septic System Characteristics

The first question on the survey evaluated participants' knowledge about household wastewater management systems. Notably, only one respondent indicated not knowing whether their household was connected to the public sewer system or served by an on-lot septic system. Those with septic systems (*n*=641) were asked the type of system they have, and most were knowledgeable about the type of septic system installed on their property, with only 4 percent of participants indicating that they were unsure of their system type (*n*=626). This suggests a relatively high level of awareness regarding their household wastewater infrastructure.

Most respondents (*n*=626) indicated that they had conventional septic systems, while only 3 percent had alternative systems. Alternative systems reported in the study included advanced treatment units such as aerobic treatment units, media filters such as coco or peat filters, and recirculating sand filters. Less than 1 percent of the respondents had both conventional and alternative systems in place. About 4 percent of the respondents relied on holding tanks, and 2 percent indicated that they had both a holding tank and a conventional septic system in place. In Pennsylvania, holding tanks are permitted as short-term waste management to temporarily store wastewater before pumping it to an approved treatment and disposal facility. It is unclear if those who had holding tanks and those who reported both holding tanks and conventional systems were relying on holding tanks due to an ongoing major repair or not. No respondent indicated having a holding tank and an alternative system on the property. Although cesspools are outdated wastewater disposal systems, they were used by about 2 percent of respondents. About 1 percent of the respondents had a conventional septic system and a cesspool. This shows that some existing cesspools may still be used as disposal systems.

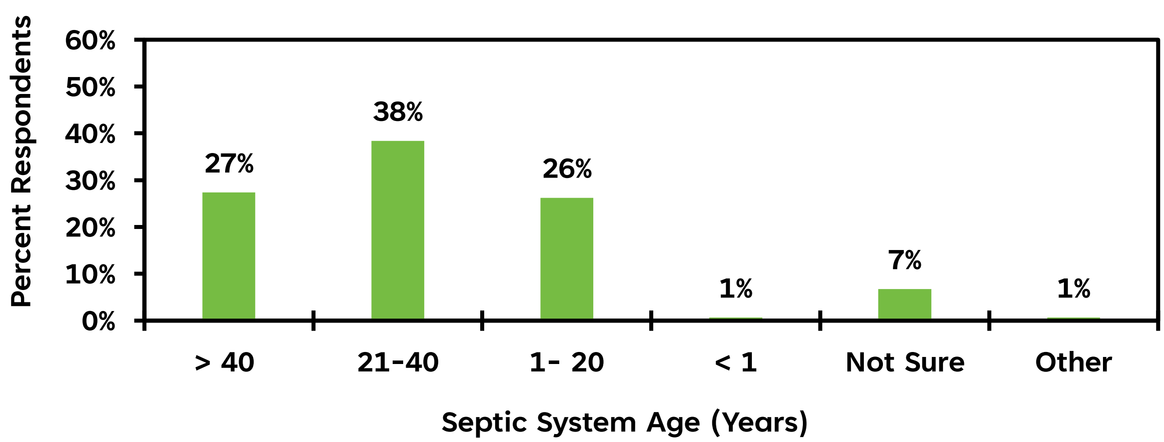
According to the responses gathered on septic system age, a majority of the participants had estimates on when their septic systems were installed (Figure 2). Only 7 percent indicated they were unaware of when their septic systems were installed. Most septic systems were between 21 to 40 years of age (38 percent) (Figure 2). One percent of the respondents selected “other” because septic systems had recent major repairs and upgrades, as well as those that were very old (i.e., one system installed in 1890, and a drainfield that was 70 years old). As expected, an analysis of septic system age based on type showed that most alternative septic systems tended to be newer (installed in the last 20 years). When looking at only conventional septic systems, a similar age distribution was observed, likely due to their long-term use in onsite wastewater treatment. About 28 percent of conventional systems (*n*=527) are over 40 years old, 40 percent are between 21 and 40 years old, and 27 percent were classified as less than 20 years old.

The US EPA reported that the average lifespan of septic systems is 15 to 40 years, but they can last longer with consistent maintenance (US EPA, 2025). When quantifying the risk that septic systems present to human health and ecological health in Athens-

Clarke County in Georgia, Capps et al. (2020) observed that roughly 70 percent of the studied septic systems in the region exhibited age-related risk as they were 25 years or older. They attributed this to the fact that older septic systems are more likely to need repairs and exhibit signs of hydraulic failure, such as wastewater backing up into the home and effluent ponds on the ground surface (Connelly et al., 2023). Consequently, aging septic systems have been repeatedly linked to contamination of surrounding water resources, likely due to outdated design or existing damage resulting in unnoticeable leaks as well as noticeable signs of hydraulic failure (Withers et al., 2014, 2012). Since at least 65 percent of septic systems (Figure 2) in this study are at or near their serviceable life according to the US EPA (15 to 40 years), users should prioritize routine maintenance and monitoring to assess the need for timely repairs.

Cesspools were reported to be over 40 years old or of unknown age, emphasizing their outdated status in on-lot wastewater treatment infrastructure. Like conventional septic systems, holding tanks were also widely distributed across the three age categories, suggesting that they continue to be installed. However, it is unclear if the holding tanks remain in active use since they are only permitted as short-term alternatives during septic system repairs or in new constructions before a permanent wastewater treatment system is installed (PA DEP, 2016).

Figure 2: Reported Septic System Age (*n*=625)

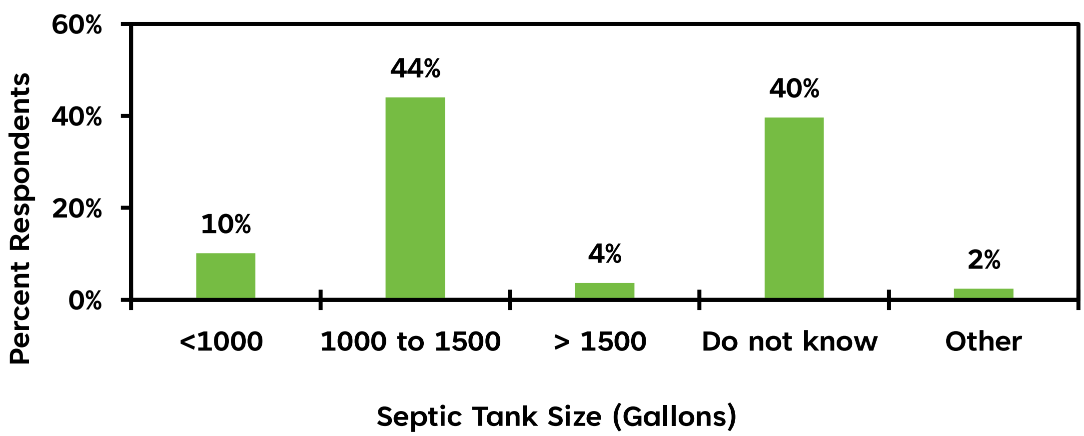


Septic tank sizes can be used for evaluating whether on-lot systems are appropriately scaled to household occupancy and usage demands. Septic systems in Pennsylvania are sized based on the original number of bedrooms of the home as an indicator of household size and volume of wastewater generated (PA DEP, 2025). While most of the participants were aware of their septic tank sizes, 40 percent did not know the size of their tanks (Figure 3). The minimum septic tank size permitted in Pennsylvania is 900 gallons for a one- to three-bedroom home, and the tank sizes increase as the number of bedrooms increases (PA DEP, 2025). The most common septic tank size reported in this survey (44 percent) was between 1000 to 1500 gallons (Figure

3). Two percent of the respondents who selected “Other” had a tank capacity that was greater than 1500 gallons because their system included two or three septic tanks of different sizes installed in a series. Pennsylvania code requires that septic tank installations consist of two-compartment tanks or multiple tanks in series (PA DEP, 2025), as they provide better treatment because of the additional settling of solids before effluent is distributed to the absorption areas.

Knowledge of septic tank size can be used to adjust pumping needs, such as increasing pumping frequency when water use in the home increases (e.g., when more people are living in the house). Because septic tanks are designed based on the original household size (PA DEP, 2025), increased occupancy in a home would overload the system with more wastewater flow to the septic tank beyond the design capacity. Increased wastewater flow would equally result in increased sludge accumulation in the tanks, creating a need for more frequent maintenance, such as pumping (Mancl, 1984). If maintenance schedules are not adjusted, there is a likelihood of reduced performance due to poor separation of solids in the tanks, in addition to potential impact on absorption areas (Cotteral et al., 1969). Overloaded septic systems were found to cause up to fifteen percent of the major system failures in Australia (Gunady et al., 2015). Therefore, limited awareness of septic system capacity among 40 percent of homeowners in this study highlights knowledge gaps that may contribute to improper maintenance practices, increased risk of system failure, and broader human and environmental health consequences.

Figure 3: Reported Septic System Tank Size (*n*=620)

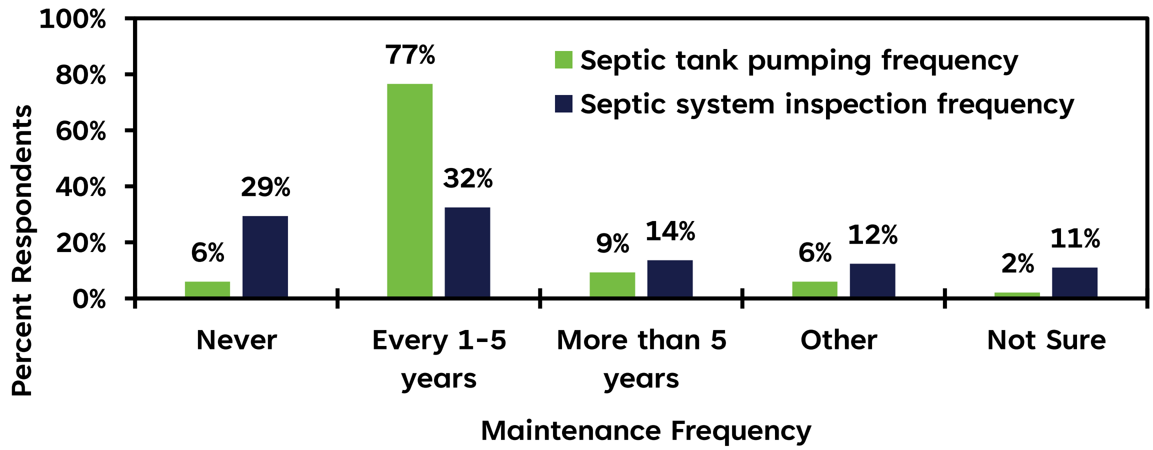


Septic System Maintenance

General septic system maintenance recommendations include having professional system inspections every three years and septic tanks being pumped every three to five years or when an inspection indicates that the accumulated sludge in septic tanks exceeds 30 percent of their volume capacity. Septic system inspections are a diagnostic procedure used to assess the structural integrity, hydraulic performance, and measurement of sludge and scum layer thickness to determine the need for pumping (i.e., if sludge is more than 30 percent of tank volume), and signs of system failure such as leaks, backups, standing water in the drainfield, etc. (US EPA, 2025). Septic tank pumping entails the removal of the accumulated sludge and scum from the tank by a PA DEP-registered septage hauler. The haulers transport the pumped materials to a wastewater treatment facility for further treatment and disposal.

As shown in Figure 4, only 32 percent of the respondents keep up with routine (every 1-5 years) septic system inspections. In contrast, 77 percent of the respondents pump their septic tanks every one to five years, and only 6 percent reported that they have never pumped. Six percent of the respondents who selected “other” for pumping indicated that they pumped annually, or on an exact schedule (e.g., every 3 years based on municipal ordinance, during a recent property transfer, once or twice over a 20 to 40 year period, and other circumstances such as new constructions or those that received recommendations not to pump following septic inspections). The respondents who selected “other” for the inspection frequency provided a variety of explanations, including self-inspections, inspections done only when there is a problem, inspections conducted during system installation or home purchase, having a relatively new system, only conducting inspections following recent municipality ordinance changes, following specific municipal inspection ordinances, relying on the pumper to do a visual inspection when the tank is pumped, and believing there is no need for an inspection because there are no issues. A comprehensive maintenance program can increase the functional life of a septic system (US EPA, 2025). However, survey findings show respondents are more engaged in routine septic tank pumping than system inspections. This is shown when 29 percent of the respondents reported that they have never inspected their system, as opposed to 6 percent who have never pumped. Without inspections, issues with critical elements such as tank baffles, distribution lines, drainfields, etc., that are not thoroughly inspected during a pumping visit may deteriorate unnoticed. Furthermore, as demonstrated by some entries for the 12 percent of respondents who selected ‘other’ for inspections, users may neglect inspections until problems arise.

Figure 4: Septic Tank Pumping (*n*=616) and Inspection Frequencies (*n*=610)



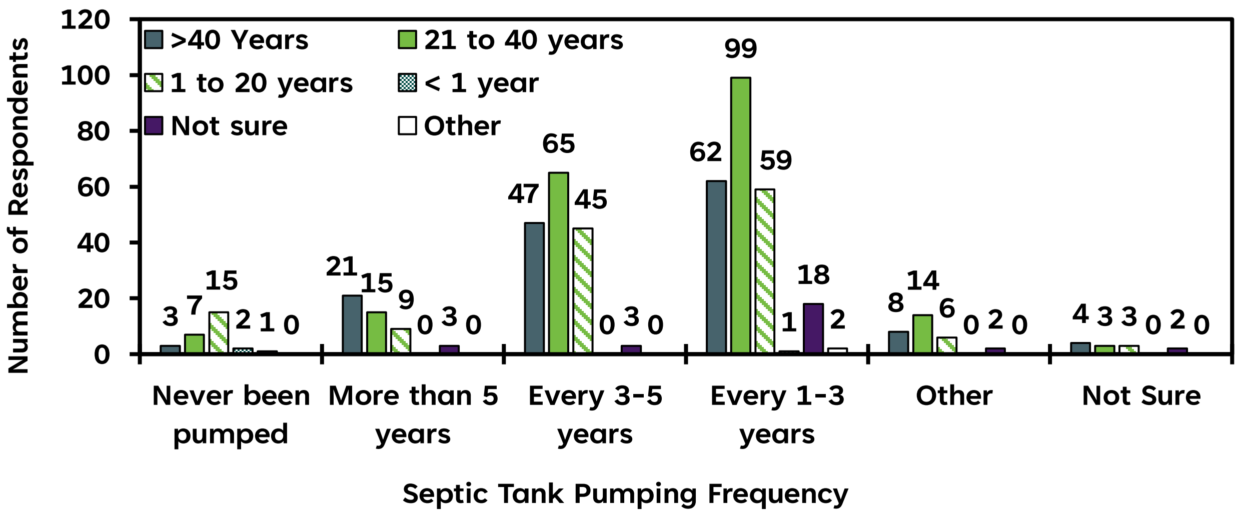
Larger households, especially those operating on a septic tank originally designed for a smaller household size, may need to pump their tanks more frequently due to more wastewater generation and sludge accumulation rates. As shown in Table 2, 3 percent of the respondents in a four- to six-person household indicated that the septic tank is less than 1,000 gallons, and they pumped their tanks every one to five years, apart from two who indicated that they have never pumped their tanks. Based on the estimated individual wastewater generation rates, these respondents should increase pumping schedules of their septic tanks to approximately every two years, as opposed to the three-year recommendation for a one- to three-person household size (Mancl, 1984). Because it may be challenging for users to determine when to adjust their pumping frequencies, system inspections can come in handy by establishing pumping periods based on system-specific characteristics such as tank capacity and sludge accumulation rates (Cotteral et al., 1969).

