Technical Report Documentation Page

1. REPORT No.
FHWA/CA/TL-86/07

2. GOVERNMENT ACCESSION No.

3. RECIPIENT'S CATALOG No.

4. TITLE AND SUBTITLE
Effects of Septic Tank Additives on Scum Accumulation in Septic Tanks

5. REPORT DATE
May 1986

6. PERFORMING ORGANIZATION

7. AUTHOR(S)
S.B.P. John and T.P. Bakker

8. PERFORMING ORGANIZATION REPORT No.
54328-637329

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Office of Transportation Laboratory
California Department of Transportation
Sacramento, California 95819

10. WORK UNIT No.

11. CONTRACT OR GRANT No.
E86TL02

12. SPONSORING AGENCY NAME AND ADDRESS
California Department of Transportation
Sacramento, California 95807

13. TYPE OF REPORT & PERIOD COVERED
Final

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES
This project was performed in cooperation with the U.S. Department of Transportation, Federal Highway Administration

16. ABSTRACT

California Department of Transportation Safety Roadside Rest Areas (SRRA) use septic tank-leach field wastewater treatment and disposal systems. Rapid scum buildup in some septic tanks has on occasion caused sewage to back up into restrooms, leach field failures, and required frequent pumping.

Use of bacterial and enzymatic additives by maintenance personnel in some roadside rest septic tanks produced mixed results. A three month study of the effectiveness of three most commonly used bacterial and enzymatic additives was initiated in 1985 to determine the optimum dose of these additives to be used for maximum scum reduction rates in septic tanks at Westley SRRA.

Each manufacturer's recommended dosage for septic tanks treating typical domestic wastewater was used in this study. The study data showed that the scum reduction rates in the treated tanks were greater than in the untreated (control) tanks by a very small amount.

It is estimated that the overloading of the tanks, the high concentration of body wastes and the large quantities of toilet paper and paper toilet seat covers create this rapid scum production problem that is not significantly decreased by the use of any of the three septic tank additives.

17. KEYWORDS
Septic tank scum, enzyme additives, bacterial additives, microorganism activity, leachfield failures

18. No. OF PAGES:
126

19. DRI WEBSITE LINK
http://www.dot.ca.gov/hq/research/researchreports/1981-1988/86-07.pdf

20. FILE NAME
86-07.pdf

STATE OF CALIFORNIA
Department of Transportation
Division of Facilities Construction
Office of Transportation Laboratory

EFFECTS OF SEPTIC TANK ADDITIVES ON SCUM ACCUMULATION IN SEPTIC TANKS (TYPE B STUDY)

Final Report

Study made by....................Office of Transportation Laboratory
Under Supervision of...........Mas Hatano, P.E.
Principal Investigator.........S. Bennett P. John, P.E.
Co-Investigator................Theodore P. Bakker, P.E.

RAYMOND A. FORSYTH, P.E.
Chief, Office of Transportation Laboratory

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO.	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
FHWA/CA/TL - 86/07		

4. TITLE AND SUBTITLE Effects of Septic Tank Additives on Scum Accumulation in Septic Tanks	5. REPORT DATE May 1986 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) S.B.P. John and T.P. Bakker	8. PERFORMING ORGANIZATION REPORT NO. 54328-637329
9. PERFORMING ORGANIZATION NAME AND ADDRESS Office of Transportation Laboratory California Department of Transportation Sacramento, California 95819	10. WORK UNIT NO 11. CONTRACT OR GRANT NO. E86TL02
12. SPONSORING AGENCY NAME AND ADDRESS California Department of Transportation Sacramento, California 95807	13. TYPE OF REPORT & PERIOD COVERED Final 14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

This project was performed in cooperation with the U. S. Department of Transportation, Federal Highway Administration

16. ABSTRACT

California Department of Transportation Safety Roadside Rest Areas (SRRA) use septic tank-leach field wastewater treatment and disposal systems. Rapid scum buildup in some septic tanks has on occasion caused sewage to back up into restrooms, leach field failures, and required frequent pumping.

Use of bacterial and enzymatic additives by maintenance personnel in some roadside rest septic tanks produced mixed results. A three month study of the effectiveness of three most commonly used bacterial and enzymatic additives was initiated in 1985 to determine the optimum dose of these additives to be used for maximum scum reduction rates in septic tanks at Westley SRRA.

Each manufacturer's recommended dosage for septic tanks treating typical domestic wastewater was used in this study. The study data showed that the scum reduction rates in the treated tanks were greater than in the untreated (control) tanks by a very small amount.

It is estimated that the overloading of the tanks, the high concentration of body wastes and the large quantities of toilet paper and paper toilet seat covers create this rapid scum production problem that is not significantly decreased by the use of any of the three septic tank additives.

17. KEY WORDS	18. DISTRIBUTION STATEMENT
Septic tank scum, enzyme additives, bacterial additives, microorganism activity, leachfield failures.	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161.

19. SECURITY CLASSIF. (OF THIS REPORT)	20. SECURITY CLASSIF. (OF THIS PAGE)	21. NO. OF PAGES	22. PRICE
Unclassified	Unclassified		

DS-TL-1242 (Rev.6/76)

CONVERSION FACTORS

English to Metric System (SI) of Measurement

Quality	English unit	Multiply by	To get metric equivalent
Length	inches (in)or(")	25.40	millimetres (mm)
		.02540	metres (m)
	feet (ft)or(')	.3048	metres (m)
	miles (mi)	1.609	kilometres (km)
Area	square inches (in^2)	6.432×10^{-4}	square metres (m^2)
	square feet (ft^2)	.09290	square metres (m^2)
	acres	.4047	hectares (ha)
Volume	gallons (gal)	3.785	litre (l)
	cubic feet (ft^3)	.02832	cubic metres (m^3)
	cubic years (yd^3)	.7646	cubic metres (m^3)
Volume/Time (Flow)	cubic feet per second (ft^3/s	28.317	litres per second l/s)
	gallons per minute (gal/min)	.06309	litres per second (l/s)
Mass	pounds (lb)	.4536	kilograms (kg)
Velocity	miles per hour (mph)	.4470	metres per second (m/s)
	feet per second (fps)	.3048	metres per second (m/s)
Acceleration	feet per second squared (ft/s^2)	.3048	metres per second squared (m/s^2)
	acceleration due to force of gravity (G) (ft/s^2)	9.807	metres per second squared (m/s^2)
Density	(lb/ft^3)	16.02	kilograms per cubic metre (kg/m^3)
Force	pounds (lbs)	4.448	newtons (N)
	(1000 lbs) kips	4448	newtons (N)
Thermal Energy	British termal unit (BTU)	1055	joules (J)
Mechanical Energy	foot-pounds (ft-lb)	1.356	joules (J)
	foot-kips (ft-k)	1356	joules (J)
Bending Moment or Torque	inch-pounds (in-lbs)	.1130	newton-metres (Nm)
	foot-pounds (ft-lbs)	1.356	newton-metres (Nm)
Pressure	pounds per square inch (psi)	6895	pascals (Pa)
	pounds per square foot (psf)	47.88	pascals (Pa)
Stress Intensity	kips per square inch square root inch ($ksi\sqrt{in}$)	1.0988	mega pascals$\sqrt{metre}$ ($MPa\sqrt{m}$)
	pounds per square inch square root inch ($psi\sqrt{in}$)	1.0988	kilo pascals$\sqrt{metre}$ ($KPa\sqrt{m}$)
Plane Angle	degrees (°)	0.0175	radians (rad)
Temperature	degrees fahrenheit (F)	$\frac{+F - 32}{1.8} = +C$	degrees celsius (°C)

FINANCIAL DISCLOSURE STATEMENT

The research summarized in the Appendix was jointly funded by the State of California, Department of Transportation (Caltrans) and the Federal Highway Administration (FHWA). The ceiling amount for this contract, RTA 13945-57D575, is $17,480.

NOTICE

The contents of this report reflect the views of the Office of Transportation Laboratory which is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

Neither the State of California nor the United States Government endorse products or manufacturers. Trade or manufacturers' names appear herein only because they are considered essential to the object of this document.

ACKNOWLEDGEMENTS

The investigators wish to thank the following Caltrans employees for their assistance in conducting this study: William Aaberg, William Grottkau, John Williams, William Nokes and Teresa Lopes.

TABLE OF CONTENTS

INTRODUCTION

Many of the Safety Roadside Rest Areas (SRRA) and maintenance stations use septic tank-leach field treatment and disposal systems to handle the wastewater generated in California Department of Transportation (Caltrans) facilities. In some of these wastewater systems rapid buildup of scum layers has become a problem.

In order to reduce septic tank pumping costs in these problem systems, some maintenance crews have been using proprietary biological agents to reduce scum layer buildup. Delay in pumping the septic tanks, in which the scum layers rapidly increase in thickness, results in blockage of septic tank inlets and flooding of comfort stations, or in extreme cases the incompletely treated scum is discharged to the leach field. Scum particles in septic tank effluent streams are considered to produce a significant plugging effect in the leach fields into which they are discharged.

Various proprietary biological agents have been purchased by Caltrans maintenance personnel in the recent past in order to reduce incomplete scum treatment problems such as septic tank inlet plugging and leach field disposal system failures. A survey of the additives being purchased by Caltrans was made and the three most common ones were selected for study by the University of California Sanitary Engineering and Environmental Health Research Laboratory in Richmond.

The three additive products are identified by the pseudonyms Additives A, B and C in the University of California report which, to the best of our knowledge, are known as Actizyme, Microbe-Lift and Septic Tank Activator, respectively.

In the field test at Westley SRRA, six septic tanks were selected for the study, four septic tanks (each with 7,500 gallon capacity) receiving rest room wastewater and two septic tanks (each with 4,500 gallon capacity) receiving recreational vehicle wastewater.

Wastewater from rest rooms on the northbound (NB) side of Westley SRRA is treated in two 7,500 gallon septic tanks. Wastewater from the southbound (SB) side is also treated in two 7,500 gallon septic tanks. The westerly 7,500 gallon SB tank was selected for treatment while the easterly SB tank was used for a control (no treatment). The NB rest room septic tanks were operated in similar fashion during the study period (one treated, one control). The SB 4,500 gallon recreational vehicle septic tank was treated with additives while the NB tank was used as a control (no treatment).

During the three month field study period, the scum thicknesses in the six septic tanks were measured and three of the six tanks were treated with additives as recommended by the manufacturers. The experimental results are shown in Tables 1, 2, and 3 in the University of California report (shown in Appendix).

CONCLUSIONS:

Based upon the University of California Westley field study data and statistical analyses along with available Caltrans information, the following conclusions have been reached:

1 - With the type of wastewater flow rates and scum (paper products) accumulation rates as evidenced at Westley SRRA during the field study period, the addition of Additives A, B, and C to the pulverized scum layers in the inlet compartment manholes of the three treated septic tanks produced no significant reduction of scum layer thicknesses when compared to the scum layer thicknesses in the control septic tanks.

2 - From these field evaluations and other related Caltrans investigations, it appears that highly concentrated domestic wastewaters are generated in the Westley SRRA rest rooms. These wastewaters contain disproportionate quantities of body wastes and toilet paper products when compared to typical household (domestic) wastewater flows.

3 - The scum accumulations in Westley SRRA restroom septic tanks appear to be mostly paper products, such as paper toilet seat covers and toilet tissues.

4 - More rapid buildup of scum occurs in Caltrans SRRA septic tanks, such as are found at Westley, than in typical household septic tanks due to the excessive use of paper products (toilet tissues and paper toilet seat covers). Very few, if any, households use paper toilet seat covers at all while their use is commonplace at Caltrans SRRAs.

5 - In Westley SRRA rest room septic tanks, paper materials that float (scum) appear to accumulate rapidly in the first compartment (behind the precast concrete construction joint) due to both high rest room usage and the large quantities of paper products discharged to waste. The problem appears to be more severe in the SB tanks due to heavier public usage and because of the "tee" type septic tank inlet provided to minimize short circuiting.

6 - It appears that natural microbiological degradation of scum material is occurring in the Westley SRRA septic tanks, but that this natural process could be made more efficient by providing a greater degree of physical contact between the scum material and the microorganisms in the wastewater.

7 - The scum accumulation problem found in the Westley SRRA recreational vehicle septic tanks does not appear to be any more severe than that of the four rest room septic tanks despite the fact that odor-reducing chemicals are usually discharged with the recreational vehicle wastes. The positive effect here may be due to the general use of more highly biodegradable toilet tissues in recreational vehicle wastewater systems.

RECOMMENDATIONS:

Based upon the findings of the University of California study made at Westley SRRA, the following recommendations are made:

Short-term Recommendations

1 - To reduce the frequent pumping of the rest room septic tanks at Westley SRRA, it is recommended that toilet paper products that are more easily degraded be used in the restrooms, or

2 - Mechanical agitation devices be installed near the water surface in the first compartment of the rest room septic tanks and operated when required to maintain better contact between the scum materials and the microorganisms in the wastewater, or

3 - High-rate reaction additives that have been determined to be capable of speeding up the biological activity of the reactive

microorganisms be mixed with the waste contents of the Westley rest room septic tanks so that scum is degraded at a rate equal to or greater than the discharge rate of the septic tanks.

Long-term Recommendations

1 - To allow for future increases in usage of rest rooms at Westley SRRA, a 20,000 to 25,000 gallon capacity septic tank should be constructed to replace the two 7,500 gallon existing septic tanks on the SB side. Design should include proper baffle placement to allow for more uniform dispersion of the scum materials in the inlet portion of the tank.

2 - After future growth predictions of rest room usage and wastewater flow rates have been completed at Westley SRRA, a reevaluation of the suitability of wastewater treatment in septic tanks should be made. Consideration should be given to oxidation pond treatment as well as septic tank-leach field treatment systems.

IMPLEMENTATION:

Copies of this report will be distributed to the Federal Highway Administration, Caltrans Headquarters and the eleven Caltrans District Offices for their information and future use. Other interested parties will be furnished copies upon request.

DISCUSSION

Objectives of this Research

The objectives of this research are: (1) selection of additives to be studied, (2) determination of additive dosages to be used, (3) additive application methods and (4) scum thickness reduction factors.

Selection of Additives to be Studied

Three additives were selected for evaluation in this study. The primary basis for selection of these additives was that Caltrans maintenance personnel had been using them for some time but the correlation between dosage and scum thickness reduction had not been established. The names of the three additives selected were Actizyme, Microbe-Lift, and Septic Tank Activator. According to the best information available to us these additives correspond to the pseudonyms A, B, and C, respectively, that are mentioned in the University of California report which is attached to this report in the Appendix.

Determination of Additive Dosages

The initial dosages used at the Westley SRRA in this field study were recommended by the suppliers of the additives. Since microbiological decomposition rates of organic matter depend to a great extent upon the quality and quantity of organic matter to be treated (scum), the concentration of additive used and the length of time that the additive is in contact with the bacteriological agents that are ingesting the organic material, the additives were added in varying rates over similar time periods. Manufacturers' suggestions for changes of schedules of additive dosages were followed as closely as possible within the limitations of manpower availability and flow rate approximations. Time schedules of additive dosages and scum thickness measurements are presented in Tables 1, 2, and 3 of the University of California Report in the Appendix.

Additive Application Methods

In the field portion of this septic tank additive study, the additive application method selected by the researchers consisted of adding the active material to the scum material through the septic tank inlet manhole after the scum layer had been pulverized with the blunt rammer. Scum thickness readings were taken before the pulverization process was initiated.

Another possible method of applying the additive to the scum material is to flush it down the stool nearest the inlet end of the septic tank. This option was not selected during this study at the Westley SRRA. There are six septic tanks at this site, two of which are recreational vehicle septic tanks.

