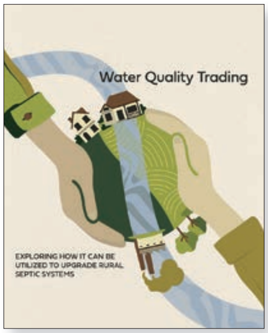


Water Quality Trading Mechanism Enhances Willingness to Upgrade Rural Household Septic Systems in the Western Lake Erie Basin, Northwest Ohio

Yanting Guo, MSc, PhD
Department of Environment, Safety, and Occupational Health
The University of Findlay

Karen Mancl, MS, MA, PhD
Department of Food, Agricultural, and Biological Engineering
The Ohio State University

Richard Moore, MA, PhD
School of Environment and Natural Resources
The Ohio State University

Abstract **Water quality trading (WQT) is a market-based mechanism that aims to improve water quality in a way that maximizes economic efficiency while conserving environmental integrity. It is a compliance approach that allows point sources, such as factories, to meet regulatory obligations by using pollutant reductions created by another source, such as local farms, which has lower pollution control costs. The objective of this study was to explore the possibility of expanding the use of WQT from agriculture to rural septic systems, an often-neglected nonpoint source of nutrients to Lake Erie. Septic system upgrades in northwestern Ohio are of special interest because the soil conditions in this area pose a limitation to the effectiveness of nutrient removal for conventional soil-based systems. We assessed the willingness of septic system users to upgrade their systems using three scenarios emphasizing climate change, governmental regulation, or WQT. We found that septic system users were most interested in upgrades under the WQT scenario. The idea of WQT was better accepted in certain locations where septic system users were more concerned about the environment, perceived the local water quality to be degraded, and were aware of the limitation of their septic systems. Pilot WQT projects should focus on approaching these users.**

Introduction

The western part of Lake Erie has suffered from increasingly severe eutrophication and frequent harmful algae blooms (HABs) since the mid-1990s (Kane, Conroy, Richards, Baker, & Culver, 2014). The toxic or potentially toxic cyanobacterial HABs have threatened the health of millions who depend on Lake Erie as a drinking water source (Michalak et al., 2013; Stumpf, Wynne, Baker, & Fahnenstiel, 2012). The Lake Erie HABs mainly have been caused by the overloading of nonpoint-source phosphorus, most of which comes from the Maumee River during springtime (Ho & Michalak, 2017). The Phosphorus Task Force of Ohio (Ohio Environmental Protection Agency, 2010) identified two main nonpoint phosphorus sources: agriculture and rural septic systems.

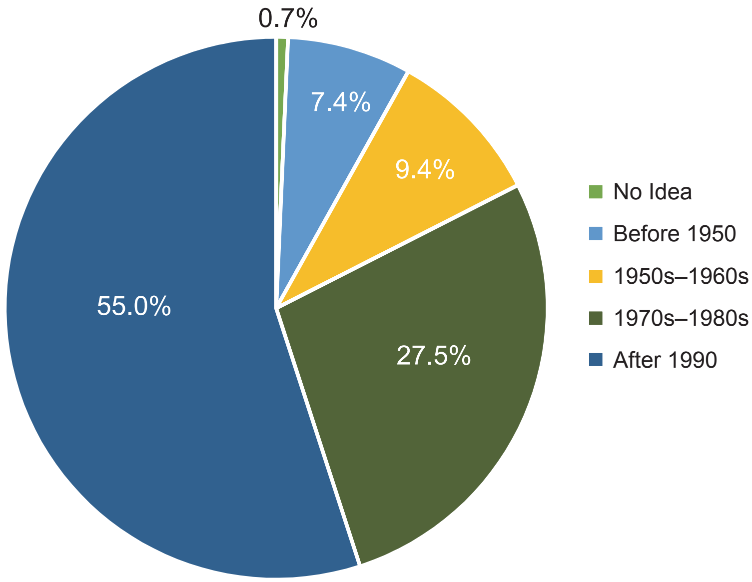
The Ohio Department of Health estimated about 352 tons/year of total phosphorus (TP) was contained in the onsite septic system effluent of the 148,000 homes discharging into the Lake Erie watershed (Ohio Department of Health, 2008). About 25% of this discharge reaches a waterway, contributing 88 tons/year of TP to Lake Erie. In our study site in the Blanchard River Watershed, a subwatershed of the Maumee River Watershed that drains into western Lake Erie, septic systems are the fourth largest source of phosphorus, contributing 7.83 tons of phosphorus to the watershed every year, which is even higher than the 6.19 tons/year contribution from point sources (Ohio Environmental Protection Agency, 2009).