Table 2: Distribution of Reported Septic Tank Sizes and Household Size (*n*=354)

Household Size	**Septic Tank Size**		
	Less than 1000 gallons	1000 to 1500 gallons	More than 1500 gallons
1 to 3 people	15%	59%	5%
4 to 6 people	3%	16%	1%
More than 7 people	0%	1%	0%

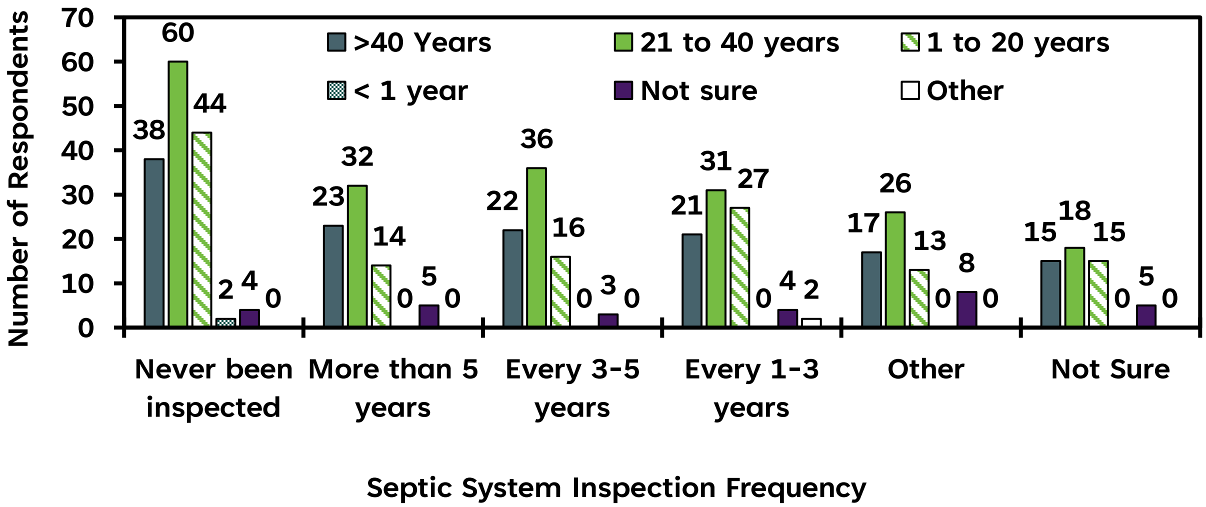
When assessing septic tank pumping frequencies and reported system age (Figure 5), most older systems (more than 40 years old) are maintained once every one to five years. However, some respondents with older systems have not kept up with system maintenance. Some example comments provided include: "*...until forced to do so last* *year, our tank was never pumped out in 30 years...", "...I have only pumped once in 40 years...", "...moved here in 1991, only needed to pump once...".*

Figure 5: Septic Tank Pumping Frequency Versus Age of System (*n*=519)



As septic systems age, failures and the need for repairs can be easily captured during system inspections. However, a significant share of septic systems older than 20 years (66 percent) have never been inspected, and many are uncertain if a septic inspection has ever been done (Figure 6). About 10 percent of septic system users conduct maintenance, such as pumping (12 percent) and inspection (11 percent), when there are noticeable issues (Figures 7 and 8). Although 72 percent of respondents (*n*=603) report that they have never observed any symptoms of septic system issues, some common issues that were reported in about 2 to 10 percent of users were sewer odors in the house, sewage back up into the house, spongy soil near septic components, standing water in the yard, poor drainage in plumbing, and dosing pump operational issues. Other issues included flow backing up from the drainfield into the tank, problems with alarm systems, and sewer odors in the yard. By the time overt signs of septic system failure become apparent, the septic system's performance has likely been compromised, and chronic environmental contamination has already occurred.

Figure 6: Septic Tank Inspection Frequency Versus Age of System (*n*=501)



Based on this research, few municipalities in Pennsylvania currently mandate routine septic system inspections and tank pumping. Twenty-five percent and 20 percent of respondents indicated that their municipalities required proof of septic tank pumping and inspection, respectively (Figures 7 and 8). Based upon survey responses to questions about proof of system maintenance, only a small number of municipalities in four counties (Adams, Berks, Centre, and Chester counties) were reported to require *proof* of septic tank pumping and system inspection (Appendix 6-1). [1] As shown in Figure 7, only 10 percent of respondents pump out septic tanks following recommendations from septic system inspections, while the majority follow a regular pumping schedule. Routine septic tank pumping is an essential maintenance practice; however, without accompanying inspection, pumping may address sludge accumulation but fails to identify structural damage, distribution line blockages, pipe leaks, or drainfield malfunction, thereby allowing significant operational issues to persist undetected. As reported by 68 percent of respondents (*n*=350), their inspection reports indicated that septic system components were functional. However, some users found that they needed some corrective measures, such as pumping out their septic tanks (13 percent), repairing or replacing septic tanks (5 percent), fixing mechanical or electrical issues with pumps or distribution lines (6 percent), and correcting issues with the drainfield (6 percent). About 12 percent indicated that they needed other repairs done on the septic baffles, backflow flaps, and drainfields to direct surface runoff away, among others, following their system inspections.

[1] These findings are based on self-reported survey responses and have not been confirmed against respondents' actual local municipal septic ordinances.

Figure 7: Reasons Why the Septic System is Inspected (*n*=351)
Respondents may have selected more than one answer.

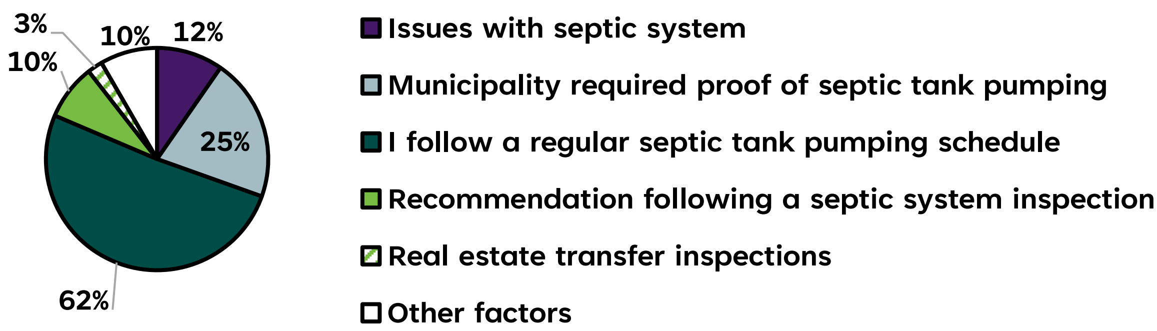


Figure 8: Reasons Why the Septic Tank is Pumped (*n*=563)
Respondents may have selected more than one answer.

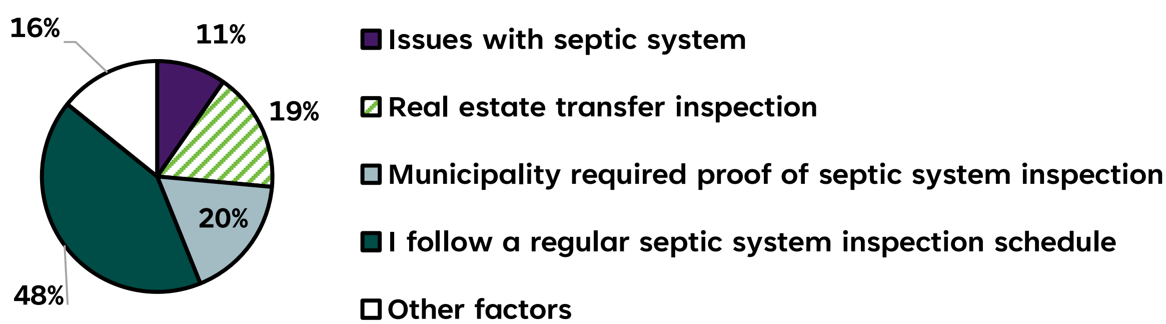
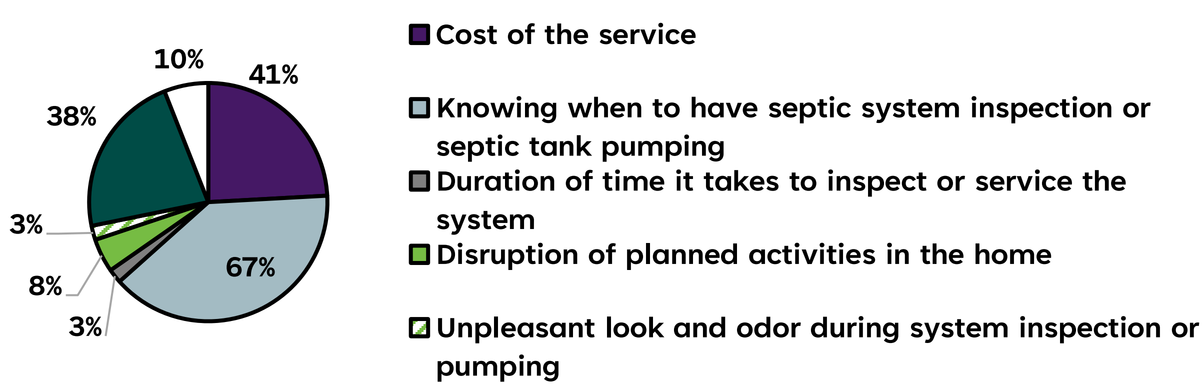


Figure 9: Factors Influencing Septic System Maintenance (*n*=580)
Respondents may have selected more than one answer.



Factors Influencing Septic System Maintenance Practices

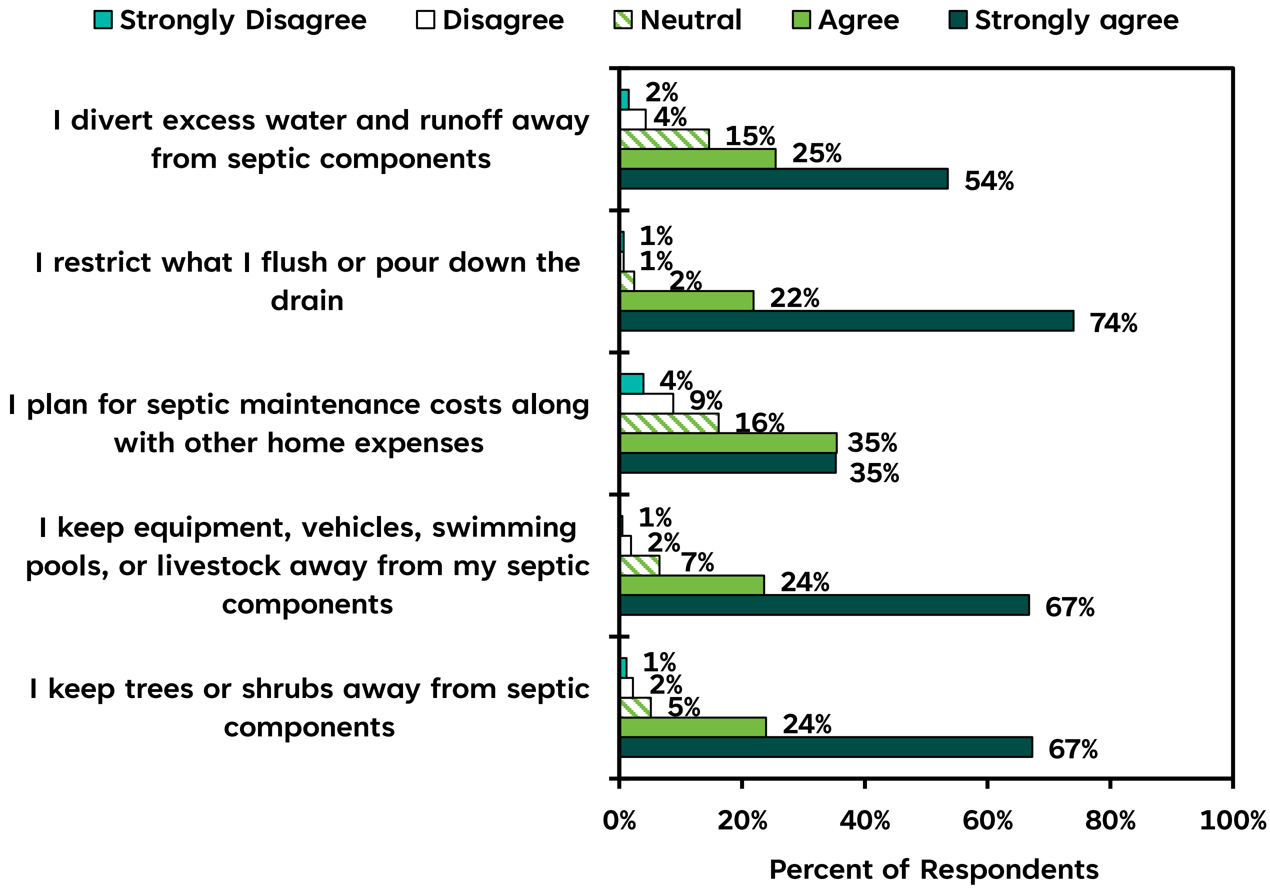
Procedural knowledge of the actions to take in order to properly care for septic systems and when to conduct routine maintenance can play a significant role. Some studies have identified gaps in user knowledge regarding septic system function and maintenance requirements as a major driver for the lack of proper system care (Devitt et al., 2016; Schwartz et al., 1998). Similarly, in the present survey, knowing when to conduct routine maintenance was reported as a primary factor (67 percent) in septic system maintenance (Figure 9). As shown in Figures 7 and 8, about 10 percent of users resort to reactive maintenance conducted when there are noticeable issues with their systems. Although over 70 percent of respondents indicated that they pump septic tanks periodically (Figure 4), many systems, including those that may be considered at risk due to age, have never been inspected (Figure 6). Based on the comments from respondents who selected "other" on pumping and inspection frequency questions, there are septic system maintenance misconceptions, such as that septic tank pumping alone is a sufficient maintenance practice, infrequent pumping is acceptable if there are no visible system issues, and that inspections are only necessary when problems occur.

Although municipalities in the Commonwealth are involved during the permitting and installation of septic systems, there is a lack of follow-up and support for homeowners to monitor and maintain their septic systems. Less than 30 percent of the respondents indicated that their municipalities required proof of periodic septic maintenance (Figures 7 and 8). Some users are more likely to engage in septic system maintenance when prompted by simple interventions such as clear guidelines or reminders. This can be inferred from some comments provided by survey respondents: "*...until forced to do so last year, our tank was never pumped out in 30 years...*"," *...until the township required it, the only time the system was inspected was 30 years earlier...*"

Furthermore, there is a wide variability in maintenance ordinances across the Commonwealth. We looked at 9 rural counties with the highest survey completion rates (Adams, Blair, Bradford, Carbon, Centre, Clinton, Huntingdon, Monroe, and Pike) to assess the guidelines offered by local townships on public-facing websites. Many municipalities in these counties did not have information on septic system maintenance on their websites, and those that did focused on septic tank pumping as opposed to system inspections (Appendix 6-2). Many recommend or require tanks to be pumped every 3 to 5 years, with flexible enforcement in some cases, or the discretion of the SEO. While some require inspections every 3 to 6 years, the majority offer vague guidance such as inspections may be done "*at any reasonable time*", "*as needed*", "*when there is a complaint*", or if "*the system is malfunctioning*" (Appendix 6-2). While these are just a few examples, they show the inconsistency in guidelines and vagueness around septic system maintenance. Municipalities with minimal or no septic system maintenance guidelines contribute to varying maintenance practices and are reliant on user awareness of maintenance needs and frequencies. Consequently, some systems may go decades without professional monitoring and maintenance.

