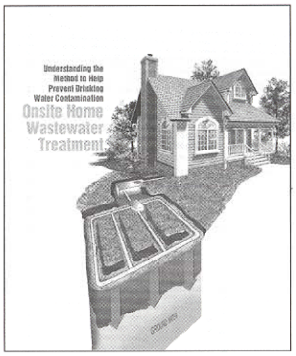


Survey of the Home Sewage Disposal Systems in Northeast Ohio

Mark A. Tumeo, PhD, JD, PE
Juliet Newland, MS, PE

Abstract

This article reports on failure rates in onsite sewage treatment systems (STS) that were found as part of a comprehensive seven-county survey that was performed under the auspices of the Northeast Ohio Areawide Coordinating Agency (NOACA) during the summer of 2000. The goal was to determine the percentage of onsite, individual home wastewater systems that were "failing." A system was identified as "failing" if, upon inspection, it had observable surfacing of effluent from the treatment system. A certified soil scientist conducted each on-site investigation to ensure consistency in methodology and to provide verification of soil types for each installation. The survey revealed that between 12.7% and 19.7% of the onsite wastewater treatment systems are allowing wastewater to surface as opposed to infiltrate (at the 95% confidence interval). The rate of failure does not vary significantly between aerobic and septic systems or between systems with or without filters.

Introduction

Water is arguably one of our most valuable resources, yet the quality of this resource remains a serious issue facing both the federal government and the state of Ohio, because these entities are challenged with the task of its protection. While we often think of waterborne diseases from contaminated drinking water as being a problem for poorer countries or third world locations, from January 2003 to December 2004, 30 reported outbreaks occurred of waterborne diseases associated with contaminated drinking water in the U.S. (Centers for Disease Control and Prevention [CDC], 2006).

A critical part of protecting water quality is the appropriate collection, treatment, and disposal of domestic wastewater. Within the U.S., while most domestic wastewater management is a centralized system (i.e., collection into sanitary sewers and treatment at a wastewater treatment plant that typically produces secondary or tertiary treated effluent), about 25% of the country's population and 33% of new developments are served by decentralized, often individual onsite wastewater treatment systems (Siegrist et al., 2005; U.S. Environmental Protection Agency [U.S. EPA], 2003). The U.S. EPA has found that such on-site treatment systems offer cost-effective alternatives for waste treatment and the protection of human health (U.S. EPA, 2002 and 2003).

Ohio does not vary from the national trend, with approximately 25% of Ohio's households being served by some type of onsite sewage treatment systems (Ohio Department of Health [ODH], 2008). From 1979 to 2000, the most commonly installed system in Ohio was the septic (anaerobic) system with a soil adsorption field for ultimate treatment and disposal, accounting for approximately 75% of the total on-site, individual wastewater treatment systems (CT Consultants [CTC], 2001). This trend seems to be holding steady or slightly increasing according to the Ohio Department of Health (ODH), which reported that between January 1 and June 30, 2007, 87% of systems installed were septic tanks discharging to soil absorption systems (ODH, 2008).

Onsite systems can also contribute to contamination of drinking water sources, however. U.S. EPA has estimated that as many as 168,000 viral illnesses and 34,000 bacterial illnesses occur each year from contaminated drinking water and that onsite sewage treatment systems (STS) are one potential source of the contamination (U.S. EPA, 2002). Yet, despite the extensive use of onsite STS in Ohio, little knowledge currently exists about the actual failure rate of these systems; some states report failure rates as high as 50% to 70% (U.S. EPA, 2002). The only comprehensive survey of systems in Ohio reported in the literature was performed by Mancl (1990). That study, however, did not examine systems in the field, but rather surveyed county health departments to estimate failing systems, which was reported to be approximately 27% statewide (Mancl, 1990). In this article, we report on failure rates in onsite STS that were found as part of a comprehensive seven-county survey that was performed under the auspices of the Northeast Ohio Areawide Coordinating Agency (NOACA) during the summer of 2000. A complete report on all aspects of the project, which included development of extensive databases, can be found in the NOACA Report (CTC, 2001). This paper focuses solely on the information collected on failing systems as part of the comprehensive report.

