Septic Tank Additive Impacts on Microbial Populations

S. Pradhan, Ph.D.
M.T. Hoover, Ph.D.
G.H. Clark, M.S.
M. Gumpertz, Ph.D.
A.G. Wollum, Ph.D.
C. Cobb, M.S.
J. Strock, Ph.D.

Abstract Environmental health specialists, other onsite wastewater professionals, scientists, and homeowners have questioned the effectiveness of septic tank additives. This paper describes an independent, third-party, field scale, research study of the effects of three liquid bacterial septic tank additives and a control (no additive) on septic tank microbial populations. Microbial populations were measured quarterly in a field study for 12 months in 48 full-size, functioning septic tanks. Bacterial populations in the 48 septic tanks were statistically analyzed with a mixed linear model. Additive effects were assessed for three septic tank maintenance levels (low, intermediate, and high). Dunnett's t-test for tank bacteria ($\alpha = .05$) indicated that none of the treatments were significantly different, overall, from the control at the statistical level tested. In addition, the additives had no significant effects on septic tank bacterial populations at any of the septic tank maintenance levels. Additional controlled, field-based research is warranted, however, to address additional additives and experimental conditions.

Introduction

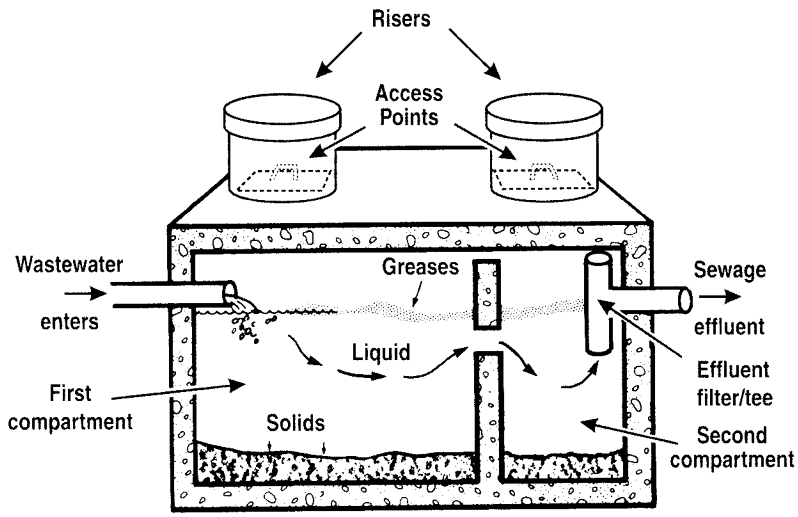
In the United States, 25 percent of the total housing units and 33 percent of all new development rely on onsite wastewater treatment systems (septic systems) for their household wastewater treatment (U.S. Environmental Protection Agency [U.S. EPA], 2005). Some states, such as North Carolina, where 50 percent of the population depends on onsite systems, utilize these technologies even more extensively. The number of onsite wastewater treatment system users increases every year as a result of continuous urban and suburban sprawl and the high cost of central sewer systems. Hence, the cumulative number of homes served by onsite wastewater systems is substantial and growing. The increasing popularity of onsite wastewater treatment systems has led to widespread production and use of septic system additives. Over 1,200 additives are currently available on the market (National Small Flows Clearinghouse, 2002). Many additive manufacturers and distributors claim additives enhance bacterial populations and eliminate or reduce septic tank pumping frequencies needed to remove solids accumulated in septic tanks (Scow, 1994).

There are three basic categories of septic tank additives: chemical, physical, and biological. Chemical additives usually are either strong oxidizing agents or organic chemicals, but this category can also include inorganic chemical compounds. Strong oxidants and organic chemicals may be detrimental to septic systems and the environment; hence, they have limited use today (Dow & Loomis, 2005; Friedman, 1996; Kaplan, 1983). Physical additives consisting of mineral microparticles have been used in Europe (Maunoir, Sabil, Rambaud, Philip, & Coletti-Previero, 1991; Philip, Maunoir, Rambaud, & Philippi, 1993). Most biological additives are designed to enhance the biological activity in the septic tank through the addition of organisms such as bacteria, enzymes, or both. Most wastewater experts are not concerned about environmental damage from biological additives (Dow & Loomis, 2005; Kaplan, 1983; Lee, Jones, & Turco, 2005).