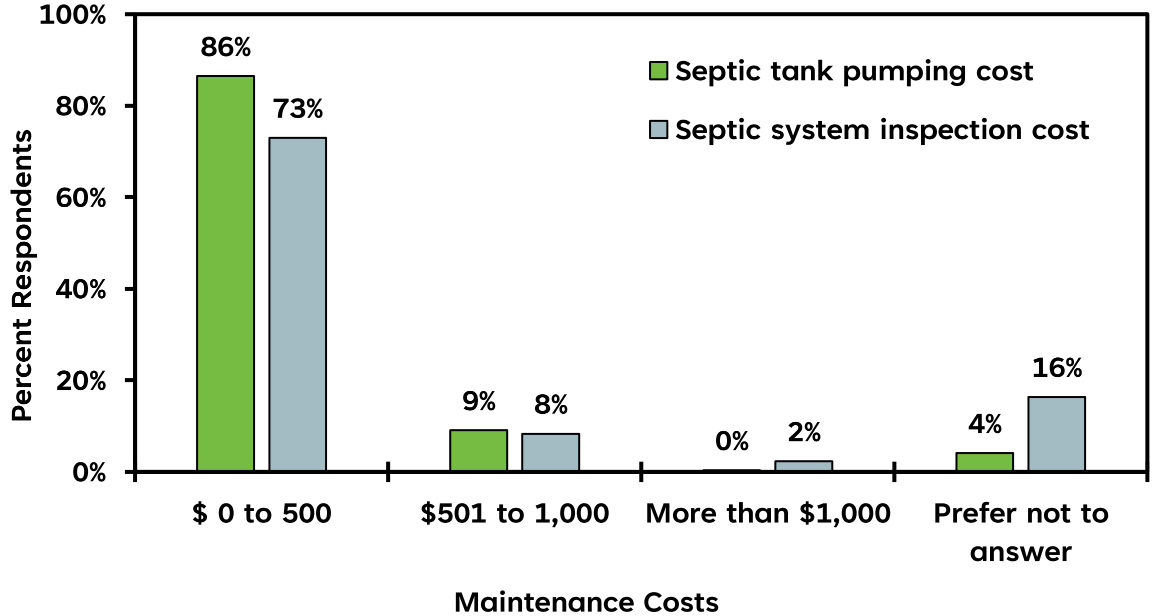
In addition to knowledge about when to conduct routine maintenance, there are general practices that can support the long-term functionality of septic systems. They include being cautious of what goes down the drain or gets flushed, diverting excess water from the tank and drainfields, and protecting septic components from heavy machinery and trees (US EPA, 2025). We used a Likert scale to assess respondents' awareness and opinions of these general septic system care practices. Almost 75 and 70 percent strongly agreed with restricting what is flushed and restricting heavy machinery and trees from septic system components, respectively (Figure 10). To restrict what goes down the drain, users are advised not to flush chemicals or items that can clog piping. Because septic system components can just be a few inches beneath the soil, heavy machinery and landscaping involving trees with invasive roots can cause damage. Additionally, 54 percent strongly agreed with diverting excess water from septic components. By effectively managing or redirecting excess water, whether from sump pumps, rainwater drains, surface runoff, or leaky or high-flow household water fixtures, users can ensure that the septic tank and drainfield are not overloaded. These survey results show that overall, there are moderate levels of user awareness with these key statements related to proper septic system care. While these responses indicate a reasonable degree of understanding among users, the variation across specific practices suggests that awareness is uneven and there are knowledge gaps on how these septic system care practices influence system performance, longevity, and their associated impacts. Lack of awareness, especially on how septic systems impact underlying water resources, was found to be a primary factor hindering septic maintenance for septic system users in North Carolina (Fizer et al., 2018).

Figure 10: Likert Scale Showing Level of Agreement with General Septic System Care Statements (*n*=581)



As opposed to other statements that more than 50 percent of the respondents strongly agreed with, only 35 percent agreed strongly with "*I plan for septic system costs*" (Figure 10). It is likely that some respondents overlook septic maintenance and repair costs in household budgets, as almost 10 percent disagree and 4 percent strongly disagree with the statement. Nonetheless, the cost of septic system services was a factor influencing septic maintenance for 41 percent of the respondents (Figure 9). As shown in Figure 11, most respondents indicated that the cost of septic system pumping and inspection was typically less than $500. However, some reported inspections cost more than $1,000. Since many service providers are private businesses, the prices can vary by region. Some of the higher (>$500) services were reported in Adams, Berks, Crawford, Dauphin, and Monroe counties.

Figure 11: Septic System Pumping (*n*=562) and Inspection Costs (*n*=348)



To assess the potential cost-related influences on septic system maintenance behavior, responses were grouped by frequency of septic system maintenance and the reported cost of services in Tables 3 (septic tank pumping) and 4 (inspections) below. Most users spend less than $500 on routine maintenance, and only 7 percent of the respondents who have never performed maintenance and those who perform maintenance at intervals greater than five years, indicated that the service costs in their regions were more than $500. Because many users who perform septic system maintenance less frequently also indicated that they were located in areas within the Commonwealth where service costs were less than $500 (Tables 3 and 4), it is likely that factors other than direct expense play a bigger role in influencing septic system maintenance practices. Eight percent indicated that they also considered disruption of planned activities when scheduling septic system maintenance, and 10 percent reported other factors, such as limited-service truck access to the property or the time required to uncover buried septic tank access.

Table 3: Distribution of Reported Septic Tank Pumping Frequencies and Costs (*n*=524)

Pumping Frequency	Estimated Cost of Pumping			
	$ 0 to 500	$501 to 1,000	More than $1,000	Prefer not to answer
Never been pumped	4%	1%	0%	0%
Every 1-3 years	41%	4%	0%	1%
Every 3-5 years	27%	2%	0%	2%
More than 5 years	8%	1%	0%	0%
Other (pumping frequencies)	5%	1%	0%	0%
Not Sure	2%	0%	0%	0%

Table 4: Distribution of Reported Septic System Inspection Frequencies and Inspection Costs (*n*=326)

Inspection Frequency	Estimated Cost of Inspection			
	$ 0 to 500	$501 to 1,000	More than $1,000	Prefer not to answer
Never been inspected	20%	3%	1%	4%
Every 1-3 years	14%	1%	1%	3%
Every 3-5 years	12%	2%	0%	2%
More than 5 years	8%	1%	0%	3%
Other (Inspection frequency)	9%	1%	0%	3%
Not Sure	10%	1%	0%	1%

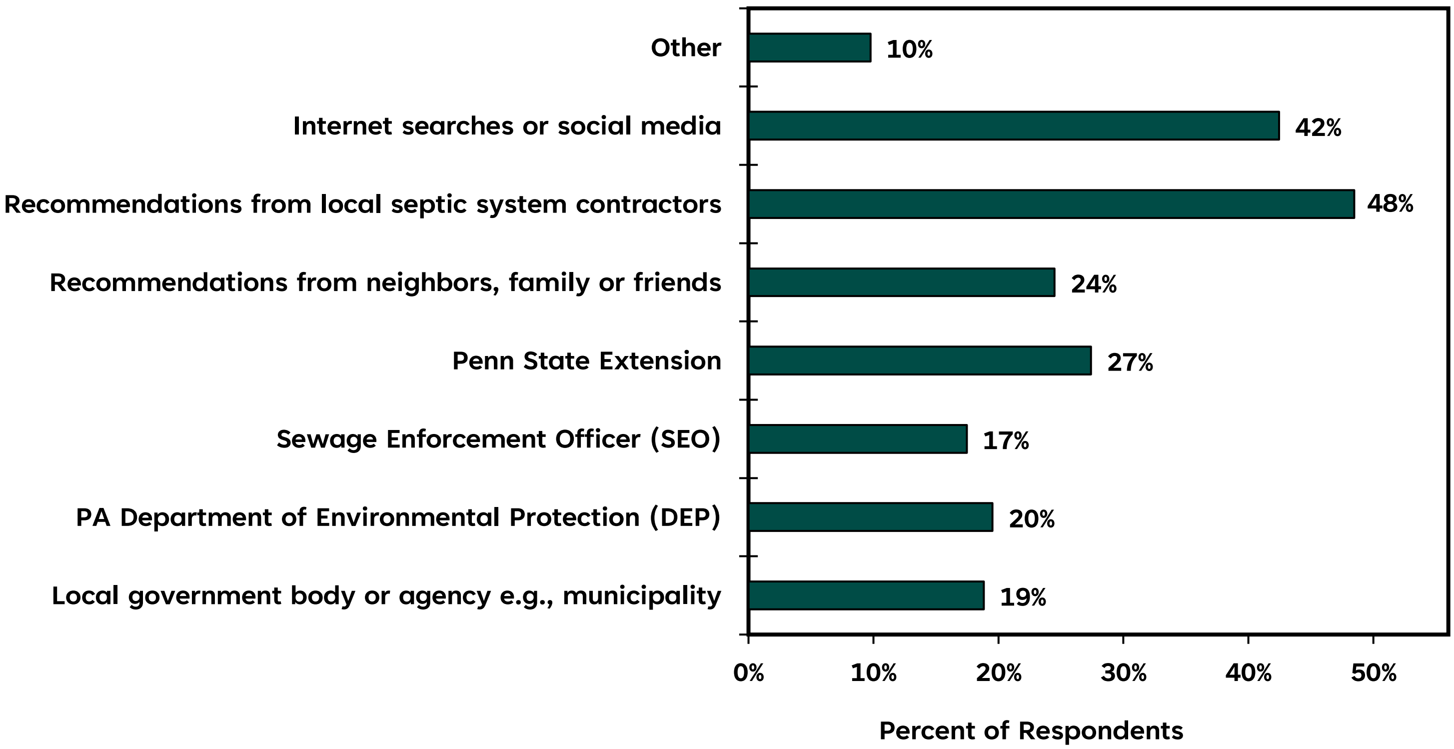
A combination of high service fees and challenges in finding the right contractor can be a barrier to routine maintenance, especially in areas without mandates to pump or inspect. Finding a qualified professional was a factor that influenced septic system maintenance for 41 percent of the respondents (Figure 9). PA DEP trains local SEOs that work with municipalities on permitting and installation of septic systems; however, there are no state-approved guidelines for service/maintenance providers. Some municipalities require that tanks be pumped by their "*authorized hauler*" listed on their websites, while others indicate "*a qualified or registered hauler or pumper*" without further guidance (Appendix 6-2). Similarly, most inspections are conducted by SEOs, within the municipalities or a combination of a registered pumper and SEO. Some municipalities provide contacts for their SEOs and there is also a website listing all active SEOs across the state (https://pacleanwateracademy.remote-learner.net/blocks/bcwseo/seoreport.php).

The Pennsylvania Septage Management Association (PSMA) is a non-profit organization that provides training and certification to septic system service providers, which they publish on their website (https://www.psma.net/locate-service-provider/). Because PA DEP registers septage haulers in the state, a public-facing list of registered haulers at the state or regional scale could be of benefit.

Almost 50 percent of the respondents report that they rely on septic system service providers as their primary source of information about care and maintenance (Figure 12). As potential frontline educators on septic system care and maintenance, it can be important to have standardized training programs and equip them with information and resources to support homeowners. Similarly, many respondents (42 percent) use internet searches and social media for septic system maintenance information. Therefore, local municipalities and state government bodies should provide electronic guidelines and resources for residents. Less than 20 percent turn to local municipalities and SEOs for information. Some townships (e.g., Butler Township, Adams County) have a list of Township-approved septic haulers that residents can use. However, it is likely that many municipalities do not provide such a list for septic users to aid in locating a service provider. Those who selected “other” (Figure 12) were septic professionals (I.e. SEOs) who had field knowledge and experience on how to care for these systems as well as respondents who relied on entities such as homeowners’ associations, community and watershed organizations, public sewer authorities, plumbers, and real estate agencies.

Figure 12: Sources of Information on Septic System Care and Maintenance (*n*=584)

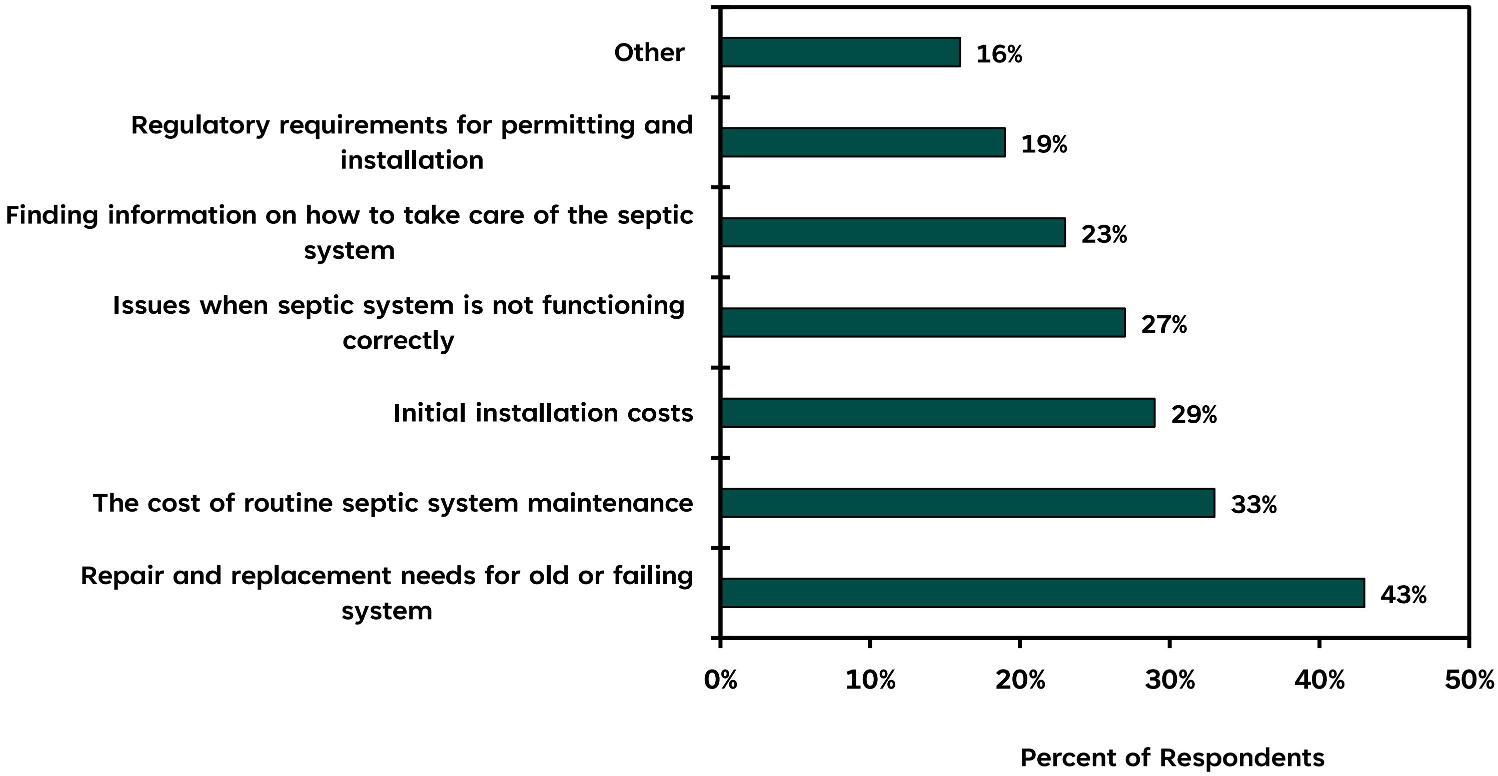
Respondents may have selected more than one answer.



Existing Challenges and Types of Support Needed

Many users express a preference for septic systems due to their independence from centralized sewer systems. Reported benefits include the lack of a sewer bill (81 percent, *n*=587), long-term reliability (42 percent), environmental benefits (41 percent), and the user's independence in caring for the system (48 percent). For some, septic systems are the only option while also providing the advantage of being able to build or live in areas not served by public sewer networks. The responsibility of system care and maintenance was a burden to some homeowners. Some of the greatest challenges reported were repair and replacement in aging systems (43 percent), costs for routine maintenance (33 percent), and initial installations (29 percent) (Figure 13). About 40 percent of the respondents (*n*=600) needed septic system repairs at some point over the life of their systems. Repairs surrounding issues with pipes, pumps, and drainfields are common. However, many respondents (28 percent) indicated they needed ‘other’ types of repairs. From those who provided more information on the other types of repairs, they noted riser access, septic tank pump replacements, electrical or alarm systems, floating tanks, reconnections of disconnected flows, installation of an entirely new system, fixing of issues caused by plants/vegetation roots, and replacement of cleanout pipes following accidental breaking.

Figure 13: Challenges With Septic Systems (*n*=566)
Respondents may have selected more than one answer.



