Hygienic Implications of Small-Scale Composting in New York State

Final Report of the

Cold Compost Project

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Abstract

Small-scale composting is an effective way to recycle organic wastes generated in the home and/or community. Little research has been done to determine potential human health risk of composts generated on a small scale. Bacteriologic testing of twenty composts from across New York State representing a wide variety of small-scale composting practices and situations was conducted. No statistical relationships were found between concentrations of total coliforms, fecal coliforms, enterococci, *Escherichia coli*, *Salmonella spp*., and *Clostridium perfringens*, indicating that none of these organisms could be considered a good indicator of general microbial presence. Compared with microbial standards for sewage sludge composts, these composts generally met those standards. Basic compost parameters were also analyzed. Water holding capacity ranged from 50% to 246%, organic matter 9% to 80.5%, C to N ratio 10.4 to 29, Total Kjeldahl Nitrogen 0.185% to 2.419%, density 24 lb/ft^3 to 82 lb/ft^3, solids 27.7% to 75.6%, moisture 24.4% to 72.3%, pH 6.54 to 8.65, and Solvita maturity from 3 to 7. No statistically significant relationships at the p=0.1 level were found between microbial concentrations and compost parameters. However, the relationship between pH and TKN was close to the statistical cut off, with higher pH and TKN associated with higher concentration of microbes. An unanticipated finding was that the two laboratories used for bacteriological testing employed different methodologies to look for the same bacteria which may account for some of the discrepancy in results between the labs. Researchers and composters alike need to ensure

methods appropriate for compost are used. The results of this research led to a recommendation to follow good hygiene practices (such as washing hands) when working with composts. Similar practices are advisable when dealing with any soil material since these too may contain bacterial pathogens.

Keywords

Small-scale compost; backyard compost; on-site compost; home compost; community compost; compost pathogens; compost hygiene

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Project Objectives

The overall goals of this study were to: 1) determine the prevalence of selected human pathogens in composts generated in typical small-scale composting systems in New York State; 2) develop guidance for composters operating small-scale systems for, minimizing pathogen risks; and 3) train and educate Extension educators and others about minimizing exposure to pathogens from small-scale composting systems.

Introduction

A majority of solid waste generated in the United States is organic material that can be recycled through composting (USEPA 1999). On-site composting of yard trimmings and food scraps at homes, businesses, and institutions is the most environmentally sound approach to organic waste recycling since it avoids transportation impacts and the impacts of large centralized facilities. It also makes the resulting compost available for use by the generator. To be successfully used, however, the quality of the compost must be appropriate for its intended purpose. For use in gardens, hygienic quality in regard to pathogenic organisms is an important quality criteria.

This work focuses on the hygienic quality of composts produced in small-scale compost systems at homes, schools and multi-family residences. While disease causing organisms represent only a very small fraction of the microbial community in compost piles, but there are factors that need to be considered. A literature search revealed very few data on this subject.

Research has shown that compost achieving the "temperature/time" regime required for proper operation of large, permitted composting facilities is effective in pathogen destruction (although subsequent recontamination of the compost and regrowth of microorganisms can be a problem) (Bollen 1990; ODEQ 2001). Although it is commonly believed that reaching temperatures of 55°C for 3 days is sufficient to essentially eliminate bacterial pathogens (Yanko et al. 1995), recent work suggests that the control of bacterial pathogens in composting is more complex and not simply the result of thermal treatment (Droffner and Brinton 1995). *Salmonella*, *E. coli*, and other bacteria survived high temperatures for a significant time (Droffner and Brinton, 1995), but whether the high temperature resistant strains are pathogenic is unknown (Droffner and Brinton 1994). Moisture level, for example, is also important in the survival of *E. coli* through the

composting process (Droffner and Brinton, 1995). It has been suggested that microbial competition is also important in the destruction of pathogenic organisms in compost. If so, if finished composts with low levels of competing microorganisms become inoculated with pathogens, there would be an increased potential for high pathogen levels due to regrowth in the absence of competition. .

A review of abstracts on manure composting and pathogens suggest the following:

- Most of the research work is done on fairly controlled compost piles, in contrast with what may actually take place on farms or at homes or schools (Skjelahugen 1992; Cooperband and Middleton 1996; Graft-Hanson et al. 1990).
- The data, even in these cases, is inconsistent. Some piles seem to rapidly lose organisms (Schleiff and Dorn 1997; Graft-Hanson et al. 1990; Forshell and Ekesbo 1993), while others take much longer (Slawon et al. 1998). In other cases, minimal change was observed (Kikuchi and Ataku 1998; Tiquia et al. 1998) or in one case the number of organisms actually increased with time (Mote et al. 1988).
- The actual organisms studied varied, but *E. coli* and *Salmonella* are a recurring theme, because they are two organisms associated with animal manures, and presumably also of food wastes, that are of concern to human health (Skjelahugen 1992; Cooperband and Middleton 1996; Schleiff and Dorn 1997). These organisms are used by US Environmental Protection Agency and many states as “indicator” organisims for products derived from sewage sludges. The term “indicator organism” is discussed in the Materials and Methods section.
- The attempt to relate critical processing and compost pile factors to the outcome of composting with respect to pathogen concentrations has received minimal attention.
- Commonly used methods for the detection of *Salmonella* and *Listeria* may fail to detect those present (Yanko et al, 1995; Droffner and Brinton 1995).

A literature review and discussions with experts turned up almost no information on the topic of safety in regard to pathogens for small-scale composting systems. One article, published by German authors, did find that small compost systems do not generate adequate heat to kill human pathogens such as *Salmonella* (Roth 1994).

Information about the time/temperature behavior of pathogens in the temperature range of interest is also limited. Data used for food service establishments where food temperatures are directed to be above 60°C or below 4.4°C are not directly relevant to these compost systems.

In large-scale composting operations, pathogen concerns may arise if either; 1) adequate temperatures are not achieved for sufficient duration to ensure pathogen destruction, or 2) recontamination occurs after the composting process is successfully achieved. The Oregon Department of Environmental Quality (2001) states that regrowth of bacterial pathogens may occur when there is available carbon, adequate moisture, and a lack of competitive organisms. In small composting systems, these conditions are frequently the norm.

Most home and small institutional and commercial compost systems do not reach 55° C, or if they do, composts may not maintain temperatures for sufficient lengths of time for pathogen reduction. The temperature as recorded (when this is done) is often hottest toward the core of the pile and cooler along the pile's edges. Given the less systematic nature of turning in most of the smaller compost systems, it is likely that even with piles that self-heat, not all of the compost will be subjected to the higher temperatures. Thus, if pathogens are present, they may persist through the composting process.

Another concern raised by Droffner and Brinton (1995) and Yanko et al. (1995), is whether the standard techniques used for microbiological characterization of pathogens are effective with compost samples. As Droffner and Brinton's experiments with *Listeria* demonstrate, the enrichment media does not enrich for those organisms that survived the high temperature regime in the compost. Comparing five methods for enumeration of *Salmonella* in composts and sludges, Yanko, et al. (1995), found that the EPA approved methods significantly under counted. Thus, standard methods may not accurately measure pathogens in the compost.

Materials and Methods

Project Duration

This project took place over a 3-year period and included two separate sampling events. The first began in April of 2001 and was completed in January of 2002. This period of time is referred to as the "early" sampling period. The second sampling event began in September of 2002 and was completed by the end of October of the same year. The second sampling period is referred to as the "late" sampling period.

Site Selection

Twenty sites across New York State were selected to participate in this study. Of these, 6 participated only in the early round of sampling, while the remaining 14 participated in the full study with samples analyzed both in 2001 and 2002. Data regarding compost management was also obtained for each site through a questionnaire. (See Appendix A for a copy of the questionnaire and a summary of the results). Sites were identified by Cornell Cooperative Extension educators in New York City, Tompkins County, and Schuyler County, New York who work with home, school and multi-family residential composters.

Sites for which data were collected include 10 homes, 6 communal compost piles (at community gardens, multi-family residences, or the workplace), 2 schools and one dormitory residence.

Sampling Protocol

Each sample consisted of 16 representative grab samples gathered from the compost pile, using standard collection techniques to prevent contamination and obtain a representative sample (See Appendix B). Each composite grab sample was placed in a 5-gallon bucket lined with a clean garbage bag. Using clean vinyl gloves, the contents were mixed thoroughly to provide as uniform a composite sample as possible. Two testing laboratories were used. For each laboratory, 2 heavy-duty 1-quart Zip-loc™ bags were filled using a portion of the composite sample, and clearly labeled.

The sealed bags were packed in insulated styrofoam containers with ice to minimize both microbial growth and death. Samples going to laboratory #1 for analysis were dropped off in

person after sampling was finished for the day. Samples going to laboratory #2 were shipped overnight.

Microorganisms of Interest

Indicator Organisms It is impractical to detect and enumerate all pathogenic organisms of concern. In assessing hygienic quality, typically certain microbes are selected to serve as "indicator organisms." The assumption is made that if the indicator organism is absent or present in sufficiently low levels, that other pathogenic organisms will also be reduced to acceptable levels. To be a good indicator of compost hygienic quality, the microbe must be present in the initial stages, it must be suitable for analysis using the appropriate methods, and it should be among the hardiest of the pathogens (Prescott et al. 1996).

In this project, several coliform bacteria and fecal Streptococcus were chosen as indicator organisms. Coliforms are part of the Enterobacteriaceae family, which includes *Escherichia coli, Enterbacter aerogens*, and *Klebsiella pneumoniae*. Coliforms represent about 10% of the intestinal microorganisms in the human gut. Defined as "facultative anaerobic, gram-negative, non-spore forming, rod-shaped bacteria that ferment lactose within 48 hours at 35°C," coliforms are widely used as indicator organisms because they are more resistant to desiccation than other microbes found in human and animal digestive systems (Prescott et al. 1996). No indicator is perfect and one study showed that *E. coli* survived longer in outdoor soil than *Streptococcus faecalis* during summer, while in spring and winter the fecal strep survived much longer (Donsel et al 1967). This makes the use of *E. coli* as an indicator questionable.

Fecal coliform are a sub-group of total coliforms (see Figure 1). Total coliform counts often include organisms that do not reside in the intestinal tract, so methods have been developed to test for fecal coliforms, which by definition are supposed to be coliform microbes that grow when a temperature of 45°C (i.e., the temperature of the human gut) is maintained during incubation. The *E. coli* and *Enterococci*, tested in this study, are fecal coliforms.

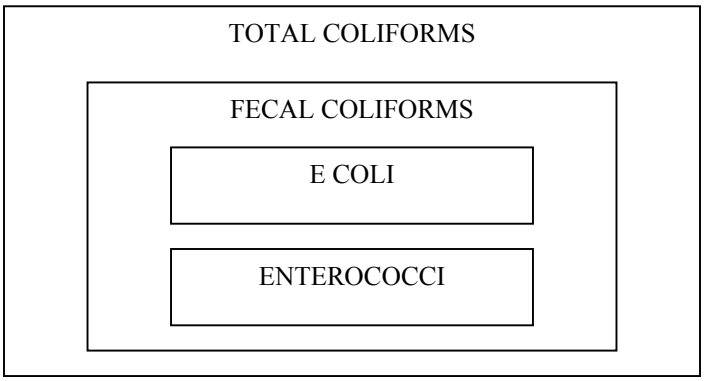

Figure 1. Hierarchy of coliform bacteria

Escherichia coli – E. coli are a natural inhabitant of the human digestive tract, and are found in the large intestine. *E. coli* are facultatively anaerobic bacteria, which means they do not need oxygen for growth, but do better in its presence. *E. coli* is the most abundant microbe in the fecal coliform group but represents only 0.1% of the total microbe population in the human gut (Prescott et al. 1996).

Often, undercooked ground beef or unprocessed milk is responsible for disease due to coliforms (Prescott et al. 1996). Potential sources of *E. coli* in a home composting environment include meat scraps as well as natural sources. An examination of soils found evidence of total coliform, fecal coliforms, total strep and fecal strep in pasture and forest soils (Faust, 1982). The fecal coliforms in the forest soils were identified primarily as *E. coli*.

Enterococci spp. - These organisms are found in the small intestine of most mammals, including humans. *E. faecalis* is the most common member of the Enterococci group, and can cause urinary tract infections, as well as endocarditis, an infection of the heart lining, in rare cases (WebMD 2003b). *Enterococci* are commonly found in the gastrointestinal tract of humans and animals, and may enter the small-scale compost pile through natural sources such as animal scat. *Enterococci* and fecal *Streptococci* are closely related, and form a subgroup of fecal coliforms (Prescott et al. 1996).

Fecal Streptococcus - *Streptococci* and *Enterococci* are closely related and part of a sizable, complicated genus of bacteria. *Streptococci* are non-motile and do not form endospores (i.e.,

thick-walled spores that can resist heat and chemicals). Members of this group are responsible for streptococcal sore throats and rheumatic fever, but some species comprise part of the natural flora of human mouth and respiratory tract. Small-scale composts may become inoculated through post consumer food waste. For this study, fecal *Streptococci* were used as an indicator organism (Prescott et al. 1996).

Pathogenic Organisms

Salmonella spp.-Some types of *Salmonella* bacteria can cause food poisoning. *Salmonella* are included because they may be found in a variety of foods that are added to home composts such as dairy and meat products, poultry, eggs, and fish. *Salmonella* survive independently of a human host, and can be transported in the intestinal tract of animals that include dogs and cats, livestock including cattle, horses, swine, sheep, and fowl, and wildlife including rodents, birds, turtles, and reptiles (Prescott et al. 1996). Home composts can be exposed to any of these, either directly or indirectly.