To flush the septic tank additive materials through the stools in the rest rooms that are served by the other four septic tanks would create a nonuniform procedure since the recreational vehicle septic tanks are not connected to a stool that could be flushed. There also is a very good possibility that additive materials that are flushed into the septic tank will not be dispersed as well throughout the scum material as they were in this study. Contact between the additives, microbiological agents and the scum material should be as uniform as possible to facilitate bacterial decomposition of the organic matter and to provide a uniform layer that may be easily measured by means of the gauging instrument. Nonuniform scum layers are very difficult to measure accurately with the type of instruments available for this study.

Scum Thickness Reduction Factors

The rate of scum degradation in a septic tank is related to many factors. Some of the most important factors are: (1) inflow rate of scum (paper) materials into the tank, (2) the composition of the liquid component of the wastewater, (3) the geometrics of the septic tank, and (4) the type and quantity of microorganisms available to degrade the scum material.

(1) Inflow rate of scum (paper) materials into the tank.

Although no wastewater flow measurements were made in this study, a recent study made by the Caltrans Laboratory on septic tank flow rates includes flow rate estimates at the Westley SRRA. These estimates indicate that the wastewater is held in the septic tanks for approximately one day when average day flows occur. When peak flows occur, the capacity for treatment is exceeded, creating a large buildup of scum layers in the upstream compartments of the septic tanks. The southbound septic tanks appear to have a more rapid accumulation of scum materials than the northbound tanks due to a greater amount of rest area usage by the public.

(2) The composition of the liquid component of the wastewater.

The concentration of soluble and suspended materials in the liquid that is discharged to the rest area septic tanks differs to some extent from that found in typical domestic wastewater septic tank flows. Rest area septic tanks receive disproportionate quantities of urine, fecal matter and paper products as compared to domestic wastewater. Domestic wastewater contains significant quantities of nontoilet wastes such as laundry wastes, food preparation wastes, dishwater and bathwater. In California rest areas, paper toilet seat covers are used by the public that are not readily degraded by microbiological agents in the septic tanks. These paper toilet seat covers may make up nearly half the total paper discharged to rest area septic tanks.

Normally, less paper is discharged to recreational vehicle septic tanks than to rest room septic tanks. A factor that largely negates the paper advantage is the fact that solids concentrations are higher and odor-control preservatives are often used which reduce the rate of bacterial decomposition.

(3) The geometrics of the septic tanks.

Generally, Caltrans SRRA septic tanks are rectangular in cross section at the scum line with either a tee-type inlet or a short wall baffle used to prevent short-circuiting of the inlet flow to the outlet structure. At Westley SRRA, the scum is concentrated in the first 8-foot chamber of the 40-foot precast concrete septic tank by the construction joint as is shown in the Appendix of the University of California report. In two of the six Westley SRRA septic tanks, a drop inlet is used to discharge the wastewater from the inlet pipe to the septic tank instead of the more conventional tee inlet.

In the University of California study, it was found that the greatest early decrease in scum thickness occurred in the test septic tank fitted with the drop inlet rather than the tee inlet with all additives. This greater decrease of scum thickness in the NB Westley SRRA septic tank that was outfitted with the drop inlet was likely caused by the increased agitation of the scum liquid mixture (better contact between the microorganisms and the scum material).

(4) The type and quantity of microorganisms available to degrade the scum material.

Microorganisms that degrade scum or paper materials are present in the septic tanks. The quantity of microorganisms that are available to degrade materials, such as paper scum, in a septic tank will depend to a great extent on the type of environment in which they find themselves. If the temperature, pH, and food are at values that encourage growth, the microorganisms will thrive and, in the process, degrade large quantities of matter. In this study the food was the paper scum. Sufficient quantities of food appeared to be available in the septic tanks at Westley SRRA but the microbiological processes seemed to be adversely affected due to insufficient contact between the microorganisms and the scum. The University of California researcher indicates some slow reaction may be caused by a low pH condition.

Generally, microorganisms require a water medium in which to live and physical contact with the food to be degraded in order to be most effective. In the Westley SRRA septic tanks it appears that the scum (paper) layers build up so rapidly that a significant portion of the paper is in contact only with other paper, rather than the water medium containing the microorganisms. For the enzymatic agents or additives to have a positive effect, the microorganisms must be in contact with these agents or have these materials available to them for a significant period of time. In the Westley SRRA septic tanks, the estimated tank detention time with peak flows is less than one day. This is normally considered to be insufficient to allow for multiplication of the microbiological agents and for appreciable degradation of the scum to occur. In other words, it appears likely that the enzymatic agents are discharged from the tanks before they can be of much benefit to the microorganisms that degrade the scum materials.

From the review of the literature furnished us by the additive suppliers, it was found that microorganisms in contact with these additives and scum materials in septic tanks with longer detention times have been effective in breaking down scum layers. In the field tests conducted at Westley SRRA by the University of California researchers, both the rapid scum buildup in the septic tanks and the short detention times would appear to create a negative environmental effect on proper microbiological activity for the microorganisms that break down scum materials. Since the field tests were not conducted under normal domestic septic tank operating conditions, the results obtained do not in anyway demonstrate the degree of effectiveness of these three additives under other less severe conditions.

APPENDIX

INVESTIGATION OF SOME BIOLOGICAL ADDITIVES FOR SCUM MITIGATION IN SEPTIC TANKS AT ROADSIDE REST AREAS

Prepared for

CALIFORNIA DEPARTMENT OF TRANSPORTATION

TRANSPORTATION LABORATORY

under

Research Technical Agreement RTA 13945-57D575

by

SANITARY ENGINEERING AND ENVIRONMENTAL HEALTH RESEARCH LABORATORY

UNIVERSITY OF CALIFORNIA, BERKELEY

REPORT UCB-SEEHRL 86-1

Frank Pearson

MAY 1986

Disclaimer

SUMMARY AND CONCLUSIONS

The research sought a method to mitigate the accumulation of scum in septic tanks at safety roadside rest areas (SRRAs). The scum appeared to be largely paper from the restrooms. Accumulation of scum in the inlet compartments of septic tanks at some SRRAs reportedly had caused occasional blockage of the inlet lines from the restrooms. In septic tanks at the Westley northbound and southbound SRRAs the thickness of the scum mat decreased on the day after the scum was pulverized, then gradually recovered or surpassed its original thickness after about two weeks. The decrease in scum mat thickness on the day following pulverization was greater in a test septic tank fitted with a drop inlet than in the other test septic tanks that were each fitted with a conventional tee-inlet. A drop inlet allows influent to tumble freely into the tank, whereas influent enters the tank more gently at water level with a tee-inlet. One tee-inlet tank treated only RV waste from a trailer sanitation station. In the tee-inlet septic tanks, the decrease in scum thickness after pulverization did not differ between the untreated control tank and tanks treated with any of the three biological additives applied, according to statistical significance testing at the 95% level. The scum was mildly acidic although the waste was alkaline. Over the evaluation period of approximately three months, the thickness of scum mats in all Westley test septic tanks was controlled by bi-weekly pulverization of the scum.

Two sets of laboratory experiments were designed to define how any of the three additives examined affected the volume of septic tank scum initially placed in the experimental laboratory process units. These process units were referred to as the columns and the batch reactors. Scum used in the process units was obtained from the Westley southbound SRRA east and west septic tanks.

For the column laboratory experiments, eight process units were set up, each containing a layer of scum floating on domestic wastewater. The rate of decrease of thickness of each mat as it disintegrated into the wastewater was determined, and these rates were compared between process units. Results provided insufficient statistical evidence at the 95% significance level to reject the null hypothesis that the rates of decrease of thickness of the scum mats spiked with any of the three additives did not differ from the rates in the untreated process units.

In the batch reactor experiments, the density and volume of additive-treated and untreated scum were observed after water was allowed to drain from the scum by gravity. These experiments were conducted on scum as received, and also on scum that had been limed to counteract acidity (pH 5.8). Over a four-week test period, the volume of unlimed scum decreased by an average of 48% of the original volume, compared to 8% for limed scum. Unlimed scum remained generally lighter than water, but limed scum was heavier and would have sunk. The relatively sensitive batch reactor studies provided some evidence of interaction between scum and additive, that was not observed in field studies or laboratory column studies. Effects observed in batch reactor studies were rather slight, e.g., the volume of scum in one set of additive-treated batch reactors was 15% lower than in a set of control reactors after 28 days contact. Effects observed in additive-treated reactors were not always obviously advantageous to scum abatement.

ACKNOWLEDGMENTS

Appreciation is expressed for constructive suggestions and expert assistance in the conduct of this research by Messers John Williams, Ted Bakker, S. Bennett P. John, and William Nokes, all from the California Department of Transportation, Transportation Laboratory. Mrs. Randy Kaack assisted with graphical work and searching of literature references.

TABLE OF CONTENTS

Table of Contents (Continued)

LIST OF FIGURES

LIST OF TABLES

LITERATURE

A literature survey was not a part of this study, but readily available sources on the use of biological additives in wastewater treatment and similar fields were compiled as follows.

Thorough recent research concerning the effect of bacterial or enzymatic additives on biological waste treatment processes is meager, judging from the paucity of such reports in reviewed technical journals. The only such recent report located described the operation of bench-scale activated sludge units for the purpose of evaluating the effect of a bacterial culture product on the activated sludge process. Some of the experimental units were dosed with the additive, while others remained undosed to serve as controls. Based on the results of the study it was concluded that the bacterial culture product tested had some effect on the sludge growth yield coefficient, Y, (approx. 7% increase), and the decay coefficient, k_d, (approx. 20% decrease), but no effect on the substrate utilization coefficients k and K_s. The increase in BOD removal from dosing the biological reaction with the bacterial culture product was 8% at a sludge age of two days, 2% at a sludge age of 6 to 8 days, and 1% at higher sludge ages. There was considered to be little effect on the performance of a well designed and well operated activated sludge plant, and it was surmised that the product may have some benefit in those plants that are already overloaded and are operating at poor organic removal efficiencies (1).

Other authors cautioned against attempting to use bacterial cultures to rectify design or operating deficiencies, stating: "Bioaugmentation with mutant bacterial cultures is recent technology that requires careful control in the field to evaluate the effectiveness of application. Improvement in several petrochemical effluents has been obtained within well engineered systems. No claims should be made to suggest that it takes the place of such a system. The improvements in effluent quality justify more field experiments. Such field trials must be accompanied by service to examine several parameters of operation, including microscopic examination of activated sludge as a check on the activity of the biomass" (2).

The only report reviewed on an investigation into the use of a biological additive in septic tanks was a study on the use of yeast as a "starter" of septic tanks, yeast reportedly being a component of some proprietary additives. However, on the basis of bottle experiments conducted, the addition of yeast to sewage was found not to stimulate digestion for at least 25 days. Although addition of yeast to mixtures of sewage and ripe sludge appeared to stimulate gas production, this was believed to be more due to the production of gas from the organic matter in the yeast suspension used (yeast plus starch), than to the stimulation of digestion in the sewage-sludge mixture (3). Another report, apparently on the use of activators on septic tanks, written in the French language, had not been translated at the time of writing (4).

Another study investigated the effectiveness of certain enzymes in sludges and manures, the effect of enzyme additive on anaerobic degradation activity, and the integrity of the additive in the course of interacting with the sludge or manure. The first question was assessed by determining whether the degradation enzymes would stimulate oxygen uptake by sludges and manures. The enzymes cellulase, lipase and protease were found ineffective, strictly from an enzymatic viewpoint, in stimulating oxygen uptake. Whenever an enzyme stimulated oxygen uptake, it did this regardless of whether the enzyme was intact (active to begin with) or denatured (inactivated due to boiling). This signifies that, at best, the enzymes were used as nutrients by microorganisms within the waste materials. Significant quantities of protease, lipase and peroxidase were inactivated or destroyed in the course of interacting with the sludges and manures, and significant quantities of cellulase remained active in the course of interaction. Since the sludges and manures by themselves exhibited high respiratory rates, indicative of a highly active microbial population, it was likely that the availability of suitable substrates was not limiting, and that the addition of an exogenous source of cellulase was superfluous (5).

As a theoretical contribution, the application of Michaelis-Menton growth kinetics to the competition between indigenous and added bacteria was considered. However, theoretical concepts were not tested experimentally, e.g., with observed values of kinetic parameters for the added bacteria. Three case summaries of bioaugmentation for enhancing waste removal performance in a waste treatment system were provided (6).

Of the other articles that were reviewed, several alluded to success in the use of bioaugmentation in waste treatment (7, 8, 9, 10, 11, 12), while another discussed the controversy surrounding their use (13), and yet another directly challenged viewpoints attributed generally to protagonists of bacterial and enzymatic additives (14).

References

(1) Qasim, S.R., and Stinehelfer, M.L., "Effect of a Bacterial Culture Product on Biological Kinetics," Journal of the Water Pollution Control Federation, 54, 3, 255-260, March, 1982.

(2) Christiansen, J.A., and Spraker, P.W., "Improving Effluent Quality of Petrochemical Wastewaters with Mutant Bacterial Cultures," Proceedings of the 37th Industrial Waste Conference, West Lafayette, IN, May 11-13, 1983, 567-576, Purdue University, 1983.

(3) Weibel, S.R., Straub, C.P., and Thoman, J.R., "Laboratory Investigation of Sludge, Yeast, as Starters," in Studies on Household Sewage Disposal Systems, Part I, Federal Security Agency, Public Health Service, Environmental Health Center, Cincinnati, Ohio, 131-138, 1949.

(4) Chelle, R. et Bazerque, F., "Etude de l'Action des Activateurs sur l'Efficate d'Epuration des Fosses Septiques," Techniques et Sciences Municipales - l'Eau, 73, 1, 43-47, January 1978.

(5) Thoret, L., Hartenstein, R. and Mitchell, M.J., "A Compost Study on the Interactions of Enzymes with Manure and Sludges," Compost Science, **19**, 1, 29-32, January-February 1978.

(6) Chambers, J.V., "Improving Waste Removal Performance Reliability of a Wastewater Treatment System Through Bioaugmentation," Proceedings of the 36th Industrial Waste Conference, West Lafayette, IN, May 12-14, 1981, 632-643, Purdue University, 1982.

(7) Thibault, G.T., and Tracy, K.D., "Demonstration of a Mutant Bacterial Additive for Enhancement of Operational Stability in Oxygen Activated Sludge," Proceedings of the 34th Industrial Waste Conference, West Lafayette, IN, May 8-10, 1979, 235-243, Purdue University, 1980.

(8) Tracy, K.D. and Zitrides, T.G., "Mutant Bacteria Aid Exxon Waste System," Hydrocarbon Processing, **59**, 10, 95-98, October 1979.

(9) Anon., "Superbugs Rescue Waste Plants," Chemical Week, p47, November 30, 1977.

(10) Geraldi, M.H., "Superbugs: Bacteria for Wastewater Treatment Plants," Public Works, **113**, 12, 37-38, December, 1982.

(11) Zitrides, T.G., "Using Customized 'Bugs' for Biological Waste Treatment," Plant Engineering, **31**, 13, 117-119, June 1977.

(12) Bitondo, M., "Cold Weather Waste Treatment," Industrial Wastes, **26**, 1, 29 & 33, January-February 1980.

(13) Anon., "Superbugs Soothe Sewage Systems," Engineering News Record, p28-29, June 11, 1981.

(14) Young, J.C., "The Use of Enzymes and Biocatalytic Additives For Wastewater Treatment Processes," Water Pollution Control Federation Highlights, **13**, 5, 1,5-7, May 1976.