In addition to their effect on Lake Erie HABs, septic systems present a public health threat. Septic systems are the major reservoir of human enteropathogens. If not properly treated, septic system effluent can contaminate groundwater and surface water. The Ohio Department of Health and Ohio Environmental Protection Agency (2013) and Vedachalam and coauthors (2012) estimated that the septic system failure rate in Ohio is around 30%. This translates to approximately 120 million gallons/day of untreated or partially treated wastewater being discharged to ground and surface waters (Vedachalam, Hacker, & Mancl, 2012).

In Ohio, the main causes of septic system malfunctioning include aging (44%), overloading (43%), soil limitations (33%), and site limitations (25%) (Ohio Department of Health & Ohio Environmental Protection

FIGURE 1

Surveyed Household Septic System Installation Years



Agency, 2013). Soil limitations are of critical importance. Only unsaturated, deep (>4 ft), and permeable soil can effectively remove suspended solids, organic matter, ammonia, bacteria, and viruses (Mancl & Slater, 2015). While 72% of all systems installed in Ohio were traditional soil-based septic systems (Vedachalam et al., 2012), 68.2% of the soil in Ohio is considered not suitable for soil-based septic systems because the soil is <4 ft deep to the water table or a restrictive layer, subject to frequent flooding, or poorly permeable soil (Mancl & Slater, 2015).

The proportion of unsuitable soil is the highest in northwest Ohio (Mancl & Slater, 2015), so not surprisingly, the estimated failure rate of septic systems in northwest Ohio is the highest (39%) compared with other parts of the state (Ohio Department of Health & Ohio Environmental Protection Agency, 2013). Northwest Ohio is where the Western Lake Erie Basin and the former Great Black Swamp overlapped. The Great Black Swamp was one of the biggest wetlands in the U.S. over a century ago. Although the area was transformed into farmland with deep, artificial drainage ditches from the 1860s to the turn of the century, most soil in this area is still easily saturated (Levy, 2017).

From 1958–2012, the amount of rainfall in what are categorized as "very heavy rain events" has increased 30–39%. This amount is predicted to increase by up to 5 times by 2081–2100 compared with the last two decades of the 20th century in the northern part of the U.S., including northwest Ohio (Walsh et al., 2014). The negative impact of failing septic systems on water quality and environmental health is expected to worsen. Unfortunately, failing septic systems have long been ignored in watershed management programs. To fill this gap, this study aimed to promote soil-based septic system upgrades on a watershed scale using an approach called water quality trading (WQT).

WQT allows point sources, such as factories and wastewater treatment plants, to meet their regulatory obligations of the National Pollutant Discharge Elimination System (NPDES) by using pollutant reductions created by another source that has lower pollution control costs (U.S. Environmental Protection Agency, 2004). For example, The Freshwater Trust has successfully operated multiple WQT projects in Oregon. A thermal credit trading between the city of Medford's wastewater treatment plant and local landowners in the Rogue River Watershed has led to the planting of nearly 90,000 native plants along 25,109 ft of stream, reducing 594 lb of nitrogen per year and 438 million kilocalories from solar energy per day (The Freshwater Trust, 2016). Implementation of this project saved the taxpayers approximately $8 million (The Freshwater Trust, 2016).

Several WQT programs have included septic system upgrades into their design. For example, in the South Nation River WQT program in Ontario, Canada, septic system upgrades were a major credit-generating conservation measure. More recent programs, such as the Chesapeake Bay Trading program (Maryland Water Quality Trading Advisory Committee, 2017) and the Montana Nutrient Trading program (Walsh, Meyer, & Kieser, 2014), also considered incorporating septic systems into their trading schemes.