Infections with *Salmonella* can cause food poisoning, and is termed Salmonellosis. Symptoms may include diarrhea and mild fever. Less frequently muscle aches, headaches and nausea might occur. These symptoms appear because *Salmonella* microbes secrete enterotoxins (i.e., toxins that affect cells in the intestinal lining) and cytotoxins (i.e., toxins or antibodies that impact only certain specific cell types). The two most common species causing Salmonellosis are *S. typhimurium* and *S. enteritidis* (Prescott et al. 1996).

Clostridium perfringens – C. perfringens is commonly found growing in reheated meat dishes, and if large quantities of this microbe are ingested, severe diarrhea can quickly occur, as well as occasional vomiting. Recovery takes place in a healthy person within 4 days, but the symptoms of *C. perfringens* infection can be serious. *C. perfringens* is naturally present in the soil and may become incorporated into composts through soil mixing. *C. perfringens* is also associated with food poising in cases were meat is rewarmed. Small-scale compost piles may be inoculated through natural sources or meat scraps in post consumer food waste (Prescott et al. 1996).

Microbial Testing

The two laboratories used different methodologies for measuring bacteria. Laboratory #1 specializes in testing water samples for microorganisms, but has limited experience working with compost and solid mediums. Laboratory #2 specializes in compost testing, and has many years of experience working with and testing solid media. See Table 1 for a comparison of test methods.

	Methodology	
	Lab 1 (Early and late samples)	Lab 2 (Late samples only)
C. perfringens	*Clostridium perfringens*: Membrane Filter Method, ICR Microbial Laboratory Manual. USEPA Office of Research and Development, Washington DC. EPA/600/R-95/178 (1996)	Compendium of Methods for the Microbiological Examination of Foods, 3rd Edition
E. coli	IDEXX Colilert System	Part 9221 F., "Standard Methods for the Examination of Water and Wastewater", 18th Edition, 1992, American Public Health Association, 1015 15th St, NW, Washington, DC 20005
Total Coliform	IDEXX Colilert System	Part 9221 B., "Standard Methods for the Examination of Water and Wastewater", 18th Edition, 1992, American Public Health Association, 1015 15th St, NW, Washington, DC 20005
Enterococci	IDEXX Enterolert System	Part 9230 B., "Standard Methods for the Examination of Water and Wastewater", 18th Edition, 1992, American Public Health Association, 1015 15th St, NW, Washington, DC 20005
Fecal Coliforms	Fecal Coliforms in Biosolids by Multiple-Tube Fermentations and Membrane Filtration Procedures: EPA Method 1680 (EPA-821-R-98-003)	Part 9221 E., "Standard Methods for the Examination of Water and Wastewater", 18th Edition, 1992, American Public Health Association, 1015 15th St, NW, Washington, DC 20005
Salmonella (early samples)	Detection and Enumeration of *Salmonella* sp. (Kenner and Clark, 1974) as published by EPA (1992) Environmental Regulations and Technology. Control of Pathogens and Vector Attraction in Sewage Sludge. pp 107-115.	Not Applicable
*Salmonella** (late samples)	Method 1682: Salmonella spp. in Biosolids by Enrichment, Selection, and Biochemical Characterization. EPA-821-R-98-004	Part 9260 D., "Standard Methods for the Examination of Water and Wastewater", 18th Edition, 1992, American Public Health Association, 1015 15th Street, NW., Washington, DC 20005

*Method of *Salmonella* Detection in second round of sampling.

Table 1. Comparison of Laboratory Methods

As a hedge against this uncertainty, in addition to using the EPA's "most probable number" (MPN) technique (EPA 40 CFR Part 503), we also examined compost samples by a different cultural method specific for *E. coli* 0157:H7 by plating on sorbitol-MacConkey-MUG agar. Low levels of fecal coliform (<1000 MPN per gram dry solids) and very low *Salmonella* (<3 MPN per 4 g solids) with a negative for *E.coli* 0157:H7 (at a detection limit of 1 cell/25 g solids) will be interpreted as a sign of a very hygienic compost.

Compost samples collected during early sampling were mostly analyzed by Lab 1. Lab 2 did some limited testing of non-microbial parameters on samples submitted toward the end of the early sampling. In the second round of sampling, lab 1 measured non-microbial parameters as well as *C. perfringens*, *E. coli*, *Enterococci*, *Salmonella*, total coliforms, fecal coliforms, and fecal *Streptococci*. Lab 2 tested for *C. perfringens*, *E. coli*, *Enterococci*, *Salmonella*, total coliforms, and fecal coliforms. Laboratory 1 changed reporting units for all of the microbes except clostridium and fecal coliform midway through the project. For example, samples collected in early 2001 reported *E. coli* in MPN (most probable number)/100mL but then switched in 2002 to MPN/g.

Statistical Analysis

We used statistical methods to address several questions.

1. Was there a significant difference between the results from laboratory 1 and laboratory 2?
2. Could values for various compost parameters (such as pH) be correlated with microbial concentrations?
3. Was there a correlation between presence and concentration of the various microbes?

Statistical methods included ANOVA, which was used to address question 1. The variance between sample means from laboratory 1 and laboratory 2 was analyzed and then compared to the variance within each laboratory data set.

Multiple regression analysis was used to address question 2. We examined the influence of a number of independent variables on the concentration of each particular microbe (the dependent variable). An example is provided below:

$Y = a + b_1*X_1 + b_2*X_2 \ldots b_P*X_P$

Where
Y = dependent variable
a = constant
b_1 = slope of independent variable 1
b_2 = slope of independent variable 2
b_p = slope of independent variable P
X_1 = value of independent variable 1
X_2 = value of independent variable 2
X_p = value of independent variable P

The independent variables used for regression analysis in this study are organic matter (OM), C:N ratio (CN), density, Total Kjeldahl Nitrogen (TKN), moisture, pH, and conductivity (salts). The dependent variable is one of the following: *Clostridium*, *E. coli*, enterococci, fecal coliforms, fecal strep, and total coliform. Multiple regression analyses were performed to determine whether microbial concentrations could be predicted from the other variables. A test of significance was used so that results are reported only when the prediction equation was 90% more likely than "guessing" to determine the average value of whatever microbe being evaluated are reported.

Question 3 was addressed by constructing scatterplot graphs comparing one microbe to another. For example, data for *E. coli* would be placed on the X-axis of a scatterplot graph, and *Salmonella* data would be placed on the Y-axis. The resulting r^2 value, a measure of correlation strength, would then be examined to see if a relationship between the two exists. If a strong correlation is found, the curve generated by the scatterplot could be used to predict the concentration of one microbe based on the other (Figure 2).

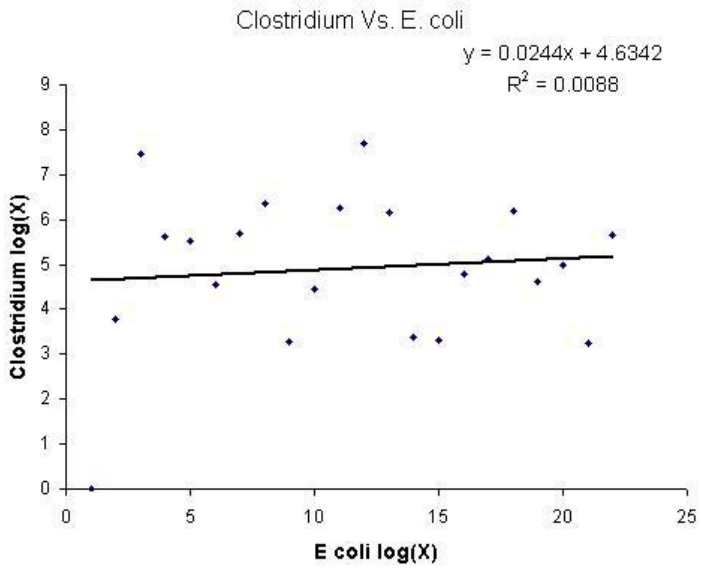

Figure 2. Example of a correlation graph between *C. perfringens* and *E. coli*. The slope of the line indicates the strength of relationship between factors. In this case, the line is flat and the "r^2" value is close to zero, which means there is no relationship.

Results

Physical Parameters

The 19 compost piles included in this project represent a variety of management practices. Of these, 15 included pre-consumer food waste and 14 added post-consumer food waste, but only 2 added meat scrap. Five sites turned the compost piles.

Physical attributes of the composts varied widely among the piles as seen in Table 2. Low organic matter is typically associated with piles into which soil is mixed. The test results for physical parameters are available in Appendix C.

Physical Parameter	**Range**
Water Holding Capacity	50% - 246%
Organic Matter	9% - 80.5%
C to N ratio	10.4 – 29
Total Kjeldahl Nitrogen	0.185% - 2.419%
pH	6.54 – 8.65
Solvita™ Maturity	3 - 7

Table 2. Ranges of small-scale compost physical parameters.

Bacterial Concentrations

The following tables provide reported ranges from all of the samples for each bacterium measured from laboratory 1 and laboratory 2. Clearly there is a very wide range in what was detected. It is noteworthy that even replicate composite samples from the same site taken on the same day and analyzed by the same laboratory often exhibited more than an order of magnitude difference. Because compost is a heterogeneous material and because only small subsamples are used for bacterial testing, there is the potential for two "identical" samples to contain different pathogens and different concentrations of those pathogens. More than 4 orders of magnitude (10,000 fold) difference in several replicates was observed in a few cases.

Appendix D includes all of the test results for the bacterial analyses. The two laboratories used in this study applied different methods to measure the same set of bacteria as discussed elsewhere in this report.

Laboratory 1

Microbe	Range
Clostridium perfringens (CFU/100ml)	0-1840000
Escherichia Coli (MPN/g)	1-180000
Total Coliform (MPN/g)	1-44900000
Enterococci (MPN/g)	1-198000
Fecal Coliform (MPN/g)	0-270000
Streptococci (MPN/g)	N/A
Salmonella (MPN/4g)	0.12-8.7

Table 3. Ranges of small-scale compost bacterial parameters for laboratory 1.

Laboratory 2

Microbe	Range
Clostridium perfringens (MPN/g)	1700-48000000
Escherichia Coli (MPN/g)	6.5-9700
Total Coliform (MPN/g)	9700-31000000
Enterococci (MPN/g)	6.5-96000
Fecal Coliform (MPN/g)	13-12000
Streptococci (MPN/g)	160-570000
Salmonella (MPN/g)	3.2-8.0

Table 4. Ranges of small-scale compost bacterial parameters for laboratory 2.

Comparison of Pathogen Concentrations Reported by Laboratory 1 and Laboratory 2

The results from laboratory 1 and laboratory 2 for a given microbe were often different by an order of magnitude or more. Considering that both labs received subsamples taken from the same composite sample of each pile, such large differences were unexpected, although other CWMI studies have shown that compost parameters can be highly variable even at a single site, or compost pile (CWMI 2003). Using analysis of variance (ANOVA) techniques, we analyzed the data to test for a pattern of difference between the two labs.

Data for *E. coli*, total coliform, *Enterococci*, and fecal coliform were transformed to a log scale for the following ANOVA tests. *Salmonella* results were used "as is." *Salmonella* was not log transformed because numbers detected in analysis were very low, unlike the other microbes that were often reported in the hundreds of thousands or millions. For detailed test results, see Appendix E.

C Perfringens - Results for *C. perfringens* from each of the two labs used were reported in different units. Laboratory 1 provided results in CFU/100 mL and Laboratory 2 gave results as MPN/g dry weight. Because of this discrepancy, and also because different methods were used to measure *C. perfringens* at each laboratory, only data from laboratory 2 was considered and an ANOVA was not performed.

E coli - Laboratory 1 provided results using two different units. In the earlier round of sampling, *E. coli* were reported as MPN/100 mL. In later sampling, results for *E. coli* are given in MPN/g dry weight. Thus the laboratory results could be compared for the later sampling. Laboratory 2 reported *E. coli* in MPN/g dry weight for all reports.

ANOVA found that Laboratory 1 reported significantly higher *E. coli* counts than Laboratory 2 at a 95% confidence level. Laboratory 1 averaged log 3.284 (or 1923 MPN/g) and Laboratory 2 averaged log 2.886 (769 MPN/g).

Total Coliform – Both laboratories reported total coliforms as MPN/g dry weight in the later round of sampling, so these data were used to perform an ANOVA.

ANOVA found that lab results for total coliform were not significantly different between the labs at a confidence level of 95%.

Enterococci – Both laboratories reported *Enterococci* as MPN/g dry weight in the later round of sampling, so these data were used to perform an ANOVA.

ANOVA revealed that Laboratory 1 reported significantly higher *Enterococci* counts than Laboratory 2 at a 95% confidence level. Laboratory 1 averaged log 3.707 (or 5093 MPN/g) and Laboratory 2 averaged log 2.979 (953 MPN/g).

Fecal Coliforms – For all sampling, both labs reported results in similar units, MPN/g dry weight. Fecal coliform is also the only microbe tested both in the early and late samples. ANOVA revealed that Laboratory 1 reported significantly higher fecal coliform counts than Laboratory 2 at a confidence level of 95%. Laboratory 1 averaged log 3.562 (3648 MPN/g) and Laboratory 2 averaged 2.839 (690 MPN/g).

Salmonella – Both laboratories reported *Salmonella* as MPN/g dry weight in the later round of sampling, so these data were used to perform an ANOVA.