STUDY OF SEPTIC TANKS IN THE FIELD

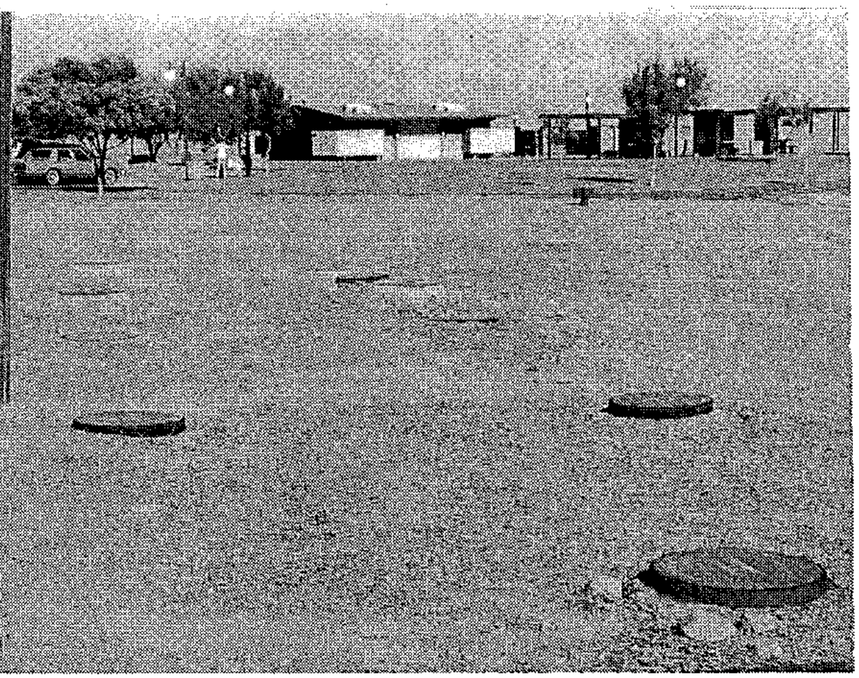
Problem Statement and Project Objective:

Of about 400 SRRA septic tanks reportedly in California, some are said to require pumping at intervals as short as a few months, primarily to remove scum. Casual observation of septic tank scum at a few California SRRAs suggests that the scum is largely paper. Certain proprietary biological products reputedly mitigate the accumulation of scum in septic tanks, thus saving part of the alternative cost of scum disposal. In order to investigate the efficacy of a few of these products identified by the California Department of Transportation Office of Structures Design, scum thickness measurements were made in untreated control septic tanks and in test tanks each treated with a product according its manufacturer's recommendations.

Study Locations: Between October and December 1985, field measurements were made of scum thickness in septic tanks at four SRRAs located in the California Central Valley, namely the Westley northbound and southbound SRRAs on Interstate 5, and the Turlock northbound and southbound SRRAs on Highway 99. At each of these SRRAs the restrooms are served by two septic tanks, with the tanks segregated by restroom sex at Turlock but not at Westley, so that Westley restroom septic tanks receive mixed womens' and mens' restroom waste. Also, the Westley northbound and southbound SRRAs provide trailer sanitation stations for dumping wastes from recreational vehicles (RVs), and each RV dump has a septic tank. So Westley has six septic tanks, and Turlock has four.

Septic Tanks Studied: California Department of Transportation construction drawings of the SRRA septic tank waste disposal systems at the Westley and Turlock study sites appear in Appendix I. All of the septic tanks monitored have several compartments, and a corresponding number of manholes to facilitate access to individual compartments. Figures 1 and 2 show the lines of septic tank manhole covers directed generally towards the restrooms at Westley northbound and southbound SRRAs. Figure 3 shows the Westley northbound trailer sanitation station (RV dump) in use. Measurements of the thickness of the floating mat of scum were taken in the first and second manholes from the inlets of the septic tanks, where essentially all of the scum gathered, as revealed by spot checking manholes further from the inlets.

Scum Differences Between Locations: At Westley SRRA, the scum mats generally covered the entire surface of the septic tank contents that was exposed at the manholes, as illustrated in Figure 4, that shows a conventional tee-inlet to the septic tank. However, at Turlock SRRAs where the manholes were larger, and where waste was introduced to all tanks by drop inlets, a 'plunge pool' of exposed liquid surrounded by scum appeared at the inlet manholes, as



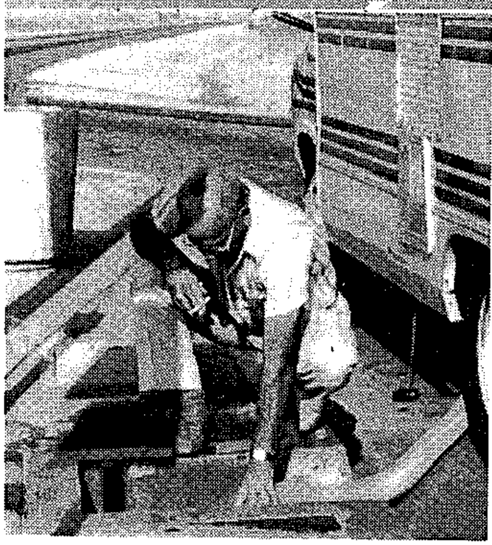


Figure 1: Westley Southbound SRRA Septic Tank Manholes. (Top left.)

Figure 2: Westley Northbound SRRA Septic Tank Manholes. (Top right.)

Figure 3: Westley Northbound Trailer Sanitation Station Receiving Waste From a Recreational Vehicle. (Left.)

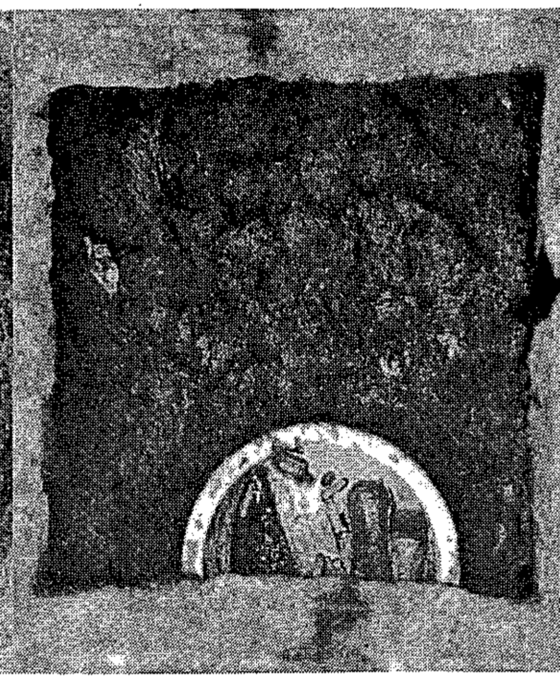


Figure 4: Scum Layer in Westley Southbound SRRA Septic Tank Inlet Manhole, With Septic Tank Fitted with Tee-Inlet. (Left.)

Figure 5: Scum Layer in Turlock Southbound SRRA Womens' Restroom Septic Tank Inlet Manhole, With Septic Tank Fitted with Drop-Inlet. (Center.)

Figure 6: Scum Layer in Turlock Southbound SRRA Mens' Restroom Septic Tank Inlet Manhole, With Septic Tank Fitted with Drop-Inlet. (Right.)

Figures 5 and 6 show. Little or no plunge pool occurred in Westley SRRA septic tanks, even where a drop inlet was fitted. In the Turlock septic tank inlet manholes, the non-uniform distribution of scum precluded characterizing scum thickness with comparable accuracy to that achieved with more uniform scum at Westley. Few measurements of scum thickness were made at Turlock, and these are not reported. But casual observation suggested that scum in septic tanks serving womens' restrooms at Turlock seemed to be more copious, and to contain more paper, than for Turlock mens' restrooms.

Scum Thickness Measuring Equipment: For measurement of scum thickness a device fabricated from a circular plate (about 10 in. diameter) hinged at the center to a handle (about 10 ft long) was employed, with means for tilting the plate by manipulation from the handle. Two models of the device that were used are shown in Figures 7-10. In the earlier model the plate was tilted by pulling on a rope that was fastened at each end to opposite points on the diameter of the circular plate orthogonal to the diametrical axis of the hinge. The improved model was designed and fabricated by California Department of Transportation personnel. It has dual parallel handles, each handle fastened by a hinge to the plate, with the hinges set parallel and equidistant from the center of plate, permitting tilting of the plate by opposite parallel movement of the handles.

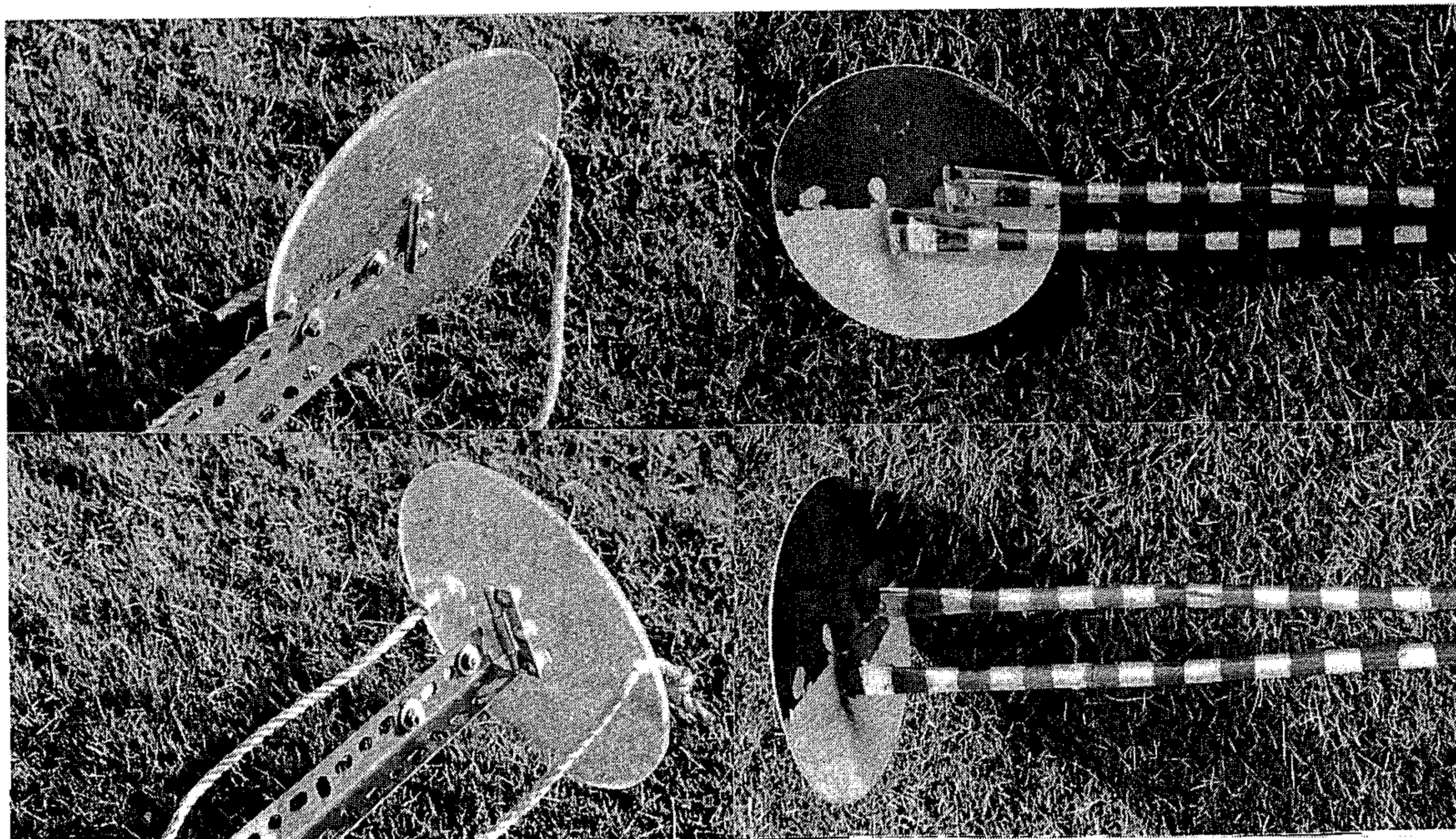


Figure 7: Scum Layer Thickness Gauging Instrument, Early Model, With Plate Vertical. (Top left.)

Figure 8: Scum Layer Thickness Gauging Instrument, Early Model, With Plate Levelled. (Bottom left.)

Figure 9: Scum Layer Thickness Gauging Instrument, Improved Model, With Plate Vertical. (Top right.)

Figure 10: Scum Layer Thickness Gauging Instrument, Improved Model, With Plate Levelled. (Bottom right.)

Method of Use of Measuring Equipment: Figure 11 shows a method of use of the improved scum thickness measuring device, involving the following steps:

a) Slice the vertical plate through the scum mat into the liquid below, working gently so as to minimize disturbance of the scum;

b) Tilt the plate to the horizontal position, and raise the device until the plate contacts the underside of the scum, as detected by resistance to further upward movement, or for thin scum layers by perceptible bulging at the exposed upper surface of the scum;

c) Read the thickness of the scum by measuring from the exposed scum surface to the top end of the handle, or by observing a calibration mark on the handle at the level of the upper surface of the scum;

d) Tilt the plate to the vertical position and retract the device; and

e) Repeat the thickness measurements until slicing of the scum by the plate destroys the structure of the scum, precluding further independent thickness measurements; generally four scum thickness measurements were obtained where the scum was sufficiently coherent to permit measurement. Multiple readings on each measuring occasion are needed for purposes of statistical inference.

Sampling Errors: Statistically significant differences between scum thickness measurements in manholes at opposite

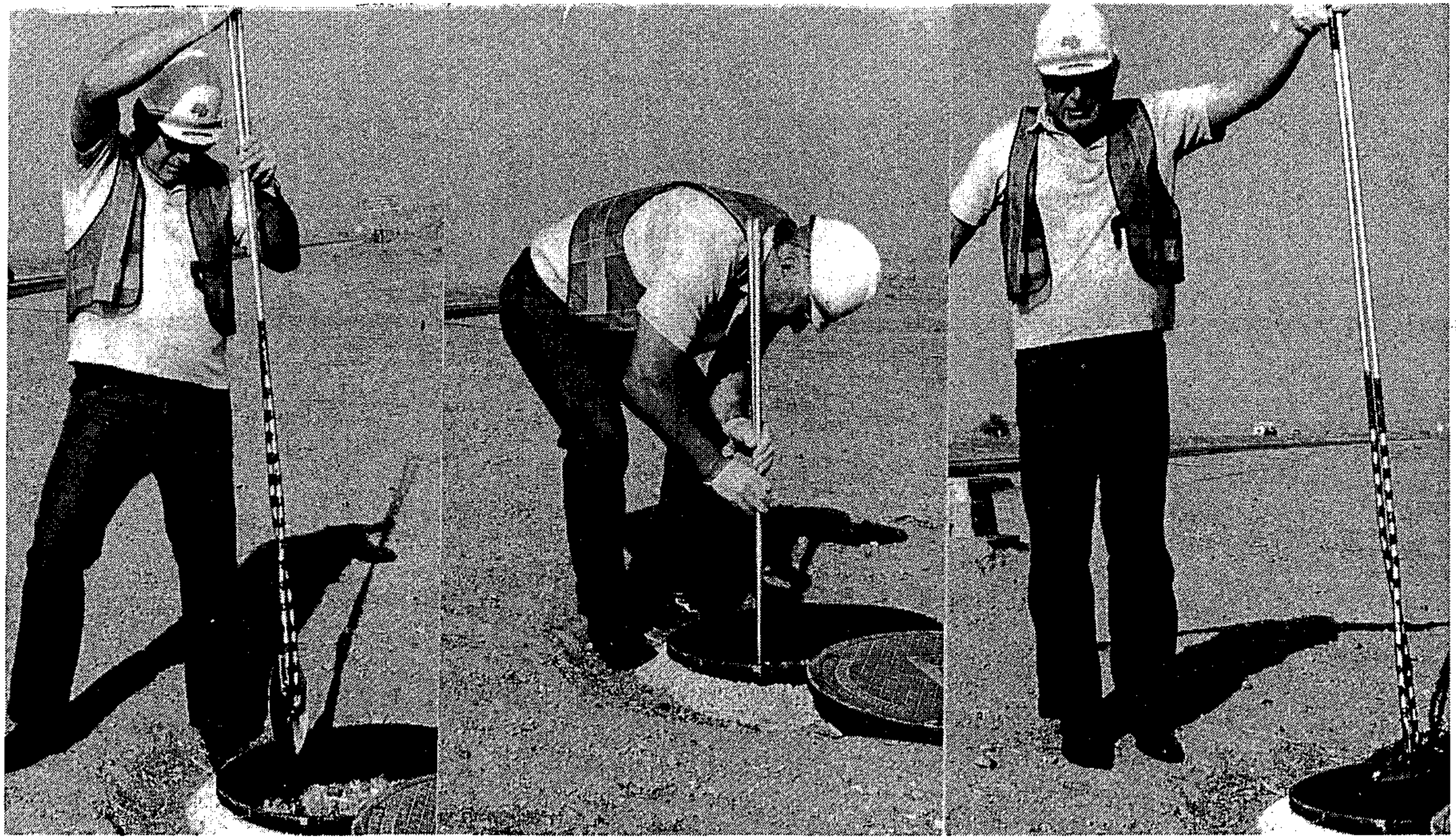


Figure 11: Probing Septic Tank at Manhole to Gauge the Thickness of the Floating Scum Mat. (These figures are illustrative only; actual testing was not performed by a Caltrans employee.)