Using as an example WQT programs that use a community-based approach, such as South Nation River (O'Grady, 2011) and Alpine Cheese and Muskingum (Moore, 2014), this study investigated the feasibility of incorporating rural septic system upgrades into WQT as a part of the watershed nutrient management scheme. This approach can bridge all rural residents—both farmers and nonfarmers—to address the environmental and public health issues as a community. To meet this objective, we studied the willingness of rural households to participate in WQT for septic system upgrades. We compared three upgrade scenarios and identified a pilot project location.

Methods

The study site was the overlapping area of Hancock County, Ohio, and the Blanchard River Watershed, a subwatershed of the Western Lake Erie Basin. The Blanchard River Watershed is a HUC 8 watershed that covers 493,415 acres spanning five counties in Ohio: Allen, Hancock, Hardin, Putnam, and Wyandotte. About three quarters of Hancock County fall within the Blanchard River Watershed, taking up over 50% of the area of the watershed. This area is a part of the former Great Black Swamp, which was drained by deep ditches and transformed into an agricultural landscape more than a century ago. Due to the legacy of the swamp and the low elevation, cities in downstream Blanchard River, such as Findlay and Ottawa, frequently flood (National Oceanic and Atmospheric Administration, n.d.).

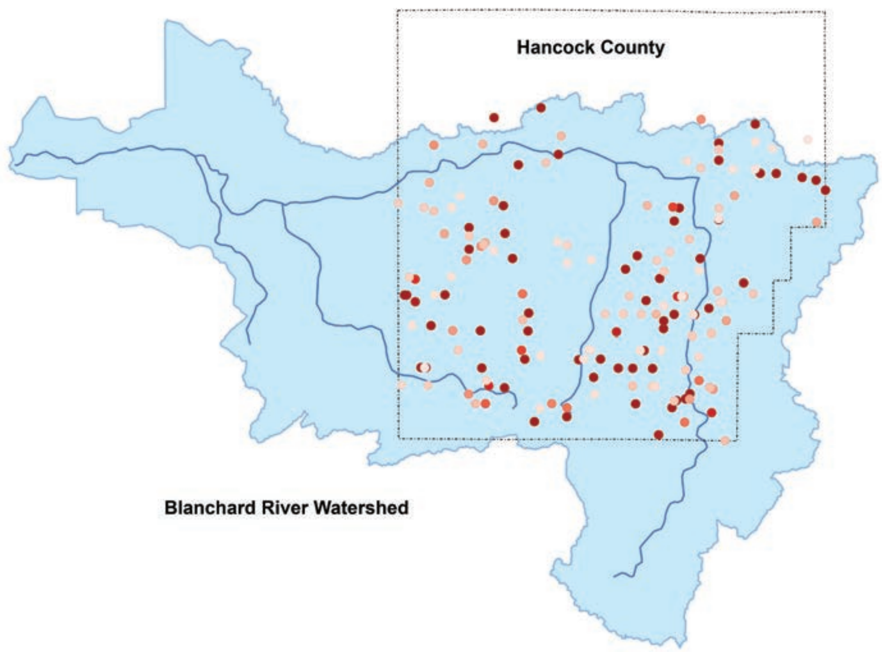
A questionnaire survey was delivered to households that use septic systems to treat their domestic wastewater within the study area. The 1,891 qualified households included 541 farming households and 1,300 nonfarming households. We used the "drop-off/pick-up" method (Melevin, Dillman, Baxter, & Lamiman, 1999) for this survey, which has the advantage of reducing nonresponse bias (Steele et al., 2001), especially in natural resource surveys (Allred & Ross-Davis, 2010). The face-to-face communication also allows the researcher to better determine the eligibility of the respondent and gain experiential insights (Allred & Ross-Davis, 2010; Steele et al., 2001).

From October 2016–February 2017, we visited 541 farming households and 359 randomly selected nonfarming households. Among these households, 578 had no adult available in the first and second visit. Of households asked to fill out the survey, the overall response rate was 57.1%. We also obtained information from the Hancock County Auditor database on house age, area, value, and number of rooms. GIS data of soil type, soil depth, elevation, and slope throughout the study area were obtained from U.S. Department of Agriculture (USDA) and U.S. Geological Survey online datasets.