ANOVA revealed that Laboratory 2 reported significantly higher counts of *Salmonella* than Laboratory 2 at a confidence level of 95%. Laboratory 1 averaged 0.524 MPN/g *Salmonella* and Laboratory 2 averaged 4.867 MPN/g *Salmonella*.

We found that differences between labs for *E. coli*, *Enterococci*, fecal coliform, total coliform, and *Enterococci* were all statistically significant - the variation in samples between laboratories was high for each of the microorganisms. This led us to ask the question of whether using either laboratory's data individually would be feasible. Again, we used ANOVA methods to look at each dataset individually and examine consistency of variation within and between samples. In

this instance, neither laboratory 1 nor laboratory 2 displayed a significant difference in variation within or between samples. While both were consistent when looked at separately, a final decision was made, based on knowledge that laboratory 2 had worked extensively with compost testing methodologies while laboratory 1 had not, to use only the dataset from laboratory 2 for the remaining analyses performed in this study.

Relation of Compost Physical Parameters to Microbial Concentration

Researchers asked the question: Do physical parameters of small-scale compost piles influence the concentration of microbes? Multiple regression analysis was performed to derive a prediction equation for each type of microbe looked at in this study. It should be noted that because ANOVA found significant differences between labs when results were compared, and other reasons outlined in the discussion section, only laboratory 2 data were used in the regression analysis. This resulted in a small dataset – 18 samples in all. See Appendix F for more detailed results. No statistically significant relationship was found between the physical parameters and microbial concentrations.

Results of Multiple Regression Analysis

Independent Variables

X_1 = % organic matter
X_2 = CN ratio
X_3 = Density
X_4 = Total Kjendhal Nitrogen
X_5 = % moisture
X_6 = pH
X_7 = conductivity (mmhos)

Salmonella

$$Y = -7.812 - 0.188*X_1 - 0.126*X_2 - 0.098*X_3 + 1.978*X_4 + 0.144*X_5 + 2.048*X_6 - 0.269*X_7$$

$R^2 = 0.628$
Significance = 0.101

Clostridium

$$\log(Y) = 31.836 + 0.289*X_1 - 1.136*X_2 - 0.173*X_3 - 9.959*X_4 + 0.036*X_5 - 0.109*X_6 - 0.497*X_7$$

$R^2 = 0.369$
Significance = 0.582

Fecal Coliform

$$\log(Y) = -1.294 + 0.014*X_1 - 0.209*X_2 + 0.016*X_3 - 0.986*X_4 + 0.050*X_5 + 0.631*X_6 - 0.079*X_7$$

$R^2 = 0.296$
Significance = 0.744

Total Coliform
$\log(Y) = -18.260 - 0.489*X_1 + 1.337*X_2 + 0.017*X_3 + 12.554*X_4 + 0.018*X_5 + 0.453*X_6 + 0.128*X_7$

$R^2 = 0.568$
Significance = 0.177

E. coli
$\log(Y) = 7.670 + 0.147*X_1 - 0.687*X_2 - 0.054*X_3 - 5.719*X_4 + 0.088*X_5 + 0.638*X_6 - 0.078*X_7$

$R^2 = 0.422$
Significance = 0.459

Enterococci
$\log(Y) = -21.316 - 0.352*X_1 + 1.026*X_2 + 0.062*X_3 + 8.813*X_4 + 0.032*X_5 + 0.756*X_6 + 0.147*X_7$

$R^2 = 0.368$
Significance = 0.584

Fecal Strep
$\log(Y) = -18.623 - 0.354*X_1 + 1.210*X_2 + 0.136*X_3 + 11.555*X_4 - 0.067*X_5 - 0.091*X_6 + 0.159*X_7$

$R^2 = 0.372$
Significance = 0.576

Correlations between Physical Compost Parameters and Microbial Concentrations

Results of multiple regression analysis were obtained using data from laboratory 2 for the reasons stated above. OM, CN ratio, density, TKN, moisture, pH, and salts were considered as independent variables and the microbial concentrations were considered the dependent variable. Of the seven microbes examined, only for *Salmonella* did the multiple regression show a significance level close to the cut-off of 0.1, or 90% (0.101).

TKN and pH were the independent variables with which *Salmonella* concentrations were most correlated. Higher pH and higher nitrogen was associated with higher levels of *Salmonella*.

Looking at slopes (b_x) of each independent variable in the prediction equation for *Salmonella*, total nitrogen (b = +1.978) and pH (b = -2.048) have the strongest influence, while all other physical compost characteristics have b values near zero. While no significant correlation between physical compost characteristics and the other microbes was found, an examination of those analyses show that among the parameters, pH and TKN showed the strongest relationship,

for all of the different types of bacteria. This suggests that pH and TKN are important influences on microbial populations, with higher pH and TKN correlated with larger microbial populations.

Relationship among Microbes

The data were analyzed to determine if the different microbes were correlated. The only correlations found were for microbes that were part of the same set of organisms. Thus total coliform was correlated with fecal coliform, for example. However no relation was found between the non-related microbes. This means that none of the microbes could be considered an appropriate indicator of general hygienic status.

Relationship of Compost Practices and Microbial Concentration

To look at the relationship between microbial populations and management practices, including addition of pre and post consumer food waste, meat scrap addition, and turning, a series of independent samples t-tests were performed. Data for each microbe were grouped according to management practice and compared to look for differences.

The only significant difference found was between samples submitted to laboratory 1 when sorted according to whether meat scrap was added to the compost piles. Results showed that piles where no meat scrap was added actually had significantly higher *E. coli* counts than piles where meat scrap was added (log 3.48 and log 2.28, respectively). For detailed results, see Appendix G.

Discussion

An unanticipated, but important, finding that came out of this study is that methodology for the analysis of composts is not standardized and is an important factor. As the results of ANOVA demonstrate, there were significant differences between laboratory 1 and laboratory 2. For all microbes measured, with the exception of total coliform, significant differences were found in results from the two labs. We suspect that this resulted from differences in methodology.

The discovery of the significant differences in results between laboratories, the change in reporting units for laboratory 1 midway through the project, and the greater consistency of results from laboratory 2 led us to use only those results in our further analysis. Thus the dataset

was half of what had been anticipated. While statistical analysis was performed on the dataset, the small sample size limits the accuracy and power of results obtained.

Results indicate that none of the microbes examined in this study are reliable indicators of compost hygiene in small-scale settings. However, the United States Environmental Protection Agency (USEPA) regulates *Salmonella* and fecal coliform concentrations in composted sewage sludges. While small-scale composts are in no way regulated, the figures provided by USEPA can be used as a benchmark to examine their hygienic quality compared to a set of established and frequently used criteria.

The limit set by USEPA for *Salmonella* spp. is less than 3 Most Probable Number (MPN)/4 grams of solid. The limit for fecal coliform concentration is less than 1000 MPN/gram of solid. The USEPA regulations state that a sludge compost need only pass either *Salmonella* or fecal coliform to be suitable for use.

Among the early samples analyzed by laboratory 1, 5 of 32 had greater than 3 MPN/4 g, and 9 of 32 exceeded 1000 MPN. But most composts passed either *Salmonella* or fecal coliform. Laboratory 2 did not report any samples in MPN/4 g, but each of the 18 samples analyzed fell below the level of detection, meaning *Salmonella* levels were still very low. 7 of 18 samples tested by laboratory 2 exceeded fecal coliform limits, but most composts fared well. Overall, 60% of the compost samples fell below 1000MPN/g of fecal coliform.

The finding of bacteria in the home-scale compost systems is not surprising since most systems are not highly managed. Consider that among the microbial groups tested in this study – total coliform and fecal coliform – disease-causing organisms posing a risk to humans represent only a small fraction of these. Add to this the fact that even within a genus such as *Salmonella*, there are multiple species, and even sub-species, and only a select few are pathogenic. In this study, all *Salmonella* were measured, but this doesn't say anything definitive about health risk.

Another factor to consider is "infectious dose." Even a pathogenic organism does not cause disease unless sufficient numbers are present. The dose that may cause disease will also vary with the susceptibility of the exposed person.

Background levels of microorganisms have been documented in a number of studies because of their importance in storm water contamination, land use practices, and other topics (Van Donsel et al 1967, Faust 1982, and Geldreich et al 1962). Background levels of microbes are an important factor that was not closely examined in this study, but are nonetheless important in understanding compost hygiene.

A 2002 study of large-scale composting facilities, sponsored by the Nordic Council of Ministers, examined several composting facilities taking in household waste, defined by the researchers as including meat scrap, soft yard waste and shredded biodegradable household items. While much larger in scale than sites examined in this current study, some important observations were made relating to the sanitization of composts made from household sources of material.

Researchers found consistently high concentrations of *E. coli* and *Enterococcis* in the end products of household waste composts that were actively composted for shorter periods of time, compared to those that composted longer. As a result, it was recommended that when high concentrations of coliforms are present in raw materials, more effective methods of thermophilic composting, and time, are needed to ensure pathogen reduction (Christensen et al., 2002).

The Nordic Council paper also suggests that fecal coliforms and Enterobacteriaceae may not be highly reliable indicators of pathogen reduction mainly because both represent very heterogeneous groups of organisms. For example, "fecal" coliforms found in raw materials of household based composts were in fact fecal in origin, whereas "fecal" coliforms in finished end product were not. The study authors support this statement by pointing out that *E. coli*, a known fecal coliform, was high in unfinished compost, but low or undetectable in finished products, while fecal coliforms were consistently high. In the case of Enterobacteriaceae, non-fecal species of this group are known to grow on decomposing plant matter found in finished composts (Christensen et al., 2002).

Conclusion

Based on the results of this study, a review of current literature, and common sense, the following guidelines are suggested for use in small-scale compost settings to minimize any potential health risks (refer to Appendix H for a fact sheet on compost hygiene for small-scale systems). Small-scale on-site compost systems provide many environmental benefits. When good hygiene practices are used, the relative health risks are low.

1. Avoid certain inputs to the compost pile such as raw poultry or meat wastes, pet feces, and plate scrapings from people who are ill.
2. Consider managing your composting system to ensure that it gets and stays hot long enough to reduce pathogens. There are methods available for small-scale compost piles.
3. Practice good personal hygiene when handling compost. Proper personal sanitation is the most effective method for controlling the impact of any pathogens that may be in the compost. Wash hands after handling compost and/or use gloves. If the compost is particularly dusty, watering is an option.
4. Persons with weakened immune systems or medical conditions that compromise the body's ability to fight infection should use caution when handling compost.
5. If possible, allow composts that are produced in a small-scale setting to age for at least a year before use.

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APPENDIX A – Survey Sample and Summary of Results

Cornell Waste Management Institute – Small-scale Composting Survey
101b Rice Hall, Cornell University, Ithaca, NY 14853. 607-255-8444

1. Composter's Name _____

   Address _____

   Phone _____ Fax _____ Email _____

2. What is the source of your materials for your compost pile?
   a. Home b. School
   c. Business (what kind? _____) d. Other _____

3. If the waste is home-generated, how many households are participating?
   a. 1 b. 2-5 c. 5 or more

4. Where is the composting system located? _____

5. a. What type of organic residuals do you compost (check all that apply)?

Type of Waste	% of pile
a. Food residuals (pre-consumption, i.e., trimmings)	
b. Food residuals (post-consumption, i.e., plate scraps)	
c. Yard waste	
d. Bulking agent	
e. Animal waste (manure)	
f. Animal carcasses	
g. Human waste (e.g., diaper material)	
h. Non-compost items (lime, wood ash, fertilizer, etc.)	
i. Other	

   b. What type of bulking agent do you use?
   a. Wood chips b. Sawdust c. Newspaper
   d. Cardboard e. Garden residuals f. Leaves g. Other

   c. What are some of the major components of your food waste?

   _____

   d. Do you include meat scraps? Chicken? Fish? Dairy?
   a. Yes b. No

6. How is the waste composted?
   a. Compost pockets (buried)
   b. Static piles (mounds, wire mesh bins, snow fence bins, cinder block bins, wooden bins, plastic bins)
   c. Turned pile (any of the above mentioned, including garbage cans)
   d. Layered method
   e. Passively aerated (including hot boxes)
   g. Vermicomposting
   h. Other _____

7. a. If you are using a purchased bin, what is the brand name? _____
   b. What are its dimensions? _____

8. a. If you are turning, how often do you turn?
   a. Daily b. More than once a week
   c. Weekly d. Monthly
   e. Other _____
   b. Do you cover your food scraps with dry material each time?
   a. Yes b. No

9. a. How large are your compost piles?
   _____ feet high
   _____ feet wide
   _____ feet long
   b. How many piles of this size do you have? _____

10. a. Do you have any indication that your compost heated up?
   a. Yes b. No
   b. If yes, how?
   a. By observation b. By measurement
   c. For how long did it say heated? _____

11. How long does it take to make finished compost?
   a. <6 months b. 6-12 months
   c. 12-18 months d. More than 18 months

12. How do you determine the compost is finished?
   a. Sight b. Temperature
   c. Moisture content d. Age of pile
   e. Color, i.e., "looks like soil" f. Other _____

"Compost Hygiene" questions:

13. What type of container do you use to store/haul the food scraps to the compost pile?

   _____

14. How often do you bring waste to the compost pile?
   a. As often as produced b. Daily
   c. More than once a week d. Weekly e. Other

15. How is the waste incorporated?
   a. Placed on top of pile b. Mixed in with hands
   c. Mixed in with gardening or other tools

16. How do you prepare the "in-house" waste-hauling container for the next batch?
   a. No preparation b. Rinsed with water
   c. Scrubbed with soap and water d. Cleaned with disinfecting chemicals
   e. Replace a liner f. Other _____

17. What precautions do you take when:
   1. Incorporating waste? _____
   2. Turning compost pile? _____
   3. Spreading compost? _____
   Choose from all that apply: a. Washing hands after coming into contact
   b. Wearing gloves
   c. Using gardening tools
   d. Other

18. Who carries out the following tasks:
    1. Incorporating waste? _____
    2. Turning compost pile? _____
    3. Spreading compost? _____

    Choose from all that apply:
    a. Child
    b. Adult
    c. Elderly adult (e.g., >65)

19. a. Have you ever had your compost analyzed by a lab? _____ If yes, for what parameters?