On the basis of manufacturer lab and bench-scale tests, additive formulations are selected to have high levels of enzyme production, rapid bacterial organism growth rates, the ability to survive environmental conditions in waste systems, and the ability to withstand a large range of pH and temperature conditions as well as detergents and household chemicals (Scow, 1994). The primary bacteria in additives include a variety of aerobes and facultative anaerobes such as members of the genera *Bacillus, Pseudomonas, Ruminococcus, Bacteroides, Lactobacillus,* and others (Scow). Many of these organisms can promote hydrolysis via liquefaction, conversion of more complex molecules to fatty acids via acid fermentation, and conversion to gases via methanogenesis and other reac-

FIGURE 1

Cross-Sectional View of Two Compartment Septic Tanks Used in the Study



Used with permission from Hoover and Konsler (2004).

tions. Additives also often include added enzymes such as proteases, amylases, lipases, and cellulase (Scow).

Septic tank additives are promoted extensively across the United States, and many homeowners desire information about their effectiveness. The advertisement of additives in local magazines, national publications, phone solicitations, Internet ads, and TV ads, as well as their easy availability in hardware stores, building supply stores, and supermarkets, is raising questions among homeowners. The question that homeowners and many onsite professionals, such as environmental health specialists, installers, and service providers, ask most frequently about maintenance of onsite wastewater, treatment systems is whether additives have any benefit. Unfortunately, very little peer-reviewed and published research exists about the microbial effectiveness of bacterial septic tank additives (Scow, 1994). Currently, verification of the effectiveness of additives relies primarily on laboratory or benchtop studies (Jantrania, Sack, & Earp, 1994), often conducted by product manufacturers, or on more theoretical literature review assessments that have not been substantiated in the field with controlled, third-party, replicated experiments (Scow).

The objective of this article is to report on a replicated and controlled field scale experiment designed to measure the impacts of selected bacterial additives on total microbial populations in septic tanks. Additive manufacturers keep bacteria and enzyme formulations confidential. Hence, neither enzyme levels nor specific genera of organisms were assessed in our study. Rather, we used the total bacterial-microbe content in septic tanks as a performance benchmark, or proxy, for assessment of efficacy.

Methods and Materials

The impacts of three septic tank additives and a control were assessed for a 12-month period in 48 full-scale functioning septic tanks at existing home sites (Clark, 1999). Levels of septic system sludge, scum, five-day biochemical oxygen demand (BOD_5), and total suspended solids (TSS) usually vary substantially from home to home because of variation in homeowner water use, chemical-cleaning-compound use, solids disposal habits, family size, and family work situation. To estimate the replication needed for this experiment, we made an informal assessment of inherent variability and variance from prior septic tank data sets. It was determined that 12 replicates were necessary for each treatment.

Additive product manufactures were not involved in the study, nor in its funding. Liquid bacterial additives were purchased in bulk at local commercial retail stores for the study. They were stored in a locked closet at room temperature in the manufacturer's containers until they were added to the septic tanks. No expiration dates were observed on the packaging for these additives.

Research Sites

The study sites were located in Chatham and Orange Counties, North Carolina. These locations included septic systems serving residences at mobile home parks. Over 80 two-compartment septic tanks (Figure 1) were initially screened at the sites before the 48 experimental units were selected (Clark, 1999). In addition, we used a homeowner survey to exclude any systems that had been utilizing septic tank additives before the study was initiated. Forty-eight septic tanks were selected for the study sample, primarily on the basis of inspection of the initial sludge depth and scum thickness. An access riser was added from the tank inlet up to the ground surface for any system that did not already have a riser.

