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Long Term Acceptance Rates of Common Floridian Soils

Prepared By
Steve Erlsten
&
Dr. David Bloomquist

Department of Civil & Coastal Engineering
University of Florida
Gainesville, Florida 32611

For the Florida Department of Health

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ABSTRACT

LONG-TERM WASTEWATER ACCEPTANCE RATES FOR TYPICAL FLORIDA SOILS

Phase 2 of the University of Florida's Onsite Sewage Treatment and Disposal Systems and Long-Term Acceptance Rate (OSTDS/LTAR) study, completed August 2000, concluded that the following factors should be used in determining the size of a restaurant's onsite drainfield: soil properties, hydraulic loading rate, and mass loading rate. The Phase 2 report suggested that mass loading rates should not exceed 0.0015 $lb/ft^2/day$ for typical soils. The purpose of Phase 3 is to further refine this mass loading threshold above which lysimeter failures consistently occur.

The dosing procedure implemented in Phase 2 continued uninterrupted and unchanged until Phase 3 began on 10 May, 2001. Included in this report is a summary of lysimeter status as Phase 3 began. Lysimeters in Phase 3 received the same hydraulic loading rates as were used in Phase 2. Eight of the original twenty-four low-strength lysimeters remained low-strength. The wastewater strength for the remaining sixteen was increased to refine the failure threshold.

Additionally, nine medium-strength lysimeters that failed in Phase 2 were used in a rejuvenation attempt. At the beginning of Phase 3, another new waste strength was developed to simulate waste produced by an aerobic treatment unit. The nine lysimeters undergoing rejuvenation received the same hydraulic loading rate as they did in Phase 2, but the waste strength was lower. All nine rejuvenated columns remained operational until Day 73, when rejuvenation dosing stopped. In Phase 2 most of the same columns failed between Day 30 and Day 50. None of the lysimeters undergoing rejuvenation testing had been dosed in the nine months prior to the beginning of Phase 3.

Four medium-strength columns and three high-strength columns were cut open and visually examined. The infiltration surface was examined for iron sulfide buildup, biomat formation, and solids accumulation. The aggregate was examined to verify that most of the material in the synthetic effluent reached the soil infiltration surface.

CHAPTER ONE

INTRODUCTION

In Phase 2 of the restaurant waste study 13 medium-strength lysimeters and 11 high-strength lysimeters failed. No low-strength lysimeters failed. Dosing continued after the end of Phase 2. After 155 total days of dosing, a total of 14 medium-strength columns and 20 high-strength columns had failed. Dosing continued for another 127 days without another lysimeter failure. The 14 remaining high- and medium-strength columns were retired after a total of 282 days of dosing. Low-strength dosing continued without failure until Day 336, when Phase 3 began.

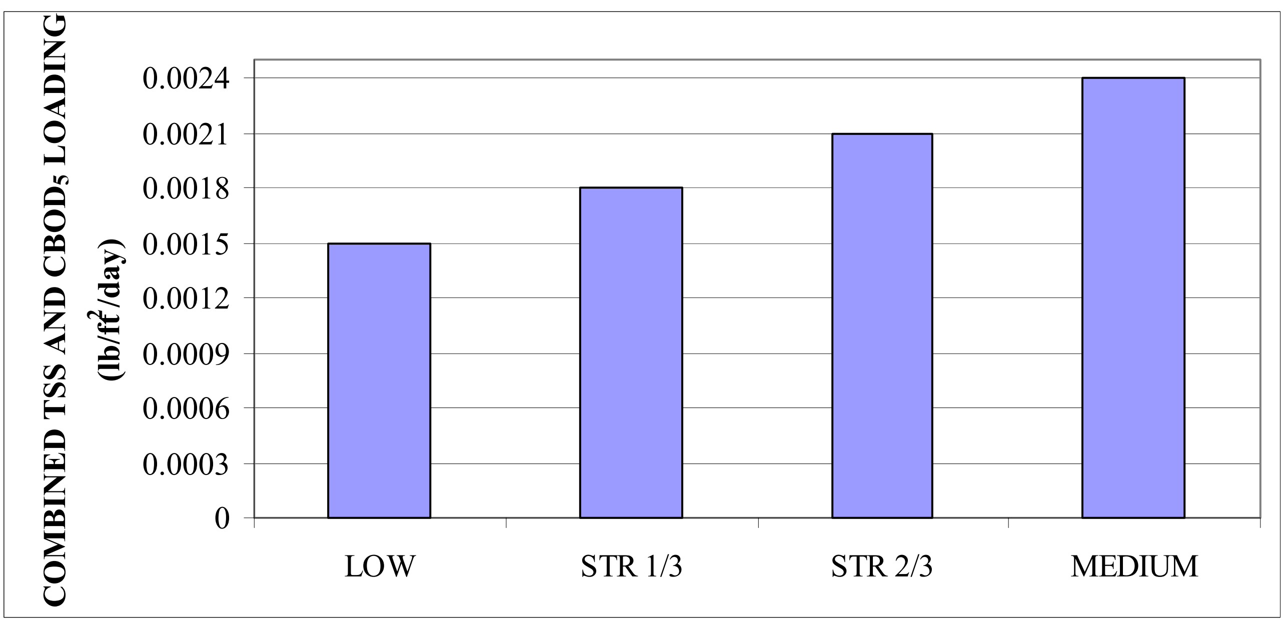
The purpose of Phase 3 was to further refine the apparent threshold above which lysimeter failure occurred consistently. This threshold was determined to lie between .0015 $lb/ft^2/day$ and .0024 $lb/ft^2/day$ for the soils tested.