a) Gauge is first sliced through scum mat with plate in vertical position. (Left.)

b) Gauge plate is levelled, and gauge is raised until plate bears on under side of scum mat, as detected by incipient bulging of exposed upper surface of mat. (Center.)

c) After measuring scum layer thickness by reading rod calibration opposite upper surface of scum mat, or by measuring from upper end of rod to scum surface, gauge is retracted. With plate levelled, gauge can serve to pulverize scum. (Right.)

ends of the inlet compartment of individual septic tanks were common, indicative of a non-uniform distribution of scum in the septic tanks. As the manholes exposed only about 10% or less of the scum surface to direct thickness measurement, sampling errors arose in estimating scum volume from the measurements. With a view to reducing these sampling errors by increasing the fraction of the scum surface sampled, the scum was probed with a rod wrapped with toweling-type fabric, which when bent to a U-shape might then be used to probe scum thickness beyond the manhole. However, probing the scum with the wrapped rod did not leave perceptible marks on the fabric at the scum interfaces; in any case, use of a toweling-covered rod is generally suggested for gauging the thickness of septic tank sludge, not scum. In the analysis of field data, explicit consideration of sampling errors associated with the direct estimation of scum volume was avoided by adopting measurements of scum thickness as surrogates for scum volume measurements. Statistical analyses for evaluating strategies for scum mitigation from field data were based on scum thickness in the septic tanks studied, as measured in the inlet manholes where scum was usually thickest.

Controlled Test Conditions: At Westley SRRAs, scum thickness in the septic tanks was monitored following dosing of some tanks with additive, primarily in order to observe any differences in scum thickness that could be associated with the use of any of the additives applied. The controlled variables in the test program were considered to be:

1) Treatment Type and Level: i.e., selection and dose of additive.

2) Scum Thickness Measurement Technique: Scum thickness measurements are relative rather than absolute quantities, and may depend on factors such as: a) measuring device design, b) operator, and c) scum consistency. By taking redundant measurements when any change in procedures was being implemented, any differential effects on thickness measurements were checked for and minimized.

3) Pulverization of Scum: At the beginning of each test run, 'Day 0', additive was applied to each treated septic tank, and the scum was pulverized to blend in the additive by vigorous plunging with the thickness measuring gauge until the scum was reduced to a slurry. In order to eliminate pulverization as a variable between treated and untreated tanks, scum was pulverized in both treated and control tanks on Day 0 of each run, but on no other day of any run.

4) Puddling of Scum and Maintenance Doses of Additive: During Runs 3 and 4, additive was sometimes applied to a treated tank other than at the beginning of a run (i.e., after Day 0). Such applications were made

without pulverizing the scum, but by simply patting the scum surface with the horizontal plate of the thickness gauge to moisten applied solid additive or to distribute liquid additive, and are referred to as 'maintenance doses' of additive.

Uncontrolled Test Conditions: Certain conditions of testing at Westley, though not monitored, appeared to vary between the septic tanks studied, and/or with time over the period of the study. These parameters and their surmised effects on conditions of operation of the septic tanks include the following:

1) Waste Load Distribution Between Septic Tanks: Patronage of the Westley SRRAs was apparently higher in the southbound direction than the northbound, and in each direction patrons preferred the closer of two available restrooms. Neither restroom patronage nor RV dump station usage was monitored.

2) Waste Load Variation With Time: At one time during the 1985 Labor Day weekend approaching 1,000 persons may have used one of the Westley SRRAs, according to an anecdote by Caltrans maintenance personnel of fourteen 63-seater busses plus other visitors. At other times there are few visitors or none.

3) Waste Type Variation: Restroom waste was discharged to four of the Westley septic tanks, and RV holding tank

waste was received by the other two septic tanks. RV waste is typically more concentrated than restroom waste, and contains odor control preservatives that interfere with biological waste degradation processes. Besides, if RV waste contains less paper and so is less prone to formation of paper-based scum than restroom waste, then the lack of scum in RV dump septic tanks may help explain any tendency for scum abatement measures to remove less scum there than in restroom septic tanks.

4) Climate: Temperature at the Westley SRRAs varied during the study, from torrid at the start to frosty at the end.

5) Septic Tank Configuration: Septic tanks serving the restrooms and the RV dumps at the Westley SRRAs are shown in construction drawings (Appendix I) as 7,500 and 4,500 gallons capacity respectively. Spacings between the first two manholes were approximately 8 and 16 feet respectively. The septic tanks are believed to be configured substantially according to the construction drawings in Appendix I. Four of the six Westley SRRA septic tanks appear to have conventional tee-inlets, but in the Westley SRRA northbound east and west septic tanks the inlets have been modified to the drop style, reportedly for the purpose of reducing blockage of the inlet by scum that previously caused blockage of sewers from the restrooms.

6) Septic tank conditions: Malodorous conditions in the septic tanks prompted taking some pH measurements on the contents on 10/7/85, since such odors in septic tanks are sometimes associated with organic acids that depress pH. The following pH measurements suggest that the Westley and Turlock septic tanks may have become 'stuck', a condition that tends to inhibit some types of microbiological activity.

Septic tank	Scum pH (inlet manhole)	Influent pH (water supply)	Effluent pH (outlet manhole)
Westley SRRAs			
Southbound west tank	5.7	7.7	8.3
Southbound east tank	5.5	--	--
Northbound east tank	6.3	7.5	8.2
Turlock SRRAs			
Southbound womens'	6.4	7.4	7.7

Casual information suggests that septic tank scum may be acidic at several California SRRAs. This situation may not be surprising, since SRRA septic tank scum (which appears to be mostly paper) is unlikely to contain substantial chemical pH buffering, as needed to resist a decline in pH into an acidic range inhospitable to rapid biodegradation of the scum. Without buffering, septic tank scum is susceptible to a pH drop due to the microbially-mediated formation of organic acids. In contrast, healthy wastewater sludge digesters commonly provide pH buffering due to abundant ammonium bicarbonate.

Test Plan: Several factors affected planning and execution of the study:

1) Additive Manufacturers' Recommendations: Recommendations for use of products were determined by informal contact with representatives of manufacturers whose products were suggested for study by the California Department of Transportation, Office of Structures Design. In this report, the three additive products studied are designated by the pseudonyms, Additives 'A', 'B' and 'C'. Designations 'D', 'E' and 'F' refer to untreated controls.

2) Logistical Limitations: These included:

   a) Operational requirements of SRRA maintenance personnel;

   b) Prior commitments of California Department of Transportation Engineers who accompanied each visit to the study sites;

   c) Study budget and schedule, considering administrative needs;

   d) Availability of research personnel; and

   e) Supply and delivery of the additives used.

3) Site Selection: No SRRA satisfies all research desiderata.

4) Site Conditions: Apart from a preliminary site visit, field work began when sufficient scum had accumulated in the septic tanks, following pumping of the tanks prior to the 1985 Labor Day weekend.

5) Data Review: The original field program was expanded based on review of data obtained in the course of the work, both from the field and from concurrent laboratory studies described later. The field program at the Westley SRRAs comprised up to five runs in each of six septic tanks, with each run initiated by applying additive to each treated tank and pulverizing scum in all tanks. The duration of successive runs generally decreased, as increasing attention was paid to the more marked effects early in the runs.

Test Data: Tables 1-3 show raw field data for the six Westley septic tanks monitored, i.e., two RV dump tanks, two northbound tanks, and two southbound tanks. For the four Westley septic tanks with sufficient scum to support study of scum abatement measures, Figure 12 plots scum thickness versus time, showing the mean of measurements made in the inlet and outlet manholes of the inlet compartments of those septic tanks, together with the subdivision of the test into individual runs.

Table 1: Scum Thickness Measurements in Westley SRRA Trailer Sanitation Station Septic Tanks.

Date, 1985	Days from pumping of septic tank	Additive designation	Additive dose, pounds	Data set ID code (a)	Scum thickness measurements Additive-treated septic tank (Southbound RV dump septic tank) Inlet manhole Individual readings, inches	Inlet manhole Mean rdg, in.	Second manhole Individual readings, inches	Second manhole Mean rdg, in.	Data set ID code	Scum thickness measurements Untreated control septic tank (Northbound RV dump septic tank) Inlet manhole Individual readings, inches	Inlet manhole Mean rdg, in.	Second manhole Individual readings, inches	Second manhole Mean rdg, in.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
08/27	0												
10/07	41	'A'	3.50	A1.0	8,10	9.00	approx 1	1.00	E1.0	approx 1	1.00	no access	--
10/08	42			A1.1	4,4	4.00	approx 1	1.00	E1.1	approx 1	1.00	no access	--
10/09	43	'A'	3.50		3,3,2	2.67	approx 1	1.00		approx 1	1.00	no access	--
10/11	45			A1.4	4,3,4	3.67	approx 1	1.00	E1.4	approx 2	2.00	no access	--
10/18	52			A1.10	8,4,9,6,5	6.40	1	1.00	E1.10	approx 1	1.00	no access	--
10/25	59				6,4,4	4.67	approx 1	1.00		2	2.00	2	2.00
11/04	69	'A'	3.50	A2.0	7,8,7,6	7.00	approx 1	1.00	E2.0	approx 2	2.00	approx 2	2.00
11/05	70	'A'	3.50	A2.1	6,5,5,4	5.00	approx 2	2.00	E2.1	approx 1	1.00	approx 1	1.00
11/08	73			A2.4	6,5,5,3	4.75	approx 1	1.00	E2.4	2	2.00	approx 2	2.00
11/19	84			A2.10	12,10,11,9	10.50	approx 1	1.00	E2.10	2,2	2.00	approx 2	2.00
11/25	90	'A'	2.00	A3.0	11,11,11,9	10.50	approx 1	1.00	E3.0	approx 1	1.00	approx 1	1.00
11/26	91	'A'	2.00	A3.1	8,6,4,6	6.00	approx 1	1.00	E3.1	approx 1	1.00	approx 1	1.00
11/29	94	'A'	2.00	A3.4	7,5,7,8	6.75	approx 1	1.00	E3.4	approx 1	1.00	approx 1	1.00
12/05	100			A3.10	10,11,11,11	10.75	approx 0.5	.50	(b)	4,5,4,3	4.00	approx 1	1.00
12/06	101	'A'	2.00		10,11,10,9	10.00	approx 0.5	.50	E4.1	5,6,5	5.33	approx 1	1.00
12/13	108	'A'	2.00		10,9,10,10	9.75	approx 0.5	.50		5,9,7,5	6.50	approx 1	1.00
12/19	114	'A'	2.00	A4.0	12,10,12,10	11.00	0	.00	(c)	7,5,7	6.33	approx 0.5	.50
12/20	115			A4.1	7,8,7,7	7.25	approx 0.5	.50	E5.1	3,4,4	3.67	approx 0.5	.50

(a) Scum was pulverized on days for which Data set ID code has a zero suffix, i.e., at start of each run. On other days when additive was applied, additive was gently 'puddled' into scum surface.

Data set ID codes: (b) = E3.10 and E4.0, (c) = E4.10 and E5.0.

Table 2: Scum Thickness Measurements in Westley Northbound SRRA Septic Tanks.

Date, 1985	Days from pumping of septic tank	Additive designation	Additive dose, pounds	Data set ID code (a)	Scum thickness measurements Additive-treated septic tank (Northbound east septic tank) Inlet manhole Individual readings, inches	Inlet manhole Mean rdg, in.	Second manhole Individual readings, inches	Second manhole Mean rdg, in.	Data set ID code	Scum thickness measurements Untreated control septic tank (Northbound west septic tank) Inlet manhole Individual readings, inches	Inlet manhole Mean rdg, in.	Second manhole Individual readings, inches	Second manhole Mean rdg, in.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
08/27	0												
10/07	41	'B'	8.35	B1.0	13,13	13.00	5,6	5.50	F1.0	approx 1	1.00	approx 1	1.00
10/08	42			B1.1	approx 2	2.00	approx 1	1.00	F1.1	approx 1	1.00	approx 1	1.00
10/09	43				approx 1	1.00	approx 1	1.00		approx 1	1.00	approx 1	1.00
10/11	45			B1.4	approx 1	1.00	2	2.00	F1.4	approx 1	1.00	approx 1	1.00
10/18	52			B1.10	3,2,3	2.67	2,3,5	3.33	F1.10	approx 1	1.00	approx 1	1.00
10/25	59				7,6,7,8	7.00	6,5,4,5	5.00		3,4,4,3	3.50	1,3	2.00
11/04	69	'B'	8.35	B2.0	13,14,13,13	13.25	4,5	4.50	F2.0	5,5,6,5	5.25	approx 2	2.00
11/05	70			B2.1	2	2.00	approx 1	1.00	F2.1	approx 1	1.00	1	1.00
11/08	73			B2.4	2,3,2	2.33	approx 1	1.00	F2.4	4,5,5	4.67	2	2.00
11/19	84			B2.10	14,13,13,13	13.25	3,3	3.00	F2.10	2,2	2.00	approx 3	3.00
11/25	90	'B'	2.09	B3.0	17,16,17,13	15.75	approx 2	2.00	F3.0	6,4,4	4.67	approx 2	2.00
11/26	91	'B'	2.09	B3.1	2,3,1,2	2.00	approx 1	1.00	F3.1	approx 1	1.00	approx 0.5	.50
11/29	94	'B'	2.09	B3.4	10,7,6,7	7.50	2,2	2.00	F3.4	approx 2	2.00	1,1	1.00
12/05	100	'A'	7.00	(b)	13,11,10	11.33	1,1	1.00	(d)	3,1,1,1	1.50	1,1	1.00
12/06	101			A5.1	1,2,3	2.00	approx 1	1.00	F4.1	1	1.00	approx 1	1.00
12/13	108				7,6,9,7	7.25	1,1	1.00		approx 1	1.00	approx 1	1.00
12/19	114	'C'	6.00	(c)	12,15,12,12	12.75	approx 0.5	.50	(e)	approx 1	1.00	approx 0.5	.50
12/20	115			C4.1	2,2,3	2.33	approx 1	1.00	F5.1	approx 0.5	.50	approx 0.5	.50

(a) Scum was pulverized on days for which Data set ID code has a zero suffix, i.e., at start of each run. On other days when additive was applied, additive was gently 'puddled' into scum surface.