The cost of repairs ranged widely from less than $1,000 (~50 percent, *n*=242) to costly repairs of up to $5,000 (23 percent), $5,000 to $10,000 (7 percent), and more than $10,000 (6 percent). In a previous survey of septic system users in Pennsylvania, most respondents (36 percent) were also paying about $2,000 for septic repairs (Day et al., 2008). We did not ask questions about the cost of each repair in the present study. However, some of the reported repairs listed can be costly (e.g., drainfield and/or whole system replacements, etc.). Although septic system inspections and maintenance are reported to cost less than $500, maintenance cost is also a challenge for 33 percent of respondents (Figure 13). Cost can be expected as a major challenge for septic users, as only 35 percent of respondents strongly agree to planning for septic system maintenance costs along with other home expenditures (Figure 10). Additionally, less than 1 percent of the respondents (*n*=237) have used any of the septic system financial support funding programs through the Pennsylvania Housing Finance Agency. The survey did not assess possible reasons for low funding program use; however, one respondent commented that "*... I had no idea that there were funding options...*" and another asked if "*...funding programs were tied to level of income...*". These suggest that there is a potential gap in awareness about the programs and their terms.

When asked about services that can help with system care and maintenance, 50 percent of users (*n*=514) reported that they could benefit from periodic reminders from their municipalities. Some municipalities (e.g., Butler Township in Adams County) send reminders. However, 52 percent of users prefer reminders unique to their system (e.g., system type or based on wastewater use and household size). Other services mentioned by users included having a service contract for periodic pumping and leaning more toward receiving reminders from contractors based on experiences with their septic systems, as opposed to working with the municipality (22 percent). About 26 percent of the respondents indicated that they would connect to a public sewer if available.

Source Water Characteristics

Eighty-four percent of survey participants (*n*=597) rely on private water systems, such as a well or spring, for their domestic drinking water supply, while 12 percent are connected to a public water supply. Two percent used bottled water, and the other 2 percent selected “other,” and some indicated that they use collected roof-capture cisterns, or a combination of bottled and well water, or spring and pond water. Seventy-six percent of private water system users (*n*=499) have gotten their water tested through a certified laboratory, 18 percent have not tested before, while 5 percent are not sure if any testing has ever been done or not. While 30 percent have their private water system tested on a routine basis *(n*=379), many indicated that testing is only conducted sporadically, such as following well drilling, during property transfer, during installation of a water treatment device, through Penn State Extension education programs, and because of land-use changes near the property. The reported value of a private water system included lack of a water bill (84 percent, *n*=494), good water quality (69 percent), and the independence of caring for the home water supply (50 percent). Notably, the biggest challenges private water system users faced included initial water source installation costs, such as drilling (26 percent, n=457), water quality issues (30 percent), and initial installation costs of water treatment devices (28 percent).

Eighty-three percent of the participants (*n*=493) were interested in private water supply testing through this study. While giving priority to residents in rural counties, interested participants were classified into four main groups describing their septic system maintenance practices, including: (i) complete, (ii) partial, (iii) irregular, and (iv) poor. Twenty-nine percent of the respondents selected for water testing (*n*=145) were classified under complete maintenance, corresponding because their septic systems were inspected and tanks pumped within the recommended frequencies of between 1 and 5 years. The partial maintenance category constituted 46 percent of the selected respondents because they performed pumping between 1 and 5 years but did not inspect; inspected between 1 and 5 years and did not pump or pumped between 1 and 5 years without knowing if the system had been inspected. Around 13 percent were classified under irregular maintenance since their systems were being inspected and pumped, but outside the recommended schedules, or where respondents were pumping at frequencies greater than 5 years with no records of inspections. Finally, systems that have never been inspected or pumped or those with unknown maintenance (7 percent) were classified under "poor maintenance." Of the 145 kits sent, 86 percent were returned to the lab for analysis, and results were sent to each participant. Each laboratory analysis report included the Extension Educator's name and contact information that the participant could reach out to for clarification of test results.

Occurrence of Measured Substances in Water Samples

To further explore potential links between septic system maintenance and water quality, a subset of survey participants volunteered for private well testing. Of the 145 participants who received testing kits, 125 submitted water samples that were analyzed for contaminants associated with septic system effluent (Appendix 7). Participants received their test results within two weeks. Of those who submitted samples, over 80 percent were located in rural counties.

General water quality characteristics such as pH and total dissolved solids (TDS) were measured in each water sample. pH measures how acidic or alkaline the water is, and pH values between 6.5 and 8.5 are recommended for drinking water sources. Measured pH values of the water samples ranged from 4.18 to 8.52, with 23 percent of the samples falling under acidic (pH less than 6.5) and only one sample being above the 8.5 threshold. pH as a water quality parameter does not have any health impacts above or below the recommended thresholds (6.5 to 8.5); however, low pH (i.e., acidic) can contribute to water being corrosive to plumbing components and can result in exposure to other substances that can impact health, such as lead and copper. TDS is a measure of dissolved substances in water, such as salts, minerals, metals, etc. While it is a great screening tool, it does not reveal what substances are contributing to the measured values, but some substances that contribute to high TDS can negatively affect human health or affect the taste, color, or smell of water. Measured TDS in this study ranged from 20 to 821 mg/L (Table 5).

Table 5: Summary of Descriptive Statistics for Detected Contaminants (*n*=125*)*

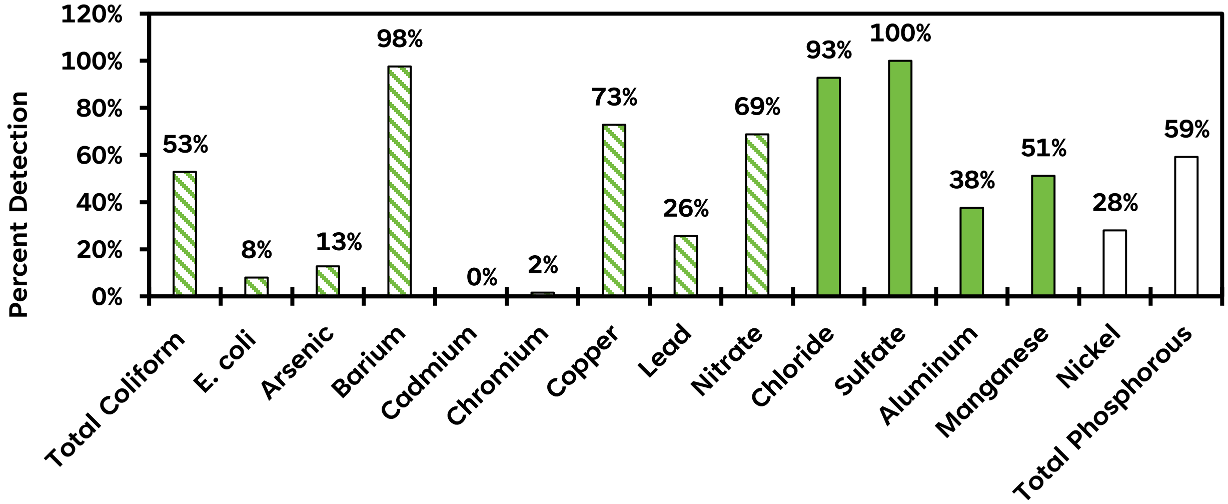
Contaminant	Minimum	Maximum	Average	Standard Deviation	US EPA MCLs
Total Coliform (MPN/100 mL)	1	201	56.212	76.776	**Zero**
E. coli (MPN/100 mL)	1	32	9.200	10.137	**Zero**
Arsenic (mg/L)	0.003	0.028	0.008	0.007	**0.01**
Barium (mg/L)	0.001	3.723	0.133	0.385	**2**
Cadmium (mg/L)	—	—	—	—	**0.005**
Chromium (mg/L)	0.018	0.059	0.039	0.000	**0.1**
Copper (mg/L)	0.005	0.668	0.068	0.072	**1.3**
Lead (mg/L)	0.003	0.127	0.013	0.007	**0.01**
Nitrate (mg/L)	0.204	24.659	3.208	3.039	**10**
Chloride (mg/L)	1.009	342.248	25.457	44.024	250
Manganese (mg/L)	1.000	145.644	18.626	23.306	0.05
Sulfate (mg/L)	0.013	37.660	0.935	5.731	250
Aluminum (mg/L)	0.006	5.268	0.343	0.889	0.05
Nickel (mg/L)	0.005	0.135	0.017	0.028	No MCL
Total Phosphorous (mg/L)	0.013	2.177	0.090	0.279	No MCL
pH	4.182	8.519	6.976	0.876	6.5 - 8.5
Total Dissolved Solids (mg/L)	20.000	821.000	191.920	145.963	500

Note: MPN/100 mL-Most probable number per 100 mL; MCL- Maximum contaminant level. MCLs shown in bold correspond with contaminants that have primary (health-based) standards, while MCLs in regular fonts correspond with contaminants that can affect the aesthetic properties of water, such as color, smell, and taste.

Tested substances that have health-based drinking water standards were total coliform, *E. coli*, nitrate, arsenic, barium, cadmium, copper, chromium, and lead (health implications shown in Table 1). The least frequently detected substances were cadmium, which was the only substance that was not present in any sample, and chromium, which was only present in 2 percent of the samples (Figure 14). The most frequently detected were barium (98 percent), copper (73 percent), nitrate (69 percent), and total coliform bacteria (53 percent) (Figure 14). *E. coli*, arsenic, and lead were present in less than 30 percent of the samples. Substances such as coliform bacteria, *E. coli,* and nitrates are associated with human excrement (Lusk et al., 2017), but arsenic, barium, copper, and chromium can be associated with household products used in cleaning (Richards et al., 2015). Lead typically originates from plumbing components in the home and can be exacerbated if water sources are corrosive. Bacteria and nitrates could also originate from other surrounding land uses that impact source water quality, such as pasture, manure, or fertilizer-amended farms, etc. Barium, arsenic, chromium, and cadmium may also originate from underlying geological materials and adjacent industrial land uses. In a review of studies monitoring groundwater sources with potential impacts from septic systems across the globe, Gyimah et al. (2024) report total coliform (0.2 to 1,000,000 MPN/100 mL), *E. coli* (0 to 600,000 MPN/100 mL), and nitrate (0 to 131 mg/L) were among the most frequently detected substances, but were present in some cases at levels at least ten times greater than what is detected in this study (Table 5).

Looking at contaminants that can affect the aesthetic or sensory properties of water (i.e., taste, color, smell), sulfate (100 percent), chloride (93 percent), and manganese (51 percent) were the most frequently detected. Sulfate and chloride can cause a salty taste in drinking water, while manganese can result in staining of water fixtures (Table 1). While sulfate and manganese can enter effluent as a result of household cleaning products, their high detection frequencies can also be associated with underlying bedrock. Sulfate minerals can originate from sandstone and shale bedrock, while manganese has been associated with crystalline rock and sand and gravel aquifers (Barker, 1986; Fleeger, 1999). Total phosphorus and nickel (28 percent) do not currently have drinking water standards. However, the detection of total phosphorus in 59 percent of the samples with concentrations as high as 2.17 mg/L (Table 5) shows the likelihood of surface water contamination when impacted groundwater mixes with adjacent streams and lakes (Rakhimbekova et al., 2021). Elevated phosphorus and nitrates can promote the development of algal blooms. For example, when lakes were classified based on existing wastewater treatment systems along the shorelines in Seattle, lakes with septic systems along the shores were eutrophic, with high concentrations of phosphorus and algal bloom indicators such as chlorophyll-a (Moore et al., 2003).

Figure 14: Contaminant Detection Frequencies of Analyzed Water Samples (*n*=125)



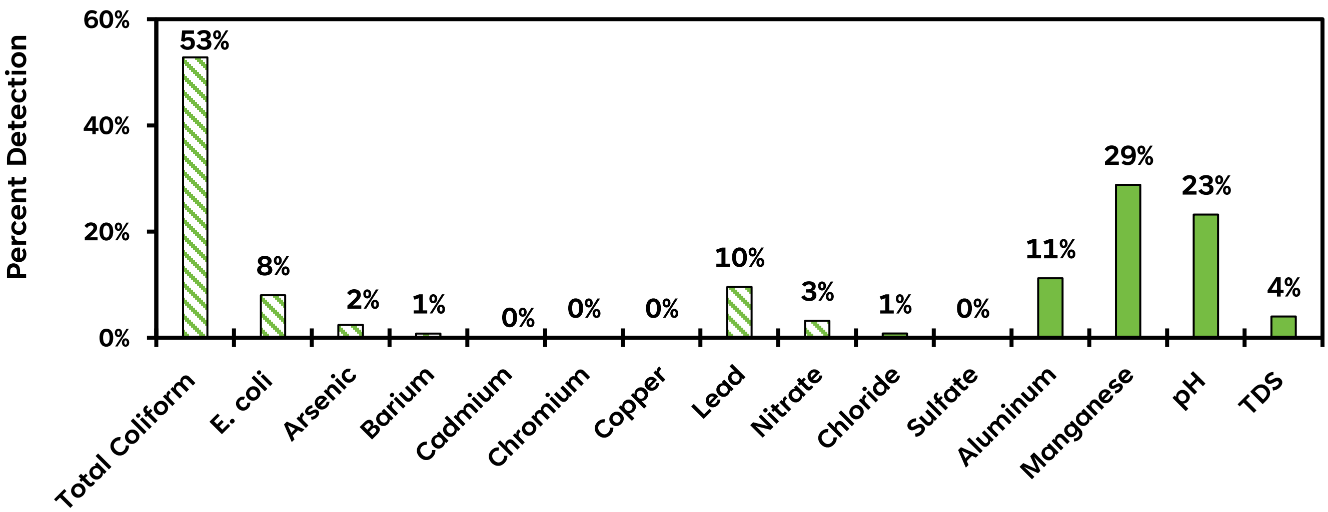
Note: Stripped bars indicate contaminants with health-based drinking water standards, solid green bars represent contaminants with aesthetic standards, and white bars show contaminants without any drinking water standards.

Comparisons with Drinking Water Standards

Water test results were compared with current health-based drinking water standards (Table 1) to see how many samples had different substances above the safety thresholds (Figure 15). Because the drinking water standard for *E. coli* and total coliforms are zero, all sites that had any detections for *E. coli* (8 percent) and total coliforms (53 percent) failed to meet the standard. Total coliforms and *E. coli* are used as indicators of disease-causing pathogens in drinking water, as their presence shows that there is a likelihood of other germs, including other bacteria, parasites, and viruses. This study did not assess associated human health impacts through the survey. However, in a review of disease outbreaks in the US associated with untreated groundwater between 1971 and 2008, Wallender et al. (2014) found that 50 percent of the outbreaks were associated with bacterial contamination, and *E. coli* contributed to about 5 percent. Furthermore, the review found that improper design, sitting, or location of the water source or septic system was the most frequent (67 percent) contributing factor to the outbreaks (Wallender et al., 2014).

For lead and arsenic, only 10 and 2 percent of samples, respectively, were above the 0.01 mg/L MCLs in drinking water. In addition to the MCLs that are legally enforced for public water systems, lead and arsenic also have Maximum Contaminant Level Goals (MCLG), which are the levels in drinking water at which there are no known or expected health risks. Based on the associated health impacts to children and adults (Table 1), the US EPA set the MCLG of zero for lead and arsenic. This indicates that no amount of lead or arsenic in drinking water is considered safe; thus, there is some level of risk in the samples where lead (16 percent) and arsenic (11 percent) were detected at levels below the MCLs.

Figure 15: Contaminant Detection Frequencies Above Drinking Water Standards (*n*=125)



Note: Stripped bars indicate contaminants with health-based drinking water standards, and solid dark green bars represent contaminants with aesthetic standards.