CHAPTER 2

EXPERIMENTAL METHODS

Except as described in this chapter, phase 3 methods of batching, testing, and dosing were identical to those used in Phase 2. The only substantial change was in waste strength. The 24 low-strength columns from the Phase 2 study were divided into three groups to be used in Phase 3. For statistical analysis, all Phase 2 columns were built in triplicate. One lysimeter of each combination of soil type and saturation condition was included in each of the three Phase 3 groups. The wastewater strength for the first group did not change. A new synthetic wastewater strength was developed for each of the other two groups. Phase 2 identified a combined $CBOD_5$ and TSS loading threshold between .0015 lb/ft^2/day and .0024 lb/ft^2/day. As Figure 2-1 illustrates, the new wastewater strengths were positioned at the *one-third points* to split that range into three equal parts.

Figure 2-1: Design of New Waste Strengths



To avoid repeating the batching and testing cycles used to develop the batching recipes for Phase 2, recipes were interpolated from the low- and medium-strength data. The new wastewater strengths were named *Strength One-Third* (STR-1/3) and *Strength Two-Thirds* (STR-2/3). Table 2-1 is the target recipe for Phase 2, and Table 2-2 is the target recipe for Phase 3. The fourth strength in Table 2-2 (Strength Aerobic Treatment Unit) was used for the rejuvenation of failed medium-strength columns. This synthetic waste was designed to be approximately half as strong as the low-strength synthetic waste.

Table 2-1: Phase 2 Target Recipe Values

FACTORED FOR A 10-GALLON BATCH				
	DEXTROSE	DOG FOOD	SPAM	CRISCO
	(g)	(g)	(g)	(g)
LOW	5.21	2.75	0.83	0.15
MEDIUM	15.52	5.61	2.79	0.75
HIGH	34.06	9.51	10.15	1.14

Table 2-2: Phase 3 Target Recipe Values

FOR A 10-GALLON BATCH				
	DEXTROSE	DOG FOOD	SPAM	CRISCO
	(g)	(g)	(g)	(g)
STR ATU	2.60	1.38	0.41	0.08
STR LOW	5.21	2.76	0.83	0.17
STR 1/3	10.37	3.71	1.48	0.36
STR 2/3	15.53	4.66	2.13	0.56

As in Phase 2, batching included measuring each ingredient on an electronic scale with 0.01–gram precision. Actual recipe values were all within 8% of the target values with two exceptions: actual Crisco values for Strengths ATU and Low were 60% and 24% above the targets, respectively. In retrospect, a better method for measuring minute amounts of Crisco (such as an eyedropper) was needed.

In Phase 2, each waste strength was used on 24 columns, which required a total of 7.8 gallons per day for each of the three waste strengths. In Phase 3, each waste strength was used for only 8 columns, requiring only 2.6 gallons per day for each strength. Batch sizes were scaled down from 17.5 gallons to 10 gallons, and batches lasted three days (six doses) rather than two days (four doses).

Because the dextrose was highly soluble, it was added directly to the batching water first. The other three ingredients were then mixed with 100°C water in a blender for 30 seconds and added to the room-temperature batching water. Finally, a small amount of activated sludge from the University of Florida's wastewater treatment plant was added. The purpose of adding the activated sludge was to add human enteric organisms, as occurs in typical onsite systems. As in Phase 2, batching water was left in holding tanks for four to ten days prior to use to allow any chlorine present in the tap water to evaporate. One control column for each soil type was dosed with dechlorinated tap water. None of the standard operating procedures from Phase 2 were changed.