Data set ID codes: (b) = B3.10 and A5.0, (c) = A5.10 and C4.0, (d) = F3.10 and F4.0, (e) = F4.10 and F5.0.

Table 3: Scum Thickness Measurements in Westley Southbound SRRA Septic Tanks.

Date, 1985	Days from pump-ing of septic tank	Additive des-ig-nat-ion	Additive dose, pou-nds	Data set ID code (a)	Scum thickness measurements Additive-treated septic tank (Southbound west septic tank) Inlet manhole Individual readings, inches	Inlet manhole Mean rdg, in.	Second manhole Individual readings, inches	Second manhole Mean rdg, in.	Data set ID code	Scum thickness measurements Untreated control septic tank (Southbound east septic tank) Inlet manhole Individual readings, inches	Inlet manhole Mean rdg, in.	Second manhole Individual readings, inches	Second manhole Mean rdg, in.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
08/27	0												
10/07	41	'C'	6.00	C1.0	19,18	18.50	5,6	5.50	D1.0	20,10,15,15	15.00	approx 1	1.00
10/08	42			C1.1	17,18,16	17.00	approx 1	1.00	D1.1	15,13	14.00	approx 1	1.00
10/09	43				14,12,13	13.00	approx 1	1.00		13,7	10.00	approx 0	.00
10/11	45			C1.4	15,13,13	13.67	2	2.00	D1.4	11,11	11.00	approx 1	1.00
10/18	52			C1.10	16,14,15,17	15.50	3,2	2.50	D1.10	12,12,10	11.33	approx 1	1.00
10/25	59				17,15,18,18	17.00	2,4,3,4	3.25		11,11,13	11.67	approx 1	1.00
11/04	69	'C'	6.00	C2.0	19,18,20,20	19.25	4,4,4	4.00	D2.0	13,14,11	12.67	approx 0	.00
11/05	70			C2.1	13,14,14,14	13.75	approx 1	1.00	D2.1	5,6,6	5.67	approx 0	.00
11/08	73			C2.4	16,17,17,16	16.50	2,3	2.50	D2.4	6,7,7,7	6.75	0	.00
11/19	84			C2.10	21,19,21,22	20.75	3,4	3.50	D2.10	13,11,12	12.00	0	.00
11/25	90	'C'	2.00	C3.0	21,21,20,22	21.00	2,2	2.00	D3.0	10,14,13,10	11.75	approx 1	1.00
11/26	91	'C'	2.00	C3.1	14,14,15,14	14.25	approx 1	1.00	D3.1	6,5,7,4	5.50	approx 0.5	.50
11/29	94	'C'	2.00	C3.4	16,17,18,16	16.75	2,2	2.00	D3.4	11,9,10	10.00	approx 1	1.00
12/05	100	'B'	8.35	(b)	17,16,20,18	17.75	5,3	4.00	(d)	10,10,10,10	10.00	2,2	2.00
12/06	101			B4.1	12,14,17,14	14.25	1,1	1.00	D4.1	6,3,6,5	5.00	approx 1	1.00
12/13	108	'B'	2.09		17,18,15,16	16.50	1,0.5	.75		9,5,5,7	6.50	1,1	1.00
12/19	114	'B'	.42	(c)	21,22,21,21	21.25	0.5,0.5	.50	(e)	9,6,9,8	8.00	1,3	2.00
12/20	115			B5.1	15,16,16,17	16.00	approx 0.5	.50	D5.1	6,5,5,7	5.75	approx 0.5	.50

(a) Scum was pulverized on days for which Data set ID code has a zero suffix, i.e., at start of each run. On other days when additive was applied, additive was gently 'puddled' into scum surface.

Data set ID codes: (b) = C3.10 and B4.0, (c) = B4.10 and B5.0, (d) = D3.10 and D4.0, and (e) = D4.10 and D5.0.

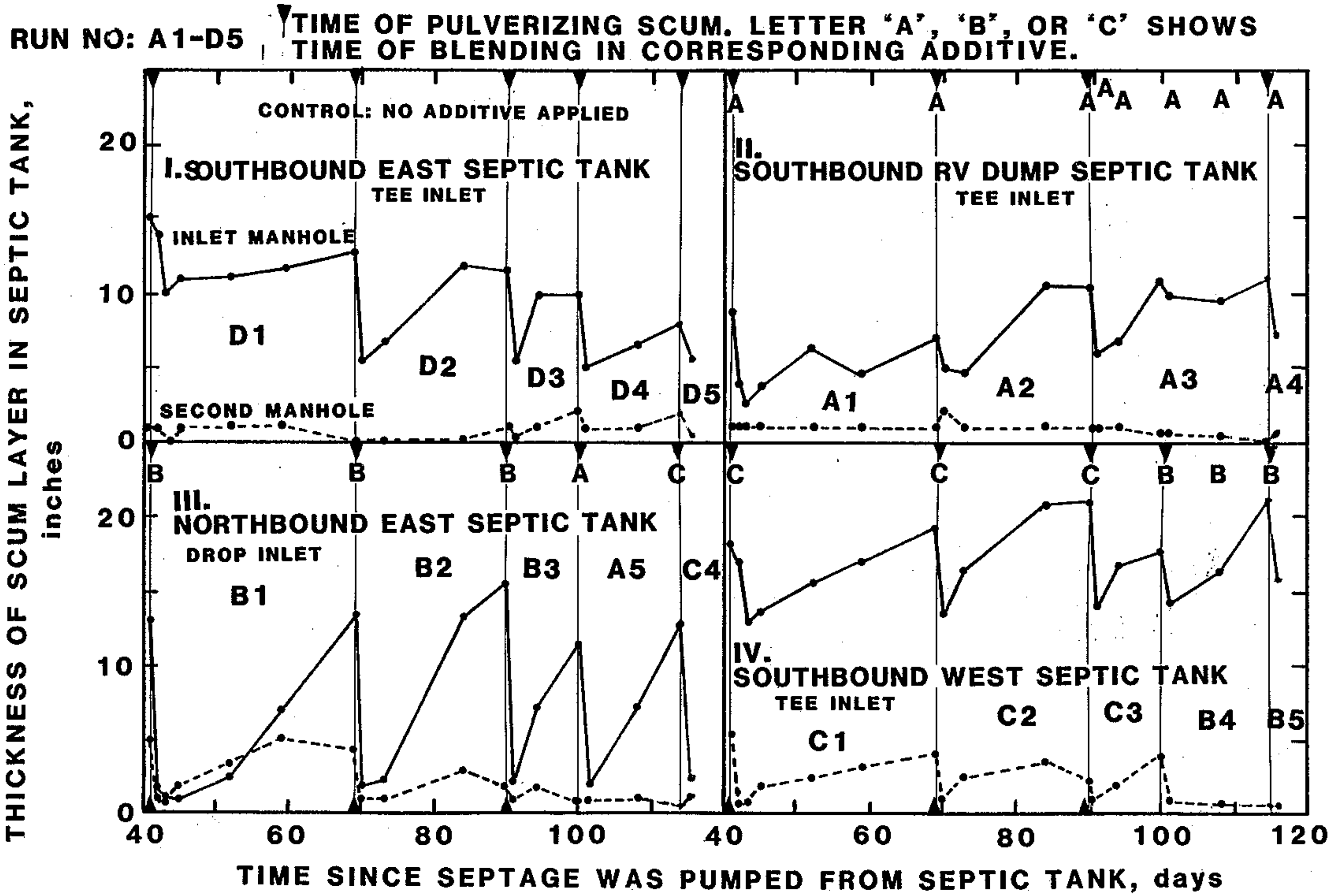


Figure 12: Scum Thickness Versus Time in Westley SRRA Septic Tanks.

Additive Applications: In Tables 1-3, Columns 3 and 4 list the additive applied to each treated tank and the dose in pounds. Additive was generally applied immediately prior to pulverizing scum at the beginning ('Day 0') of each run, indicated by a zero suffix for the data set ID code (Column 5). Other additive applications on days for which the suffix of the data set ID code is non-zero are referred to as 'maintenance doses'; these were puddled into the scum surface, rather than pulverizing the scum. In cases where additives were rotated between septic tanks, a single septic tank could have different runs designated by different letters. For example, consider the southbound west tank shown in Table 3, Columns 3-9. In this case scum thickness data for the initial days of successive runs are designated C1.0, C2.0, C3.0, B4.0 and B5.0, indicating a change in additive from 'C' to 'B' in that septic tank at the beginning of the fourth run. Additive was not applied to treated tanks on all visits, some visits being solely for the purpose of monitoring scum thickness.

Scum Thickness Data Set Designation: In Tables 1-3, Column 5, most scum thickness measurements are designated by a data set ID code comprising:

a) A prefix letter corresponding to the additive initially applied, i.e., 'A', 'B' and 'C' for additive-treated tanks, or 'D', 'E' and 'F' for tanks not receiving additive, followed by;

b) The run number, i.e., 1, 2, 3, 4, or 5, then a decimal point, and;

c) A suffix stating the number of days from the start of the run, i.e., 0, 1, 4, 10, 11, 14 or 15.

e.g., data item A3.1 represents scum thickness measurements in the septic tank dosed with the third application of additive 'A' as measured on Day 1, the day after dosing. Scum thickness measurements that were not subsequently compared between runs are not assigned data item codes in Tables 1-3. Thickness measurements were rounded to the nearest inch.

Estimated Scum Thicknesses: Certain lesser scum thicknesses in Tables 1-3 are designated 'approx'. This indicates a value that was estimated because the scum mat was too thin for use of the thickness measuring device, or because the scum mat disintegrated on attempting to use the device. The minimum measurable scum thickness of a coherent mat was about one inch after gaining experience with the device, although some thicker mats of less cohesive scum disintegrated before thickness measurements could be obtained. Estimated scum thicknesses are handled similarly to measured values in the statistical analyses, though less weight is generally attached to estimates because they are not reported as replicate readings as are most measured thicknesses in Tables 1-3.

Rejected Scum Thickness Data: For the northbound RV dump septic tank ('E' series, Table 1) and the northbound west tank ('F' series, Table 2), scum in the inlet manholes was frequently too thin to be measurable with the available measuring equipment so as not to provide useful data. The 'E' and 'F' data sets were both for untreated controls; neither was essential experimentally because another control was available for all treated tanks, the untreated southbound east tank ('D' series, Table 3).

Also, only in the inlet manhole of any septic tank was the scum layer sufficient for studying effects of pulverization or treatment on scum thickness. Scum was much shallower even only 8 ft or 16 ft beyond the first manhole, as the 'second manhole' scum profiles in Figure 1 show. Only thickness data from the inlet manhole are analyzed in this report.

Data Analysis and Evaluation: After pulverizing the scum and applying any additive dose into a septic tank, the thickness of the scum layer in the inlet manhole decreased. Scum thickness changed with time after treatment and varied between septic tanks. The statistical significance of changes of scum thickness, and of differences between these changes, was investigated by comparing arithmetic mean scum thickness values:

a) Scum thickness at various times after pulverizing scum and applying any additive versus initial thickness of scum before pulverization;

b) Scum thickness at particular times after pulverizing scum and applying any additive versus thickness of scum at the same time after pulverization in different runs:

   i) Under the same conditions (i.e., same additive);

   ii) Between different additives; and

   iii) Between different septic tanks.

Statistical techniques, i.e., t-testing, analysis of variance and multiple regression analysis, were used to compare scum thickness values at different points in time after pulverization and any dosing, and to compare changes in scum thickness between the test septic tanks used.

Student's t-test: This test was used to investigate the statistical significance of differences between the means of sets of scum thickness readings. Consider a thickness difference calculated from two sets of thickness readings, with the mean, standard deviation and number of readings in the first and second set designated m_1, s_1 and n_1, and m_2, s_2 and n_2 respectively. To use the t-test on the null hypothesis that the population means of the two sets of readings are equal (assuming equal population variances), compute the t-statistic, where:

$$t = (m_1 - m_2)/[s(1/n_1 + 1/n_2^{0.5}]$$

in which:

$$s^2 = [(n_1-1)s_1^2 + (n_2-1)s_2^2]/(n_1 + n_2 - 2)$$

Now reject the null hypothesis if the absolute magnitude of t exceeds the critical single tailed t-value in statistical tables for the desired significance level and $n_1 + n_2 - 2$ degrees of freedom.

Statistical Significance: In subsequent statistical tabulations:

a) Cases where the null hypothesis (of two equal sets of values) was not rejected at the 95% level of significance are designated '-';

b) Cases where differences were statistically significant at the 95% level are designated '<' or '>' to show a decrease or increase respectively from the initial value or other control value; or

c) '<<' or '>>' for differences significant at the 99% level; or

d) '<<<' or '>>>' for differences significant at the 99.95% level.

<u>Change in Scum Thickness After Pulverizing and Dosing:</u> Consider the thickness of scum in the inlet manholes of the test septic tanks at zero time of each run ('Day 0' = immediately before pulverizing the scum and applying any additive), and at various times after. The change in scum thickness at any time is the mean of scum thickness readings at that time less the mean of scum thickness readings at 'Day 0' for the same septic tank and experimental run. Scum thickness decreased after pulverization, so thickness

changes are negative, at least until more scum accumulates in the septic tank than was present at 'Day 0'.

Scum Thickness Change Data: Table 4 summarizes nineteen sets of data from Table 1-3 field measurements of scum thickness at stated times after pulverization and dosing of the scum, after rejecting data from tanks where the scum was too thin for accurate measurement. In Table 4, thickness readings are transformed into changes from the initial scum thickness by subtracting from all thickness readings the mean of the 'Day 0' thickness readings for that run. These scum thickness changes are tested against the null hypothesis of zero change by comparing each thickness change with the 'Day 0' thickness change for that run. (The mean 'Day 0' thickness change is zero.) For each of the three treatments plus the control, for up to five runs, and up to four observation days on each run, Table 4 lists the following data:

a) The amount of the change in scum thickness from the initial thickness, the latter measured on 'Day 0', immediately before pulverizing the scum and mixing in any additive;

b) The degrees of freedom for the t-test (to indicate data set size);

c) Symbolic results of significance testing against the null hypothesis, e.g., '-', '<', '>' etc;

d) The additive used, if any; and

Table 4: Summarized Scum Thickness Changes in Westley SRRA Septic Tanks.