Lead and copper can enter drinking water through corrosion of household from household plumbing, especially in older homes with lead or copper piping or lead solders. Although these metals can enter water through other land uses, such as industrial activity, they are more likely to leach from plumbing if the water is corrosive and can dissolve metals from plumbing. One of the main indicators of corrosive water is low pH, which means the water is more acidic. About 25 percent of the samples failed to meet the pH criteria for drinking water because the pH was less than 6.5 and therefore acidic (Figure 15). This indicates that the water is potentially corrosive and may leach lead from plumbing and fixtures containing lead. Other water quality parameters that also contribute to corrosivity, such as alkalinity and calcium hardness levels, were not measured in this study; therefore, corrosivity was not calculated. However, 43 percent of all lead detections were in the samples (*n*=28) that were classified as acidic due to low pH.

Only 3 percent of the samples had levels above the 10 mg/L safety standard for nitrate. However, about 7 percent of the samples had nitrate levels close to the MCL (6 to 9 mg/L) and would warrant additional monitoring, as it indicates that there is a potential of exceeding safety thresholds if conditions change. For example, a study evaluating the impact of septic systems on aquifers found that nitrate levels in groundwater in a sandy aquifer increased during periods of high precipitation (Arnade, 1999). As the groundwater table rises due to factors such as precipitation, the vertical separation distance between the bottom of drainfields and the groundwater table limiting zone shrinks and there is a higher chance of contamination due to reduced overall removal of contaminants such as nitrate (Cox et al., 2020).

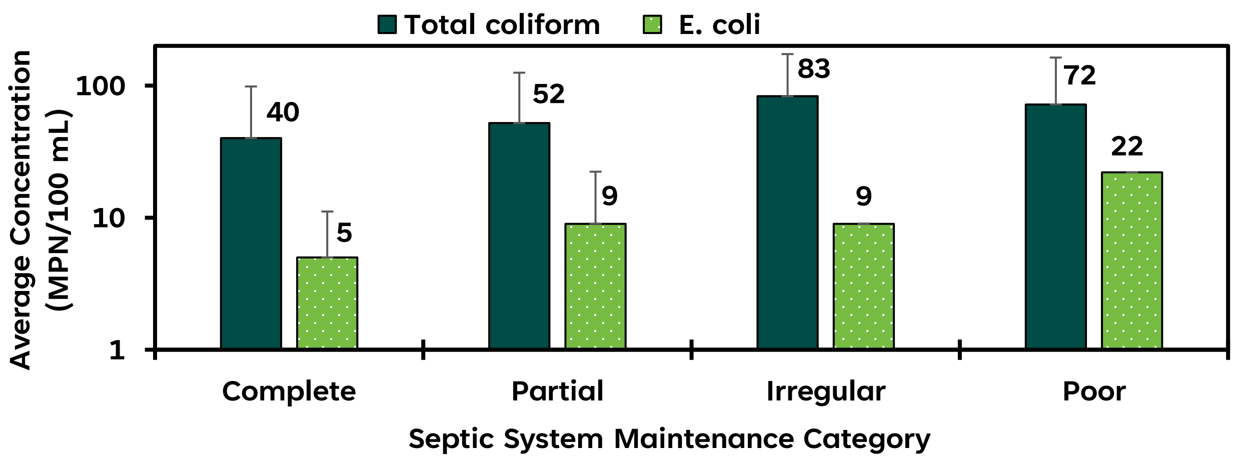
The majority of the samples met the secondary drinking water standards for substances that can influence the aesthetic or sensory properties (taste, smell, color) of water, such as sulfate, chloride, TDS, and aluminum (Figure 15). Manganese and pH were failing to meet the secondary drinking water standards in 29 percent and 23 percent of the samples, respectively.

Influence of Septic System and Source Water Characteristics and Maintenance

Septic systems can introduce a wide variety of substances into the surrounding groundwater and surface water sources (Richards et al., 2016). Overall contamination issues can be influenced by factors such as septic system design, installation, and routine maintenance (Withers et al., 2014, 2012). The survey gathered information on septic system maintenance practices, grouped respondents into maintenance categories, and evaluated whether overall water quality conditions varied by maintenance category. Complete maintenance corresponds with systems inspected and pumped within the recommended frequencies and partial maintenance constitutes pumping without inspection or inspection with no pumping. Systems with irregular maintenance were inspected and pumped outside the recommended schedules, while poor maintenance was for systems that have never been inspected, pumped, or those with unknown maintenance records.

In comparison to users practicing complete septic system maintenance, total coliform concentrations were moderately higher (by 30 percent) in the water samples collected from properties categorized under partial septic system maintenance and almost twice as much in samples where corresponding septic systems are maintained outside the recommended schedules (Figure 16). There was minimal difference in *E. coli* concentrations across the first three maintenance groups, but the highest average concentrations were recorded for the poor maintenance category that consisted of systems that have never been inspected or pumped, or those with unknown maintenance records. Average concentrations for other assessed substances were within the same orders of magnitude across all four maintenance categories (Appendix 8-1). This analysis is limited as it did not evaluate other confounding factors that may influence groundwater contamination from septic systems, such as soil and hydrogeological characteristics, separation distance between septic system and drinking water source, septic and source water characteristics, and other factors like depth to water table, aquifer type, etc.(Gyimah et al., 2024).

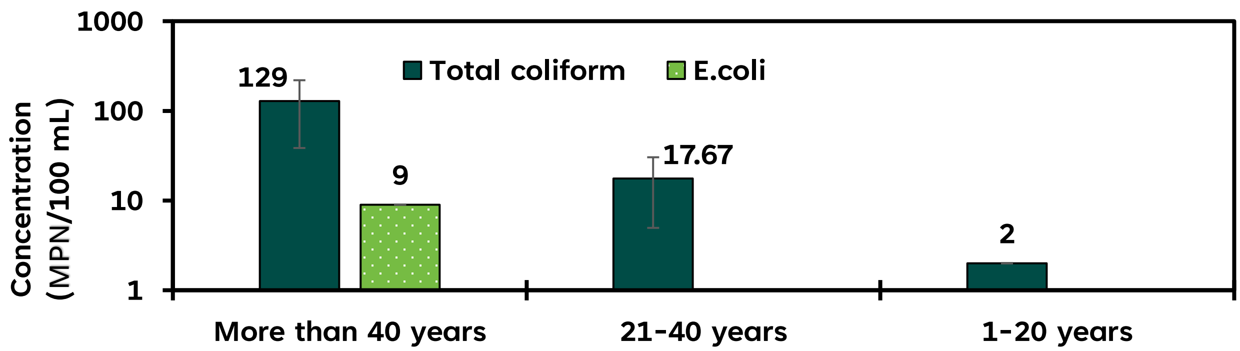
Figure 16: Variation of Average Concentrations of Total Coliform and *E. coli* Across Four Different Maintenance Categories



Note: Error bars show standard deviation. Complete maintenance (n=39) corresponds with systems inspected and pumped within the recommended frequencies, and partial maintenance (n=54) constitutes pumping without inspection or inspection with no pumping. Systems with irregular maintenance (n=15) were inspected and pumped outside the recommended schedules, while poor maintenance (n=8) was for systems that have never been inspected, pumped, or those with unknown maintenance records.

The difference in concentrations was also assessed based on reported septic system age. While the majority of the substances did not differ in water samples across the reported system age in average concentrations (Appendix 8-2), samples from properties with older septic systems that were irregularly maintained had higher total coliform and *E. coli* concentrations (Figure 17). Aging septic systems are considered high risk due to a higher likelihood of failure in comparison to well-designed and properly maintained newer systems (Capps et al., 2020) and have been linked to contamination of surrounding water resources (Withers et al., 2014, 2012). Besides system age, other factors that were not evaluated in this study may also be influencing observed concentrations.

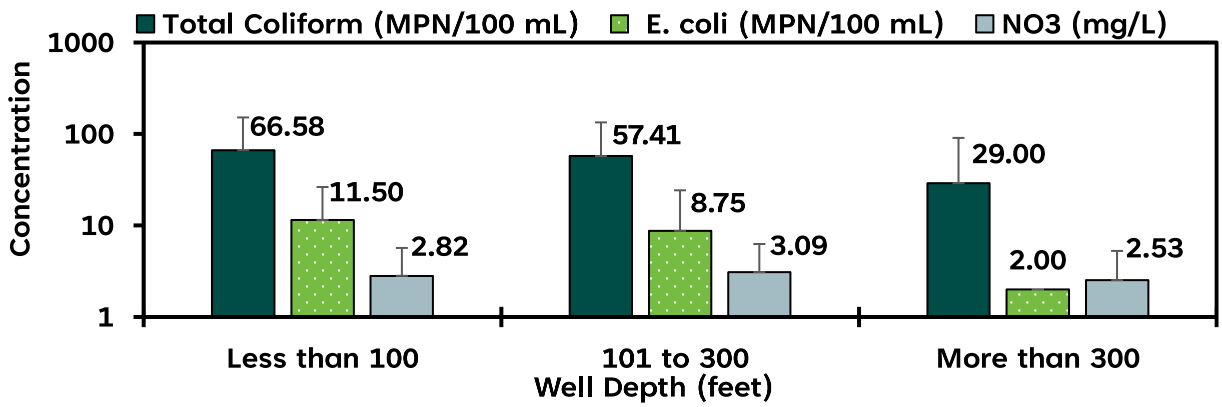
Figure 17: Variation of Average Concentrations of Total Coliform and *E. coli* in Water Samples Collected From Properties Where Septic Systems are Maintained on an Irregular Basis



Note: Reported septic system ages ranged from more than 40 years (n=8), 21 to 40 years (n=4), and 1 to 20 years (n=3).

Previous studies have documented that shallower wells have the greatest impact from septic systems and any other adjacent pollution sources because they may pull younger groundwater that has had lesser time travel time through the soil to allow for natural degradation of substances that may impact water quality and health (Schaider et al., 2016b). Although concentrations were generally within the same order of magnitude, Figure 18 shows that the lowest concentrations of total coliform and *E. coli* were observed in deeper wells (more than 300 feet). Similarly, samples where both *E. coli* and coliform bacteria were not detected were collected from wells reported to be 120 to 750 feet in depth. There was no notable difference in nitrate concentrations across the different depths and average concentrations were below the drinking water standard of 10 mg/L. However, other studies have shown that deeper private wells tend to have lower nitrate concentrations (Knobeloch et al., 2013).

Figure 18: Variation of Average Concentrations Based on Reported Source Water Depth Including Less Than 100 Feet (*N*=17), 101 to 300 Feet (*N*=54), and More Than 300 Feet (*N*=24)

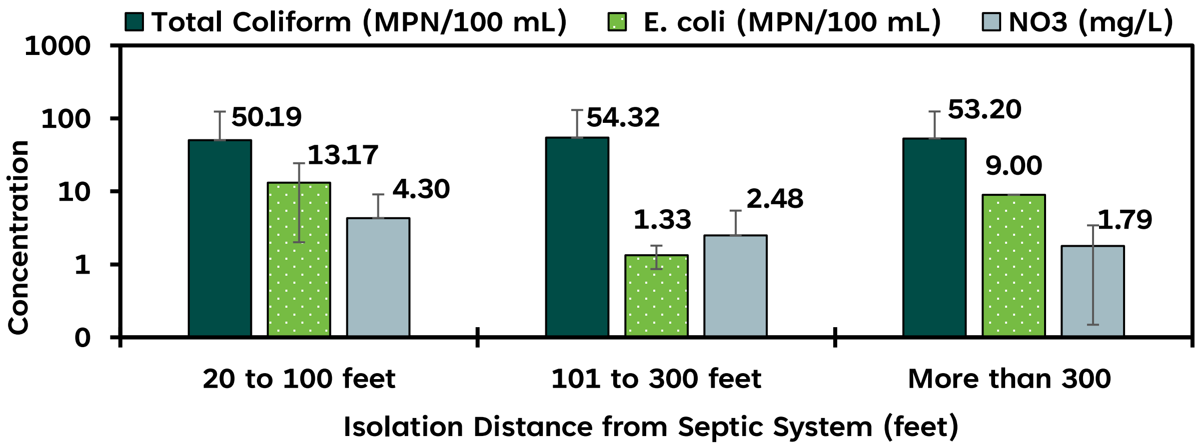


Note: *E. coli* values in the category of more than 300 feet represent detection in only one sample.

Sanitary well construction features that are often recommended to protect private water systems from contamination include an above-ground casing, grout seal, a sanitary well cap, and a spring box (for springs). When assessing well construction features, only one respondent indicated they had all three sanitary well construction features (i.e., above-ground well casing, sanitary well cap, and grout seal). About 35 percent had an above-ground well casing and sanitary well cap, 40 percent reported an above-ground casing only, and 10 percent had only a sanitary well cap. In this study, the single respondent who had three construction features had no bacteria detected in the sample collected. Wells with a combination of sanitary construction features have been found in the past to have lower detection of bacteria (Swistock et al., 2009).

Septic system components should have adequate isolation distances from drinking water supplies to protect water quality. Pennsylvania code for on-lot septic systems (PA DEP, 2025) requires that private water supply sources have isolation or setback distances of at least 50 and 100 feet from septic tanks and drainfields, respectively. Reported isolation distances from septic system components ranged from 20 to 2000 feet. While average *E. coli* was lowest in samples collected from sources between 101 and 300 feet from septic system components (Figure 19), there was only one detection (9 MPN/100 mL) in the group with more isolation distances (more than 300 feet). Decreasing *E. coli* levels with increasing isolation distances were also observed in both wet and dry seasons (Arnade, 1999). While average concentrations for nitrate were typically below the safety standard of 10 mg/L for all groups, higher levels were observed in the shortest isolation distances (20 to 100 feet). Depending on the underlying geology, soil properties, density of septic systems in a region, and private water system construction features, larger setback distances may be needed to protect drinking water sources (Blaschke et al., 2016).

Figure 19: Variation of Average Concentrations Based on Reported Isolation Distances Between Septic System Components and Source Water Including Less Than 100 Feet (*N*=49), 101 to 300 Feet (*N*=47), and More Than 300 Feet (*N*=17)



Note: *E. coli* values in the more than 300 feet category represent detection in only one sample.

Conclusion

Overall, the findings indicate that homeowners are highly aware of their systems' characteristics, including septic system type, age, and tank size. Most respondents use conventional systems, and only a small proportion rely on alternative technologies or temporary solutions such as holding tanks. About 40 percent of septic systems are between 21 and 40 years old, while 27 percent are older than 40. The U.S. EPA reported that the average lifespan of septic systems is 15 to 40 years (US EPA, 2025). Since septic systems in this study are at or near their serviceable life, users should prioritize routine septic system maintenance to ensure timely identification and resolution of existing system malfunctions or failures.

Survey results reveal a significant gap between routine septic tank pumping and system inspections. While many users (77 percent) are taking essential steps to pump their tanks every one to five years, only 32 percent keep up with system inspections, and 29 percent have never inspected their systems. Because users prioritize pumping over comprehensive septic system inspections, septic system components not evaluated during routine pumping may be vulnerable to unnoticed issues that are not resolved promptly. Furthermore, responses under "other" indicate that some inspections occur only during property transfers, system installation, or when problems arise, rather than as part of a proactive maintenance plan. About 40 percent of respondents reported that they did not know the size of their septic tanks, which could result in system overload if household size changes. Routine inspections can help users adjust pumping intervals.

Although some municipalities have mandates that promote comprehensive maintenance (inspections and pumping), in some cases, guidelines are vague. Only 25 percent of respondents reported that their municipality requires proof of pumping and 20 percent require proof of inspections, reflecting inconsistent local approaches.

Repairs and replacements for old and failing systems (43 percent) and the cost for routine maintenance (33 percent) are the top two challenges reported. Repairs may be a challenge to many since most systems are also at or near their serviceable life. If many users are neglecting routine inspections, it is also likely that repair needs are not identified in a timely manner. Most users reported that system maintenance costs are less than $500, while repairs are often less than $5,000. Interestingly, only 35 percent of users strongly agreed with including septic system care and maintenance in household financial planning. Inadequate financial planning may indicate that users may defer maintenance or needed repairs if there are financial constraints.