Binary logistic regression models were employed to investigate the relation between willingness to upgrade the septic system under three different scenarios: 1) increased intensity rainfall scenario, 2) new regulation scenario, and 3) WQT scenario. The independent variables were septic system conditions, environmental perceptions, demographics, and house characteristics. Kernel density analysis using ArcGIS was employed to study the spatial distribution of households with different willingness to upgrade in the three scenarios.

FIGURE **2**

Age of Houses in Survey



Note. The darker colored dots indicate older houses.

Results and Discussion

Current Status of Septic Systems in the Blanchard River Watershed

Aging is the most common cause of septic system failure in Ohio (Ohio Department of Health & Ohio Environmental Protection Agency, 2013). The useful life of a septic system is between 20 to 30 years. Many (45%) of the sampled septic systems were installed before 1990 and are now considered out of date (Figure 1). Older houses tend to have older systems. It is notable that in this area, 45% of the sampled houses were over 100 years old. These old houses were scattered throughout the study site (Figure 2).

Soil limitation is also causing septic system malfunctioning. In Hancock County, approximately 40% of soils are hydric (U.S. Department of Agriculture [USDA], 2006). Pewamo is the most common soil type in Hancock County. This soil type is poorly drained, shallow to the water table, and frequently ponds—which disqualifies it from being suitable for septic system leach fields. According to the USDA Soil Survey (2006), 98% of the soil in Hancock County was ranked "very limited" for the use of septic system leach fields because "the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected" (USDA, 2006).

Fortunately, a majority of the households in the study area were responsible users of septic systems. In the past 5 years, 41% of the septic systems were inspected and 66% were pumped out. Some (39%) were treated with treatment products and 17% of the households did not do anything to maintain their septic systems. Unfortunately, septic system routine maintenance is not able to overcome the problems caused by deteriorating tanks, undersized systems, and soil limitations. Septic system upgrades are still necessary. All owners need to learn that septic systems need regular maintenance and replacement, like other home fixtures.

Household Willingness to Upgrade Septic Systems

In this study, we assessed household willingness to upgrade their septic systems in three scenarios:

1. increase in the frequency of heavy rain events in the area, causing more severe water pollution;
2. a new state regulation regarding septic systems in January 2015; and

FIGURE 3

Household Willingness to Upgrade Septic Systems Under the Three Study Scenarios

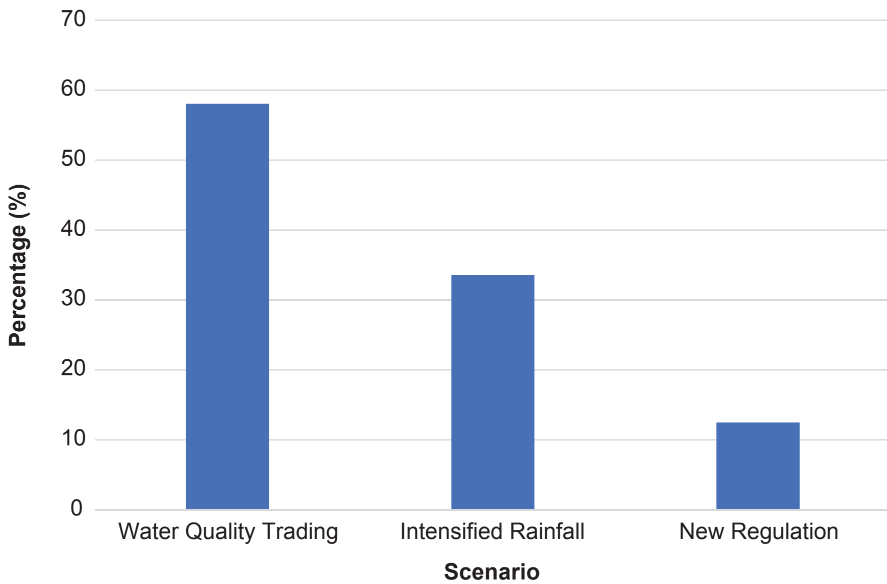


TABLE 1

Household Interest in the Three Water Quality Trading (WQT) Models

Trading Model	Not Interested (%)	Slightly Interested (%)	Somewhat Interested (%)	Very Interested (%)
Interest in the general idea of WQT	56.79	27.78	14.20	1.23
Interest in WQT with an annual payment ($50)	57.86	30.19	10.69	1.26
Interest in WQT with a professional management plan	56.52	29.19	12.42	1.86
Overall interest in any of the above three WQT models	41.94	41.29	14.84	1.94

3. WQT concept, presented as three trading models.

The three WQT training models were:

1. the return from participating in WQT was not specified;
2. participating household would receive an annual payment of $50/household as return; and
3. instead of payment, the trading fund would be used to hire a local professional to manage the participating household septic system.