Materials and Methods

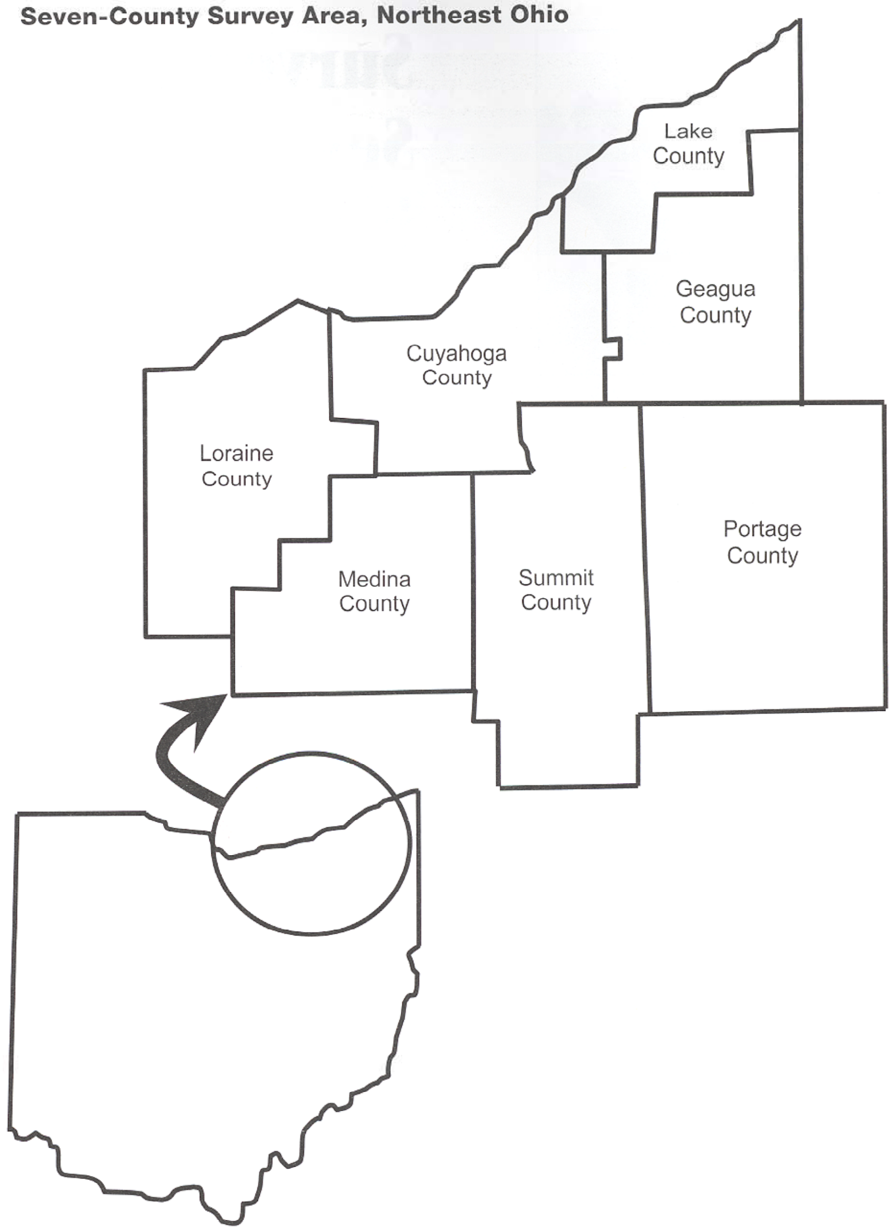
Definition of Failure

The ultimate goal of a home sewage disposal system (HSDS) is to treat and dispose of home wastewater by infiltration into a soil system. Typically, design criteria implemented by the counties through regulation are designed to ensure that systems are installed significantly above the water table to avoid groundwater contamination. While many factors can contribute to HSDS failure, soil unsuitability is often a primary cause (Canter, 1985). Unfortunately, the majority of soil types in the northeast Ohio are classified as being severely limited for subsurface disposal of effluent by the USDA Soil Conservation Service. For example, out of 60 different soil types found in Geauga County, 95.0% are severely limited based on soil type, degree of slope, and depth to bedrock. Only 3.3% of the soil types are rated as being moderately limited, while the remaining 1.7% are classified as being only slightly limited (USDA, 1982). Hence, the issue of most concern to county health officials is failure of these systems through surfacing of wastewater. The goal of the study reported here, then, was to determine the percentage of systems in the seven-county area that were "failing" with respect to the elimination of the direct introduction of wastewater into surface waters.

In reality, failure of the system can occur in one of two modes. Either the system can fail to filter and biologically degrade the waste before it reaches the groundwater table, or the soil system becomes overloaded and wastewater rises to the surface. Because it was prohibitively expensive and practically impossible to drill wells, collect soil and groundwater samples, and analyze for various wastewater constituents (e.g., nutrients, coliform bacteria) for the large number of systems across the seven counties involved in our survey, a system was identified as "failing" if, upon inspection, it had observable surfacing of effluent from the treatment system. For analyses, a system was identified as "surfacing" if surfacing effluent was seen.

FIGURE 1

Seven-County Survey Area, Northeast Ohio



Sampling Approach

Number of Systems to Investigate