Although, many participants (76 percent) have had their water supply tested before, only about 30 percent conduct routine testing. It is often recommended to test private water systems at least annually. Frequent monitoring can help detect potential contamination issues even from septic systems that may not show obvious signs of malfunction. Testing conducted as part of this study found that contaminants linked to septic system sources, such as nitrate, coliform bacteria, and *E. coli*, were present in 69, 53, and 8 percent of tested samples, respectively. However, violations of safe drinking water standards were observed in 3 (nitrate), 53 (coliform bacteria), and 8 percent (*E. coli*) of samples. There were lower total coliform concentrations in samples collected from sources where septic systems received complete (inspections and pumping) routine maintenance. Similarly, there was higher total coliform and *E. coli* in water samples collected from participants with older systems receiving irregular maintenance outside the recommended schedules. Lower *E. coli* concentrations were observed in deeper wells and drinking water sources with longer isolation distances from septic system components. Further assessments should evaluate how site-specific septic and source water properties influence source water quality.

Policy Considerations

General septic system maintenance recommendations include having professional system inspections every three years and septic tanks being pumped every three to five years or when an inspection indicates that the accumulated sludge in septic tanks exceeds 30 percent of their volume capacity. Based on the survey in this study, while many users (77 percent) report taking essential steps to pump their tanks every one to five years, only 32 percent keep up with system inspections. Some municipalities in Pennsylvania have mandated complete system maintenance (routine inspections and pumping), some only require routine pumping, while others have no guidelines. Given that most septic users are not keeping up with inspections, municipalities should consider the importance of encouraging maintenance inspections. Septic system inspections are a diagnostic procedure used to assess the structural integrity, hydraulic performance, and measurement of sludge and scum layer thickness to determine the need for pumping (i.e., if sludge is more than 30 percent of tank volume), and signs of system failure such as leaks, backups, standing water in the drainfield, etc. (US EPA, 2025). This would benefit septic system users, given that the majority of systems are old (more than 20 years old) and repair and replacement needs are a leading system challenge for residents (43 percent).

Regulatory bodies in the state could adopt uniform language for system care and maintenance recommendations and mandates that can provide clarity and consistency on system maintenance. For example, Pennsylvania's Standard for On Lot Sewage Facilities does not specify a system inspection or pumping frequencies. PA DEP recommends that septic systems be pumped out at least every three to five years, but does not offer guidance on inspections. Such variability in recommendations can be a significant source of confusion for users, regardless of whether they are in a region with mandated system care practices. Furthermore, because PA DEP registers septage haulers in the state and also trains SEOs, a public-facing list of registered service providers at the state or regional scale could also be of benefit.

In addition to state regulations, there are also variations and sometimes vagueness, in municipal ordinances. Therefore, we suggest that there is a need to provide clearer and standardized guidelines across jurisdictions and targeted education on routine comprehensive septic system maintenance and why it matters. To support maintenance needs, government entities should also provide residents with lists of qualified service providers. After reviewing municipalities in several selected counties, this study found that many recommend or require tanks to be pumped every three to five years, with flexible enforcement in some cases, or the discretion of the SEO. While some require inspections every three to six years, the majority offer vague guidance such as inspections may be done "*at any reasonable time*", "*as needed*", "*when there is a complaint*", or if "*the system is malfunctioning*". Some municipalities do not offer any descriptions on what their septic system inspections entail, while others only conduct surface and visual checks of components. System inspections for some municipalities are more detailed and constitute checking for structural integrity of septic components and leaks, effluent and water sample collection, tracer studies to assess flow, and other important details. Almost 70 percent of respondents indicated that knowing when to inspect and pump these systems and finding a service provider (38 percent) were the top factors they consider when thinking about maintenance. Some municipalities provide a list of service providers to support maintenance needs, while others do not.

Our results also underscore the need for policy interventions and user education on financial support programs, such as loan and grant programs available through the Pennsylvania Housing Finance Agency, US Department of Agriculture (USDA) Rural Development, and the Pennsylvania Department of Community and Economic Development. The cost of repairs and routine maintenance was cited as a challenge by many respondents. However, many users do not include septic system care and maintenance in household financial planning, and only 1 percent were aware of existing state financial support programs. The potential for regional management of on-lot septic system maintenance and repair was assessed by Noss and Billa, (1988). They found that such arrangements would not only ensure timely maintenance and rehabilitation of failing systems but would also lower individual user costs (Noss and Billa, 1988). There is still a need to explore whether users at a regional scale would embrace some of these services, and whether it would result in improved system maintenance practices and reduced environmental impacts.

In addition to financial considerations for septic systems, other identified educational needs from this study include how septic systems are designed and how they treat wastewater, the maintenance of septic systems, proper landscaping around septic systems, and the impact of septic systems on water resources. Some of these topics were covered in the 2024 and 2025 Penn State Extension septic system webinar series (Appendix 9).

There is a need for statewide construction standards for private wells in Pennsylvania to provide clarity for both homeowners and drillers. Sanitary well construction features such as casing to the bedrock, grout seals, above-ground well casing, sanitary well cap, and well-head protection areas have been documented in previous monitoring to be associated with water quality benefits (Swistock et al., 2009). Participants in the study had drilled wells, while one had a pounded well. Reported depths ranged from 40 to 750 feet. Isolation distances from septic system components were estimated to be from 20 to 2000 feet. Water tests showed that average concentrations for nitrates were typically below the safety standard of 10 mg/L for all groups, but higher levels were observed at the shortest isolation distances (20 to 100 feet). Depending on the underlying geology, soil properties, density of septic systems in a region, and private water system construction features, larger setback distances may be needed to protect drinking water sources (Blaschke et al., 2016). While a majority of the respondents had at least two sanitary well construction features (above-ground casing and a sanitary well cap), only two indicated they had wells that were grouted to the bedrock. While some of these safety features, such as a sanitary well cap, could be easily installed by a well owner, isolation distances are costly to change. It is estimated that 20,000 new wells are drilled in Pennsylvania each year (Penn State Extension, 2022). Establishing uniform statewide standards would align Pennsylvania with management practices adopted by other states and provide clear requirements for new well constructions.

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Appendix 1: Recruitment Survey

The goal of the study is to characterize user practices for septic system care and maintenance and to identify existing needs in Pennsylvania. Please answer the questions below to let us know of your interest and to see if you qualify for the study. At the end of the study, some respondents will be selected for a free well water testing.

1. Do you use a septic system to treat your domestic wastewater?
   - ☐ Yes
   - ☐ No
   - ☐ Not sure
2. What is your drinking water source?
   - ☐ Well
   - ☐ Spring
   - ☐ Municipal or city water
   - ☐ Other
3. We would like to learn more about your use and maintenance practices for your septic system. Would you be interested in completing a follow-up 15-minute survey?
   - ☐ Yes
   - ☐ No
4. How would you like to complete the survey?
   - ☐ Paper survey
   - ☐ Online survey **(if online survey is preferred skip to question 6)**
5. To send you the paper survey, please share your preferred contact information below.
   - Name____
   - Phone number______________________________
   - Mailing address____

     ____

     ____
6. To send you the survey link, please share your preferred contact information below
   - Name____
   - Email address____

- Phone number____

7. What county in Pennsylvania do you live in? ______________________________

Appendix 2: Follow-Up Survey

On-lot septic systems are used to treat and dispose of wastewater from sinks, laundry, showers, and toilets from homes or buildings in most of rural Pennsylvania. They include typical septic tanks and drainfields, advanced treatment systems, holding tanks, cesspools or any other on-lot system. Septic system owners or users are typically responsible for system care and maintenance.

The purpose of this survey is to understand owner/user practices related to septic system operation and maintenance across Pennsylvania. Information collected through the survey is for research purposes only.

Ultimately, findings will be used to identify existing needs for septic system maintenance in Pennsylvania and to design future Extension programs on septic system and private water system care and maintenance.

As part of this study, we will select qualifying participants for a free private well or spring water testing.

The survey will take about 15 minutes to complete and is divided into the following sections:

- **Section 1 - Household Characteristics (Page 2)**
  In this section we would like to learn about the home where your on-lot waste management system (septic system) is located.

- **Section 2 - Septic System Type (Page 3)**
  In this section we would like to learn more about the type and characteristics of your septic system.

- **Section 3 - Septic System Management (Pages 4 – 10)**
  In this section we would like to learn about how you manage your septic system, including any problems or challenges you may have faced in the past.

- **Section 4 - Drinking Water (Pages 11 – 13)**
  In this section we want to learn about your domestic household water supply and how you manage your water system.

If you have any questions about the survey or if you would prefer to complete it in a different format, call us at 814-863-4622 or email ffk5024@psu.edu.

Thank you for taking the time to participate in the survey.

Section 1- Household Characteristics

In this section we would like to learn about the home where your on-lot waste management system (septic system) is located

1. Do you live in a home where household wastewater from toilets, showers, sinks, and laundry is disposed of using a septic system?

   ☐ Yes
   ☐ No
   ☐ Not sure

If *No* or *Not sure*, then skip to Page 11 - Section 4, Question 27

2. Is this your primary residence?

   ☐ Yes
   ☐ No
   ☐ Prefer not to answer

3. Please tell us the county and municipality where the residence is located in Pennsylvania.

   County____

   Municipality (e.g. township, borough, city) ______________________________

4. Septic tanks are often designed to match the size of the home. How many bedrooms are in the home?

   ☐ 1 - 3
   ☐ 4 - 6
   ☐ 7 - 9
   ☐ More than 9
   ☐ Other (*Please describe*)

   ____

5. Volume of wastewater from the house is influenced by the number of persons in the household. How many people (adults and children) live in the household?

   ____ people.

Section 2-Septic System Type

In this section we would like to learn more about the type and characteristics of your septic system.

6. What type of septic system do you have?

- ☐ Septic tank with a drainfield/leachfield/soil absorption area (e.g. sand mound, inground trenches or bed)
- ☐ Septic tank with an advanced treatment unit (e.g. aerobic treatment units, media filters such as coco or peat filters, recirculating sand filter)
- ☐ Individual residential spray irrigation system
- ☐ Holding tank
- ☐ Cesspool
- ☐ Not sure
- ☐ Other (*Please describe*) ______________________________

7. When was the septic system installed?

- ☐ Installed less than 12 months ago
- ☐ Installed 1-20 years ago
- ☐ Installed 21-40 years ago
- ☐ More than 40 years ago
- ☐ Not sure
- ☐ Other (*Please describe*) ____

8. What is the size of your septic tank?

- ☐ Less than 1000 gallons
- ☐ 1000 – 1500 gallons
- ☐ More than 1500 gallons
- ☐ Do not know tank size
- ☐ Other (*Please specify*) ____

Section 3-Septic System Management

In this section we would like to learn about how you manage your septic system, including any problems or challenges you may have faced in the past.

9. How frequently do you usually pump out your septic tank?

- ☐ Never been pumped
- ☐ Two times every year
- ☐ Every 1-3 years
- ☐ Every 3-5 years
- ☐ More than 5 years
- ☐ Not sure
- ☐ Other (*Please describe*) ____

If *__Never been pumped__* or *__Not sure__* skip to Question 12 on Page 5

10. Which of the following factors prompt you to get your tank pumped? (*Check all that apply*)

- ☐ Issues with septic system (e.g. sewer odors in the house or drinking water, sewage back up into house plumbing, surface discharge on lawn, etc.)
- ☐ Municipality required proof of septic tank pumping
- ☐ I follow a regular septic tank pumping schedule
- ☐ Recommendation following a septic system inspection
- ☐ Real estate transfer inspections
- ☐ Other factors (*Please describe*)

____

11. About how much did it cost the last time you had your septic tank pumped?

- ☐ $ 0 to 500
- ☐ $ 501 to 1000
- ☐ More than $ 1000
- ☐ Prefer not to answer

12. Users may observe symptoms indicating that the septic system is not working well. Which of the following symptoms have you observed before? (*Check all that apply*)

- ☐ Sewer odors in the house
- ☐ Back up of sewage or water into house plumbing
- ☐ Spongy soil around septic tank, distribution box, or drainfield
- ☐ Doing pump running constantly or not at all
- ☐ Toilet running sluggishly
- ☐ Standing water on drainfield or near septic tanks
- ☐ Bright green grass over septic tanks or drainfield
- ☐ I have not observed any sign of septic system failing
- ☐ Other (*Please describe*) ______________________________

13. A septic system inspection is when a septic professional looks at all septic system parts (these include the septic tanks, distribution box, pipes, drainfield) to ensure everything is working properly. How frequently do you have your septic system inspected?

- ☐ Never been inspected
- ☐ Every 1-3 years

☐ Every 3-5 years
☐ More than 5 years
☐ Not sure
☐ Other (*Please describe*) ____

If *Never been inspected* or *Not sure*, skip to Question 17 on Page 7

14. Which of the following factors prompt you to get your septic system inspected? (*Check all that apply*)

☐ Issues with septic system (e.g. sewer odors in the house or drinking water, sewage back up into house plumbing, surface discharge on lawn, etc.)
☐ Real estate transfer inspection
☐ Municipality required proof of septic system inspection
☐ I follow a regular septic system inspection schedule
☐ Other factors (*Please describe*)

____

15. About how much did it cost the last time you had your septic system inspected?

☐ $ 0 to 500
☐ $ 501 to 1000
☐ More than $ 1000
☐ Do not know
☐ Prefer not to answer

16. What was the outcome of your last septic system inspection? (*Check all that apply*)

☐ All septic system components were functioning properly, and no action was necessary
☐ It was recommended that the septic tank be pumped out
☐ Septic tank needed replacement or repair
☐ There were mechanical issues within the pumps or pipes etc.
☐ There were issues with the drainfield
☐ Other (*Please describe*)

____

17. What factors do you consider before scheduling a septic tank pumping or system inspection? *Check all that apply*

- ☐ Cost of the service
- ☐ Knowing when to have septic system inspection or septic tank pumping
- ☐ Duration of time it takes to inspect or service the system
- ☐ Disruption of planned activities in the home
- ☐ Unpleasant look and odor during system inspection or pumping
- ☐ Finding the right contractor/professional to conduct the inspection or pumping
- ☐ Other (*Please describe*) ____

18. As far as you can recall, have you ever done any septic system repairs or replacements?

- ☐ Yes
- ☐ No

If *No*, skip to Question 22 on Page 8

19. Thinking about the last repair/replacement, what needed to be repaired or replaced? *Check all that apply*

- ☐ Entire septic system
- ☐ Septic tank
- ☐ Septic tank baffles
- ☐ Dosing pump
- ☐ Distribution box
- ☐ Pipes
- ☐ Drainfield
- ☐ Other (*Please describe*) ____________________________________

20. About how much did you spend on the last septic system repair or replacement you did?

- ☐ $ 0 to 500
- ☐ $ 501 to 1000
- ☐ $ 1001 to 5000
- ☐ $ 5001 to 10000
- ☐ More than $10000
- ☐ Do not know
- ☐ Prefer not to answer

21. Which of the following septic system repair funding programs have you used before? *Check all that apply*

- ☐ I have not used any funding program for septic system repairs
- ☐ Pennsylvania Infrastructure Investment Authority (PENNVEST)
- ☐ USDA Rural Development
- ☐ Pennsylvania Housing Finance Agency (PHFA)
- ☐ I use other funding programs (*Please describe*)

____

22. In your view, what are the benefits of having a private septic system? *Check all that apply*

- ☐ No sewer bill
- ☐ Long term reliability
- ☐ Environmentally friendly
- ☐ Ability to care for my own system
- ☐ Other (*Please describe*) ______________________________

23. What are your biggest challenges with having a septic system? *Check all that apply*

- ☐ Regulatory requirements for permitting and installation
- ☐ Initial installation costs
- ☐ The cost of routine septic system inspections and septic tank pumping
- ☐ Issues when septic system is not functioning correctly (e.g. sewer odors in the home, sewage back up into house plumbing, sewage discharge on lawn, etc.)
- ☐ Repair and replacement needs for old or failing system
- ☐ Finding information on how to take care of the septic system
- ☐ Other (*Please describe*) ______________________________

24. Where do you get relevant information on septic system care and maintenance? *Check all that apply*

- ☐ Local government body or agency e.g., municipality
- ☐ PA Department of Environmental Protection (DEP)
- ☐ Sewage Enforcement Officer (SEO)
- ☐ Penn State Extension
- ☐ Recommendations from neighbors, family or friends
- ☐ Recommendations from local septic system contractors
- ☐ Internet searches or social media
- ☐ Other (*Please describe*) ______________________________

25. Which of the following services would you consider if they were available in your area to help with managing your septic system? *Check all that apply.*

    ☐ Receiving generalized reminders by mail, email, or phone about septic system operation, care, and maintenance from your municipality
    ☐ Receiving reminders unique to your septic system about operation and care as well as time for inspection, pump outs, and maintenance from your municipality
    ☐ Contracting a third-party entity to keep up with and ensure all septic system functionality, care, inspection, pump outs, and maintenance
    ☐ Connecting to local public sewer
    ☐ Other comments (*Please describe*)

    ____

26. To what extent do you agree or disagree with the following statements about your septic system?

Statement	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I plan for septic system inspection and pumping costs along with other home maintenance costs	○	○	○	○	○
I restrict what I flush or pour down the drain to protect my septic system	○	○	○	○	○
I typically divert run-off from paved surfaces, downspouts, sump pumps, and pool overflows away from my septic tank and drainfield	○	○	○	○	○
I keep equipment, vehicles, swimming pools, or livestock away from my septic tank and drainfield	○	○	○	○	○
I do not plant trees or shrubs over my septic system or drainfield	○	○	○	○	○

Section 4- Drinking Water

In this section we want to learn about your domestic household water supply and how you manage your water system.