We found that the responding households were much more willing to upgrade their septic systems in the scenario of WQT than in the other two scenarios (Figure 3). The households showed no preference to any of the three WQT models (Table 1): 43.21% had some degree of interest in the general idea of WQT, 42.14% were interested in the annual payment model, and 43.48% were interested in the professional management model. Overall, 58.06% of the households showed some degree of interest in at least one of the three trading models for septic system upgrades.

O'Grady (2011) of the South Nation River WQT project, which had successfully incorporated septic system upgrades into its scheme, pointed out that community agreement was a critical condition for a WQT project to succeed. In the Blanchard River Watershed, the idea of WQT was accepted by a majority of rural households, suggesting its potential to serve as an incentive for septic system upgrades. It should also be noted that, because WQT is still a new concept in the area, more effort should be made to communicate the concept to the local community on a broader scope.

The spatial analysis showed the clustering of households that were likely to upgrade septic systems under the WQT scenario, intensified rainfall scenario, and new regulation scenario (Figure 4). The overlapping area of households willing to upgrade in each scenario was located around the upstream area of the Blanchard River main stem and Eagle Creek tributary within Jackson, Delaware, and Eagle townships of Hancock County, Ohio, suggesting that this area might have greater potential for a pilot rural wastewater management project than other areas in the watershed.

Factors Associated With Household Willingness to Upgrade Septic Systems

Among all independent variables, perceived effectiveness of septic systems, perceived water quality in nearby streams, environmental concerns, concerns about governmental regulation, household income, and age of house were significantly related to household willingness to upgrade their septic systems. The perceived effectiveness of the septic system in removing sewage, pathogens, and nutrients had a negative relationship with willingness to upgrade the system. For the perceived effectiveness to increase by 1 unit, the odds of a household becoming willing to upgrade decrease by 14.10% in the intensified rainfall scenario and decease by 10.73% in the WQT scenario.

Households that considered their septic systems to be more effective saw less necessity for upgrading, implying that the limitation of soil condition in this area and the fact that septic systems have a finite lifespan were largely neglected. As discussed previ-

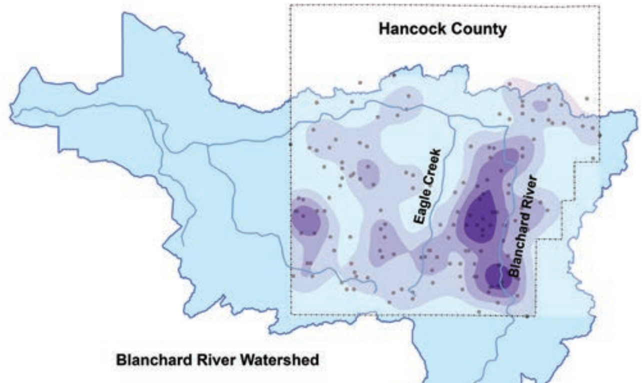
ously, education of the factors limiting septic system effectiveness is critical in enhancing household awareness of the need for system upgrades. The concerns about governmental regulation had a negative impact on household willingness to upgrade in the intensified rainfall scenario. The odds of those who were "somewhat concerned" or "very concerned" about increasing regulation to upgrade were approximately 95% lower than those households that had no idea about this issue.

The perceived water quality in nearby streams was positively related to upgrade willingness in all three scenarios. For households that considered the local water quality to be "poor," the odds of being willing to upgrade were 71.59 times higher than households that had no idea about water quality in the regulation scenario. For households that considered water quality to be "fair," the odds of being willing to upgrade were 58.38 times higher (versus those households that had no idea about water quality) in the intensified rainfall scenario and 14.64 times higher in the WQT scenario. For those households that considered water quality to be "average," the odds of being willing to upgrade were 72.75 times higher in the regulation scenario and 4.71 higher in the WQT scenario. Moreover, the odds of households that considered water quality to be "good" or "excellent" to be willing to upgrade were lower.