The hydraulic loading rates for the four soil types also remained the same. Table 2-4 lists hydraulic loading rates used in Phases 2 and 3.

Table 2-4: Phase 2 and Phase 3 Volumetric Loading Rates

Loading Rate		Soil Type
Liters/day/column	GPD/ft^2	
0.898	0.65	Pomona/Candler
1.106	0.80	Pomona/Astatula
1.258	0.91	Millhopper
1.658	1.20	Candler

Of the 34 failed lysimeters, 9 were selected for the rejuvenation attempt. The nine most recently failed columns were selected. Additionally, all other columns being dosed were to go through the rejuvenation process upon failure. The period for resting and draining of the freshly failed columns was planned to be five days. The columns were to receive no dosing during the resting period. At the end of the resting period, dosing with the Aerobic Treatment Unit Strength (STR-ATU) began. All nine columns selected for rejuvenation were dosed with this lowest waste strength.

Phase 2 testing found the standard deviations associated with waste strength to be up to 40% of the mean value. Because of this variability, tests were performed to verify the strength of the synthetic waste produced in Phase 3. Five-Day Carbonaceous Biochemical Oxygen Demand ($CBOD_5$) and Total Suspended Solids (TSS) tests were each performed on five batches. The $CBOD_5$ tests were performed in accordance with EPA Method 405.1, and the TSS tests were performed in accordance with EPA Method 160.2. These are the same methods that were used for testing in Phase 2.

As in Phase 2, the volumetric loading rate was divided into two equal doses per day. Dosing was performed with the measuring cups and dosing cups that were used in Phase 2. Temperatures and relative humidity levels were also comparable to those observed in Phase 2. Figure 2-2 shows daily minimum and maximum air temperatures in the laboratory during Phase 3. Figure 2-3 shows daily minimum and maximum relative humidity levels.