27. What is your drinking water source?

    ☐ Private well or spring

- ☐ Roadside or communal spring
- ☐ City/Municipal water
- ☐ Bottled water
- ☐ Other (*Please describe*) ____________________

If *Private well or spring*, we would like to learn more about your system. Please continue to Question 28.

If *Roadside spring, City/municipal water, or Bottled water*, this is the end of the survey. Thank you so much for taking the time to complete the survey.

28. Has your private well or spring water been tested using a certified laboratory?

- ☐ Yes
- ☐ No
- ☐ Unsure

If *No* or *Unsure*, skip to Question 30 on Page 12

29. What prompted you to get the well or spring water tested? (*check all that apply*)

- ☐ Well or spring inspection
- ☐ Changes in water taste, smell, appearance and/or feel
- ☐ A pollution source near well or spring
- ☐ I get well or spring tested routinely (*Please describe*)
  ____
- ☐ Real estate transfer
- ☐ Other (*Please describe*) ____________________

30. In your view, what do you enjoy about having and using a private water system? *Check all that apply*

- ☐ No water bill
- ☐ Long term reliability
- ☐ Good water quality
- ☐ Ability to care for my own water source and treat my own water
- ☐ Other (*Please describe*) ____________________

31. What are the biggest challenges you face with having a private water system? *Check all that apply*

- ☐ Regulatory requirements for installation
- ☐ Initial installation costs
- ☐ The cost of routine inspections and water testing

- ☐ Water quality issues
- ☐ Initial installation cost of water treatment devices
- ☐ Requirements for maintaining water treatment devices
- ☐ Water quantity issues
- ☐ Finding resources for caring and maintaining private water systems
- ☐ Other (*Please describe*) ____________________

32. What are your opinions about the following statements about your private water system?

Statement	**Strongly Agree**	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
I have enough information about how to care for my private water system	○	○	○	○	○
It is easy to find professionals to inspect my private water system	○	○	○	○	○
It is easy to find certified laboratories to test my private water system	○	○	○	○	○
I understand how to protect my private drinking water source from septic system contamination	○	○	○	○	○
It is challenging to understand how to treat my drinking water	○	○	○	○	○

33. As part of this study, we will select qualifying individuals for a free well or spring water testing. If you qualify, would you be willing to be contacted for the well water testing program?

- ☐ Yes
- ☐ No

If *Yes*, Please answer Question 34 below.

If *No*, this is the end of the survey. Thank you so much for taking the time to complete the survey.

34. If you answered '*Yes*' to question 33 above and you would like to be considered for the water testing program, please share your contact information below so that we can reach out to you if you qualify:

a. Name ____

b. Phone number____ or

c. Email address ____

Thank you so much for taking the time to completely answer the survey!

Appendix 3: Sample Collection Procedure

Thank you for participating in the study. Please read all instructions before collecting your water sample. You have received a water test kit that consists of the following:

- Sample Collection Procedure
- Sample Submission Form
- Ziplock plastic bags for ice
- Bacteria Sample Bottle (Green Label)
- Inorganics Sample Bottle (Yellow Label)
- Prepaid overnight FedEx label
- Foam cooler and shipping box

General Instructions:

- Find a sample collection location to collect your raw (untreated) well or spring water. Ideal locations might be from your well tank spigot or an outdoor spigot bypassing any water treatment devices you may have. Fill all sample bottles.
- Ensure that you have ice that will be used to preserve the samples during packaging the night before sample collection. This is critical to ensure that your samples are preserved during transit.
- We have an overnight FedEx shipping label. Identify a FedEx shipping or drop-off location ahead of time. Please collect and ship your samples on Mondays, Tuesdays, or Wednesdays to ensure that samples are delivered during business hours.

Step 1: Bacteria Sample Bottle (Green Label):

- Use the identified sample collection location that allows for your raw (untreated) well or spring water to be collected. Run the water for about 5 minutes to ensure that the samples represent water from your water supply
- The bacteria bottle has been sterilized and contains a reagent, sodium thiosulfate (in tablet or powder form). Do not remove the sodium thiosulfate tablet or powder.
- Take care not to touch or otherwise contaminate the inside of the bottle or lid. Carefully remove the lid from the sample container and hold the lid by the outside.
- Fill the container with water to the line marked “100 mL”. Screw the lid tightly.

Step 2: Inorganics Sample Bottle (Yellow Label):

- Collect this sample from the same sampling location for your raw (untreated) well or spring water. If you have already run the water for five minutes to collect the bacteria sample, you do not need to run the water again for this sample.
- Rinse this bottle three times with water from your faucet by filling it about one third full, screw the lid on and shake the bottle a few times. Dump out the water and repeat this procedure two more times to completely rinse the bottle.
- Fill the bottle to the top and screw the lid on tightly to prevent leakage. Refrigerate the sample until you are ready to deliver it to the laboratory.

Step 3: Packaging Collected Samples

- Fill out the enclosed sample submission form. Fill Ziplock bags with ice and pack them with collected samples inside the foam cooler. Refrigerate samples until you are ready to send to the laboratory. Samples for bacteria analysis must arrive at the laboratory within 30 hours of collection to produce accurate results.

Appendix 4: Sample Submission Form

Drinking Water
Sample Submission Form

Agricultural Analytical Services Laboratory

Your name and contact information:
Name: ______________________________
Address: ______________________________
City: ______________________________
State: ______________ Zip: ____________
Telephone: ______________________________
Email: ______________________________

Additional copy to name and contact information:
Name: ______________________________
Address: ______________________________
City: ______________________________
State: ______________ Zip: ____________
Telephone: ______________________________
Email: ______________________________

Sample Information-PSU Septic System Survey

Sample ID *(i.e. Kitchen faucet, etc...)*:____________________ Date sampled:____________ Time sampled: ________ AM or PM
(Date and time sampled must be completed)

County location: ______________________________

What water supply source did you sample from? (*check one*)
___Drilled well
___Hand-dug well
___Spring
___Rainwater cistern
___Other (please specify)____________

If you have a well, how deep is it?________ Feet

Which of the following private water supply construction features do you have? *(select all that apply to the water source that you sampled from)*

___Above ground well casing ____Spring box
___Sanitary well cap ___Watertight cistern cover
___Group seal ___None
___Do not know

Approximately what year was your water supply drilled/constructed/installed?________

What is the distance between your water supply relative to your septic tank/drainfield?________ Feet

What water treatment devices do you have installed to treat your water supply before use?

___No water treatment ___Water softener ___Aeration system
___Ultraviolet light ___Reverse osmosis system ___Chlorination system
___Distillation unit ___Iron removal (oxidizing filter) ___Nitrate removal system
___Carbon filter ___Small faucet filter (Brita® , etc.) ___Sediment filter
Other (*please specify*):____________________

Sample Receipt (lab use only)

# of containers:	Container(s) in good condition?	Sample cooled or on ice?	Ice melted: Y or N	Temp °C:	Data entry

PennState Extension

Agricultural Analytical Services Laboratory
720 Tower Rd. • The Pennsylvania State University
University Park, PA 16802 • Phone: 814-863-0841
Fax: 814-863-4540 • Web: **agsci.psu.edu/aasl**

Appendix 5: Summary of Analytical Methods Used

Analyte Category	Analyte	Lower Limit of Quantification (LOQ)	Sample Preservation	Analytical Method
Microbial contaminants with primary (Health-based) drinking water standards	Total Coliform			
	Escherichia coli (*E. coli)*	1 MPN[1]100/mL	Sodium thiosulfate, <10 °C but not frozen	SM 9223 B[2]
Inorganics with primary (Health-based) drinking water standards	Arsenic	0.003 mg/L	HNO_3, pH <2	EPA 200.5[3]
	Barium	0.001 mg/L	HNO_3, pH <2	EPA 200.7[4]
	Copper	0.005 mg/L	HNO_3, pH <2	EPA 200.7[4]
	Lead	0.05 mg/L	HNO_3, pH <2	EPA 200.5[3]
	Nitrate	0.2 mg/L	Cool, ≤6 °C	SM 4110 B
Analytes with secondary (Aesthetic) drinking water standards	Aluminum	0.01 mg/L	HNO_3, pH <2	EPA 200.7[4]
	Chloride	1.0 mg/L	None required	SM 4110 B[2]
	Copper	0.005 mg/L	HNO_3, pH <2	EPA 200.7[4]
	Iron	0.05 mg/L	HNO_3, pH <2	EPA 200.7[4]
	Manganese	0.005 mg/L	HNO_3, pH <2	EPA 200.7[4]
	pH	--	None required	SM 4500-H^+ B[2]
	Sulfate	1.0 mg/L	Cool, ≤6 °C	SM 4110 B[2]
	Total dissolved solids (TDS)	--	--	Calculated
Analytes that have not been regulated yet in drinking water	Nickel	0.005 mg/L	HNO_3, pH <2	EPA 200.7[4]
	Total Phosphorous	0.025 mg/L		EPA 200.7[4]

1) Most probable number; 2APHA, AWWA, & WEF. 2017; 3USEPA 2002; 4USEPA (1994); HNO_3-Nitric acid.

Appendix 6: Summary of Local Septic System Maintenance Ordinances Across the Commonwealth

Appendix 6-1: Municipalities where survey participants reported that they were required to show proof of system inspection and septic tank pumping.

County	Municipality	Proof of Inspection	Proof of Pumping
Adams	Carroll Valley Borough	x	x
Adams	Hamiltonban Township	x	x
Adams	Butler Township	x	x
Adams	Tyrone Township	x	x
Adams	Latimore Township		x
Adams	Franklin Township	x	x
Berks	Upper Bern Township		x
Berks	Robeson Township	x	x
Berks	Tilden Township	x	x
Berks	Centre Township	x	x
Berks	Longswamp Township		x
Berks	Ruscombmanor Township	x	x
Berks	Earl Township	x	x
Blair	Snyder Township		x
Bucks	Milford Township	x	x
Bucks	Solebury Township	x	x
Bucks	Haycock Township		x
Bucks	Wrightstown Township	x	x
Bucks	Nockamixon Township	x	x
Centre	Ferguson Township	x	x
Centre	Patton Township	x	x
Centre	Potter Township	x	x
Centre	Benner Township	x	x
Centre	Halfmoon Township	x	x
Centre	Gregg Township	x	x
Chester	Upper Uwchlan Township	x	x
Chester	London Britain Township		x
Chester	London Grove Township		x
Chester	Pennsbury Township		x
Chester	West Goshen Township		x
Chester	Westtown Township	x	x
Chester	East Vincent Township	x	x
Chester	New London Township	x	x
Chester	West Sadsbury Township	x	x

Chester	East Bradford Township	x	x
Chester	Wallace Township	x	x
Cumberland	Upper Allen Township	x	x
Cumberland	Dickinson Township	x	x
Cumberland	South Middleton Township	x	x
Cumberland	West Pennsboro Township	x	x
Dauphin	East Hanover Township		x
Dauphin	South Hanover Township	x	x
Elk	Ridgway Township		x
Franklin	Southampton Township		x
Franklin	Guilford Township		x
Franklin	Metal Township		x
Fulton	Bethel Township	x	x
Huntingdon	Warriors Mark Township	x	x
Lancaster	East Lampeter Township		x
Lancaster	West Cocalico Township	x	x
Lancaster	Rapho Township	x	x
Lancaster	East Cocalico Township	x	x
Lancaster	Elizabeth Township	x	x
Lancaster	West Earl Township		x
Lancaster	Leacock Township		x
Lebanon	South Lebanon Township		x
Lebanon	North Cornwall Township	x	x
Lebanon	East Hanover Township		x
Lebanon	North Londonderry Twp	x	x
Lebanon	North Annville Township		x
Lebanon	Heidelberg Township		x
Lehigh	Upper Macungie Township	x	x
Lehigh	Lower Macungie Township	x	x
Lycoming	Muncy Township	x	x
Lycoming	Loyalsock Township	x	x
Lycoming	Wolf Township		x
Monroe	Tobyhanna Township	x	x
Montgomery	Towamencin Township	x	x
Montgomery	Lower Frederick Township		x
Northumberland	Lewis Township		x
Schuylkill	South Manheim Township	x	x
Venango	Sugarcreek Borough		x
York	North Codorus Township		x
York	Newberry Township		x
York	Jacobus Borough	x	x
York	West Manchester Township		x

York	Fawn Grove Borough	x	x
York	Dover Township		x
York	Jackson Township	x	x
York	Lower Windsor Township	x	x
York	Hellam Township		x
York	Hopewell Township	x	x
York	Warrington Township	x	x
York	Chanceford Township	x	x
York	Spring Garden Township		x

Appendix 6-2: Septic Ordinances for Selected Pennsylvania Municipalities With the Highest Number of Survey Responses

County	Municipality	Pumping Frequency	Who Pumps?	Waivers Allowed?	Inspection Frequency	Who Inspects	Inspection Details
Adams	Abbottstown Borough	Every 3 years	Registered hauler	--	Every time pumped	Registered pumper and Borough SEO	Dye tracing, sampling, physical tour
Adams	Berwick Township	Every 4 years or solids > ⅓	Licensed hauler	--	Any reasonable time	SEO	Physical tour of the property; water samples,
Adams	Butler Township	Every 3 years or solids > ⅓	Qualified hauler	--	Every time pumped	SEO	Physical property tour, water and sewage sampling, and dye tracing
Adams	Carroll Valley Borough	Every 3 years or solids > ⅓; Receipts submitted within 14 days	Qualified hauler	--	Every 3 years	SEO or authorized agent	Water sampling, sewage inspection
Adams	Franklin Township	Every 3 years or solids > ⅓	Qualified hauler	--	Any reasonable time	SEO	Full inspection
Adams	Mt Joy Township	Every 4 years or solids > ⅓	Qualified hauler	--	Routine or complaint-based	SEO	Full inspection with dye tracing
Adams	Smithfield Township	Every 3 years; maybe reduced	Qualified hauler	Yes	Any reasonable time	SEO	Full inspection with sampling and dye tracing