Run	Day	Septic tank scum dosed with Additive 'A'				Septic tank scum dosed with Additive 'B'				Septic tank scum dosed with Additive 'C'				Septic tank scum not dosed with additive			
no. (1)	no. (2)	Change, in. (3)	df (4)	Sig (5)	Septic tank used (6)	Change, in. (7)	df (8)	Sig (9)	Septic tank used (10)	Change, in. (11)	df (12)	Sig (13)	Septic tank used (14)	Change, in. (15)	df (16)	Sig (17)	Septic tank used (18)
1	0	.0	-	-	South-	.0	-	-	North-	.0	-	-	South-	.0	-	-	South-
	1	-5.0	2	<	bound	-11.0	1	<<<	bound,	-1.5	3	-	bound,	-1.0	4	-	bound,
	4	-5.3	3	<<	RV	-12.0	1	<<<	east	-4.8	3	<<	west	-4.0	4	-	east
	11	-2.6	5	-	dump	-10.3	3	<<<	tank	-3.0	4	<	tank	-3.0	5	-	tank
2	0	.0	-	-	South-	.0	-	-	North-	.0	-	-	South-	.0	-	-	South-
	1	-2.0	6	<<	bound	-11.3	3	<<<	bound,	-5.5	6	<<<	bound,	-7.0	4	<<	bound,
	4	-2.3	6	<	RV	-10.9	5	<<<	east	-2.8	6	<<	west	-5.9	5	<<<	east
	15	3.5	6	>>	dump	.0	6	-	tank	1.5	6	-	tank	-.7	4	-	tank
3	0	.0	-	-	South-	.0	-	-	North-	.0	-	-	South-	.0	-	-	South-
	1	-4.5	6	<<	bound	-13.8	6	<<<	bound,	-6.8	6	<<<	bound,	-6.3	6	<<	bound,
	4	-3.8	6	<<	RV	-8.3	6	<<<	east	-4.3	6	<<<	west	-1.8	5	-	east
	10	.3	6	-	dump	-4.4	5	<	tank	-3.3	6	<<	tank	-1.8	6	-	tank
1-3	0	.0	-	-	South-	.0	-	-	North-	.0	-	-	South-	.0	-	-	South-
	1	-3.6	18	<<<	bound	-12.2	14	<<<	bound,	-5.0	19	<<<	bound,	-5.7	18	<<	bound,
	4	-3.6	19	<<<	RV	-9.5	16	<<<	east	-4.0	19	<<<	west	-4.4	18	<<	east
	10-15	.2	21	-	dump	-4.7	18	<<	tank	-1.8	20	<	tank	-2.1	19	<	tank
4	0	.0	-	-	South-	.0	-	-	South-	.0	-	-	North-	.0	-	-	South-
	1	-3.8	6	<<<	bound	-3.5	6	<	bound,	-10.4	5	<<<	bound,	-5.0	6	<<<	bound,
	14				RVdump	3.5	6	>>	west	-	-	-	east	-2.0	6	<	east
5	0	.0	-	-	North-	.0	-	-	South-	-	-	-	-	.0	-	-	South-
	1	-9.3	4	<<<	bound	-5.3	6	<<<	bound,	-	-	-	-	-2.3	6	<	bound,
	14	1.4	5	-	east	-	-	-	west	-	-	-	-	-	-	-	east

Cols. 3, 7, 11 & 15 show change in mean scum thickness from Day 0 mean thickness, inches.
Cols. 4, 8, 12 & 16 show degrees of freedom in statistical t-test for significant change.
Cols. 5, 9, 13 & 17 show "-" for a statistically insignificant scum thickness change (<95%), "<" for decrease significant at 95% level, "<<" at 99% level, "<<<" at 99.95% level, etc.

e) The septic tank used.

Additional details of the tests and test results appear in Tables 5-8, for tests in tanks dosed with Additives 'A', 'B' and 'C', and for the untreated control respectively.

Homogeneity of Scum Thickness Changes: Proper use of the t-test and several other statistical tests requires that test data be normally distributed. Testing of data from individual runs against the normal distribution was inconclusive, with few data items in each run. However, runs in a homogeneous group may be pooled. Table 9 tests the homogeneity of scum thickness changes among Runs 1-3, showing that pooling of Runs 1-3 provided data groups that were close to being homogeneous, and larger than any individual group.

Normality of Scum Thickness Data: The Kolmogorov-Smirnov goodness-of-fit test may be used to compare distributions of scum thickness measurements with the normal distribution. The test involves calculating the cumulative probability distribution of a homogeneous set of observed scum thickness values, and finding the maximum probability divergence between this empirical distribution and a normal cumulative probability distribution with the same mean and standard deviation. The null hypothesis of normality of the empirical distribution is rejected if this maximum probability divergence exceeds the Kolmogorov-Smirnov

Table 5: Statistical Analysis of Selected Scum Depth Readings. Westley SRRA Septic Tanks Dosed with Additive 'A'.

Run no.	Days from dosing	Scum depth readings in septic tank inlet manhole, in.					Mean depth, in.	Std. devn, in.	Depth change in.	Change statistic,t	Degrees of freedom	Chg #	Septic tank used
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
1	0	8	10	-	-	-	9.00	1.41	-	-	-	-	South-
	1	4	4	-	-	-	4.00	.00	-5.00	-5.000	2	<	bound
	4	4	3	4	-	-	3.67	.58	-5.33	-6.197	3	<<	RV
	11	8	4	9	6	5	6.40	2.07	-2.60	-1.586	5	-	dump
2	0	7	8	7	6	-	7.00	.82	.00	-	-	-	South-
	1	6	5	5	4	-	5.00	.82	-2.00	-3.464	6	<<	bound
	4	6	5	5	3	-	4.75	1.26	-2.25	-3.000	6	<	RV
	15	12	10	11	9	-	10.50	1.29	3.50	4.583	6	>>	dump
3	0	11	11	11	9	-	10.50	1.00	.00	-	-	-	South-
	1	8	6	4	6	-	6.00	1.63	-4.50	-4.700	6	<<	bound
	4	7	5	7	8	-	6.75	1.26	-3.75	-4.666	6	<<	RV
	10	10	11	11	11	-	10.75	.50	.25	.447	6	-	dump
1-3	0	See 10 values above					8.80	1.87	.00	-	-	-	South-
	1	See 10 values above					5.20	1.32	-3.60	-4.971	18	<<<	bound
	4	See 11 values above					5.18	1.66	-3.62	-4.690	19	<<<	RV
	10-15	See 13 values above					9.00	2.55	.20	.208	21	-	dump
4	0	12	10	12	10	-	11.00	1.15	.00	-	-	-	South-
	1	7	8	7	7	-	7.25	.50	-3.75	-5.960	6	<<<	bound
													RVdump
													tank
5	0	13	11	10	-	-	11.33	1.53	.00	-	-	-	North-
	1	1	2	3	-	-	2.00	1.00	-9.33	-8.854	4	<<<	bound
	14	12	15	12	12	-	12.75	1.50	1.42	1.228	5	-	east

Stat. signif.: '-' = none; > or < = .9500; >> or << = .99;>>> or <<< = .9995.

Table 6: Statistical Analysis of Selected Scum Depth Readings.
Westley SRRA Septic Tanks Dosed with Additive 'B'.

Run no. (1)	Days from dosing (2)	Scum depth readings in septic tank inlet manhole, in. (3)	(4)	(5)	(6)	(7)	Mean depth, in. (8)	Std. devn, in. (9)	Depth change in. (10)	Change stati-stic,t (11)	Degr-ees of freedom (12)	Chg # (13)	Septic tank used (14)
1	0	13	13	-	-	-	13.00	.00	.00	-	-	-	North-
	1	2	-	-	-	-	2.00	.00	-11.00	high	1	<<<	bound,
	4	1	-	-	-	-	1.00	.00	-12.00	high	1	<<<	east
	11	3	2	3	-	-	2.67	.58	-10.33	-24.013	3	<<<	tank
2	0	13	14	13	13	-	13.25	.50	.00	-	-	-	North-
	1	2	-	-	-	-	2.00	.00	-11.25	-20.125	3	<<<	bound,
	4	2	3	2	-	-	2.33	.58	-10.92	-26.852	5	<<<	east
	15	14	13	13	13	-	13.25	.50	.00	.000	6	-	tank
3	0	17	16	17	13	-	15.75	1.89	.00	-	-	-	North-
	1	2	3	1	2	-	2.00	.82	-13.75	-13.339	6	<<<	bound,
	4	10	7	6	7	-	7.50	1.73	-8.25	-6.431	6	<<<	east
	10	13	11	10	-	-	11.33	1.53	-4.42	-3.293	5	<	tank
1-3	0	See 10 values above					14.20	1.75	.00	-	-	-	North-
	1	See 6 values above					2.00	.63	-12.20	-16.248	14	<<<	bound,
	4	See 8 values above					4.75	3.20	-9.45	-8.005	16	<<<	east
	10-15	See 10 values above					9.50	4.86	-4.70	-2.878	18	<<	tank
4	0	17	16	20	18	-	17.75	1.71	.00	-	-	-	South-
	1	12	14	17	14	-	14.25	2.06	-3.50	-2.615	6	<	bound,
	14	21	22	21	21	-	21.25	.50	3.50	3.934	6	>>	west
5	0	21	22	21	21	-	21.25	.50	.00	-	-	-	South-
	1	15	16	16	17	-	16.00	.82	-5.25	-10.967	6	<<<	bound,
	14	-	-	-	-	-	-	-	-	-	-	-	west

Stat. signif.: '-' = none; > or < = .9500; >> or << = .9900; >>> or <<< = .9995.

Table 7: Statistical Analysis of Selected Scum Depth Readings. Westley SRRA Septic Tanks Dosed with Additive 'C'.

Run no.	Days from dosing	Scum depth readings in septic tank inlet manhole, in.					Mean depth, in.	Std. devn, in.	Depth change in.	Change statistic,t	Degrees of freedom	Chg #	Septic tank used
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
1	0	19	18	-	-	-	18.50	.71	.00	-	-	-	South-
	1	17	18	16	-	-	17.00	1.00	-1.50	-1.800	3	-	bound,
	4	15	13	13	-	-	13.67	1.15	-4.83	-5.153	3	<<	west
	11	16	14	15	17	-	15.50	1.29	-3.00	-2.954	4	<	tank
2	0	19	18	20	20	-	19.25	.96	.00	-	-	-	South-
	1	13	14	14	14	-	13.75	.50	-5.50	-10.184	6	<<<	bound,
	4	16	17	17	16	-	16.50	.58	-2.75	-4.919	6	<<	west
	15	21	19	21	22	-	20.75	1.26	1.50	1.897	6	-	tank
3	0	21	21	20	22	-	21.00	.82	.00	-	-	-	South-
	1	14	14	15	14	-	14.25	.50	-6.75	-14.100	6	<<<	bound,
	4	16	17	18	16	-	16.75	.96	-4.25	-6.755	6	<<<	west
	10	17	16	20	18	-	17.75	1.71	-3.25	-3.434	6	<<	tank
1-3	0	See 10 values above					19.80	1.32	.00	-	-	-	South-
	1	See 11 values above					14.82	1.54	-4.98	-7.934	19	<<<	bound,
	4	See 11 values above					15.82	1.60	-3.98	-6.186	19	<<<	west
	10-15	See 12 values above					18.00	2.59	-1.80	-1.986	20	<	tank
4	0	12	15	12	12	-	12.75	1.50	.00	-	-	-	North-
	1	2	2	3	-	-	2.33	.58	-10.42	-11.198	5	<<<	bound, east

Statistical signif.: '-' = none; > or < = .9500; >> or << =9900; >>> or <<< = .9995.

Table 8: Statistical Analysis of Selected Scum Depth Readings. Westley SRRA Septic Tank Not Dosed with Additive.

Run no. (1)	Days from dosing (2)	Scum depth readings in septic tank inlet manhole, in. (3)	(4)	(5)	(6)	(7)	Mean depth, in. (8)	Std. devn, in. (9)	Depth change in. (10)	Change statistic, t (11)	Degrees of freedom (12)	Chg # (13	Septic tank used (14)
1	0	20	10	15	15	-	15.00	4.08	.00	-	-	-	South-
	1	15	13	-	-	-	14.00	1.41	-1.00	-.320	4	-	bound,
	4	11	11	-	-	-	11.00	.00	-4.00	-1.306	4	-	east
	11	12	12	-	-	-	12.00	1.15	-3.00	-1.479	5	-	tank
2	0	13	14	11	-	-	12.67	1.53	.00	-	-	-	South-
	1	5	6	6	-	-	5.67	.58	-7.00	-7.425	4	<<	bound,
	4	6	7	7	7	-	6.75	.50	-5.92	-7.443	5	<<<	east
	15	13	12	11	-	-	12.00	1.00	-.67	-.632	4	-	tank
3	0	10	14	13	10	-	11.75	2.06	.00	-	-	-	South-
	1	6	5	7	4	-	5.50	1.29	-6.25	-5.139	6	<<	bound,
	4	11	10	9	-	-	10.00	1.00	-1.75	-1.334	5	-	east
	10	10	10	10	10	-	10.00	.00	-1.75	-1.698	6	-	tank
1-3	0	See 11 values above					13.18	2.99	.00	-	-	-	South-
	1	See 9 values above					7.44	3.84	-5.74	-3.756	18	<<	bound,
	4	See 9 values above					8.78	2.05	-4.40	-3.745	18	<<	east
	10-15	See 10 values above					11.11	1.15	-2.07	-2.159	19	<	tank
4	0	10	10	10	10	-	10.00	.00	.00	-	-	-	South-
	1	6	3	6	5	-	5.00	1.41	-5.00	-7.071	6	<<<	bound,
	14	9	6	9	8	-	8.00	1.41	-2.00	-2.828	6	<	east
5	0	9	6	9	8	-	8.00	1.41	.00	-	-	-	South-
	1	6	5	5	7	-	5.75	.96	-2.25	-2.635	6	<	bound,
	14	-	-	-	-	-	-	-	-	-	-	-	east

Stat. signif.: '-' = none; > or < = .9500; >> or << = .9900; >>> or <<< = .9995.

Table 9: Comparison of Scum Thickness Decreases in Individual Runs With Pooled Run Values.

Runs	Day no.	Septic tank scum dosed with Additive 'A'				Septic tank scum dosed with Additive 'B'				Septic tank scum dosed with Additive 'C'				Septic tank scum not dosed with additive			
		Statistic t	df	Sig	Septic tank used	Statistic t	df	Sig	Septic tank used	Statistic t	df	Sig	Septic tank used	Statistic t	df	Sig	Septic tank used
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
1	1	1.447	10	-	South-	-1.757	5	-	North-	-3.657	12	<<	South-	-1.658	9	-	South-
vs.	4	1.715	12	-	bound	.752	7	-	bound,	.851	12	-	bound,	-.268	9	-	bound,
1-3	11	2.181	16	>	RVdump	1.944	11	>	east	.875	14	-	west	1.953	11	>	east
2	1	-2.233	12	<	South-	-1.391	5	-	North-	.648	13	-	South-	.549	10	-	South-
vs.	4	-1.485	13	-	bound	.765	9	-	bound,	-1.474	13	-	bound,	1.425	11	-	bound,
1-3	15	-2.454	15	<	RVdump	-1.885	12	<	east	-2.410	14	<	west	-2.040	11	<	east
3	1	1.085	12	-	South-	3.396	8	>>	North-	2.211	13	>	South-	.255	11	-	South-
vs.	4	.143	13	-	bound	-.691	10	-	bound,	.311	13	-	bound,	-2.111	10	<	bound,
1-3	10	-.038	15	-	RVdump	-.097	11	-	east	1.033	14	-	west	-.730	12	-	east
3	1	1.952	8	>	South-	4.219	4	>>	North-	2.979	9	>>	South-	.517	7	-	South-
vs.	4	.506	9	-	bound	-3.046	6	<	bound,	.571	9	-	bound,	-2.949	7	<	bound,
1-2	10	.217	11	-	RVdump	-.010	8	-	east	1.429	10	-	west	-1.107	8	-	east
4	0				South-				South-				North-				South-
vs.	1	.217	12	-	bound	-9.926	8	<<<	bound,	5.863	12	>>>	bound,	-.365	11	-	bound,
1-3	14				RVdump	-3.288	12	<<	west				east	-.251	12	-	east
5	0				North-				South-								South-
vs.	1	6.886	11	>>>	bound	-15.277	8	<<<	bound,					-1.750	11	-	bound,
1-3	14	-.895	15	-	east				west					-	-	-	east

Cols. 3, 7, 11 & 15 show t-test statistic for difference between decreases in scum thickness.
Cols. 4, 8, 12 & 16 show degrees of freedom in statistical t-test for significant difference.
Cols. 5, 9, 13 & 17 show "-" for a statistically insignificant scum thickness difference (<95%), < or > for difference significant at 95% level, << or >> at 99%, <<< or >>> at 99.95%.
>, >> or >>> indicates that a decrease in a stated run was greater than in pooled runs.
e.g., for Additive 'A', Day 1, the Run 5 decrease was greater (>>>) than for Runs 1-3.

statistic (obtained from statistical tables) corresponding to the number of data points, and the desired level of significance of the test.