On-lot systems represent approximately 70% of the total number of home sewage disposal systems present in the seven-county area. The remaining 30% discharge off lot and collect waste from a small group of homes, a small community, or a business. Because 700 total home sewage disposal systems were inspected during the project, we decided to inspect 490 on-lot systems to maintain the same percentage during inspections. The remaining 210 site visits were allocated to investigating off-lot systems and are not discussed further in this paper. As the project progressed, inclement weather and issues with access to some sites resulted in it not being possible to inspect all 490 targeted systems within the time frame allotted. For example, systems could not be inspected during or immediately after significant precipitation events, as it would not have been possible to distinguish failure (surfacing wastewater) from ponded precipitation. In addition, with the onset of winter, inspections of systems during freezing periods would have resulted in potentially biased data. Hence, we decided to only inspect systems from May through November, and consequently, we only inspected 427 total systems, distributed across the counties as follows: Cuyahoga (five systems), Geauga (93 systems), Lake (105 systems), Lorain (58 systems), Medina (one system), Portage (78 systems), and Summit (87 systems). The location of the seven counties included in the survey is shown in Figure 1.

TABLE 1

Grouping of On-Lot Systems for Data Analyses

Type	Control Characteristics	Total Installed (Estimate)	% of Total Installed	Targeted for Investigation	Actual Investigations	% of Total Investigated
A	Anaerobic with filter	4381	13.9%	24	52	12.2%
B	Anaerobic without filter	23559	74.7%	408	318	74.5%
C	Aerobic with filter	1438	4.6%	25	24	5.6%
D	Aerobic without filter	2165	6.9%	33	33	7.7%
Totals		31543	100.0%	490	427	100.0%

TABLE 2

Percentage of Surfacing On-Lot Systems

System Type	%	Confidence Interval		No. of Samples
		95%	90%	
Anaerobic with filter	19.2%	11.1%	9.3%	52
Anaerobic without filter	15.1%	3.9%	3.3%	318
Aerobic with filter	12.5%	14.3%	11.8%	24
Aerobic without filter	24.2%	15.4%	12.8%	33
All anaerobic (A+B)	15.7%	3.7%	3.1%	370
All aerobic (C+D)	19.3%	10.6%	8.8%	57
Overall	16.2%	3.5%	2.9%	427