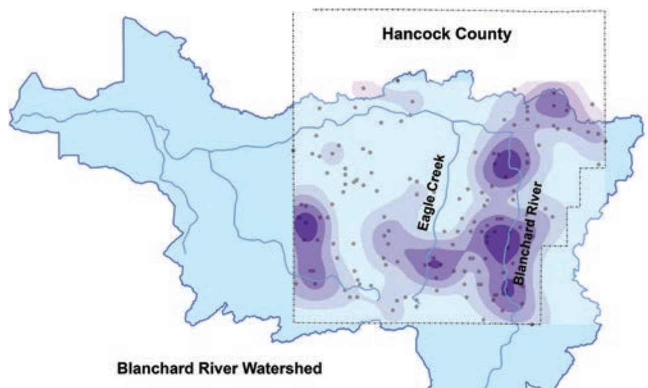
Household concern over environmental issues was also an important factor. As 1 unit increased in the environmental concern score, the odds of a household being willing to upgrade the septic system increased by 1.35 times in the intensified rainfall scenario. The more concerned a household was about the local aquatic environment, the more likely they would upgrade the septic system. As found in other studies (Moore et al., 2016; Morton et al., 2016; Prokopy, Floress, Klotthor-Weinkauf, & Baumgart-Getz, 2008; Prokup, Wilson, Zubko, Heeren, & Roe, 2017), the awareness of local environment degradation and concern of environment quality had a positive effect on behavior change. Future rural household wastewater management programs should focus on the education of local environmental issues and fostering environmental awareness.

FIGURE **4**

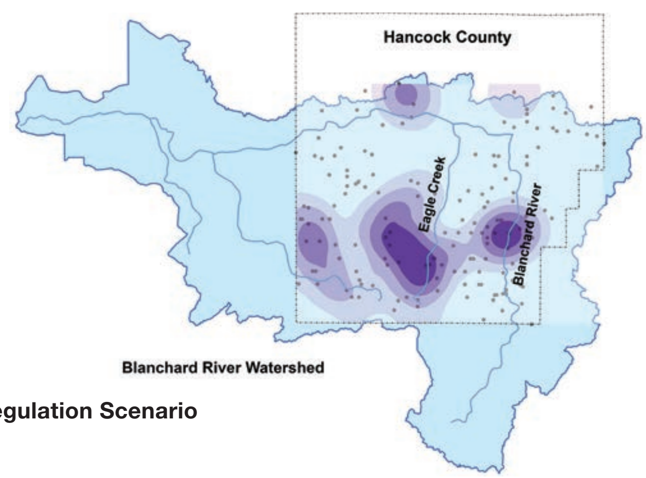
Spatial Distribution of Household Willingness to Upgrade Septic Systems in the Three Study Scenarios



A. Water Quality Trading Scenario



B. Intensified Rainfall Scenario



C. New Regulation Scenario

Note. The darker color indicates a higher willingness.
Sources: USGS, ESRI, Airbus DS, NGA, NASA, CGIAR, N. Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap, HERE, Garmin, FAO, NOAA, OpenStreetMap, and the GIS user community.

Households with high incomes were also more likely to upgrade septic systems. In the intensified rainfall scenario, the odds of high-income (annual income >$100,000) households being willing to upgrade were 3.92 times higher than the low-income households (annual income <$50,000); in the WQT scenario, the odds were 3.59 times higher. Cost is a major prohibiting factor in septic system upgrades. According to the Ohio Department of Health (2008), in northwest Ohio the average cost of installing a septic system with shallow leach lines was $7,988 and $11,355 for a sand mound system.