Normality Test Results: Table 10 shows normality tests on 16 sets of pooled Run 1-3 scum thickness data from Tables 1-3. The 16 data sets derive from 4 treatments (3 additives plus control) multiplied by 4 time periods (0, 1, 4 and 10-15 days). For each data set Table 10 shows:

a) Scum thickness values sorted in decreasing order;
b) Corresponding standardized deviate, t = (value minus mean), divided by the standard deviation;
c) Observed probability of exceedance, p = (order number of value minus 0.5), divided by the total number of values;
d) Predicted theoretical probability of exceedance corresponding to the observed standardized deviate according to the normal distribution, e.g., for zero standardized deviate, $P(t=0) = 0.5$;
e) Observed minus theoretical probability, a parameter whose absolute magnitude may not exceed the Kolmogorov-Smirnov statistic in order for the hypothesis of normality for the distribution of scum thickness not to be rejected; and
f) The Kolmogorov-Smirnov statistic corresponding to the number of scum thickness readings comprising the distribution, and a significance level of 5%. None of the 16 observed distributions of scum thickness diverge

Table 10: Tests for Normality of Scum Thickness Change.

Days from start of run	Scum dosed with additive 'A'					Scum dosed with additive 'B'				
	Scum depth ,in.	Std. dev- iate	Exceedance prob. Obs- erved	Pred- icted	Diff- erence	Scum depth ,in.	Std. dev- iate	Exceedance prob. Obs- erved	Pred- icted	Diff- erence
0	11	1.17	0.05	0.12	-0.07	17	1.60	0.05	0.05	0.00
	11	1.17	0.15	0.12	0.03	17	1.60	0.15	0.05	0.10
	11	1.17	0.25	0.12	0.13	16	1.03	0.25	0.15	0.10
	10	0.64	0.35	0.26	0.09	14	-0.11	0.35	0.55	-0.20
	9	0.11	0.45	0.46	-0.01	13	-0.69	0.45	0.75	-0.30
	8	-0.43	0.55	0.67	-0.12	13	-0.69	0.55	0.75	-0.20
	8	-0.43	0.65	0.67	-0.02	13	-0.69	0.65	0.75	-0.10
	7	-0.96	0.75	0.83	-0.08	13	-0.69	0.75	0.75	0.00
	7	-0.96	0.85	0.83	0.02	13	-0.69	0.85	0.75	0.10
	6	-1.49	0.95	0.93	0.02	13	-0.69	0.95	0.75	0.20
	Kolmogorov-Smirnov stat=0.41					Kolmogorov-Smirnov stat=0.41				
1	8	2.13	0.05	0.02	0.03	3	1.58	0.08	0.06	0.03
	6	0.61	0.15	0.27	-0.12	2	0.00	0.25	0.50	-0.25
	6	0.61	0.25	0.27	-0.02	2	0.00	0.42	0.50	-0.08
	6	0.61	0.35	0.27	0.08	2	0.00	0.58	0.50	0.08
	5	-0.15	0.45	0.56	-0.11	2	0.00	0.75	0.50	0.25
	5	-0.15	0.55	0.56	-0.01	1	-1.58	0.92	0.94	-0.03
	4	-0.91	0.65	0.82	-0.17	Kolmogorov-Smirnov stat=0.52				
	4	-0.91	0.75	0.82	-0.07					
	4	-0.91	0.85	0.82	0.03					
	4	-0.91	0.95	0.82	0.13					
	Kolmogorov-Smirnov stat=0.41									
4	8	1.70	0.05	0.05	0.00	10	1.64	0.06	0.05	0.01
	7	1.09	0.14	0.14	0.00	7	0.70	0.19	0.24	-0.05
	7	1.09	0.23	0.14	0.09	7	0.70	0.31	0.24	0.07
	6	0.49	0.32	0.31	0.01	6	0.39	0.44	0.35	0.09
	5	-0.11	0.41	0.54	-0.13	3	-0.55	0.56	0.71	-0.15
	5	-0.11	0.50	0.54	-0.04	2	-0.86	0.69	0.81	-0.12
	5	-0.11	0.59	0.54	0.05	2	-0.86	0.81	0.81	0.01
	4	-0.71	0.68	0.76	-0.08	1	-1.17	0.94	0.88	0.06
	4	-0.71	0.77	0.76	0.01	Kolmogorov-Smirnov stat=0.46				
	3	-1.31	0.86	0.91	-0.04					
	3	-1.31	0.95	0.91	0.05					
	Kolmogorov-Smirnov stat=0.39									
10-15	12	1.18	0.04	0.12	-0.08	14	0.93	0.05	0.18	-0.13
	11	0.78	0.12	0.22	-0.10	13	0.72	0.15	0.24	-0.09
	11	0.78	0.19	0.22	-0.02	13	0.72	0.25	0.24	0.01
	11	0.78	0.27	0.22	0.05	13	0.72	0.35	0.24	0.11
	11	0.78	0.35	0.22	0.13	13	0.72	0.45	0.24	0.21
	10	0.39	0.42	0.35	0.08	11	0.31	0.55	0.38	0.17
	10	0.39	0.50	0.35	0.15	10	0.10	0.65	0.46	0.19
	9	0.00	0.58	0.50	0.08	3	-1.34	0.75	0.91	-0.16
	9	0.00	0.65	0.50	0.15	3	-1.34	0.85	0.91	-0.06
	8	-0.39	0.73	0.65	0.08	2	-1.54	0.95	0.94	0.01
	6	-1.18	0.81	0.88	-0.07	Kolmogorov-Smirnov stat=0.41				
	5	-1.57	0.88	0.94	-0.06					
	4	-1.96	0.96	0.98	-0.01					
	Kolmogorov-Smirnov stat=0.36									

Table 10: Tests for Normality of Scum Thickness Change (Contd).

Days	Scum dosed with additive 'C'					Scum not dosed with additive				
from	Scum	Std.	Exceedance prob.			Scum	Std.	Exceedance prob.		
start of run	depth ,in.	dev-iate	Obs-erved	Pred-icted	Diff-erence	depth ,in.	dev-iate	Obs-erved	Pred-icted	Diff-erence
0	22	1.67	0.05	0.05	0.00	20	2.28	0.05	0.01	0.03
	21	0.91	0.15	0.18	-0.03	15	0.61	0.14	0.27	-0.14
	21	0.91	0.25	0.18	0.07	15	0.61	0.23	0.27	-0.04
	20	0.15	0.35	0.44	-0.09	14	0.27	0.32	0.39	-0.07
	20	0.15	0.45	0.44	0.01	14	0.27	0.41	0.39	0.02
	20	0.15	0.55	0.44	0.11	13	-0.06	0.50	0.52	-0.02
	19	-0.61	0.65	0.73	-0.08	13	-0.06	0.60	0.52	0.07
	19	-0.61	0.75	0.73	0.02	11	-0.73	0.68	0.77	-0.09
	18	-1.37	0.85	0.91	-0.06	10	-1.06	0.77	0.86	-0.08
	18	-1.37	0.95	0.91	0.04	10	-1.06	0.86	0.86	0.01
	Kolmogorov-Smirnov stat=0.41					10	-1.06	0.95	0.86	0.10
						Kolmogorov-Smirnov stat=0.39				
1	18	2.07	0.05	0.02	0.03	15	1.97	0.06	0.02	0.03
	17	1.42	0.14	0.08	0.06	13	1.45	0.17	0.07	0.09
	16	0.77	0.23	0.22	0.01	7	-0.12	0.28	0.55	-0.27
	15	0.12	0.32	0.45	-0.13	6	-0.38	0.39	0.65	-0.26
	14	-0.53	0.41	0.70	-0.29	6	-0.38	0.50	0.65	-0.15
	14	-0.53	0.50	0.70	-0.20	6	-0.38	0.61	0.65	-0.04
	14	-0.53	0.59	0.70	-0.11	5	-0.64	0.72	0.74	-0.02
	14	-0.53	0.68	0.70	-0.02	5	-0.64	0.83	0.74	0.10
	14	-0.53	0.77	0.70	0.07	4	-0.90	0.94	0.81	0.13
	14	-0.53	0.86	0.70	0.16	Kolmogorov-Smirnov stat=0.43				
	13	-1.18	0.95	0.88	0.07					
	Kolmogorov-Smirnov stat=0.39									
4	18	1.36	0.05	0.09	-0.04	11	1.09	0.06	0.14	-0.08
	17	0.74	0.14	0.23	-0.09	11	1.09	0.17	0.14	0.03
	17	0.74	0.23	0.23	0.00	11	1.09	0.28	0.14	0.14
	17	0.74	0.32	0.23	0.09	10	0.60	0.39	0.28	0.11
	16	0.11	0.41	0.45	-0.05	9	0.11	0.50	0.46	0.04
	16	0.11	0.50	0.45	0.05	7	-0.87	0.61	0.81	-0.20
	16	0.11	0.59	0.45	0.14	7	-0.87	0.72	0.81	-0.09
	16	0.11	0.68	0.45	0.23	7	-0.87	0.83	0.81	0.03
	15	-0.51	0.77	0.70	0.08	6	-1.36	0.94	0.91	0.03
	13	-1.76	0.86	0.96	-0.10	Kolmogorov-Smirnov stat=0.43				
	13	-1.76	0.95	0.96	-0.01					
	Kolmogorov-Smirnov stat=0.39									
10-15	22	1.54	0.04	0.06	-0.02	13	1.62	0.06	0.05	0.00
	21	1.16	0.13	0.12	0.00	12	0.76	0.17	0.22	-0.06
	21	1.16	0.21	0.12	0.08	12	0.76	0.28	0.22	0.05
	20	0.77	0.29	0.22	0.07	12	0.76	0.39	0.22	0.17
	19	0.39	0.38	0.35	0.03	11	-0.10	0.50	0.54	-0.04
	18	0.00	0.46	0.50	-0.04	10	-0.95	0.61	0.83	-0.22
	17	-0.39	0.54	0.65	-0.11	10	-0.95	0.72	0.83	-0.11
	17	-0.39	0.63	0.65	-0.03	10	-0.95	0.83	0.83	0.00
	16	-0.77	0.71	0.78	-0.07	10	-0.95	0.94	0.83	0.11
	16	-0.77	0.79	0.78	0.01	Kolmogorov-Smirnov stat=0.43				
	15	-1.16	0.88	0.88	0.00					
	14	-1.54	0.96	0.94	0.02					
	Kolmogorov-Smirnov stat=0.38									

from the normal distribution by as much as the Kolmogorov-Smirnov statistic, so that the hypothesis of normality of these measurements was not rejected for any data set.

<u>Differences Between Scum Thickness Changes:</u> Tables 1-8 show that:

a) For Runs 1-3 additives were not switched between septic tanks;

b) Thickness changes from Runs 1-3 pooled together show that scum thickness decreased significantly on the first and fourth days after pulverizing scum and applying additive to treated tanks, in the three additive-treated tanks, and in the treated control;

c) The magnitude of the early decrease in scum thickness was greatest in the septic tank that was fitted with a drop inlet (northbound east tank), rather than a conventional tee-inlet as used in the other three test tanks. (Figures 4-6 show the two types of inlet);

d) Even after additives were rotated among treated septic tanks to some extent in Runs 4 and 5, the drop inlet (northbound east) tank continued to show the greatest decrease in scum thickness;

e) After 10 to 15 days the thickness of scum had generally restored to values insignificantly different from before pulverization; and

f) The method of applying additive as a single dose at the start of Runs 1 and 2 was varied in Run 3 for Additives

'A' and 'B', when these additives were applied as a series of smaller 'maintenance doses' through the runs. However, Table 9 shows litle difference in scum thickness change between Run 3 and Runs 1-2 for Additive 'A', while for Additive 'B' the differences are equivocal.

Regression of Scum Thickness Change on Additive Chosen and Septic Tank Used: The preceding observations suggest that differences in scum thickness change between the test septic tanks may depend on the selection among the septic tanks, and not only on the use or choice of additive as perceived in the original research plan. Effort expended towards statistical analysis of study data did not succeed in defining individual effects of additive choice and septic tank selection on scum thickness change. But a portion of the data were examined using multiple regression analysis. Multiple regression analysis can serve to gauge the strength of a functional relationship between a dependent variable (i.e., the change in scum thickness), and each of a number of independent variables (viz. additive selection and septic tank selection). This analysis assumes a linear dependence of scum thickness change on parameters representing additive selection and septic tank selection.

To apply regression analysis for this purpose, a dummy parameter is set up for each independent variable, and assigned the value zero for one possible value of the independent variable, or unity for the other possible value, only two values being permitted. For this analysis, an arbitrary choice is made to set the additive selection dummy variable to 0 for cases where Additive 'C' is used, or to 1 is when Additive 'B' is used. Similarly, the septic tank dummy variable is arbitrarily set to 0 for the southbound west tank, or to 1 for the northbound east tank. Use of the term 'dummy' merely indicates that these variables serve as selection indicators or numerical switches, and are not measured values like scum thickness decrease, or most other variables.

The regression analysis produces a linear functional expression relating observations of the change in scum thickness to the values of the two dummy variables. For the problem in hand this expression may be written:

$$C = a\,A + b\,B + c$$

where C = Day 1 change in scum thickness, A = additive dummy variable, and B = septic tank dummy variable. That is, the regression calculates values for the constants a, b and c, which when taken together with the values of 0 or 1 for A and for B, best match the observed scum thickness decrease values. Consider e.g., the case with A=0 for the use of Additive 'C' and B=0 for use of the southbound west septic tank. Then the above equation shows that the Day 1 scum thickness decrease, C, is best described by $C = a(0) + b(0) + c = c$, so that the value c is the best (i.e., leastsquares) linear estimate of the mean scum thickness decrease in the southbound west septic tank when Additive 'C' is used.

Table 11 lists the Day 1 scum thickness change data together with the 'zero or one' values for the dummy parameters A and B, that are analyzed by multiple regression. The analysis yields the strength of the dependence of scum thickness on each dummy variable (as expressed by the values of the coefficients a and b), and the component of scum thickness change that is independent of either dummy variable (the constant c).

With the above notation for the variables the regression equation was:

$$C = 0.17A + 7.3B + 4.7 \pm 2.2$$

showing a standard error in scum thickness change of 2.2 in.

The above regression equation mirrors Table 11 data showing that variation in scum thickness change values is primarily associated with variation in the septic tank dummy parameter, B, with a coefficient of b = 7.3, which exceeds by more than an order of magnitude the coefficient of a = 0.17 for the additive parameter dummy, A. Thus, the regression coefficients, a and b, indicate that scum thickness change is related to the choice of septic tanks more strongly than to the choice of additives.

Table 11: Data Tabulation for Regression Analysis of Additive and Tank Selection on Day 0 to Day 1 Change in Scum Thickness.