Experiment Design

A randomized complete block design was utilized for this study. The 48 septic tanks (experimental units) were stratified into 12 blocks. Each block consisted of four experimental units that contained similar initial solids contents (sludge depth and scum thickness). The initial solids contents represented one of three maintenance levels (low, intermediate, or high prior maintenance). Maintenance level was defined as the site parameter in the statistical model, since the maintenance level was consistent within each of the three sites: All low-maintenance tanks were located at one of the three sites, and so forth. Three blocks consisting of 12 experimental units at the Chatham County location had the lowest level of maintenance (greatest initial sludge depth and scum thickness). These tanks had not been pumped during the prior 15 to 20 years. Hence the initial existing sludge and scum levels were greater here than at the other two maintenance levels. The Orange County location included two sites: an old section of a mobile home park and a new section of the same mobile home park. Five blocks consisting of 20 experimental units in the new mobile home park at the Orange County location were, at the start of the experiment, at a high level of maintenance—all had been pumped two to three years before initiation of the study. Four blocks consisting of 16 experimental units in the old section of the mobile home park at the Orange County location had an intermediate initial maintenance level. As a result, there were 12 replicates of each treatment: three blocks at the low maintenance level, four at the intermediate maintenance level, and five at the high maintenance level.

Distribution, Sampling, and Analysis of Additives

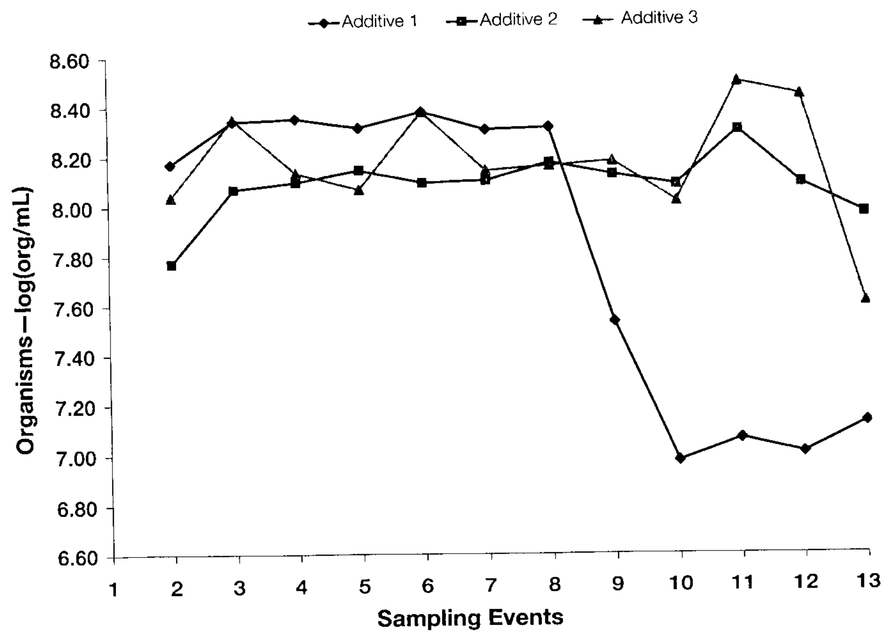
Distribution of the additive application treatments followed the double-blind approach commonly used in the medical community. Secondary researchers randomly assigned the three additives and the control to the four experimental units within each block. These secondary researchers then applied the additives each month following collection of the experimental data by the primary researchers. The primary researchers made field measurements, collected samples, and analyzed the data, but had no information about which treatments (or control) were assigned to the experimental units. The liquid bacterial septic tank additives selected for the study were added approximately once a month (every four weeks) to the septic tanks. Three treatments were evaluated: a Drano septic tank additive (Additive 1), a Liquid-Plumr septic tank additive (Additive 2), and a Rid-X septic tank additive (Additive 3). The volumes added monthly were 591.5 mL (20 oz) of Additive 1 and Additive 2, and 310.5 mL (10.5 oz) of Additive 3.

The viability of biological organisms in the additive containers was evaluated monthly with a small sub-sample collected before their application. A 5-mL sample collected from each additive container was diluted and plated onto tryptic soy agar with a spiral plater (Wollum, 1982). The plates were checked daily, and colony forming units (CFUs) were counted as growth appeared (Clark, 1999).