    _____

    b. What did you learn?_____

20. a. Do you think you have ever gotten sick from working with your compost?
    a. Yes b. No
    b. If yes, please explain _____

21. Have you had any problems with pests?
    a. Pets b. Flies or other insects c. Rodents
    d. Birds e. Other _____

22. How is finished compost used?
    a. Spread in vegetable garden
    b. Spread in flower garden
    c. Spread around trees
    d. Spread on lawn
    e. Given away to _____
    f. Sold to _____
    g. Other _____

23. Where do you get your information on composting methods? Compost use?

    _____

Interview's Name _____

Small-scale Composting Survey Results

A total of 19 home compost sites were part of this project. Of those only 12 responded to the survey included as part of this appendix.

Out of 13 respondants:

Source of Organic Material
8 report composting household sources of organics.
2 report composting school sources of organics.
2 report composting business sources of organics.
3 report compost other sources of organics.

Households Served
6 compost sites serve a single household.
2 compost sites serve from 2 to 5 households.
2 compost sites serve more than 5 households.

Types of Composted Materials
12 sites add pre-consumer food waste to their compost piles.
12 sites add post-consumer food waste to their compost piles.
9 sites add yard waste to their compost piles.
6 compost sites are bulked with wood chips.
2 compost sites are bulked with saw dust.
1 compost site is bulked with newspaper.
4 compost sites bulk with straw.
6 compost sites bulk with garden residuals.
8 compost sites bulk with leaves.
2 compost sites add meat scrap.

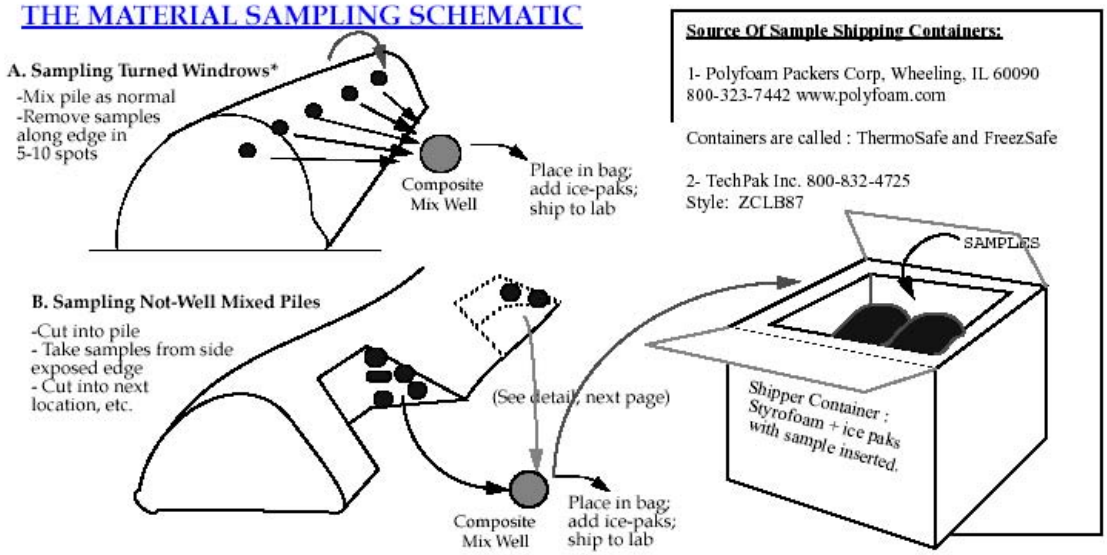
Turning Frequency and Turning Method
6 compost sites are never turned.
6 sites use a layering compost method.
2 sites use passive aeration as a compost method.
1 site uses a turning unit as a compost method.
1 compost site turns daily
1 compost site turns weekly
1 compost site turns monthly
2 compost sites turn every 4 months.
3 compost sites turn once a year.
1 compost site turns less than once a year
10 compost sites cover food scraps after addition.

Compost Production
2 sites produce compost in less than 6 months.
5 sites produce compost in 6 to 12 months.
4 sites produce compost in 12 to 18 months.
1 site produces compost in 18+ months.
11 composters use visual appearance to determine if compost is finished.
3 composters use temperature to determine if compost is finished.
2 composters use moisture content to determine if compost is finished.
7 composters use age to determine if compost is finished.
6 composters use color to determine if compost is finished.
4 composters use other methods to determine if compost is finished.
1 composter adds to the compost pile as needed.
3 composters add to their pile daily.

8 composters add to their pile more than once a week.
1 compost adds to the compost pile weekly.
9 compost sites place scraps on top of the pile.
4 sites mix scraps into the pile.

Compost Pile Dimensions
Compost dimensions provided by respondees range from 3 – 5 ft in height, 3 – 6 feet in width, and 3 – 20 ft in length.

APPENDIX B – Sampling Protocol for Compost Piles



A. Well Mixed Piles* (turned within 4 hours): Take 5 sub-samples each from each side of pile; mix-well in bucket and remove 1-gallon and ship to lab in cardboard/styrofoam containers with ice-paks.

B: Not Well-Mixed piles: Cut cross-section with loader; take 5-sub-samples each from side-wall of cut; repeat operation at 3-5 other locations; remove 1-gallon and ship to lab with ice-paks.

Diagram obtained from Woods End Research Laboratory, Inc. 2004

APPENDIX C – Physical Data

Data Key
Note: units are on dry weight basis.

Field	Description
Site	Arbitrary number assigned to each small scale compost pile for identification.
Sample	Arbitrary number assigned to each sample collected at a given farm.
Date	Date sample was collected.
%WHC	Percent water holding capacity.
%OM	Percent organic matter.
CN_ratio	Ratio of carbon to nitrogen. C:N ratio.
%_TKN	Percent total nitrogen.
Density	Density, in pounds per cubic foot.
Solids	Percent solids.
Moisture	Percent moisture.
Inert	Percent inert and oversize matter.
pH	pH.
C03	Carbonate rating.
S_CO2	Solvita carbon dioxide rating.
S_NH3	Solvita ammonia rating.
M_index	Woods End Research Laboratory maturity index value.

Data

Site	Sample	Lab	Date	%WHC	%OM	CN_ratio	%TKN	Density	Solids	Moisture	Inert	pH	CO3	Salts	S_C02	S_NH3	M_index
1	2	**2**	9/17/2002	100	27.2	13.6	1.082	45	52	48	8.6	7.17	3	1.1	5	5	5
1	3	**2**	9/17/2002	109	30.5	14.6	1.13	46	50.5	49.5	16.3	7.18	3	1.2	5	5	5
2	2	**2**	9/17/2002	178	55.5	12.4	2.419	34	27.8	72.2	4.2	7.51	3	1.6	5	5	5
2	3	**2**	9/17/2002	146	44	12.2	1.944	36	43.5	56.5	1.4	8.1	2	2.8	7	5	7
3	3	**2**	12/3/2001	246	80.5	29	1.5	39	27.7	72.3	22.8	6.57	1	1.3	3	5	3
6	2	**2**	9/17/2002	82	20.6	10.7	1.045	55	47.5	52.5	45	7	3	1.5	7	5	7
6	3	**2**	9/17/2002	90	23.8	11.6	1.104	51	44.8	55.2	2.7	7.87	3	1.5	7	5	7
8	2	**2**	1/23/2002	85	21.9	14	0.843	57	53.2	46.8	0.4	6.55	2	0.3	5	5	5
8	3	**2**	1/23/2002	73	17.4	15.7	0.601	63	58.4	41.6	1.9	6.79	2	0.3	5	5	5
8	4	**2**	1/23/2002	76	18.6	15.4	0.655	59	56	44	0.7	6.54	3	0.6	5	5	5
9	2	**2**	9/17/2002	118	34	15.6	1.179	47	39.7	60.3	10.5	7.28	3	1.1	5	5	5
9	3	**2**	9/17/2002	119	34.3	17.5	1.055	44	38.7	61.3	20.4	7.29	3	0.9	5	5	5

Site	Sample	Lab	Date	%WHC	%OM	CN_ratio	%TKN	Density	Solids	Moisture	Inert	pH	CO3	Salts	S_C02	S_NH3	M_index
13	2	**2**	9/17/2001	83	21.2	12.9	0.89	40	66.4	33.6	4.9	6.93	3	3.5	6	5	6
13	3	**2**	10/1/2002	108	30.2	12.5	1.301	41	61.6	38.4	1.4	7.94	3	2.7	6	5	6
13	4	**2**	10/1/2002	106	29.6	12.3	1.3	42	61.1	38.9	6	7.9	3	2.7	6	5	6
14	1	**2**	9/11/2001	165	50.8	16.1	1.703	34	41.6	58.4	6.1	8.07	3	5.8	6	5	6
14	2	**2**	9/17/2002	193	61	18.7	1.762	43	30	70	4.5	8.2	3	2.4	7	5	7
14	3	**2**	9/17/2002	194	61.4	18.4	1.802	40	30.6	69.4	1.3	8.29	3	2.7	7	5	7
15	1	**2**	9/11/2001	172	53.5	12.8	2.251	34	40.7	59.3	4.9	7.43	2	5	5	5	5
15	2	**2**	9/17/2002	178	55.8	15	2.005	27	48.9	51.1	0	8	2	1.9	7	5	7
15	3	**2**	9/17/2002	181	56.9	15.1	2.031	35	28.8	71.2	1.3	7.67	3	1.1	5	5	5
16	1	**2**	9/11/2001	88	22.7	12.5	0.982	42	53.5	46.5	5.3	7.35	3	7.3	5	5	5
16	2	**2**	9/17/2002	112	31.7	13.8	1.238	33	54.5	45.5	15.9	7.32	3	5.8	3	5	3
16	3	**2**	9/17/2002	122	35.1	16.7	1.137	33	54.8	45.2	14.9	7.95	3	5	3	5	3
17	1	**2**	11/30/2001	128	37.6	10.4	1.961	24	34.2	65.8	1.4	6.83	3	0.6	4	5	4
17	2	**2**	10/1/2002	138	41.1	11.6	1.915	45	36.6	63.4	15.7	6.66	3	2.5	5	5	5
17	3	**2**	10/1/2002	148	44.7	13.2	1.828	42	36.9	63.1	10.2	6.55	3	2.4	5	5	5
18	1	**2**	1/23/2002	90	23.5	13.1	0.968	52	49.3	50.7	4.1	7.51	2	3.2	5	5	5
18	2	**2**	1/23/2002	88	22.8	12.3	1.003	55	50.4	49.6	1.6	7.04	2	2	5	5	5
18	3	**2**	1/23/2002	90	23.8	15	0.854	52	50.4	49.6	3.2	7.38	2	2.1	4	5	4
19	1	**2**	1/29/2002	102	27.9	15	1.008	50	52	48	3	7	2	4.3	6	5	6
19	2	**2**	1/29/2002	125	36.4	18.3	1.075	39	47.7	52.3	4.4	6.58	2	6.3	5	5	5
19	3	**2**	1/29/2002	117	33.3	18.4	0.977	46	46.5	53.5	10	7.1	2	3.2	6	5	6
20	1	**2**	2/12/2002	52	9.9	28.9	0.185	82	71.2	28.8	9.3	8.65	3	5.9	5	5	5
20	2	**2**	2/12/2002	51	9.4	27	0.188	80	75.6	24.4	9.9	8.01	2	3.1	6	5	6
20	3	**2**	2/12/2002	50	9	18.6	0.261	62	70.2	29.8	3.3	7.78	2	4.1	4	5	4

APPENDIX D – Bacterial Data

Data Key
Note: units are on dry weight basis.

Field	Description
Site	Arbitrary number assigned to each small scale compost pile for identification.
Sample	Arbitrary number assigned to each sample collected at a given site. Samples taken the same day at the same site are replicate composite samples..
Lab	Laboratory number
Date	Date sample was collected.
Perf	*Clostristium perfringens* result for given sample.
Perf_unit	Reporting unit for corresponding *Clostridium perfringens* sample.
E_coli	*E. coli* result for given sample.
E_coli_units	Reporting unit for corresponding *E. coli* sample.
Col	Total coliform result for given sample.
Col_units	Reporting unit for corresponding Total coliform sample.
Entero	*Enterococci* result for given sample.
Entero_units	Reporting unit for corresponding *Enterococci* sample.
Fec	Fecal coliform result for given sample.
Fec_units	Reporting unit for corresponding fecal coliform sample.
Strep	Fecal streptococci result for given sample.
Strep_units	Reporting unit for corresponding fecal streptococci sample.
Salm	*Salmonella* result for given sample.
Salm_units	Reporting unit for corresponding *Salmonella* sample. Note some results are in MPN/g and some are MNP/4g.