Grouping of On-Lot System Types and Controlling Variables

Because numerous system types and several potential controlling variables exist, it was not possible to develop a sampling scheme with 490 "samples" (number of on-lot system inspections initially planned to be performed) that would allow statistically and scientifically valid analyses of all potential contributors to system malfunction. Therefore, based on the type of systems actually sampled, and after discussions with the County Health Department representatives, NOACA, and their consultant, we decided to focus on the effect of two control variables: oxygen status (aerobic vs. septic) and filtration (filter vs. no filter). The systems were grouped into four sets based on the two control variables. The resulting data parameters, estimated number of systems in each group, and the proposed and actual number of investigations performed are shown in Table 1. The data in Table 1 indicates that the inspection scheme resulted in a data set that satisfactorily approximates the distribution of the system types installed in the counties.

Field Survey

A certified soil scientist accompanied by a representative of the relevant local health district conducted each on-site investigation for this study. By having the same soil scientist do all surveys, consistency in methodology of assessing the site and determining if the system was surfacing were ensured throughout the seven-county area. In addition, the soil scientist was able to provide verification of soil types for each installation.

Statistical Methods

Confidence Intervals

During the investigation, on-lot systems were recorded as either surfacing or not surfacing. Similarly, off-lot systems were recorded as having poor effluent or not based on odor and color. To calculate a confidence interval, these "yes-no" answers were converted to 0s and 1s. It does not matter statistically what numerical values are used for "yes" and "no" because the statistical method normalizes for this selection. Standard practice, however, is to use 0 for "yes" and 1 for "no." This protocol was followed throughout the analyses in this report. Both the 95% and 90% confidence intervals are discussed below.

Significant Difference in Means

The sampling rationale and system grouping built into the survey design allowed comparative analyses to be conducted on the data collected from the inspected systems, as well as grouping system types to allow more robust statistical analyses. The grouping of the systems was designed to allow the analysis of the effect of aeration and filtration on system performance. The percentage of systems failing (i.e., surfacing) was compared across groupings using a standard t-distribution and comparison of the means (Box, Hunter, & Hunter, 1978). Difference is significant when

$$d > (ta/2)\ (s) = (1/na + 1/nb)1/2 \qquad (1)$$

where

d = absolute value of the difference between the means;
$(ta/2)$ = t-value at desired confidence interval (90% used);
na and nb = number of samples in populations a and b, respectively; and
s = pooled standard error, calculated using Equation 2 (below)
and

$$s = \{[(na - 1)sa2 + (nb - 1)sb2]/[(na - 1) + (nb - 1)]\}1/2. \qquad (2)$$

Results and Discussion

Table 2 provides the total percentage of surfacing systems and the failure rates by control variable (system type and the 90% and 95% confidence intervals for each value). From the data, one can be 95% sure that at least 12.7% and as much as 19.7% (16.2% ± 3.5%)

TABLE 3

Comparison of Surfacing Percentages Between System Groups

Anaerobic Systems w/o Filters		All Other Systems		Results
% Surfacing	No. of Samples	% Surfacing	No. of Samples	
15.10%	318	19.30%	109	No significant difference between groups
Anaerobic systems w/o filters		**Aerobic systems w/o filters**		
% Surfacing	No. of Samples	% Surfacing	No. of Samples	
15.10%	318	12.50%	24	No significant difference between groups
Aerobic systems w/ filters		**Aerobic systems w/o filters**		
% Surfacing	No. of Samples	% Surfacing	No. of Samples	
24.20%	33	12.50%	24	No significant difference between groups
All systems w/o filters		**All systems w/ filters**		
% Surfacing	No. of Samples	% Surfacing	No. of Samples	
16.00%	351	17.10%	76	No significant difference between groups
All aerobic systems		**All anaerobic systems**		
% Surfacing	No. of Samples	% Surfacing	No. of Samples	
19.30%	57	15.70%	370	No significant difference between groups