Additives were added directly to the inlet of all septic tanks except the 12 control septic tanks. Total organism counts (Wollum, 1982) in the septic tanks were measured at approximately 12-week intervals (quarterly) for all 48 experimental units. The first count was not taken until the 12th week of the study. A cross-sectional sample was collected from near the inlet of the septic tank with a Pinpointer™ sampler for each experimental unit (Clark, 1999). Wastewater collected in the Pinpointer™ sampler was poured into a bottle, held in a cooler, and transported to the lab. The sample was allowed to settle, a supernatant sub-sample was diluted, and aliquots were plated onto tryptic soy agar with a spiral plater (Wollum, 1982).

FIGURE 2

Mean Number of Bacterial Colony-Forming Units Present in Bacterial Additives



The total countable bacterial population in the septic tanks was used as a biological benchmark for assessment of the bacterial efficacy of the additives. This method was used because additive formulations (number and types of organisms, enzymes, and so forth) are company trade secrets and not readily available.

Statistical Assessment

The total-bacterial-count repeated-measures data from the experimental units were log-transformed because of the high variability of the data and then were statistically analyzed according to a mixed linear model, with repeated measures implemented according to the MIXED procedure (Little, Henry, & Ammerman, 1998) in the SAS System (SAS, 2003). The model used for this study was as follows:

$$Y = \text{Site} + \text{Block (Site)} + \text{Treatment} + \text{Treatment*Site} + \text{Time} + \text{Time*Site} + \text{Time*Treatment} + \text{Time*Treatment*Site} + \text{within-tank error}$$

Block (site) and within-tank error are random, and all other terms are fixed effects. Observations are assumed to be correlated over time within a tank. Dunnett's *t*-test at an $\alpha = .05$ level according to the Hsu correction was used to compare the effectiveness of treatments to the control and to test for significant differences.

Results and Discussion

Additive Viability in Containers

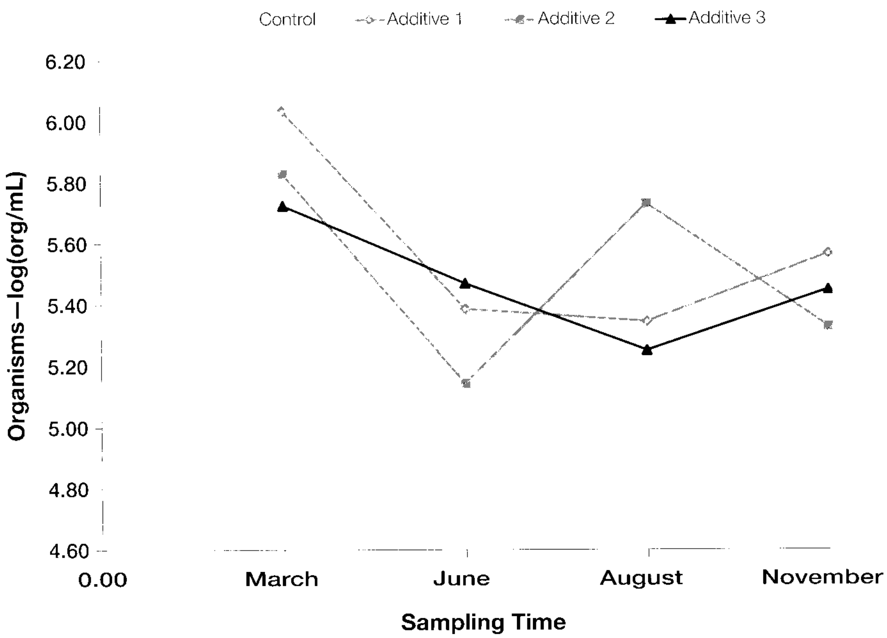
Monthly analysis of the products revealed that all additive containers had substantial numbers of viable microbes at the time of enumeration (Figure 2). The geometric mean CFU concentrations in Additive 1, Additive 2, and Additive 3 were 0.66×10^8/mL, 1.21×10^8/mL, and 1.46×10^8/mL, respectively. For comparison, these bacterial populations were similar to another bacterial additive called Super Shock, which claims to have 1.00×10^8/mL bacteria according to the manufacturer's literature (Septic-1™, 2005).