Figure 2-2: Laboratory Air Temperature During Phase 3

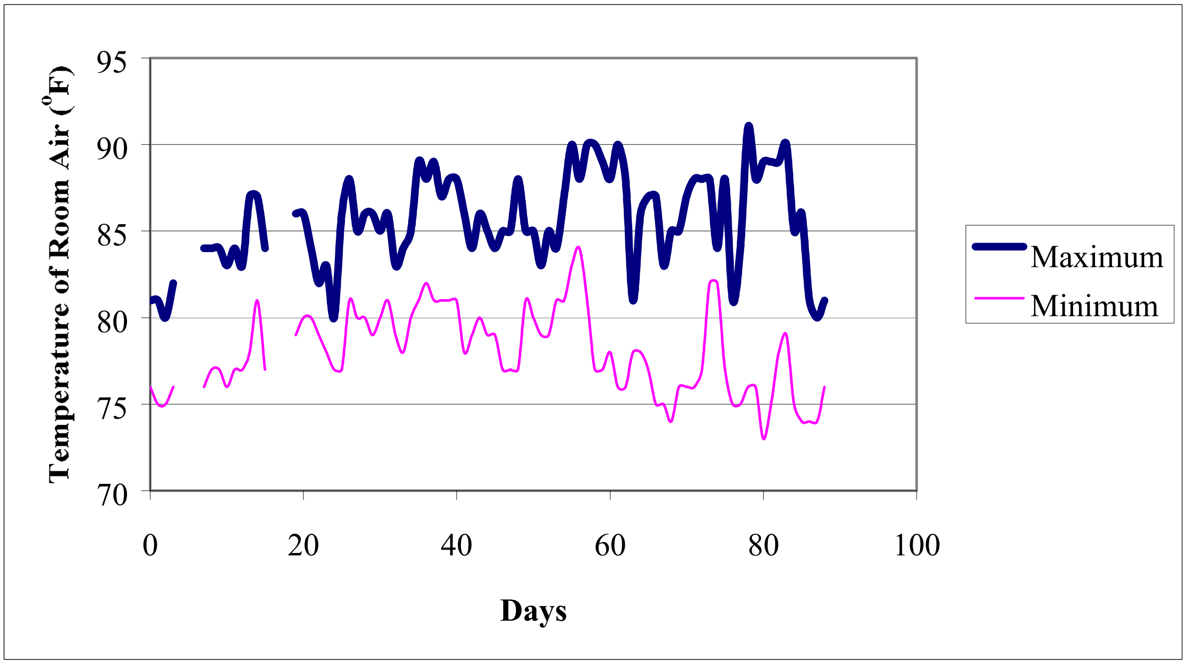
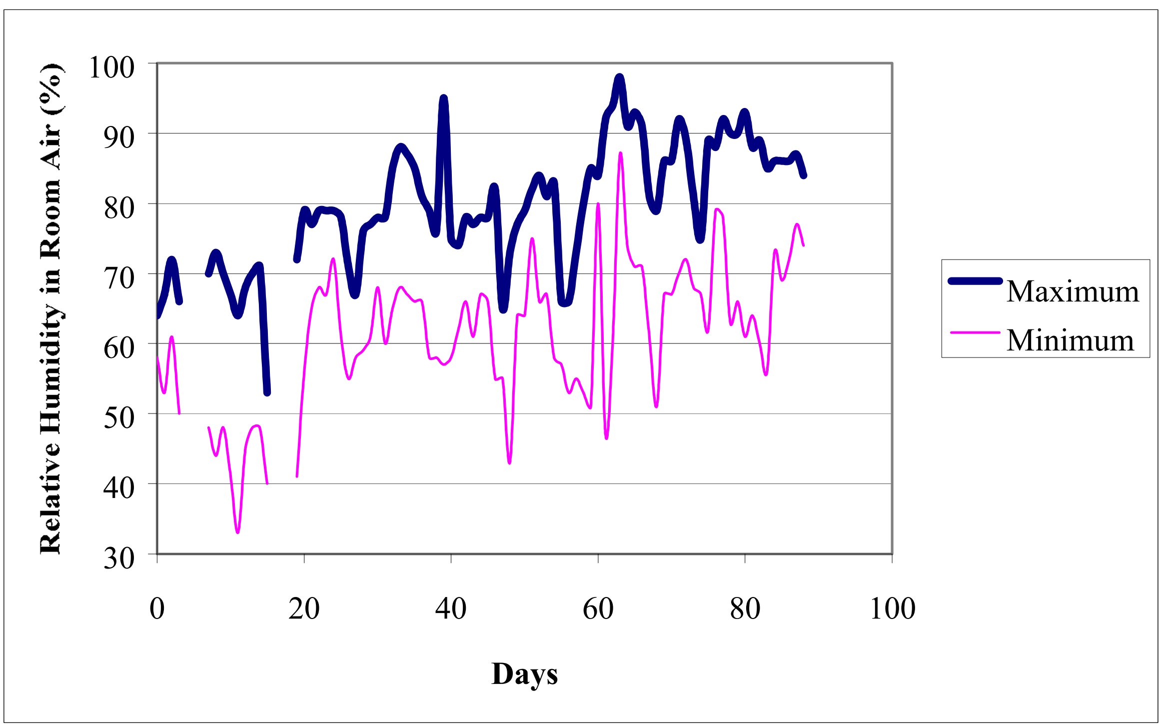


Figure 2-3: Laboratory Air Relative Humidity During Phase 3



Lysimeters 25, 28, 35, 48, 57, 67, 68, and 69 were dissected, visually examined, and photographed. Soil cohesion provided enough stability that the columns could be dissected in an upright position. The PVC piping was cut away, exposing the soil and aggregate. Once it had been examined and photographed, the aggregate was removed by hand. The exposed soil infiltration surface was then examined and photographed with a color digital camera. Photographs of all dissected columns are located in Appendix A.

CHAPTER 3

RESULTS AND CONCLUSION

Table 3-1 lists the average of the actual recipe values for the 28 batches in Phase 3. The coefficient of variation is the standard deviation divided by the mean, expressed as a percentage. As in Phase 2, measurement of Crisco involved the greatest variability.

Table 3-1: Phase 3 Actual Recipe Values for 10-Gallon Batches

		Dextrose (g)	Dog Food (g)	Spam (g)	Crisco (g)
ATU	Mean	2.58	1.48	0.43	0.13
	C.V.	1.8%	17.0%	16.8%	45.1%
LOW	Mean	5.19	2.73	0.81	0.21
	C.V.	1.3%	2.0%	4.7%	29.1%
STR-1/3	Mean	10.35	3.69	1.44	0.36
	C.V.	0.9%	2.1%	5.0%	17.6%
STR-2/3	Mean	15.49	4.64	2.12	0.54
	C.V.	0.7%	2.0%	2.2%	11.9%

Synthetic effluent strength, measured in $CBOD_5$ tests for five batches and TSS samples for five batches, was higher than predicted. Table 3-2 summarizes the results of testing. Table 3-3 lists volumetric loading and mass loading rates for each soil in each strength category. To be consistent with Phase 2 analysis, the mass loading rate is the combined $CBOD_5$ and TSS loading. Oils and greases were considered separately in Phase 2 calculations, and were not included in Phase 3 testing.