TABLE 4

Percentages of Surfacing Systems in Different Soil Types

Soil Type	%	Confidence Interval		No. of Samples	Comparison
		95%	90%		
Overall	16.20%	3.50%	2.90%	427	
Chili (and complexes)	0.0%	0.0%	0.0%	48	Significantly lower than the overall percent surfacing at the 95% confidence level.
Ellsworth	15.8%	12.2%	10.1%	38	Not significantly different than overall.
Mahoning (and complexes)	27.7%	9.2%	7.7%	94	Significantly higher than the overall percent surfacing at the 95% confidence level.
Platea (and Platea-Mahoning)	30.0%	22.0%	18.2%	20	Not significantly different than overall.
Wadsworth (and complexes)	31.8%	21.1%	17.5%	22	Significantly higher than the overall percent surfacing at the 90% confidence level.
Ravenna (and complexes)	45.5%	35.1%	28.5%	11	Significantly higher than the overall percent surfacing at the 95% confidence level.

of all on-lot systems in the seven-county survey area met the definition of a surfacing system as defined in this study.

Table 3 shows the comparison of the data for various control variables. The data does not show any significant differences in the percentages of surfacing systems between any of the various groupings possible. This indicates that the addition or exclusion of either an aeration system or a filter to a home sewage disposal system does not significantly impact the probability of the system failing due to surfacing.

Effect of Soil Rating

The inspection team also verified soil classification and rating at the location of the on-lot systems inspected. Because soil type is considered to be a significant factor in on-lot system performance, it is of great interest to examine the differences in the percentages of systems surfacing in different soil types. Soil ratings and classifications were based on the USDA county surveys of soil types (Ernst, Musgrove, & Hayhurst, 1976; Hayhurst & Milleron, 1977; Musgrove & Holleran, 1980; Ritchie, Bauder, Christman, & Reese, 1978; Ritchie & Reider, 1979; USDA, 1982). It is important to note that the soil ratings and classifications found in the records at the various counties did not correspond completely with the reality found in the field. All analyses in this study were performed on soil ratings and soil classifications as verified during the inspections.

The data indicates that systems installed in severe soils have a significantly higher percentage of systems that were found to

TABLE 3

Correlations in Overall On-Lot Inspection Data

Correlation Between	Number of Data Pairs	Correlation Coefficient	Interpretation
Number of bedrooms and surfacing systems	394	0.086	No significant correlation between these two variables.
Tank volume and surfacing systems	350	0.085	No significant correlation between these two variables.
Filter area and surfacing systems	62	-0.056	No significant correlation between these two variables.
ET area and surfacing systems	53	0.178	No significant correlation between these two variables.
Slope and surfacing systems	422	-0.09	No significant correlation between these two variables.
Minimum depth to groundwater and surfacing systems	368	-0.217	Slightly correlated, as minimum depth to groundwater increases, the probability of system being identified as surfacing decreases.
Runoff received and surfacing systems	427	0.043	No significant correlation between these two variables.
Landscape position and surfacing systems	420	0.118	No significant correlation between these two variables.
Trench length and surfacing systems	358	0.131	No significant correlation between these two variables.

have surfacing effluent (23.3%) than the overall percentage of surfacing systems (16.2%) at the 95% confidence level. Even with a limited data set for non-severe soils, the data show that systems in "slightly inadequate" soils show a significantly lower percentage of surfacing systems (2.8%) at the 90% confidence level.

Because the severe soil classification represents 63% of the systems investigated, additional information on the parameters leading to a severe soil rating were also analyzed. A soil is rated as "severe" in the soil classification handbook for six reasons: a) excessive wetness (categorized as "wet"); b) slow permeability ("slow"); c) shallow bedrock ("shallow"); d) inappropriate slope; e) susceptibility to flooding; and f) susceptibility to ponding. Sufficient data existed to show soils that were rated as severe because they were wet, wet and slow, or wet, slow, and shallow with respect to the impact on the percentage of systems found to be surfacing. The data indicates that systems in soils that have any combination of excessive wetness, poor permeability, or shallow bedrock have a significantly higher probability of surfacing than systems in other soils rated "severe" by inspection (e.g., inappropriate slope, susceptibility to flooding, and susceptibility to ponding).