Data

Site	Sample	Lab	Date	Perf	Perf_units	E_coli	E_coli_units	Col	Col_units	Entero	Entero_units	Fec	Fec_units	Strep	Strep_units	Salm	Salm_units
1	1	**1**	4/24/2001									3.7	MPN/g			<0.13	MPN/4g
1	2	**1**	9/17/2002	6200	CFU/100ml	812	MPN/g	3900000	MPN/g	6500	MPN/g	891	MPN/g			<0.4	MPN/g
1	3	**1**	9/17/2002	5300	CFU/100ml	1800	MPN/g	7700000	MPN/g	2900	MPN/g	377	MPN/g			<0.4	MPN/g
2	1	**1**	4/26/2001									7	MPN/g			0.5	MPN/4g
2	2	**1**	9/17/2002	ND	CFU/100ml	3950	MPN/g	5190000	MPN/g	7300	MPN/g	4400	MPN/g			<0.6	MPN/g
2	3	**1**	9/17/2002	ND	CFU/100ml	8400	MPN/g	44900000	MPN/g	6670	MPN/g	11500	MPN/g			<0.5	MPN/g
3	1	**1**	4/30/2001									6300	MPN/g			2.8	MPN/4g

Site	Sample	Lab	Date	Perf	Perf_units	E_coli	E_coli_units	Col	Col_units	Entero	Entero_units	Fec	Fec_units	Strep	Strep_units	Salm	Salm_units
3	2	1	6/27/2001									2588	MPN/g			0.19	MPN/4g
3	3	1	12/3/2001	50	CFU/100ml	1	MPN/100ml	307.6	MPN/100ml	146.4	CFU/100mL	724.6	MPN/g			8.7	MPN/4g
4	1	1	5/2/2001									<0.37	MPN/g			<0.15	MPN/4g
5	1	1	5/8/2001									1.9	MPN/g			0.8	MPN/4g
6	1	1	5/8/2001									<0.5	MPN/g			0.2	MPN/4g
6	2	1	9/17/2002	ND	CFU/100ml	449	MPN/g	4500000	MPN/g	7370	MPN/g	<449	MPN/g			<0.5	MPN/g
6	3	1	9/17/2002	ND	CFU/100ml	444	MPN/g	6900000	MPN/g	4470	MPN/g	444	MPN/g			<0.5	MPN/g
7	1	1	5/15/2001									5.5	MPN/g			<0.2	MPN/4g
8	1	1	5/15/2001									5000	MPN/g			0.2	MPN/4g
8	2	1	1/23/2002	800	CFU/100ml	5.1	MPN/100ml	37.7	MPN/100ml	2	CFU/100mL	438.6	MPN/g			1.8	MPN/4g
8	3	1	1/23/2002	100	CFU/100ml	2	MPN/100ml	3.1	MPN/100ml	2	CFU/100mL	758.9	MPN/g			4.7	MPN/4g
8	4	1	1/23/2002	250	CFU/100ml	2	MPN/100ml	13.4	MPN/100ml	<1	CFU/100mL	<369.0	MPN/g			2.96	MPN/4g
9	1	1	6/5/2001									61	MPN/g			0.6	MPN/4g
9	2	1	9/17/2002	ND	CFU/100ml	2100	MPN/g	5900000	MPN/g	608	MPN/g	15500	MPN/g			<0.4	MPN/g
9	3	1	9/17/2002	ND	CFU/100ml	4200	MPN/g	2600000	MPN/g	526	MPN/g	21000	MPN/g			0.53	MPN/g
10	1	1	6/11/2001									18	MPN/g			0.3	MPN/4g
11	1	1	6/26/2001									0	MPN/g			0.12	MPN/4g
12	1	1	7/1/2001									40322.6	MPN/g			0.108	MPN/4g
12	2	1	7/1/2001									222.98	MPN/g			0.892	MPN/4g
13	1	1	8/7/2001									1252	MPN/g			0.135	MPN/4g
13	2	1	9/17/2001	4600	CFU/100ml	<1	MPN/100ml	648.8	MPN/100ml	53.3	CFU/100mL	180000	MPN/g			2.56	MPN/4g
13	3	1	10/1/2002	1840000	CFU/100ml	<160	MPN/g	1600000	MPN/g	<320	MPN/g	<288	MPN/g			<0.4	MPN/g
13	4	1	10/1/2002	1460000	CFU/100ml	<162	MPN/g	150000	MPN/g	5310	MPN/g	325	MPN/g			<0.4	MPN/g
14	1	1	9/11/2001	10	CFU/100ml	<1	MPN/100ml	178.9	MPN/100ml	2419.17		<510.2	MPN/g			34	MPN/4g
14	2	1	9/17/2002	ND	CFU/100ml	140000	MPN/g	3200000	MPN/g	2000	MPN/g	100000	MPN/g			<0.7	MPN/g
14	3	1	9/17/2002	ND	CFU/100ml	180000	MPN/g	3400000	MPN/g	2900	MPN/g	270000	MPN/g			<0.7	MPN/g
15	1	1	9/11/2001	60	MPN/g	<1	MPN/100ml	1986.28	MPN/100ml	1046.24	CFU/100mL	<434.8	MPN/g			3.48	MPN/4g
15	2	1	9/17/2002	ND	CFU/100ml	25000	MPN/g	27000000	MPN/g	21900	MPN/g	33000	MPN/g			<0.8	MPN/g
15	3	1	9/17/2002	ND	CFU/100ml	6300	MPN/g	10000000	MPN/g	198000	MPN/g	10600	MPN/g			<0.7	MPN/g
16	1	1	9/11/2001	ND	CFU/100ml	<1	MPN/100ml	344.8	MPN/100ml	268.2	CFU/100mL	5750	MPN/g			3.63	MPN/4g
16	2	1	9/17/2002	ND	CFU/100ml	577	MPN/g	3800000	MPN/g	180000	MPN/g	27000	MPN/g			<0.4	MPN/g
16	3	1	9/17/2002	ND	CFU/100ml	363	MPN/g	430000	MPN/g	150000	MPN/g	2000	MPN/g			<0.4	MPN/g
17	1	1	11/30/2001	10	CFU/100ml	446	MPN/100ml	93.3	MPN/100ml	195.6	MPN/g	<675.7	MPN/g			2.7	MPN/g
17	2	1	10/1/2002	ND	CFU/100ml	<250	MPN/g	180000	MPN/g	1750	MPN/g	<450	MPN/g			<0.5	MPN/g
17	3	1	10/1/2002	ND	CFU/100ml	<270	MPN/g	3900	MPN/g	<270	MPN/g	540	MPN/g			<0.6	MPN/g
18	1	1	1/23/2002	ND	CFU/100ml	<1	MPN/100ml	65	MPN/100ml	24.7	CFU/100mL	361.7	MPN/g			1.4	MPN/4g
18	2	1	1/23/2002	40	CFU/100ml	<1	MPN/100ml	21.3	MPN/100ml	16.9	CFU/100mL	<369.7	MPN/g			<1.5	MPN/4g
18	3	1	1/23/2002	40	CFU/100ml	4.1	MPN/100ml	66.3	MPN/100ml	47.2	CFU/100mL	374.5	MPN/g			<1.5	MPN/4g
19	1	1	1/29/2002	ND	CFU/100ml	<1	MPN/100ml	104.6	MPN/100ml	10.5	CFU/100mL	17142.9	MPN/g			1.8	MPN/4g
19	2	1	1/29/2002	ND	CFU/100ml	<1	MPN/100ml	21.6	MPN/100ml	18.3	CFU/100mL	3921.6	MPN/g			1.6	MPN/4g
19	3	1	1/29/2002	20	CFU/100ml	<1	MPN/100ml	11	MPN/100ml	16.7	CFU/100mL	799.3	MPN/g			<1.4	MPN/4g
20	1	1	2/12/2002	130	CFU/100ml	2	MPN/100ml	5.2	MPN/100ml	1	CFU/100mL	<358.4	MPN/g			<1.43	MPN/4g
20	2	1	2/12/2002	80	CFU/100ml	<1	MPN/100ml	<1	MPN/100ml	17.1	CFU/100mL	<361.0	MPN/g			<1.44	MPN/4g

Site	Sample	Lab	Date	Perf	Perf_units	E_coli	E_coli_units	Col	Col_units	Entero	Entero_units	Fec	Fec_units	Strep	Strep_units	Salm	Salm_units
20	3	**1**	2/12/2002	120	CFU/100ml	<1	MPN/100ml	<1	MPN/100ml	31.4	CFU/100mL	<346.0	MPN/g			2.77	MPN/4g
1	2	**2**	9/17/2002	29000000	MPN/g	2800	MPN/g	300000	MPN/g	490	MPN/g	2800	MPN/g	2800	MPN/g	<4.3	MPN/g
1	3	**2**	9/17/2002	410000	MPN/g	48	MPN/g	10000	MPN/g	630	MPN/g	100	MPN/g	630	MPN/g	<4.2	MPN/g
2	2	**2**	9/17/2002	330000	MPN/g	2800	MPN/g	8800000	MPN/g	12000	MPN/g	12000	MPN/g	12000	MPN/g	<8.0	MPN/g
2	3	**2**	9/17/2002	<36000	MPN/g	82	MPN/g	2900000	MPN/g	930	MPN/g	82	MPN/g	930	MPN/g	<7.1	MPN/g
3	3	**2**	12/3/2001														
6	2	**2**	9/17/2002	500000	MPN/g	7900	MPN/g	76000	MPN/g	590	MPN/g	7900	MPN/g	590	MPN/g	<6.9	MPN/g
6	3	**2**	9/17/2002	2300000	MPN/g	9700	MPN/g	9700	MPN/g	160	MPN/g	9700	MPN/g	160	MPN/g	<6.5	MPN/g
8	2	**2**	1/23/2002														
8	3	**2**	1/23/2002														
8	4	**2**	1/23/2002														
9	2	**2**	9/17/2002	<1900	MPN/g	150	MPN/g	31000000	MPN/g	*96000	MPN/g	420	MPN/g	96000	MPN/g	<3.8	MPN/g
9	3	**2**	9/17/2002	<29000	MPN/g	94	MPN/g	8000000	MPN/g	*2300	MPN/g	630	MPN/g	2300	MPN/g	<5.7	MPN/g
13	2	**2**	9/17/2001														
13	3	**2**	10/1/2002	48000000	MPN/g	6.5	MPN/g	370000	MPN/g	*6.5	MPN/g	13	MPN/g	230	MPN/g	<3.2	MPN/g
13	4	**2**	10/1/2002	<2400	MPN/g	260	MPN/g	1700000	MPN/g	*19000	MPN/g	7900	MPN/g	120000	MPN/g	<4.8	MPN/g
14	1	**2**	9/11/2001														
14	2	**2**	9/17/2002	<2100	MPN/g	1100	MPN/g	110000	MPN/g	*3600	MPN/g	4700	MPN/g	3600	MPN/g	<4.3	MPN/g
14	3	**2**	9/17/2002	60000	MPN/g	510	MPN/g	78000	MPN/g	*1100	MPN/g	510	MPN/g	1100	MPN/g	<4.4	MPN/g
15	1	**2**	9/11/2001														
15	2	**2**	9/17/2002	130000	MPN/g	610	MPN/g	58000	MPN/g	*61	MPN/g	610	MPN/g	1300	MPN/g	<5.3	MPN/g
15	3	**2**	9/17/2002	1600000	MPN/g	240	MPN/g	480000	MPN/g	*520	MPN/g	570	MPN/g	650	MPN/g	<4.3	MPN/g
16	1	**2**	9/11/2001														
16	2	**2**	9/17/2002	41000	MPN/g	98	MPN/g	590000	MPN/g	*450	MPN/g	98	MPN/g	550	MPN/g	<3.9	MPN/g
16	3	**2**	9/17/2002	96000	MPN/g	250	MPN/g	4700000	MPN/g	*9800	MPN/g	250	MPN/g	18000	MPN/g	<3.9	MPN/g
17	1	**2**	11/30/2001														
17	2	**2**	10/1/2002	1700	MPN/g	320	MPN/g	6600000	MPN/g	*3200	MPN/g	4200	MPN/g	570000	MPN/g	<3.8	MPN/g
17	3	**2**	10/1/2002	440000	MPN/g	13	MPN/g	79000	MPN/g	*21	MPN/g	22	MPN/g	480	MPN/g	<3.2	MPN/g
18	1	**2**	1/23/2002														
18	2	**2**	1/23/2002														
18	3	**2**	1/23/2002														
19	1	**2**	1/29/2002														
19	2	**2**	1/29/2002														
19	3	**2**	1/29/2002														
20	1	**2**	2/12/2002														
20	2	**2**	2/12/2002														
20	3	**2**	2/12/2002														

APPENDIX E – Between Lab ANOVA Results of Microbial Concentrations

Lab vs. log (clostridium)

Descriptives

LOGCLOST

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
EAL	18	1.1081	2.21490	.52206	.0067	2.2096	.00	6.26
WERL	18	5.1056	1.33131	.31379	4.4436	5.7677	3.23	7.68
Total	36	3.1069	2.71162	.45194	2.1894	4.0244	.00	7.68

ANOVA

LOGCLOST

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	143.823	1	143.823	43.072	.000
Within Groups	113.529	34	3.339		
Total	257.352	35			

Lab vs. log (*E. coli*)

Descriptives

LOGECOLI

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
EAL	18	3.2837	.94051	.22168	2.8160	3.7515	2.21	5.26
WERL	18	2.4891	.85761	.20214	2.0626	2.9155	.88	3.99
Total	36	2.8864	.97431	.16238	2.5567	3.2161	.88	5.26

ANOVA

LOGECOLI

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	5.684	1	5.684	7.017	.012
Within Groups	27.541	34	.810		
Total	33.225	35			

Lab vs. log (enterococci)