Septic Tank Bacterial Populations

The septic tank log average bacterial populations were 5.98/mL, 5.94/mL, 5.83/mL and 5.98/mL, for experimental units receiving Additive 1, Additive 2, and Additive 3, and for the control, respectively. These concentrations correspond to geometric mean bac-

FIGURE 3

Least-Square Means for Treatments at Each Sampling Time



Expressed as log 10 (concentration) of organisms per mL of septic tank liquid. Standard errors for a single treatment at a single sampling period ranged from 0.12 to 0.32.

TABLE 1

Type 3 Effects for Fixed Effects on Bacterial Population

Effect	*F* value	Pr > *F*
Site (maintenance level)	1.32	0.3145
Treatment	0.17	0.9194
Site*Treatment	2.10	0.0581
Time	3.67	0.0142
Site*Time	0.67	0.6772
Treatment*Time	1.92	0.0552
Site*Treatment*Time	0.62	0.8800

terial populations in the septic tanks of 9.50 × 10^5/mL, 8.63 × 10^5/mL, 6.81 × 10^5/mL, and 9.60 × 10^5/mL of septic tank liquid for Additive 1, Additive 2, Additive 3, and the control, respectively. The mass number of organisms added to the septic tanks per month via the additives were typically less than the cumulative mass number of organisms already present in the control septic tanks. For instance, Additive 2 added 1.21 × 10^8 CFUs/mL, which is equivalent to a mass of 7.15 × 10^{10} organisms added from one container of Additive 2 to a septic tank. The control tanks, however, already contained a geometric mean of 9.60 × 10^5 CFUs/mL, which is equivalent to a total cumulative mass of 3.64 × 10^{12} organisms in the 3,780-L (1,000-gallon) tanks, without the benefit of any additives. Hence, the mass number of organisms in the non-additive control tanks was between 10-fold and 100-fold greater than the number of organisms added from Additive 2. During the four quarterly sampling events, the average bacterial populations for the control and for the three additives did not indicate a pattern of any one additive having a greater effect than the others on the total numbers of bacteria in the septic tank (Figure 3).

Additive Effects and Interactions

No significant effect on septic tank bacterial population was found (i.e., total bacteria concentrations in CFUs/mL) over the period of study (Table 1). On the other hand, both the treatment*time interaction and site*treatment interaction effect on bacterial concentrations in septic tanks were nearly significant at the $\alpha = .05$ level.

Estimated-least-square means plots for treatment effects at different times (Figure 3) and for different sites (maintenance levels) indicated that the means for the controls were not consistently less than the means for the additives (Figure 4). This result demonstrated that the additives were not having the desired biological effect, at least with respect to total bacteria concentrations in the septic tanks. It is of interest that at the low-maintenance site (i.e., the septic tanks that had not been pumped during 15 to 20 years of operation), the bacterial populations in additive-treated septic tanks were numerically greater than those in the control tanks (Figure 4). On the other hand, Dunnett's *t*-test for septic tank bacterial populations for Site 1 (low maintenance level) indicated that none of the treatments gave results significantly different than the control ($\alpha = .05$ level). While our study did not show any significant interaction effects, additional assessments of potential interactions between additives and prior maintenance levels in septic tanks should be studied since some interactions were almost significant at the $\alpha = .05$ level. Also, we recommend that controlled, full-scale field studies be conducted for assessment of any potential additive effects on specific aerobic and facultative anaerobic genera and species important to hydrolysis, fermentation, anaerobic oxidation, sulfate reduction, or methanogenesis processes within poorly maintained septic tanks.

Time Effects

The time effect was significant at the $\alpha = .05$ level (Table 1). The reason for a time effect over the entire study period is unknown. It is important to note, however, that despite the relative downturn in bacterial concentrations in the June sampling period (Figure 3), all 48 experimental units still maintained very high numbers of organisms throughout the entire study. Bacterial populations had ranges of

1.48×10^3–1.72×10^7 CFUs/mL, 1.04×10^4–7.80×10^6 CFUs/mL, 2.09×10^4–6.74×10^6 CFUs/mL, and 4.90×10^1–6.13×10^6 CFUs/mL in the tanks receiving Additive 1, Additive 2, and Additive 3, and in the control, respectively. Dunnett's *t*-tests over time showed no significant difference ($\alpha = .05$) in total microbial concentrations between treated and control tanks at any of the individual sampling events, including the June sampling event.