Effect of Soil Classification

Only those soil classifications in which at least 10 or more systems were investigated and in which the variance of the control variable (presence of surfacing effluent) was sufficiently low could be used to calculate reliable statistics on the percentage of surfacing systems. For five soils, sufficient data was collected to calculate reliable statistics. The results are provided in Table 4. The data reveals that those systems in Chili soils or soil complexes have a significantly lower percentage of failing systems at the 95% confidence interval. Out of 48 systems inspected in this soil type, none was reported as surfacing. Conversely, systems installed in either Mahoning or Ravenna soils (or soil complexes predominantly of these types) have a significantly higher percentage of trouble. Systems installed in Wadsworth soil or soil complexes have a significantly higher percentage of surfacing systems at the 90% confidence interval, but are not significantly different from the overall percentage at the 95% confidence level.

Effect of Inspection Date

Because numerous systems were inspected, a time factor existed in the inspection scheme. In addition, different weather patterns before an inspection (e.g., significant precipitation

pact on the determination of whether or not effluent was surfacing in a given system. To examine the effects of the date of inspection, the systems were grouped by the month inspected, and the percentage of surfacing systems compared.

An analysis of the percentage of surfacing systems found during each month indicates that little effect occurred in the rate at which systems were identified as "surfacing" depending on the month in which the system was inspected. Only systems inspected in May were more likely to be identified as surfacing, and then only at the 90% confidence level. Because only about 5% of the total number of systems inspected were inspected in May, this difference does not represent an overall significant effect on the data collected.

Correlations between Selected Disposal System/Site Characteristics and Surfacing Effluent

During the investigation of on-lot systems, information on the number of bedrooms, tank volume, and other variables was collected. This data was used to determine whether systems that were found to be surfacing were more often associated with characteristics of the homes (e.g., number of bedrooms) or system design characteristics (e.g., tank size filter bed area, surface slope, and depth to ground water as indicated in as-builts). Sample correlation coefficients were calculated between comparison sets of data were calculated using Equation 3 as follows.

$$R(y_1,y_2) = \frac{S[(y_1 - y_{ave1})(y_2 - y_{ave2})]/(n - 1)}{s_1 s_2} \quad (3)$$

where

$R(y_1,y_2)$ = the *sample correlation coefficient* between variable y_1 and y_2;
y_{ave1} = average of variable y_1;
y_{ave2} = average of variable y_2;
n = number of sample pairs; and
s_1 and s_2 = standard deviation for variable 1 and 2, respectively (calculated by Equation 2).

The coefficient ranges between 1 and –1 and indicates if the two variables are more similar than would be expected if the two variables were completely independent. A sample correlation coefficient of 1 means the parameters are directly correlated and a coefficient of –1 indicates an inverse relationship. The closer the correlation coefficient is to either 1 or –1, the stronger the correlation between the two variables. It is important to understand, however, that correlation does not indicate causation but merely that the two variables appear related in the data. Table 5 shows the result of the analysis of correlations from the data.

Conclusion

This study represents a comprehensive survey of onsite home wastewater treatment systems in Northeast Ohio. The survey revealed several important facts about this method of wastewater treatment and disposal in the region. Most importantly, the survey revealed that at least one in eight (12.7% and up to as many as one in five [19.7%]) of the onsite wastewater treatment systems are failing in that they are allowing wastewater to surface as opposed to infiltrate. The rate of failure of these systems does not vary significantly between aerobic and septic systems or between systems with or without filters. Systems installed in soils rated as "severe" are significantly more likely to fail than those installed in soils having good or moderate ratings for wastewater introduction. Finally, while inconclusive statistically, the study did tend to indicate that systems installed in areas with higher seasonal water tables were slightly more likely to fail.