Descriptives

LOGENTER

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
EAL	18	3.7071	.87270	.20570	3.2731	4.1411	2.43	5.30
WERL	18	2.9787	1.03299	.24348	2.4650	3.4924	.88	4.98
Total	36	3.3429	1.01225	.16871	3.0004	3.6854	.88	5.30

ANOVA

LOGENTER

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4.775	1	4.775	5.223	.029
Within Groups	31.088	34	.914		
Total	35.863	35			

Lab vs. log (fecal coliform)

Descriptives

LOGFECCO

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
EAL	18	3.5620	.95706	.22558	3.0860	4.0379	2.46	5.43
WERL	18	2.8392	.91864	.21653	2.3824	3.2961	1.15	4.08
Total	36	3.2006	.99454	.16576	2.8641	3.5371	1.15	5.43

ANOVA

LOGFECCO

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4.701	1	4.701	5.343	.027
Within Groups	29.918	34	.880		
Total	34.619	35			

Lab vs. log (total coliform)

Descriptives

LOGTOTCO

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
EAL	18	6.3573	.94279	.22222	5.8884	6.8261	3.59	7.65
WERL	18	5.6935	1.04152	.24549	5.1756	6.2114	3.99	7.49
Total	36	6.0254	1.03533	.17255	5.6751	6.3757	3.59	7.65

ANOVA

LOGTOTCO

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3.965	1	3.965	4.018	.053
Within Groups	33.551	34	.987		
Total	37.517	35			

Lab vs. Salmonella

Descriptives

SALM4G

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
EAL	18	.524	.1308	.0308	.459	.589	.4	.8
WERL	18	19.467	5.6419	1.3298	16.661	22.272	12.8	32.0
Total	36	9.995	10.3797	1.7300	6.483	13.507	.4	32.0

ANOVA

SALM4G

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3229.459	1	3229.459	202.807	.000
Within Groups	541.411	34	15.924		
Total	3770.870	35			

APPENDIX F – Microbe Regression Analysis

Univariate Analysis of Variance

Tests of Between-Subjects Effects

Dependent Variable: CLOST1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4.966(a)	5	.993	.474	.789
Intercept	17.722	1	17.722	8.451	.013
OM * CN_RATIO	.766	1	.766	.365	.557
OM * TKN	.064	1	.064	.030	.865
OM * PH	.260	1	.260	.124	.731
OM * MMHOS	1.813	1	1.813	.865	.371
OM * SLDS	.113	1	.113	.054	.821
Error	25.165	12	2.097		
Total	499.348	18			
Corrected Total	30.131	17			

a R Squared = .165 (Adjusted R Squared = -.183)

General Estimable Function (a)

Parameter	Contrast					
	L1	L2	L3	L4	L5	L6
Intercept	1	0	0	0	0	0
OM * CN_RATIO	0	1	0	0	0	0
OM * TKN	0	0	1	0	0	0
OM * PH	0	0	0	1	0	0
OM * MMHOS	0	0	0	0	1	0
OM * SLDS	0	0	0	0	0	1

a Design: Intercept+OM * CN_RATIO+OM * TKN+OM * PH+OM * MMHOS+OM * SLDS

Univariate Analysis of Variance

Warnings

The following factors or covariates are not used in the model: OM

Tests of Between-Subjects Effects

Dependent Variable: CLOST1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4.659(a)	4	1.165	.594	.673
Intercept	9.877	1	9.877	5.041	.043
CN_RATIO * TKN	.080	1	.080	.041	.843

CN_RATIO * PH	1.001	1	1.001	.511	.487
CN_RATIO * MMHOS	1.802	1	1.802	.920	.355
CN_RATIO * SLDS	1.226	1	1.226	.626	.443
Error	25.472	13	1.959		
Total	499.348	18			
Corrected Total	30.131	17			

a R Squared = .155 (Adjusted R Squared = -.105)

General Estimable Function (a)

Parameter	Contrast				
	L1	L2	L3	L4	L5
Intercept	1	0	0	0	0
CN_RATIO * TKN	0	1	0	0	0
CN_RATIO * PH	0	0	1	0	0
CN_RATIO * MMHOS	0	0	0	1	0
CN_RATIO * SLDS	0	0	0	0	1

a Design: Intercept+CN_RATIO * TKN+CN_RATIO * PH+CN_RATIO * MMHOS+CN_RATIO * SLDS

Univariate Analysis of Variance

Warnings

The following factors or covariates are not used in the model: OM, CN_RATIO

Tests of Between-Subjects Effects

Dependent Variable: CLOST1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4.389(a)	3	1.463	.796	.516
Intercept	19.193	1	19.193	10.439	.006
TKN * PH	.318	1	.318	.173	.684
TKN * MMHOS	3.357	1	3.357	1.826	.198
TKN * SLDS	1.688	1	1.688	.918	.354
Error	25.742	14	1.839		
Total	499.348	18			
Corrected Total	30.131	17			

a R Squared = .146 (Adjusted R Squared = -.037)

General Estimable Function (a)

Parameter	Contrast			
	L1	L2	L3	L4
Intercept	1	0	0	0

TKN * PH	0	1	0	0
TKN * MMHOS	0	0	1	0
TKN * SLDS	0	0	0	1

a Design: Intercept+TKN * PH+TKN * MMHOS+TKN * SLDS

Univariate Analysis of Variance

Warnings

The following factors or covariates are not used in the model: OM, CN_RATIO, TKN

Tests of Between-Subjects Effects

Dependent Variable: CLOST1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4.894(a)	2	2.447	1.454	.265
Intercept	17.619	1	17.619	10.472	.006
PH * MMHOS	3.279	1	3.279	1.949	.183
PH * SLDS	3.733	1	3.733	2.219	.157
Error	25.237	15	1.682		
Total	499.348	18			
Corrected Total	30.131	17			

a R Squared = .162 (Adjusted R Squared = .051)

General Estimable Function (a)

Parameter	Contrast		
	L1	L2	L3
Intercept	1	0	0
PH * MMHOS	0	1	0
PH * SLDS	0	0	1

a Design: Intercept+PH * MMHOS+PH * SLDS

Univariate Analysis of Variance

Warnings

The following factors or covariates are not used in the model: OM, CN_RATIO, TKN, PH

Tests of Between-Subjects Effects

Dependent Variable: CLOST1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.204(a)	1	.204	.109	.745
Intercept	175.294	1	175.294	93.720	.000
MMHOS * SLDS	.204	1	.204	.109	.745
Error	29.927	16	1.870		
Total	499.348	18			
Corrected Total	30.131	17			

a R Squared = .007 (Adjusted R Squared = -.055)

General Estimable Function (a)

Parameter	Contrast	
	L1	L2
Intercept	1	0
MMHOS * SLDS	0	1

a Design: Intercept+MMHOS * SLDS

Univariate Analysis of Variance

Tests of Between-Subjects Effects

Dependent Variable: SALM1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.080(a)	5	.016	2.274	.113
Intercept	.355	1	.355	50.666	.000
OM * CN_RATIO	.050	1	.050	7.134	.020
OM * TKN	.010	1	.010	1.427	.255
OM * PH	.039	1	.039	5.629	.035
OM * MMHOS	.004	1	.004	.629	.443
OM * SLDS	.025	1	.025	3.517	.085
Error	.084	12	.007		
Total	10.492	18			
Corrected Total	.164	17			

a R Squared = .486 (Adjusted R Squared = .273)

General Estimable Function (a)

Parameter	Contrast					
	L1	L2	L3	L4	L5	L6
Intercept	1	0	0	0	0	0
OM * CN_RATIO	0	1	0	0	0	0
OM * TKN	0	0	1	0	0	0
OM * PH	0	0	0	1	0	0
OM * MMHOS	0	0	0	0	1	0

OM * SLDS	0	0	0	0	0	1

a Design: Intercept+OM * CN_RATIO+OM * TKN+OM * PH+OM * MMHOS+OM * SLDS

Univariate Analysis of Variance

Warnings

The following factors or covariates are not used in the model: OM

Tests of Between-Subjects Effects

Dependent Variable: SALM1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.034(a)	4	.009	.863	.511
Intercept	.318	1	.318	31.974	.000
CN_RATIO * TKN	.003	1	.003	.329	.576
CN_RATIO * PH	.002	1	.002	.160	.696
CN_RATIO * MMHOS	.002	1	.002	.226	.642
CN_RATIO * SLDS	.013	1	.013	1.269	.280
Error	.129	13	.010		
Total	10.492	18			
Corrected Total	.164	17			

a R Squared = .210 (Adjusted R Squared = -.033)

General Estimable Function (a)

	Contrast				
Parameter	L1	L2	L3	L4	L5
Intercept	1	0	0	0	0
CN_RATIO * TKN	0	1	0	0	0
CN_RATIO * PH	0	0	1	0	0
CN_RATIO * MMHOS	0	0	0	1	0
CN_RATIO * SLDS	0	0	0	0	1

a Design: Intercept+CN_RATIO * TKN+CN_RATIO * PH+CN_RATIO * MMHOS+CN_RATIO * SLDS

Univariate Analysis of Variance

Warnings

The following factors or covariates are not used in the model: OM, CN_RATIO

Tests of Between-Subjects Effects

Dependent Variable: SALM1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.028(a)	3	.009	.950	.443
Intercept	.394	1	.394		.000
TKN * PH	.021	1	.021	2.117	.168
TKN * MMHOS	.013	1	.013	1.339	.267
TKN * SLDS	.000	1	.000	.030	.865
Error	.136	14	.010		
Total	10.492	18			
Corrected Total	.164	17			

a R Squared = .169 (Adjusted R Squared = -.009)

General Estimable Function (a)

Parameter	Contrast			
	L1	L2	L3	L4
Intercept	1	0	0	0
TKN * PH	0	1	0	0
TKN * MMHOS	0	0	1	0
TKN * SLDS	0	0	0	1

a Design: Intercept+TKN * PH+TKN * MMHOS+TKN * SLDS

Univariate Analysis of Variance

Warnings

The following factors or covariates are not used in the model: OM, CN_RATIO, TKN

Tests of Between-Subjects Effects

Dependent Variable: SALM1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.012(a)	2	.006	.617	.553
Intercept	.749	1	.749	74.198	.000
PH * MMHOS	.008	1	.008	.824	.378
PH * SLDS	.000	1	.000	.033	.858
Error	.151	15	.010		
Total	10.492	18			
Corrected Total	.164	17			

a R Squared = .076 (Adjusted R Squared = -.047)

General Estimable Function (a)

Parameter	Contrast		
	L1	L2	L3
Intercept	1	0	0
PH * MMHOS	0	1	0
PH * SLDS	0	0	1

a Design: Intercept+PH * MMHOS+PH * SLDS

Univariate Analysis of Variance

Warnings

The following factors or covariates are not used in the model: OM, CN_RATIO, TKN, PH

Tests of Between-Subjects Effects

Dependent Variable: SALM1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.016(a)	1	.016	1.770	.202
Intercept	4.053	1	4.053	439.521	.000
MMHOS * SLDS	.016	1	.016	1.770	.202
Error	.148	16	.009		
Total	10.492	18			
Corrected Total	.164	17			

a R Squared = .100 (Adjusted R Squared = .043)

General Estimable Function (a)

Parameter	Contrast	
	L1	L2
Intercept	1	0
MMHOS * SLDS	0	1

a Design: Intercept+MMHOS * SLDS

Univariate Analysis of Variance

Warnings

The following factors or covariates are not used in the model: CN_RATIO, TKN, PH, MMHOS, SLDS

Tests of Between-Subjects Effects

Dependent Variable: SALM1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.034(a)	3	.011	1.238	.333
Intercept	.599	1	.599	64.734	.000
OM * WHC	.007	1	.007	.798	.387
OM * DNS	.031	1	.031	3.315	.090
OM * MOIST	.025	1	.025	2.692	.123
Error	.129	14	.009		
Total	10.492	18			
Corrected Total	.164	17			

a R Squared = .210 (Adjusted R Squared = .040)

General Estimable Function (a)

Parameter	Contrast L1	L2	L3	L4
Intercept	1	0	0	0
OM * WHC	0	1	0	0
OM * DNS	0	0	1	0
OM * MOIST	0	0	0	1

a Design: Intercept+OM * WHC+OM * DNS+OM * MOIST

Univariate Analysis of Variance

Warnings

The following factors or covariates are not used in the model: OM, TKN, PH, MMHOS, SLDS

Tests of Between-Subjects Effects

Dependent Variable: SALM1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.031(a)	3	.010	1.084	.388
Intercept	.536	1	.536	56.426	.000
CN_RATIO * WHC	.021	1	.021	2.253	.156
CN_RATIO * DNS	.026	1	.026	2.736	.120
CN_RATIO * MOIST	.023	1	.023	2.421	.142
Error	.133	14	.009		
Total	10.492	18			
Corrected Total	.164	17			

a R Squared = .188 (Adjusted R Squared = .015)

General Estimable Function (a)

Parameter	Contrast			
	L1	L2	L3	L4
Intercept	1	0	0	0
CN_RATIO * WHC	0	1	0	0
CN_RATIO * DNS	0	0	1	0
CN_RATIO * MOIST	0	0	0	1

a Design: Intercept+CN_RATIO * WHC+CN_RATIO * DNS+CN_RATIO * MOIST

Univariate Analysis of Variance

Warnings

The following factors or covariates are not used in the model: OM, CN_RATIO, PH, MMHOS, SLDS