In summary, there were consistently large quantities of microorganisms in the septic tanks assessed in our study, regardless of the significant time effect and the June bacterial population reduction. It is theoretically possible that reductions in bacterial populations in June resulted from ubiquitous spring-cleaning activities during April and May.

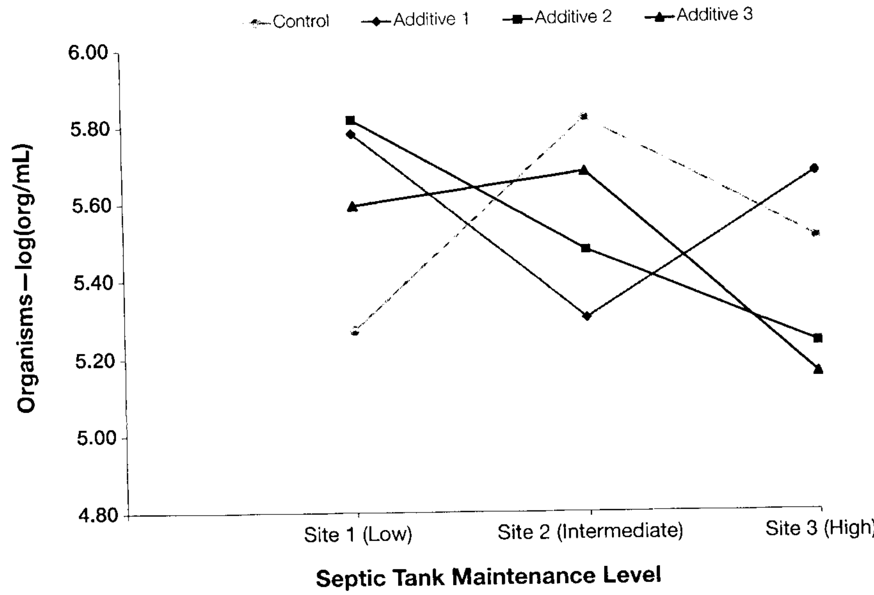
Summary and Conclusions

All treatments maintained large total organism populations throughout the study. Across all maintenance levels, the septic tank additives did not significantly increase total bacterial concentrations in the septic tanks compared with concentrations in the control (no additives). Dunnett's *t*-tests, performed to evaluate treatment effects by site at the $\alpha = .05$ level, indicated that the treatments did not give results that were significantly different from those obtained in the control tanks for any given maintenance level (low, intermediate, or high). Therefore, none of the additives significantly increased the number of organisms in the septic tanks. In addition, the total mass load of bacteria in the control septic tanks exceeded the mass of bacteria added via these additives. Note, that while the site*treatment interaction and the treatment*time interaction were not significant, they were almost significant at the $\alpha = .05$ level (Table 1). Hence, *t*-tests made at other α levels could give different results. An $\alpha = .05$ level of significance was selected before the field assessment to minimize any chance that erroneous study results could affect the guidance provided by thousands of scientists, environmental health specialists, and other onsite wastewater professionals to the millions of homeowners using septic tank systems.

Finally, our experiment did not attempt to measure the effects of biological additives on concentrations of specific bacterial genera or species or related enzymes that could potentially influence hydrolysis, fatty acid dissolution, or methanogenesis. In addition, only three of the 1,200+ septic tank additives on the market were assessed in the study. Therefore, additional replicated, controlled, full-scale field research studies should be designed to determine whether these findings about septic tank additives can be expanded beyond the experimental conditions tested here.

FIGURE 4

Least-Square Means for Treatments by Site (i.e., Maintenance Level)



Standard errors for treatment means for each site ranged from 0.16 to 0.23.

Acknowledgements: Appreciation is extended to the Orange County Health Department (Tom Konsler and Greg Grimes) and the Chatham County Health Department (Jimmy Collins) and to Walter Bright (*in requiem*), Joanna and Anthony Bright, Wayland McFarland, and Lee Lambert for assisting with locating and providing access to the study sites. This study is dedicated to Mr. Walter Bright in memory of his forward-thinking and willing cooperation during many years of collaboration.