Adams	Oxford	Every 4 years or solids > ⅓	Qualified hauler	--	Visual inspection every 1 year and when pumped	SEO and authorized pumper	Surface visual check only
Adams	Reading Townships	Every 4 years or solids > ⅓	Authorized hauler	--	Every 5 years or solids > ⅓	Any authorized agent	Visual inspection of surrounding area, sampling of tank and groundwater, traceable substances in plumbing to make a full report
Adams	Union	Every 4 years unless extended due to low use	Qualified pumper/hauler	--	May be inspected whenever tank is pumped	SEO and pumper	Physical tour, Water sampling, introduction of traceable substance into plumbing to track wastewater path
Adams	Straban and Tyrone	Every 3 years based on the designated district rotation	Registered pumper	--	Every 3 years	SEO and pumper	Physical tour, water sampling, dye testing;
Blair	Allegheny	Every 3 years	--	--	Any reasonable time	SEO	--
Blair	Catharine Township	Every 5 years or solids > ⅓	Qualified pumper/hauler	--	Any reasonable time	Authorized agent	Property tour, water sampling, effluent path tracing
Blair	Logan Township	Every 3 years or solids > ⅓; holding tanks as needed	Licensed hauler	--	As needed	BCSAC or designee	Effluent testing for chlorine, BOD, coliform, solids
Blair	Woodbury Township	Every 3 years or solids > ⅓	Licensed hauler	--	Any reasonable time	SEO	Full inspection with dye tracing
Bradford	Athens Township	Every 3 years	Agency selected by Township	--	Any on-lot system may be inspected in different months of the year if septic system is malfunctioning, if pumping is required more frequently, if	Township or authorized agent	May include sampling surface/groundwater sources nearby

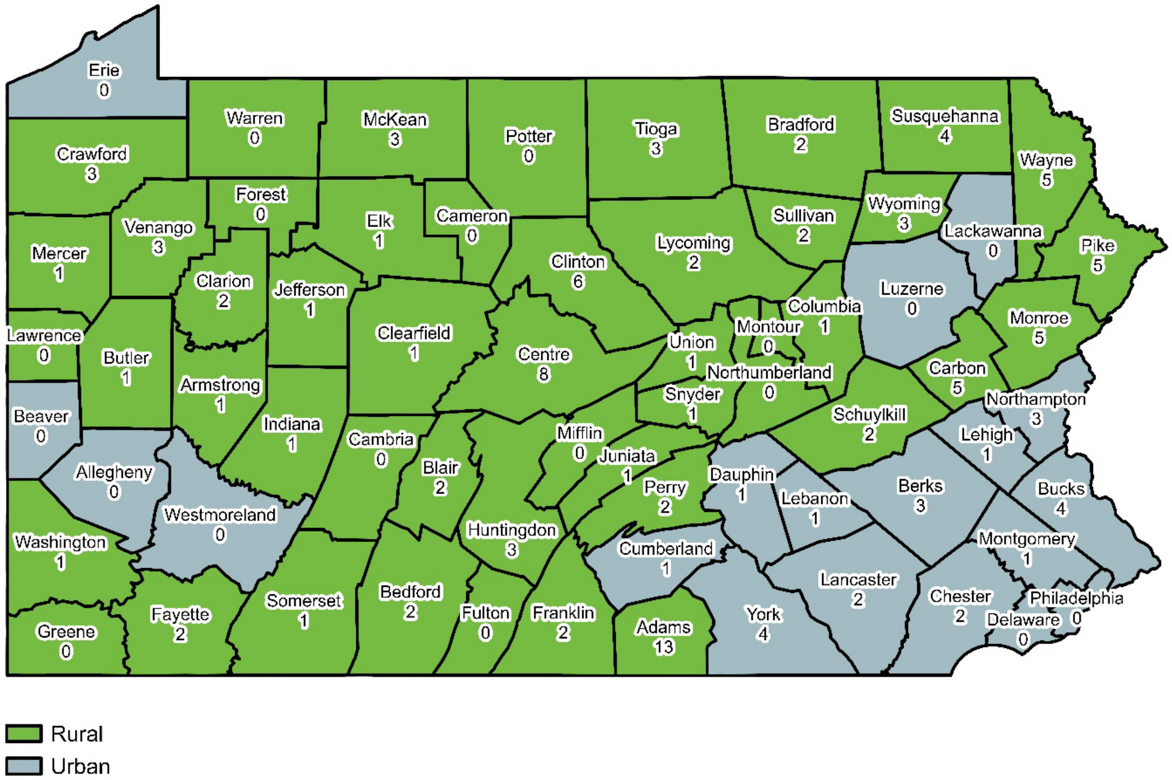
					occupancy increases		
Bradford	Borough of Sayre	Every 3 years	--	--	Any on-lot system may be inspected in different months of the year if septic system is malfunctioning, if pumping is required more frequently, if occupancy increases	Township, SEO, or authorized agent	Inspection of the septic system components and may include surface/groundwater sources nearby
Carbon	Jim Thorpe Borough	Every 5 years or sooner if solids > ⅓	Licensed hauler	--	Any reasonable time	Borough	Receipt and inspection report required
Centre	Benner, Halfmoon, Harris, Potter, and Spring Townships	Every 3 years; receipts due in 30 days	Qualified pumper/hauler	Yes	Every 6 years	Certified SEO	Same as Benner
Clinton	Greene Township	Every 3 years or solids > ⅓	Licensed hauler	Yes	Routine or triggered by a complaint	SEO	Full inspection, dye tracing, water sampling
Clinton	Potter Township	Every 3 years; may be more frequent if tank is undersized	Qualified pumper/hauler	--	Any reasonable time and routinely if needed	SEO or authorized agent	Physical tour, sampling of surface/groundwater, contents, tracing flow with dye or tracer
Huntingdon	Juniata Township	Every 3 years	Qualified hauler	--	When pumped (every 3 years)	SEO	Visual inspection of tank and its surroundings for signs of malfunctions
Huntingdon	Shirley Township	Every 4 years; sewer required when accessible	Licensed hauler	Yes	When pumped (every 4 years) or malfunction-based	SEO	Visual tour, sampling of surface water, wells, or system contents; dye testing

Huntingdon	Smithfield Township	Every 3 years; sewer required when accessible	Authorized hauler	Yes	Any reasonable time	SEO	Physical tour, sampling of surface water, wells, system contents, dye testing
Huntingdon	Walker Township	Authority checks every 3 years and pumps if needed	Qualified hauler	--	Every 3 years	Authority personnel (SEO or Township engineer)	Structural compliance, watertight tank, placement, risers
Huntingdon	Warriors Mark Township	Every 3 years or more if inspection shows solids > ⅓	Qualified hauler	Yes	Every 6 years	SEO	Checking tanks and baffles, solids and scum levels.
Monroe	Barrett Township	Only if malfunctioning or SEO discretion	Qualified hauler	--	As needed; routine may be established for malfunctioning systems	SEO	Dye tracing, baffle inspection
Monroe	Coolbaugh Township	Every 5 years or solids > ⅓	Qualified hauler	--	Initial inspection within 5 years; routine inspection optional after	SEO	Baffle inspection and receipt submission
Monroe	Mount Pocono Borough	Every 3 years or solids > ⅓	Qualified hauler	--	Every 3 years when pumped	--	Baffle inspection required
Monroe	Pocono Township	Every 3 years or solids > ⅓	Qualified hauler	--	As needed; routine may be established for malfunctioning systems	--	--
Monroe	Smithfield Township	Every 3 years, can be adjusted if approved by SEO	Qualified hauler	Yes, if the system is underused, oversized, or in good condition. SEO approval needed	No fixed schedule; Township has the right to inspect any system at any reasonable time	SEO or authorized agent	May include property walk-through, sampling of surface water/wells/sewage, dye testing, and system condition checks

Pike	Delaware Township	Every 3 years or solids > ⅓	Licensed hauler	--	Every 3 years	SEO	Tank diagram, sludge depth, hauler info
Pike	Dingman Township	Triggered by complaints or health risk evidence	Licensed hauler	--	After corrective action for malfunctions or periodic in high-risk areas	SEO	Property inspection, soil survey analysis
Pike	Lackawaxen Township	As needed; based on malfunction history, risk or household size	Licensed hauler	--	Complaint-based or high-risk areas	SEO	Dye testing or bacteriological sampling
Pike	Matamoras Borough	No set frequency; based on risk or complaints	Licensed hauler	--	Any reasonable time; Complaint-based or high-risk areas	SEO	--
Pike	Milford Borough	As needed; council discretion	Licensed hauler	--	As needed. Follow-up at 6 months and 2 years if malfunction	SEO or authorized agent	Dye testing, surface discharge check, plot plan

Note: Information is reported for municipalities with ordinances on a publicly accessible website only.

Appendix 7: Distribution of Water Testing Participants Across Pennsylvania (*n*=125)



Appendix 8: Summary Water Quality Statistics Based on Septic System Maintenance and Characteristics

Appendix 8-1: Average concentrations of different substances when grouped based on self-reported septic maintenance practices. Complete maintenance corresponds with systems inspected and pumped within the recommended frequencies and partial maintenance constitutes pumping without inspection or inspection with no pumping. Systems with irregular maintenance were inspected and pumped outside the recommended schedules, while poor maintenance was for systems that have never been inspected or pumped or those with unknown maintenance records

Contaminant	**Complete Maintenance (*n*=39)**	**Partial Maintenance (*n*=54)**	**Irregular Maintenance (*n*=15)**	**Poor Maintenance (*n*=8)**
Total Coliform (MPN/100 mL)	40 ± 58.51	52 ± 73.26	83 ± 90.26	72 ± 91.16
E. coli (MPN/100 mL)	5 ± 6.13	9 ± 13.29	9 ± 0.00	22 ± 0.00
Arsenic (mg/L)	0.009 ± 0.01	0.01 ± 0.01	0.01 ± 0.002	0.004 ± 0.00
Barium (mg/L)	0.112 ± 0.17	0.16 ± 0.51	0.11 ± 0.17	0.151 ± 0.19
Cadmium (mg/L)	—	—	—	—
Chromium (mg/L)	0.059 ± 0.00	0.02 ± 0.00	—	—
Copper (mg/L)	0.051 ± 0.06	0.08 ± 0.14	0.03 ± 0.04	0.137 ± 0.16
Lead (mg/L)	0.007 ± 0.01	0.02 ± 0.03	0.01 ± 0.01	0.009 ± 0.004
Nitrate (mg/L)	4 ± 4.93	3 ± 3.26	2 ± 2.18	3 ± 2.86
Chloride (mg/L)	28 ± 37.64	25 ± 35.18	36 ± 89.04	10 ± 9.12
Manganese (mg/L)	0.120 ± 0.28	0.56 ± 1.15	0.11 ± 0.09	0.377 ± 0.34
Sulfate (mg/L)	16 ± 13.99	20 ± 26.93	22 ± 25.90	19 ± 20.21
Aluminum (mg/L)	2 ± 8.85	0.18 ± 0.48	0.27 ± 0.30	0.111 ± 0.10
Nickel (mg/L)	0.021 ± 0.04	0.02 ± 0.02	0.01 ± 0.001	0.016 ± 0.01
Total Phosphorous (mg/L)	0.171 ± 0.46	0.07 ± 0.08	0.05 ± 0.03	0.021 ± 0.01
pH	7 ± 0.89	7 ± 0.87	7 ± 0.57	7 ± 0.91
Total Dissolved Solids (mg/L)	208 ± 139.29	194 ± 147.46	204 ± 188.27	131 ± 76.21

Appendix 8-2: Average concentrations of different substances when grouped based on self-reported age of septic maintenance practices.

Contaminant	>40 Years (*n*=40)	21-40 Years (*n*=36)	1-20 Years (*n*=36)
Total Coliform (MPN/100 mL)	61.96 ± 82.31	25.19 ± 44.67	86.23 ± 86.72
E. coli (MPN/100 mL)	11.00 ± 10.47	1.50 ± 0.50	11.50 ± 10.50
Arsenic (mg/L)	0.006 ± 0.003	0.010 ± 0.007	0.0091 ± 0.0086
Barium (mg/L)	0.17 ± 0.58	0.087 ± 0.119	0.142 ± 0.194
Cadmium (mg/L)	—	—	—
Chromium (mg/L)	0.018 ± 0.00	0.059 ± 0.00	—
Copper (mg/L)	0.091 ± 0.15	0.062 ± 0.101	0.0480 ± 0.0493
Lead (mg/L)	0.019 ± 0.036	0.0085 ± 0.0063	0.0093 ± 0.0066
Nitrate (mg/L)	3.49 ± 3.49	2.27 ± 1.97	3.73 ± 5.36
Chloride (mg/L)	39.36 ± 68.64	18.35 ± 23.15	20.52 ± 24.68
Manganese (mg/L)	0.37 ± 0.79	0.32 ± 0.52	0.432 ± 1.187
Sulfate (mg/L)	24.16 ± 31.21	14.90 ± 13.49	17.24 ± 18.87
Aluminum (mg/L)	0.25 ± 0.47	3.16 ± 10.40	0.0547 ± 0.0608
Nickel (mg/L)	0.016 ± 0.021	0.016 ± 0.009	0.0222 ± 0.0378
Total Phosphorous (mg/L)	0.087 ± 0.119	0.19 ± 0.50	0.040 ± 0.028
pH	6.88 ± 1.02	7.04 ± 0.77	6.90 ± 0.76
Total Dissolved Solids (mg/L)	231.20 ± 189.38	170.00 ± 122.19	177.53 ± 105.38

Appendix 9: Summary Penn State Extension Webinars on Septic Systems

In collaboration with the Pennsylvania Septage Management Association (PSMA) and the Pennsylvania Association of Sewage Enforcement Officers (PASEO), Penn State Extension has provided a variety of webinars for the general public. All the webinars were recorded and links sent to everyone who registered. The links are active for 6 months.

2024 septic system webinar series covered:

- Introduction to On-Lot Septic Systems - 10/1/24. The instructor was Faith Kibuye (PSU Extension)
- Installation of On-Lot Septic Systems - 10/15/24. The instructor was Roger Lehmann (PASEO),
- Maintenance of On-Lot Septic Systems - 10/29/24. The instructor was Peter Wulfhorst (PSU Extension)
- Common Issues with On-Lot Septic Systems - 11/12/24. The instructors were Craig Morris and Frank Perker (PSMA)
- Do On-Lot Septic Systems Impact Water Quality - 11/26/24. The instructor was Faith Kibuye (PSU Extension).
- On-Lot Septic System Q&A - 12/10/24. The panelists were PA Department of Environmental Protection representatives including Tomisa Kiskadden, Annamaria De Sanctis, Janice Vollero), Rachel Wick-Evangelista (PSMA), and Roger Lehmann (PASEO),

2025 septic system webinar series covered:

- Septic System Basics - 09/16/25. Instructors were Faith Kibuye and Andy Yencha (PSU Extension), Roger Lehmann (PASEO), and Rachel Wick-Evangelista (PSMA). Webinar recording: https://psu.mediaspace.kaltura.com/media/Septic+System+Basics/1_ulgbak02
- Alternative Septic Systems - 09/30/25. The instructor was Roger Lehmann (PASEO). Webinar recording: https://psu.mediaspace.kaltura.com/media/Septic+System+Series%3A+Alternative+Septic+Systems/1_j3t6c7iz
- Landscaping Around Septic Systems - 10/14/25. Instructors were Craig Morris and Frank Perker (PSMA). Webinar recording: https://psu.mediaspace.kaltura.com/media/Septic+System+Series%3A+Landscaping+Around+Septic+Systems/1_hgsumhum
- Real Estate Transactions and Septic Systems - 10/28/25. The instructor was Rachel Wick-Evangelista (PSMA). Webinar recording: https://psu.mediaspace.kaltura.com/media/Septic+System+Series%3A+Real+Estate+and+Septic+Systems/1_up0l19vq

- Septic-Water Connections - 11/11/25 (PSU Extension). The instructors were Faith Kibuye and Susan Boser (PSU Extension). This webinar included some survey and water testing data collected from this study. Webinar recording: https://psu.mediaspace.kaltura.com/media/Septic+System+Series%3A+Septic-Water+Connections+/1_pxlwanrp
- Septic System Finances - 11/25/25. The instructors were Faith Kibuye (PSU Extension), Rachel Wick-Evangelista (PSMA), Roverta Schwalm (PA Housing Finance Agency), Gary S. Reed (USDA Rural Development), and Teri Provost (PA Department of Community & Economic Development). This webinar included some survey data on the costs of septic system maintenance and repairs collected from this study. Webinar recording: https://psu.mediaspace.kaltura.com/media/Septic+System+Series%3A+Finances/1_dlcnntu6

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