Tests of Between-Subjects Effects

Dependent Variable: SALM1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.020(a)	3	.007	.663	.589
Intercept	.378	1	.378	36.835	.000
TKN * WHC	.010	1	.010	.987	.337
TKN * DNS	.007	1	.007	.716	.412
TKN * MOIST	.016	1	.016	1.579	.230
Error	.143	14	.010		
Total	10.492	18			
Corrected Total	.164	17			

a R Squared = .124 (Adjusted R Squared = -.063)

General Estimable Function (a)

Parameter	Contrast			
	L1	L2	L3	L4
Intercept	1	0	0	0
TKN * WHC	0	1	0	0
TKN * DNS	0	0	1	0
TKN * MOIST	0	0	0	1

a Design: Intercept+TKN * WHC+TKN * DNS+TKN * MOIST

Univariate Analysis of Variance

Warnings

The following factors or covariates are not used in the model: OM, CN_RATIO, TKN, MMHOS, SLDS

Tests of Between-Subjects Effects

Dependent Variable: SALM1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.025(a)	3	.008	.837	.496
Intercept	.082	1	.082	8.293	.012
PH * WHC	.008	1	.008	.848	.373
PH * DNS	.000	1	.000	.014	.909
PH * MOIST	.019	1	.019	1.915	.188
Error	.139	14	.010		
Total	10.492	18			
Corrected Total	.164	17			

a R Squared = .152 (Adjusted R Squared = -.030)

General Estimable Function (a)

Parameter	Contrast			
	L1	L2	L3	L4
Intercept	1	0	0	0
PH * WHC	0	1	0	0
PH * DNS	0	0	1	0
PH * MOIST	0	0	0	1

a Design: Intercept+PH * WHC+PH * DNS+PH * MOIST

Univariate Analysis of Variance

Warnings

The following factors or covariates are not used in the model: OM, CN_RATIO, TKN, PH, SLDS

Tests of Between-Subjects Effects

Dependent Variable: SALM1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.027(a)	3	.009	.938	.448
Intercept	1.945	1	1.945	199.581	.000
MMHOS * WHC	.006	1	.006	.588	.456
MMHOS * DNS	.015	1	.015	1.571	.231
MMHOS * MOIST	.008	1	.008	.830	.378
Error	.136	14	.010		
Total	10.492	18			

Corrected Total	.164	17			

a R Squared = .167 (Adjusted R Squared = -.011)

General Estimable Function (a)

Parameter	Contrast			
		L2	L3	L4
Intercept	1	0	0	0
MMHOS * WHC	0	1	0	0
MMHOS * DNS	0	0	1	0
MMHOS * MOIST	0	0	0	1

a Design: Intercept+MMHOS * WHC+MMHOS * DNS+MMHOS * MOIST

Univariate Analysis of Variance

Warnings

The following factors or covariates are not used in the model: OM, CN_RATIO, TKN, PH, MMHOS

Tests of Between-Subjects Effects

Dependent Variable: SALM1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.018(a)	3	.006	.575	.641
Intercept	.030	1	.030	2.894	.111
SLDS * WHC	.016	1	.016	1.529	.237
SLDS * DNS	.008	1	.008	.737	.405
SLDS * MOIST	.004	1	.004	.368	.554
Error	.146	14	.010		
Total	10.492	18			
Corrected Total	.164	17			

a R Squared = .110 (Adjusted R Squared = -.081)

General Estimable Function (a)

Parameter	Contrast			
	L1	L2	L3	L4
Intercept	1	0	0	0
SLDS * WHC	0	1	0	0
SLDS * DNS	0	0	1	0
SLDS * MOIST	0	0	0	1

a Design: Intercept+SLDS * WHC+SLDS * DNS+SLDS * MOIST

Univariate Analysis of Variance

Warnings

The following factors or covariates are not used in the model: OM, CN_RATIO, TKN, PH, MMHOS, SLDS

Tests of Between-Subjects Effects

Dependent Variable: SALM1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.018(a)	2		.930	.416
Intercept	.445	1	.445	45.778	.000
WHC * MOIST	.017	1	.017	1.782	.202
WHC * DNS		1	.017	1.710	.211
Error	.146	15	.010		
Total	10.492	18			
Corrected Total	.164	17			

a R Squared = .110 (Adjusted R Squared = -.008)

General Estimable Function (a)

Parameter	Contrast		
	L1	L2	L3
Intercept	1	0	0
WHC * MOIST	0	1	0
WHC * DNS	0	0	1

a Design: Intercept+WHC * MOIST+WHC * DNS

Univariate Analysis of Variance

Warnings

The following factors or covariates are not used in the model: OM, CN_RATIO, TKN, PH, MMHOS, SLDS, WHC

Tests of Between-Subjects Effects

Dependent Variable: SALM1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.005(a)	1	.005	.454	.510
Intercept	.465	1	.465	46.668	.000
DNS * MOIST	.005	1	.005	.454	.510
Error	.159	16	.010		

Total	10.492	18			
Corrected Total	.164	17			

a R Squared = .028 (Adjusted R Squared = -.033)

General Estimable Function (a)

Parameter	Contrast	
	L1	L2
Intercept		0
DNS * MOIST	0	1

a Design: Intercept+DNS * MOIST

Univariate Analysis of Variance

Warnings

The following factors or covariates are not used in the model: WHC, DNS, MOIST

Tests of Between-Subjects Effects

Dependent Variable: FECCOL1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3.946(a)	5	.789	.911	.506
Intercept	9.178	1		10.590	.007
OM * CN_RATIO	.539	1	.539	.622	.446
OM * TKN	.116	1	.116	.134	.721
OM * PH	.640	1	.640	.738	.407
OM * MMHOS	.254	1	.254	.293	.598
OM * SLDS	2.253	1	2.253	2.599	.133
Error	10.400	12	.867		
Total	159.449	18			
Corrected Total	14.346	17			

a R Squared = .275 (Adjusted R Squared = -.027)

General Estimable Function (a)

Parameter	Contrast					
	L1	L2	L3	L4	L5	L6
Intercept	1	0	0	0	0	0
OM * CN_RATIO	0	1	0	0	0	0
OM * TKN	0	0	1	0	0	0
OM * PH	0	0	0	1	0	0
OM * MMHOS	0	0	0	0	1	0

OM * SLDS	0	0	0	0	0	1

a Design: Intercept+OM * CN_RATIO+OM * TKN+OM * PH+OM * MMHOS+OM * SLDS

Univariate Analysis of Variance

Tests of Between-Subjects Effects

Dependent Variable: FECCOL1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	7.553(a)	8	.944	1.251	.371
Intercept	6.450	1	6.450	8.544	.017
OM * CN_RATIO	1.363	1	1.363	1.805	.212
OM * TKN	1.657	1	1.657	2.195	.173
OM * PH	.004	1	.004		.947
OM * MMHOS	.022	1	.022	.029	.868
OM * SLDS	3.688	1	3.688	4.885	.054
OM * WHC	.205	1	.205	.272	.615
OM * DNS	.317	1	.317	.420	.533
OM * MOIST	2.732	1	2.732	3.619	.090
Error	6.794	9	.755		
Total	159.449	18			
Corrected Total	14.346	17			

a R Squared = .526 (Adjusted R Squared = .106)

General Estimable Function (a)

Parameter	Contrast								
	L1	L2	L3	L4	L5	L6	L7	L8	L9
Intercept	1	0	0	0	0	0	0	0	0
OM * CN_RATIO	0	1	0	0	0	0	0	0	0
OM * TKN	0	0	1	0	0	0	0	0	0
OM * PH	0	0		1	0	0	0	0	0
OM * MMHOS	0	0	0	0	1	0	0	0	0
OM * SLDS	0	0	0	0	0	1	0	0	0
OM * WHC	0	0	0	0	0	0	1	0	0
OM * DNS	0	0	0	0	0	0	0	1	0
OM * MOIST	0	0	0	0	0	0	0	0	1

a Design: Intercept+OM * CN_RATIO+OM * TKN+OM * PH+OM * MMHOS+OM * SLDS+OM * WHC+OM * DNS+OM * MOIST

Univariate Analysis of Variance

Tests of Between-Subjects Effects

Dependent Variable: FECCOL1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3.946(a)	5	.789	.911	.506
Intercept	9.178	1	9.178	10.590	.007
OM * CN_RATIO	.539	1	.539	.622	.446
OM * TKN	.116	1	.116	.134	.721
OM * PH	.640	1	.640	.738	.407
OM * MMHOS	.254	1	.254	.293	.598
OM * SLDS	2.253	1	2.253	2.599	.133
Error	10.400	12	.867		
Total	159.449	18			
Corrected Total	14.346	17			

a R Squared = .275 (Adjusted R Squared = -.027)

General Estimable Function (a)

Parameter	Contrast					
	L1	L2	L3	L4	L5	L6
Intercept	1	0	0	0	0	0
OM * CN_RATIO	0	1	0	0	0	0
OM * TKN	0	0	1	0	0	0
OM * PH	0	0	0	1	0	0
OM * MMHOS	0	0	0	0	1	0
OM * SLDS	0	0	0	0	0	1

a Design: Intercept+OM * CN_RATIO+OM * TKN+OM * PH+OM * MMHOS+OM * SLDS

Univariate Analysis of Variance

Warnings

The following factors or covariates are not used in the model: OM

Tests of Between-Subjects Effects

Dependent Variable: FECCOL1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3.361(a)	4	.840	.994	.445
Intercept	8.141	1	8.141	9.634	.008
CN_RATIO * TKN	.935	1	.935	1.106	.312
CN_RATIO * PH	.801	1	.801	.947	.348
CN_RATIO * MMHOS	.098	1	.098	.116	.739
CN_RATIO * SLDS	1.917	1	1.917	2.269	.156
Error	10.986	13	.845		
Total	159.449	18			

Corrected Total	14.346	17			

a R Squared = .234 (Adjusted R Squared = -.001)

General Estimable Function (a)

Parameter	Contrast L1		L3	L4	L5
Intercept	1		0	0	0
	0	1	0	0	0
CN_RATIO * PH	0	0	1	0	0
CN_RATIO * MMHOS	0	0	0	1	0
CN_RATIO * SLDS	0	0	0	0	1

a Design: Intercept+CN_RATIO * TKN+CN_RATIO * PH+CN_RATIO * MMHOS+CN_RATIO * SLDS

Univariate Analysis of Variance

Warnings

The following factors or covariates are not used in the model: OM, CN_RATIO

Tests of Between-Subjects Effects

Dependent Variable: FECCOL1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2.634(a)	3	.878	1.050	.401
Intercept	9.539	1	9.539	11.403	.005
TKN * PH	1.102	1	1.102	1.318	.270
TKN * MMHOS	.775	1		.927	.352
TKN * SLDS		1	.769	.920	.354
Error		14	.837		
Total		18			
Corrected Total	14.346	17			

a R Squared = .184 (Adjusted R Squared = .009)

General Estimable Function (a)

Parameter	Contrast L1	L2	L3	L4
Intercept	1	0	0	0
TKN * PH	0	1	0	0
MMHOS	0	0	1	0
TKN * SLDS	0	0	0	1

a Design: Intercept+TKN * PH+TKN * MMHOS+TKN * SLDS

Univariate Analysis of Variance

Warnings

The following factors or covariates are not used in the model: OM, CN_RATIO, TKN

Tests of Between-Subjects Effects

Dependent Variable: FECCOL1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1.654(a)	2	.827	.977	.399
Intercept	15.348	1	15.348	18.139	.001
PH * MMHOS	.789	1	.789	.932	.350
PH * SLDS	.203	1	.203	.240	.631
Error	12.692	15	.846		
Total	159.449	18			
Corrected Total	14.346	17			

a R Squared = .115 (Adjusted R Squared = -.003)

General Estimable Function (a)

Parameter	Contrast		
	L1	L2	L3
Intercept	1	0	0
PH * MMHOS	0	1	0
PH * SLDS	0	0	1

a Design: Intercept+PH * MMHOS+PH * SLDS

Univariate Analysis of Variance

Warnings

The following factors or covariates are not used in the model: OM, CN_RATIO, TKN, PH

Tests of Between-Subjects Effects

Dependent Variable: FECCOL1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1.822(a)	1	1.822	2.327	.147
Intercept	67.996	1	67.996	86.865	.000
MMHOS * SLDS	1.822	1	1.822	2.327	.147

Error	12.524	16	.783		
Total	159.449	18			
Corrected Total	14.346	17			

a R Squared = .127 (Adjusted R Squared = .072)

General Estimable Function (a)

Parameter	Contrast	
	L1	L2
Intercept	1	0
MMHOS * SLDS	0	1

a Design: Intercept+MMHOS * SLDS

Univariate Analysis of Variance

Tests of Between-Subjects Effects

Dependent Variable: FECCOL1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model		1	1.822	2.327	.147
Intercept	67.996	1	67.996	86.865	.000
MMHOS * SLDS	1.822	1	1.822	2.327	.147
Error	12.524	16	.783		
Total	159.449	18			
Corrected Total	14.346	17			

a R Squared = .127 (Adjusted R Squared = .072)

General Estimable Function (a)

Parameter	Contrast	
	L1	L2
Intercept	1	0
MMHOS * SLDS	0	1

a Design: Intercept+MMHOS * SLDS

Univariate Analysis of Variance

Tests of Between-Subjects Effects

Dependent Variable: SALM1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.118(a)	8	.015	2.857	.069
Intercept	.047	1	.047	9.205	.014