Corresponding author: Michael T. Hoover, Professor, North Carolina State University, Soil Science Dept., Raleigh, NC 27607-7619. E-mail: mike_hoover@ncsu.edu.

REFERENCES

Clark, G.H. (1999). *The effect of bacterial additives on septic tank performance.* Unpublished master's thesis, Soil Science Department, North Carolina State University, Raleigh, NC.

Dow, D., & Loomis, G. (2005). *Septic tank additives* (Cooperative Extension—Water Quality Program, University of Rhode Island). Retrieved May 11, 2006, from http://www.uri.edu/ce/wq/owtc/html/owtc_sepadd.html.

Friedman, D. (1996). *Septic system additives and chemicals.* Retrieved May 16, 2006, from http://www.inspect-ny.com/septic/septadds.htm

Hoover, M. T., & Konsler, T. (2004). *Septic systems and their maintenance* (Pub. No. AG-439-13, North Carolina Cooperative Extension, North Carolina State University). Retrieved May 7, 2007, from http://www.soil.ncsu.edu/publications/Soilfacts/AG-439-13/AG-439-13.pdf.

REFERENCES

Jantrania, A., Sack, W.A., & Earp, V. (1994). Evaluation of additives for improving septic tank operation under stressful conditions. In *Proceedings of the Seventh International Symposium on Individual and Small Community Sewer Systems* (pp. 49-57). Atlanta, GA: ASAE—The Society for Engineering in Agricultural, Food, and Biological Systems.

Kaplan, B. (1983). Some additives to septic systems may poison groundwater. *Journal of Environmental Health, 45*(5), 259.

Lee, B., Jones, D., & Turco, R. (2005). *Septic system additives* (Purdue Extension—Home and Environment, Purdue University). Retrieved May 11, 2006, from http://www.ces.purdue.edu/henv/SepticSystems.htm.

Little, R.C., Henry, P.R., & Ammerman, C.B. (1998). Statistical analysis of repeated measure data using SAS procedures. *Journal of Animal Science, 76,* 1216-1231.

Maunoir, S., Philip, H., & Rambaud, A. (1990). Stimulation of psychrophilic methanation with a septic tank biological activator. *Journal of Water Resources, 24*(2), 195-205.

Maunoir, S., Sabil, N., Rambaud, A., Philip, H., & Coletti-Previero, M.A. (1991). Role of insoluble enzymes in anaerobic wastewater treatment and enzyme-bioactivator interactions. *Journal of Environmental Technology, 12*(4), 313-323.

National Small Flow Clearinghouse. (2002). Septic tank additives. *Small Flows Quarterly, 3*(1). Retrieved May 11, 2006, from http://www.doh.wa.gov/ehp/ts/WW/Septic-Additives-SFQ-Wint2002.pdf.

Philip, H., Maunoir, S., & Rambaud, A. (1993). Septic tank sludges: Accumulation rate and biochemical characteristics. *Water Science Technology Journal, 28*(10), 57-64.

SAS Institute, Inc. (2003). *SAS, Version 9.1.* Cary, NC: Author.

Scow, K.M. (1994). The efficacy and environmental impact of biological additives to septic systems. Unpublished manuscript, University of California, Davis. Available from the National Small Flows Clearinghouse, West Virginia University, Morgantown, WV, (800) 624-8301.

Septic-1™. (2005). *Septic tank treatment.* Retrieved May 11, 2006, from http://septic-1.com/.

U.S. Environmental Protection Agency. (2005, January 11). *WaterNews for January 11, 2005.* Retrieved September 24, 2007, from http://www.epa.gov/water/waternews/2005/050111.html.

Wollum, A.G., II. (1982). Cultural methods for soil microorganisms. In A.L. Page (Ed.), *Methods of soil analysis: Part 2. Chemical and microbiological properties* (2nd ed., ch. 37). Madison, WI: American Society of Agronomy, Inc., and Soil Science Society of America, Inc.