Table 3-2: Phase 3 Synthetic Waste Concentrations

		STR-ATU	LOW	STR 1/3	STR 2/3
BOD (mg/L)	Mean	77	151	245	319
	Std. Dev.	24	27	21	34
	C.V.	32%	18%	8%	11%
TSS (mg/L)	Mean	N/A	23	53	94
	Std. Dev.	N/A	8	26	16
	C.V.	N/A	34%	48%	17%

Table 3-3: Volumetric Loading Rates and Combined Mass Loading Rates

Waste Strength	Soil	Volumetric Loading Rate	Combined $CBOD_5$ and TSS mass loading rate	Days to Failure
		GPD/ft^2	$lb/ft^2/day$	NF = No Failure
ATU	Pomona/Candler	0.65	0.0004	NF
	Pomona/Astatula	0.80	0.0005	NF
	Millhopper	0.91	0.0006	NF
	Candler	1.20	0.0008	NF
LOW	Pomona/Candler	0.65	0.0009	NF
	Pomona/Astatula	0.80	0.0012	NF
	Millhopper	0.91	0.0013	NF
	Candler	1.20	0.0017	NF
1/3	Pomona/Candler	0.65	0.0016	NF
	Pomona/Astatula	0.80	0.0020	NF
	Millhopper	0.91	0.0023	NF
	Candler	1.20	0.0030	87
2/3	Pomona/Candler	0.65	0.0022	NF
	Pomona/Astatula	0.80	0.0028	NF
	Millhopper	0.91	0.0031	NF
	Candler	1.20	0.0041	NF

While batches were higher in strength than was intended, only one lysimeter failure occurred during the testing period. Lysimeter 8 failed after 87 days of dosing. Sixteen lysimeters received dosing above the .0015 lb/ft^2/day failure threshold identified in Phase 2. Lysimeter 8, which failed after 87 days of dosing, received .0030 lb/ft^2/day. These results suggest that the failure threshold increases as the drainfield matures. Phase 3 has also confirmed that the .0015 lb/ft^2/day threshold is a reasonable strength to base system designs on.

One possible reason for the lack of failures in the 1/3 and 2/3 strength categories is a well developed biomat in the lysimeters. During Phase 2 the low-strength lysimeters received consistent doses of weak waste containing activated treatment plant sludge. It is assumed that this consistent diet encouraged the growth of microbes capable of digesting the waste. Therefore, unlike the beginning of Phase 2, the microbes were already present in the lysimeters at the beginning of Phase 3. This explains why many of the low-strength columns received twice as much mass as failed high- and medium-strength counterparts. It also explains why dosing during Phase 3 took longer to induce failure in lysimeter number 8 despite its waste strength being similar to the medium strength from Phase 2.

Because the failed medium-strength columns had resting periods ranging from 9 months to 14 months, they had all recuperated well enough to receive the ATU strength without failure. No failures occurred in the lysimeters undergoing rejuvenation testing. No other columns failed early enough in the study to test rejuvenation with the target five-day resting period.

Phase 3 included the visual inspection of seven lysimeters that had failed due to Phase 2 dosing. These lysimeters did not receive wastewater during Phase 3. Visual examination of the failed lysimeters revealed a number of things. Dissected lysimeters showed no signs of iron sulfide build-up. Solids accumulation at the infiltration surface was noticeable, but not as thick as was expected. Bare sand particles were still visible through a light dusting of waste solids. Aggregate coating, the phenomenon of waste sticking to the aggregate rather than flowing to the infiltration surface, was not observed. There was limited biological growth on the aggregate, particularly in the lower region of the aggregate, but most biological growth occurred within ¼" of the infiltration surface. Differences between medium-strength and high-strength wastes were barely noticeable despite the high-strength lysimeters having received substantially more mass. This indicates that the microbes at the infiltration surface did a sufficient job of breaking down suspended solids.

Future research should involve using the new waste strengths on lysimeters that have not already developed healthy microbial populations. This will model a new drainfield being put into use. In Phase 2, the threshold was shown to lie between .0015 lb/ft^2/day and .0024 lb/ft^2/day of combined $CBOD_5$ and TSS loading. Phase 3 has confirmed this upper limit. Further research should refine the threshold by testing fresh soil with the new mass loading rates of .0018 lb/ft^2/day, .0021 lb/ft^2/day, and .0024 lb/ft^2/day. In addition, control columns should be dosed with dechlorinated tap water to verify that failures are not due to lack of soil permeability.

REFERENCES

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