The high cost of replacing or upgrading a septic system could present a significant financial hardship to low-income households. In the study area, for instance, 19.4% of the households had an annual income <$50,000; financial support programs are necessary to help these households. The following are examples of programs that offer funding opportunities: the U.S. Department of Housing and Urban Development's Community Development Block Grant Program and Federal Housing Administration; USDA's Office of Rural Development, Section 502 Direct Loan Program, and Section 504 Home Repair Program; the Community Housing Improvement Program; and the Ohio Housing Trust Fund. Many of these grants, however, are either highly competitive or restricted to households with certain eligibilities (Ohio Department of Health, 2008). More funding opportunities should be made available to households that need septic system upgrades or replacement.

Limitations

This study used the drop-off/pick-up method to collect survey responses. Face-to-face interaction increases response rate but it is also time- and cost-consuming, especially when the households were less accessible, such as in the rural area. In this study, many households had no one home when the survey was delivered. Although we made sure at least one drop-off attempt was made to every potentially eligible household within the study area, the missed households (nonresponders) might introduce some bias.

Another limitation comes from the understanding of the concept of WQT, which is relatively new and has been practiced in only several states in the country. For most respondents, their first time hearing about this concept was when they took the survey. Given their heterogeneous background, respondents might have different understanding of WQT; therefore, the same response to one question might have different implications. In future research, a more detailed introduction of WQT and a focus group discussion could be helpful to minimize the bias originating from inconsistent understanding of the concept.

Conclusion

The failing rate of household septic systems in northwest Ohio where the Blanchard Watershed is located was 39%, the highest in Ohio (Ohio Department of Health & Ohio Environmental Protection Agency, 2013). The inadequately treated household wastewater from malfunctioning septic systems is a source of nutrients that can cause Lake Erie HABs and threaten public health. Failure is largely caused by old and poorly sited systems. Soil in the former Great Black Swamp in northwest Ohio is wet and poorly drained, resulting in poor performance of regular soil-based septic systems. As routine maintenance is unable to overcome these challenges, septic system upgrades are needed. Most watershed management programs, however, have failed to address the failing septic system issue.

In this study, we considered the feasibility of incorporating septic system upgrades in a WQT program. Most (58.07%) of the responding households in the Blanchard River Watershed were willing to upgrade their septic systems in a WQT program, which is much higher than the upgrade willingness in the intensified rainfall (33.55%) or new regulation scenarios (12.50%). WQT, therefore, has the potential to serve as an incentive for septic system upgrades. The households willing to upgrade were clustered in the upstream area of the Blanchard River main stem and Eagle Creek tributary within Jackson, Delaware, and Eagle townships of Hancock County, Ohio. Pilot projects are likely to work well in this area.

For a septic system upgrade program to succeed in northwest Ohio, it should focus on the following aspects:

1. Education about the impacts of soil limitations on septic system performance. Septic systems, like other home fixtures, have a finite life expectancy. Old septic systems were designed by a different standard than the modern systems and system components deteriorate over time. The soil limitations cannot be overcome with regular systems and routine maintenance. Households that better understood the limitation of system effectiveness were more likely to upgrade their septic systems.
2. Enhanced awareness of local environment degradation and concern for environmental quality have a positive effect on household willingness to upgrade septic systems. Households that perceived local water quality to be "fair" or "average" and those more concerned about local environmental issues were more willing to upgrade. Education should have a local focus and relate to the nearby aquatic environment.
3. Financial support should be made available for septic system upgrades. Given that septic system replacement or upgrades are expensive, the high-income households (annual income >$100,000) have significantly higher willingness to upgrade their septic systems compared with the low-income households (annual income <$50,000). Some funding sources for septic systems are available, but programs should make sure these opportunities are known and accessible for households that need them.

Based on the finding that certain groups of households were more willing to upgrade their septic systems in WQT, future studies should focus on the design and implementation of these programs.

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Corresponding Author: Yanting Guo, Assistant Professor, Department of Environment, Safety, and Occupational Health, The University of Findlay, 1000 North Main Street, Findlay, OH 45840.
E-mail: yanting.guo@findlay.edu.

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Did You Know?

Septic systems can be damaged and might fail to operate correctly after a disaster. NEHA worked with subject matter experts and national partners to develop a toolkit with guidance documents for different types of disasters such as hurricanes and flooding, wildfires, earthquakes, freezing temperatures, and power outages. Access the toolkit at www.neha.org/eh-topic/preparedness-response-septic-systems.