Acknowledgements: The authors would like to acknowledge the support and cooperation of the Northeast Ohio Areawide Coordinating Agency (NOACA), CT Consultants, and the health departments of Cuyahoga, Geauga, Lake, Lorain, Medina, Portage, and Summit counties during the planning and execution of the work described in this paper. In addition, this study, and the larger project of which it was a part, could not have been accomplished without the active involvement and guidance of the Ohio Department of Health, the Ohio Environmental Protection agency, Cleveland State University, and local health department officials.

Corresponding Author: Mark A. Tumeo, Professor, Civil and Environmental Engineering, Cleveland State University, Department of Civil and Environmental Engineering, 2121 Euclid AVE (SH 119), Cleveland, OH 44115. E-mail: m.tumeo@csuohio.edu.

REFERENCES

Box, G.E.P., Hunter, W.G., & Hunter, J.S. (1978). *Statistics for experimenters: An introduction to design, data analysis, and model building*. New York: John Wiley & Sons.

Canter, L.W., & Knox, R.C. (1985). *Septic tank system effects on ground water quality*. Chelsea, MI: Lewis Publishers.

Centers for Disease Control and Prevention. (2006). Surveillance for waterborne disease outbreaks associated with drinking water and water not intended for drinking in the United States, 2003–2004. *Morbidity and Mortality Weekly Report, 55*(SS-12), 31–58.

CT Consultants, Incorporated. (2001). *Survey of northeast Ohio home sewage disposal systems and semi-public sewage disposal systems*. Willoughby, OH: Author.

Ernst, J., Musgrove, D.K., & Hayhurst, E.N. (1976). *Soil survey of Lorain County, Ohio*. Washington, DC: U.S. Department of Agriculture Soil Conservation Service.

Hayhurst, E.N., & Milleron, E.L. (1977). *Soil survey of Medina County, Ohio*. Washington, DC: U.S. Department of Agriculture Soil Conservation Service.

Mancl, K. (1990). A survey of small sewage treatment facilities in Ohio. *Ohio Journal of Science, 90*(4), 112–117.

Musgrove, D.K., & Holleran, P.M. (1980). *Soil survey of Cuyahoga County, Ohio*. Washington, DC: U.S. Department of Agriculture Soil Conservation Service.

Ohio Department of Health. (2008). *Report to the household sewage and small flow on-site sewage treatment system study commission, January 1, 2008*. Columbus, OH: Author.

Ritchie, A., & Reider, N.E. (1979). *Soil survey of Lake County, Ohio*. Washington, DC: U.S. Department of Agriculture Soil Conservation Service.

Ritchie, A., Bauder, J.R., Christman, R.L., & Reese, P.W. (1978). *Soil survey of Portage County, Ohio*. Washington, DC: U.S. Department of Agriculture Soil Conservation Service.

Siegrist, R.L., McCray, J., Weintraub, L., Chen, C., Bagdol, J., Lemonds, P., Van Cuyk, S., Lowe, K., Goldstein, R., & Rada, J. (2005). *Quantifying site-scale processes and watershed-scale cumulative effects of decentralized wastewater systems* (Project No. WU-HT-00-27, prepared for the National Decentralized Water Resources Capacity Development Project, Washington University, St. Louis, MO). Golden, CO: Colorado School of Mines.

U.S. Environmental Protection Agency. (2002). *Onsite wastewater treatment systems manual* (Report No. EPA 625/R-00/008). Washington, DC: Author.

U.S. Environmental Protection Agency. (2003). *Voluntary national guidelines for management of onsite and clustered (decentralized) wastewater treatment systems* (Report No. EPA 832-B-03-001). Washington, DC: Author.

U.S. Department of Agriculture and Ohio Department of Natural Resources. (1982). *Soil survey of Geauga County, Ohio*. Washington, DC: U.S. Department of Agriculture Soil Conservation Service.