CN_RATIO * PH * OM	2.521E-06	1	2.521E-06	.000	.983
CN_RATIO * SLDS * OM	2.137E-07	1	2.137E-07	.000	.995
CN_RATIO * DNS * OM	.002	1	.002	.417	.535
CN_RATIO * PH * SLDS	.014	1	.014	2.633	.139
CN_RATIO * PH * DNS	.031	1	.031	6.012	.037
PH * SLDS * OM	.002	1	.002	.370	.558
SLDS * DNS * OM		1	.005	.954	.354
PH * DNS * OM	.001	1	.001	.106	.752
Error	.046	9	.005		
Total	10.492	18			
Corrected Total	.164	17			

a R Squared = .717 (Adjusted R Squared = .466)

Parameter	Contrast								
	L1	L2	L3	L4	L5	L6	L7	L8	L9
Intercept	1	0	0	0	0	0	0	0	0
CN_RATIO * PH * OM	0	1	0	0	0	0	0	0	0
CN_RATIO * SLDS * OM	0	0		0	0	0	0	0	0
CN_RATIO * DNS * OM	0	0	0	1	0	0	0	0	0
CN_RATIO * PH * SLDS	0	0	0	0	1	0	0	0	0
CN_RATIO * PH * DNS	0	0	0	0	0	1	0	0	0
PH * SLDS * OM	0	0	0	0	0	0	1	0	0
SLDS * DNS * OM	0	0	0	0	0	0	0	1	0
PH * DNS * OM	0	0	0	0	0	0	0	0	1

General Estimable Function (a)

a Design: Intercept+CN_RATIO * PH * OM+CN_RATIO * SLDS * OM+CN_RATIO * DNS * OM+CN_RATIO * PH * SLDS+CN_RATIO * PH * DNS+PH * SLDS * OM+SLDS * DNS * OM+PH * DNS * OM

APPENDIX G – Independent Samples t-tests Microbes vs. Management Practices

Analysis #1a - Independent Samples t-Test of EAL log(E coli) Data Using Addition of Post-consumer Food Waste as the Grouping Variable

Group Statistics

	PST_FD	N	Mean	Std. Deviation	Std. Error Mean
LOG	added	16	3.1494	1.06203	.26551
	not added	2	3.7605	.23167	.16381

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
LOG	Equal variances assumed	2.388	.142	-.791	16	.440	-.6111	.77245	-2.24861	1.02644
	Equal variances not assumed				9.010	.082	-.6111	.31198	-1.31670	.09453

Analysis #1b - Independent Samples t-Test of EAL log(E coli) Data Using Addition of Meat Scrap as the Grouping Variable

Group Statistics

	MEAT	N	Mean	Std. Deviation	
LOG	added	4	2.2810	.42704	.21352
	not added		3.4849	.98371	.26291

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means					
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference

									Lower	Upper
LOG	Equal variances assumed	1.757	.204	-2.344	16	.032	-1.2039	.51353	-2.29253	-.11527
	Equal variances not assumed			-3.555	12.410	.004	-1.2039	.33869	-1.93915	-.46865

Analysis #1c - Independent Samples t-Test of EAL log(E coli) Data Using Turning Frequency as the Grouping Variable

Group Statistics

	TURNED	N	Mean	Std. Deviation	Std. Error Mean
LOG	turned	4	3.9311	1.46897	.73448
	not turned	10	3.0720	.95311	.30140

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
LOG	Equal variances assumed	5.915	.032	1.314	12	.213	.8591	.65366	-.56513	2.28327
	Equal variances not assumed			1.082	4.057	.339	.8591	.79392	-1.33303	3.05117

Analysis #2a - Independent Samples t-Test of WEL log(E coli) Data Using Addition of Post-consumer Food Waste as the Grouping Variable

Group Statistics

	PST_FD	N	Mean	Std. Deviation	Std. Error Mean
LOG	added	16	2.4648	.86606	.21651
	not added	2	2.6832	1.08063	.76412

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
LOG	Equal variances assumed	.093	.764	-.331	16	.745	-.2184	.66075	-1.61914	1.18232
	Equal variances not assumed			-.275	1.167	.824	-.2184	.79420	-7.46831	7.03150

Analysis #2b - Independent Samples t-Test of WEL log(E coli) Data Using Addition of Meat Scrap as the Grouping Variable

Group Statistics

	MEAT	N	Mean	Std. Deviation	Std. Error Mean
LOG	added	4	2.7941	1.46807	.73403
	not added	14	2.4019	.65394	.17477

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
LOG	Equal variances assumed	6.462	.022	.798	16	.437	.3921	.49150	-.64980	1.43407
	Equal variances not assumed			.520	3.347	.636	.3921	.75455	-1.87421	2.65848

Analysis #2c - Independent Samples t-Test of WEL log(E coli) Data Using Turning Frequency as the Grouping Variable

Group Statistics

	TURNED	N	Mean	Std. Deviation	Std. Error Mean
LOG	turned	4	2.5364	.44577	.22288
	not turned	10	2.1635	.74943	.23699

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
LOG	Equal variances assumed	.678	.426	.918	12	.377	.3728	.40598	-.51172	1.25738
	Equal variances not assumed			1.146	9.549	.280	.3728		-.35672	1.10238

Analysis #3a - Independent Samples t-Test of EAL log(fec col) Data Using Addition of Post-consumer Food Scrap Waste as the Grouping Variable

Group Statistics

	PST_FD	N	Mean	Std. Deviation	Std. Error Mean
LOG	added	36	3.0617	1.22932	.20489
	not added	3	2.8691	1.71537	.99037

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means					
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference

									Lower	Upper
LOG	Equal variances assumed	.632	.432	.254	37	.801	.1926	.75740	-1.34206	1.72723
	Equal variances not assumed			.190	2.175	.865	.1926	1.01134	-3.84056	4.22573

Analysis #3b - Independent Samples t-Test of EAL log (fec col) Data Using Addition of Meat Scrap as the Grouping Variable

Group Statistics

	MEAT	N	Mean	Std. Deviation	Std. Error Mean
LOG	added	7	2.5895	1.51802	.57376
	not added	32	3.1470	1.18143	.20885

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
LOG	Equal variances assumed	.003	.956	-1.076	37	.289	-.5575	.51833	-1.60774	.49274
	Equal variances not assumed			-.913	7.669	.389	-.5575	.61059	-1.97615	.86116

Analysis #3c - Independent Samples t-Test of EAL log (fec col) Data Using Turning Frequency as the Grouping Variable

Group Statistics

	TURNED	N	Mean	Std. Deviation	Std. Error Mean
LOG	turned	13	3.5076	1.25107	.34698
	not turned	16	3.1525	1.17550	.29387

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
LOG	Equal variances assumed	.194	.663	.786	27	.439	.3551	.45168	-.57172	1.28183
	Equal variances not assumed			.781	25.070	.442	.3551	.45471	-.58130	1.29141

Analysis #4a - Independent Samples t-Test of WEL log (fec col) Data Using Addition of Post-consumer Food Scrap Waste as the Grouping Variable

Group Statistics

	PST_FD	N	Mean	Std. Deviation	Std. Error Mean
LOG	added	16	2.8192	.89277	.22319
	not added	2	2.9991	1.52745	1.08007

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
LOG	Equal variances assumed	.999	.333	-.254	16	.803	-.1799	.70876	-1.68241	1.32260
	Equal variances not assumed			-.163	1.087	.895	-.1799	1.10289	-11.79984	11.44003

Analysis #4b - Independent Samples t-Test of WEL log (fec col) Data Using Addition of Meat Scrap as the Grouping Variable

Group Statistics

	MEAT	N	Mean	Std. Deviation	Std. Error Mean
LOG	added	4	3.2321	1.39127	.69563
	not added	14	2.7270	.77190	.20630

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
LOG	Equal variances assumed	2.372	.143	.968	16	.347	.5051	.52179	-.60106	1.61122
	Equal variances not assumed			.696	3.545	.529	.5051	.72558	-1.61575	2.62592

Analysis #3c – Independent Sample t-Test of Wel log(fec col) Data Using Turning Frequency as the Grouping Variable

Group Statistics

	TURNED	N	Mean	Std. Deviation	Std. Error Mean
LOG	turned	4	2.6940	.71447	.35724
	not turned	10	2.6994	1.00172	

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
LOG	Equal variances assumed	.554	.471	-.010	12	.992	-.0054	.55504	-1.21476	1.20389

	Equal variances not assumed			-.011	7.937	.991	-.0054	.47745	-1.10797	1.09710

Analysis #5a - Independent Samples t-Test of EAL salm Data Using Addition of Post-consumer Food Scrap Waste as the Grouping Variable

Group Statistics

	PST_FD	N	Mean	Std. Deviation	Std. Error Mean
SALM	1	36	2.7329	5.80428	.96738
	0	3	.9000	.36056	.20817

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		'	ig.		f	ig. (2-ailed)	Mean Differenc	td. Error Difference	5% Confidence nterval of the Difference	
									.ower	Jpper
ALM	Equal ariances ssumed	585	413	540	7	592	.8329	.39273	5.04141	.70725
	Equal ariances ot ssumed				6.931	072	.8329	98952	.17218	.83801

Analysis #4b - Independent Samples t-Test of EAL salm Data using Addition of Meat Scrap Waste as the Grouping Variable

Group Statistics

	MEAT	N	Mean	Std. Deviation	Mean
SALM	added	7	.9279	.80264	.30337
	not added	32	2.9559	6.12033	1.08193

Independent Samples Test

		Levene's Test for Equality of Variances	t-test for Equality of Means

		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
SALM	Equal variances assumed	1.468	.233	-.866	37	.392	-2.0281	2.34145	-6.77231	2.71615
	Equal variances not assumed			-1.805	34.950	.080	-2.0281	1.12366	-4.30935	.25319

Analysis #5c - Independent Samples t-Test of EAL salm Data Using Turning Frequency as the Grouping Variable

Group Statistics

	TURNED	N	Mean	Std. Deviation	Std. Error Mean
SALM	added	13	4.5092	9.13118	2.53253
	not added	16	1.8084	2.53046	.63262

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
SALM	Equal variances assumed	3.819	.061	1.135	27	.266	2.7008	2.37962	-2.18178	7.58337
	Equal variances not assumed			1.035	13.502	.319		2.61035	-2.91728	8.31887

APPENDIX H – Small Scale Guidance Fact Sheet

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Health and Safety Guidance for Small Scale Composting

A significant fraction of the solid waste generated in the United States is organic material that can be recycled through home scale composting. There are many advantages to this strategy of waste management. Households, businesses and institutions may save money by composting items such as food scraps and yard trimmings while sending less waste to landfills and incinerators. In addition, small scale composting is often the most environmentally sound way of recycling organic materials. The finished compost is a good soil amendment for a variety of gardening and landscape uses.

A possible concern with composting is the potential for the presence of human pathogens (disease-causing organisms). In situations where materials such as plate scrapings are added to a compost pile, questions have been raised about relative health risks and transmittal of human pathogens - particularly when composting involves multiple households. Pathogen reduction occurs in larger compost piles (3'x3'x3' minimum) due to self heating if properly managed. In small compost piles, raised temperatures are often not achieved, and the potential for the survival of pathogens is increased as a result.

Many designs are available for composting. Some generate heat and others do not.

Many pathogens found in commonly used materials such as potting mixes and garden soils are also found in small compost piles, and require the same level of attention.

Little is known about pathogens in typical small scale compost piles. The Cornell Waste Management Institute (CWMI) completed a study to explore the presence and distribution of pathogens in composts made in small scale bins and piles that are common in home, multi-family,

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For more information go to:
http://cwmi.css.cornell.edu/smallscalecomposting.htm

Project cooperators included Cornell Cooperative Extension Educators in Essex, Schuyler, and Tompkins Counties, and New York City. Support for this project was provided by Cornell University Agricultural Experiment Station; Cornell College of Agriculture and Life Sciences and Cornell Cooperative Extension.

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and school settings. A goal was to develop guidance for the public on ways to minimize any potential health risks (see the full report at: http://cwmi.css.cornell.edu/coldcompost.pdf).

The criteria for choosing bacteria to measure in this study were 1) that they are themselves pathogens of concern, or 2) that they are representative of a family containing pathogens of concern. Fungal spores, molds, and other composting byproducts were not examined.

Results of testing 20 small scale compost piles several times showed no correlation between the various microbes analyzed in the project, meaning that the number of one type of bacteria present in the samples could not be used to predict the number of a different bacterium present in the same pile. No single test was considered to be a reliable indicator of compost hygiene.

The quality of compost from small scale piles is not regulated. But for the purposes of this study, CWMI chose to compare test results of small scale composts to pathogen standards established by the US Environmental Protection Agency for composted sewage sludges. Using these bacterial standards as a measurement for hygienic quality, most small scale composts analyzed in the project fared well.

Based on the results of this study, a review of current literature, and common sense, the following guidelines are suggested for use in small scale compost settings to minimize any potential health risks. Small scale compost provides many environmental benefits. When good hygiene practices are used, the relative health risks are low.

GUIDELINES FOR PRUDENT COMPOSTING

1. Avoid certain inputs to the compost pile such as raw poultry or meat wastes, pet feces, and plate scrapings from people who are ill.
2. Consider managing your composting system to ensure that it gets and stays hot long enough to reduce pathogens. There are methods available for small scale compost piles.

   For more information visit:
   http://cwmi.css.cornell.edu/smallscalecomposting.htm
3. Practice good personal hygiene when handling compost. Proper personal sanitation is the most effective method for controlling the impact of any pathogens that may be in the compost. Wash hands after handling compost and/or use gloves. If the compost is particularly dusty, watering is an option.
4. Persons with weakened immune systems or medical conditions that compromise the body's ability to fight infection should use caution when handling compost.
5. If possible, allow composts that are produced in a small-scale setting to age for at least a year before use.