Additive 'B' northbound east septic tank (A=1, B=1)				Additive 'B' southbound west septic tank (A=1, B=0)				Additive 'C' northbound east septic tank (A=0, B=1)				Additive 'C' southbound west septic tank (A=0, B=0)			
Run no.	Thickness of scum, inches			Run no.	Thickness of scum, inches			Run no.	Thickness of scum, inches			Run no.	Thickness of scum, inches		
	Day 0	Day 1	Cha-nge		Day 0	Day 1	Cha-nge		Day 0	Day 1	Cha-nge		Day 0	Day 1	Cha-nge
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16
1	13	2	-11	4	17	12	-5	4	12	2	-10	1	19	17	-2
	13	--	--		16	14	-2		15	2	-13		18	18	-0
2	13	2	-11		20	17	-3		12	3	-9		--	16	--
	14	--	--		18	14	-4		12	--	--	2	19	13	-6
	13	--	--	5	21	15	-6						18	14	-4
	13	--	--		22	16	-6						20	14	-6
3	17	2	-15		21	16	-5						20	14	-6
	16	3	-13		21	17	-4					3	21	14	-7
	17	1	-16										21	14	-7
	13	2	-11										20	15	-5
													22	14	-8

The relative effects of additive choice and septic choice on scum thickness change are also indicated by the correlation coefficients produced by the regression analysis. Partial correlation coefficients against scum thickness change were 0.041 for the additive selection dummy variable, and 0.853 for the septic tank selection dummy. With 27 sets of data in the analysis as listed in Table 11, and three variables (i.e., scum thickness change, additive dummy and septic tank dummy), statistical tables indicate that partial correlation coefficients are statistically significant at the 95% level if their magnitude exceeds 0.396, or at the 99% level for a value of 0.505 or higher. Thus, the Table 11 decreases in scum thickness are uncorrelated (<95% significance) with the selection of additive between 'B' and 'C', but correlated (>99%) with the selection between the two septic tanks. Within the scope of the comparison, additive selection did not affect scum thickness change, but the selection between the drop inlet (northbound east) and the tee inlet (southbound west) septic tanks did.

Reanalysis of Scum Thickness Change Excluding Drop Inlet Septic Tank: Of the four Westley SRRA septic tanks included in the preceding evaluation, only the northbound east septic tank was fitted with a drop inlet. Having identified the northbound east (drop inlet) septic tank as perturbating scum thickness change, it appears reasonable to reanalyze scum thickness changes after eliminating values obtained from that tank. Table 12 shows the result of this selective

Table 12: Statistical Significance of Differences Between Selected Day 0 to Day 1 Scum Thickness Changes.

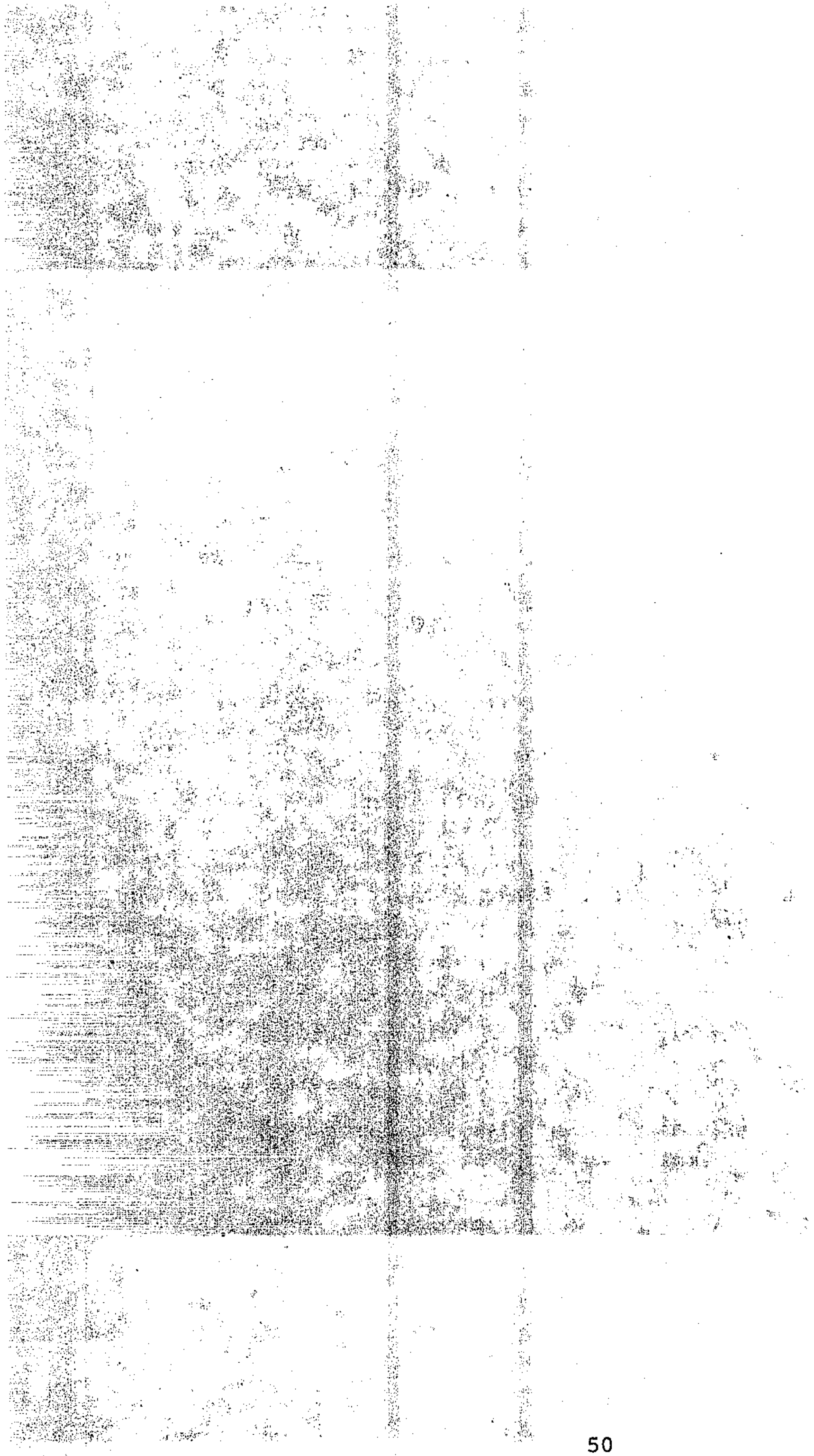
Day no	Scum thickness reading no.	Additive 'A'-treated Southbound RV dump Inlet manhole Scum thickness, in. Day0	Day1	Change	Additive 'B'-treated Southbound west tank Inlet manhole Scum thickness, in. Day0	Day1	Change	Additive 'C'-treated Southbound west tank Inlet manhole Scum thickness, in. Day0	Day1	Change	Untreated control Southbound east tank Inlet manhole Scum thickness, in. Day0	Day1	Change
1	1	8	4	-4	--	--	--	19	17	-2	20	15	-5
	2	10	4	-6	--	--	--	18	18	0	10	13	3
	3	--	--	--	--	--	--	--	16	--	15	--	--
	4	--	--	--	--	--	--	--	--	--	15	--	--
2	1	7	6	-1	--	--	--	19	13	-6	13	5	-8
	2	8	5	-3	--	--	--	18	14	-4	14	6	-8
	3	7	5	-2	--	--	--	20	14	-6	11	6	-5
	4	6	4	-2	--	--	--	20	14	-6	--	--	--
3	1	11	8	-3	--	--	--	21	14	-7	10	6	-4
	2	11	6	-5	--	--	--	21	14	-7	14	5	-9
	3	11	4	-7	--	--	--	20	15	-5	13	7	-6
	4	9	6	-3	--	--	--	22	14	-8	10	4	-6
4	1	12	7	-5	17	12	-5	--	--	--	10	6	-4
	2	10	8	-2	16	14	-2	--	--	--	10	3	-7
	3	12	7	-5	20	17	-3	--	--	--	10	6	-4
	4	10	7	-3	18	14	-4	--	--	--	10	5	-5
5	1	--	--	--	21	15	-6	--	--	--	9	6	-3
	2	--	--	--	22	16	-6	--	--	--	6	5	-1
	3	--	--	--	21	16	-5	--	--	--	9	5	-4
	4	--	--	--	21	17	-4	--	--	--	8	7	-1
		Mean change		-3.64	Mean change		-4.38	Mean change		-5.10	Mean change		-4.53
		Std.dev. change		1.74	Std.dev. change		1.41	Std.dev. change		2.47	Std.dev. change		2.96
		No. of values		14	No. of values		8	No. of values		10	No. of values		17

Compared with	Signif. diff?	Degrees of freedom	Diff. statistic,t	Signif. diff?	Degrees of freedom	Diff. statistic,t	Signif. diff?	Degrees of freedom	Diff. statistic,t
Control	No	29	-0.988	No	23	-0.139	No	25	0.512
Add. 'C'	No	22	-1.702	No	16	-0.737			
Add. 'B'	No	20	-1.014						

analysis for tee-inlet tanks only. The upper part of Table 12 shows Day 0 to Day 1 scum thickness changes. In the lower part of Table 12 t-tests compare these Day 0 to Day 1 scum thickness changes, showing no significant difference at the 95% level among any of the tanks, the three additive-treated tee-inlet septic tanks and the untreated tee-inlet septic tank.

Recapitulation:

The research sought a method to mitigate the accumulation of scum in septic tanks at SRRAs. The scum appeared to be largely paper from the restrooms. In test septic tanks at the Westley SRRAs the thickness of the scum mat decreased after the scum was pulverized. The decrease in scum mat thickness was greatest in the test septic tank that was fitted with a drop inlet, rather than a conventional tee-inlet for the other test septic tanks. One tee-inlet tank treated only RV waste from a trailer sanitation station. In the tee-inlet septic tanks, the decrease in scum thickness on the day after pulverization did not differ between the untreated control tank and any of the three additive-treated tanks, or between any pair of additive-treated tanks, according to statistical significance t-testing at the 95% level. About two weeks after pulverization, the scum mats had restored to their original thickness.



LABORATORY INVESTIGATIONS

Types of Laboratory Experiment: The effect of each of three additives on the volume of septic tank scum was investigated in two sets of experiments, the column experiments and the batch reactor experiments. Figure 13 illustrates the experimental apparatus. In the column experiments, eight transparent vertical tubular columns were set up, each containing a layer of septic tank scum floating on wastewater. Observations were made to evaluate the progressive decrease of thickness of the scum layer, apparently due to disintegration of the scum into the wastewater below. The batch reactor experiments involved observing batches of scum in flasks. Partitioning of the scum into liquid and semi-solid fractions sometimes occurred to form a pool of leachate beneath, apparently due to drainage of liquid from pores in the scum.

Scum: Scum used in all experiments was obtained from the Westley southbound east and west septic tanks. A single collection of scum (25 gallons, on September 16, 1985) was used in all experiments, except for the first (Series A) batch reactor tests. The scum was homogenized using a paint mixer, and larger solid items were removed, before the scum was loaded into the experimental process units. The pH of a sample of scum was initially 5.8, and fell to 4.7 over a four-week test period.

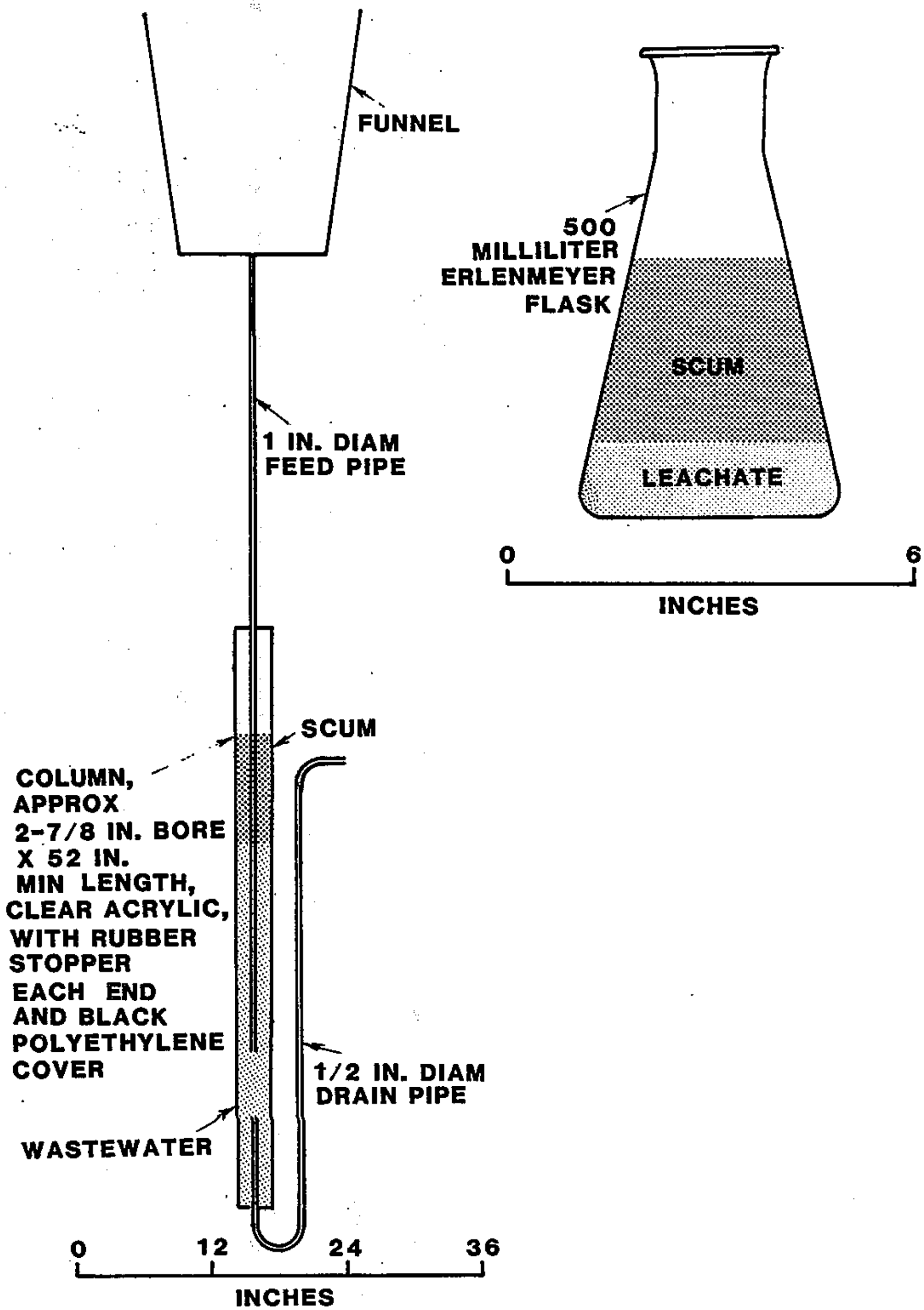


Figure 13: Laboratory Experimental Apparatus.

1) Column. (Left.)

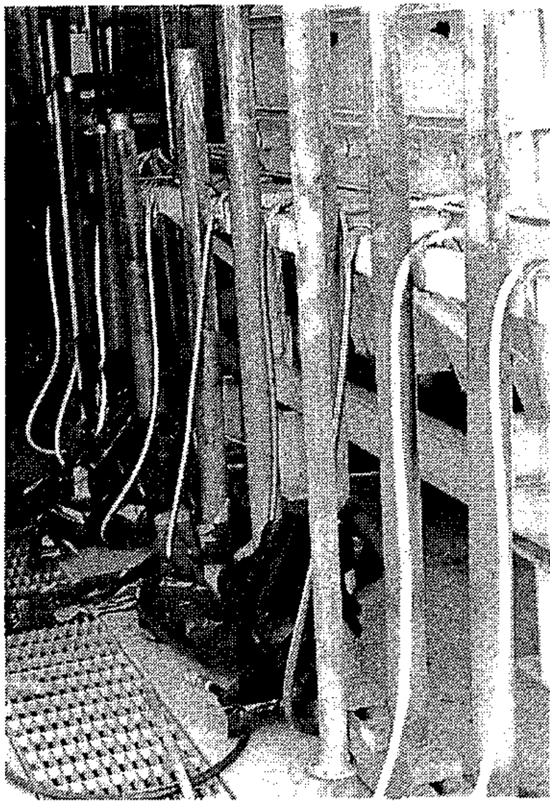
2) Batch Reactor. (Right.)

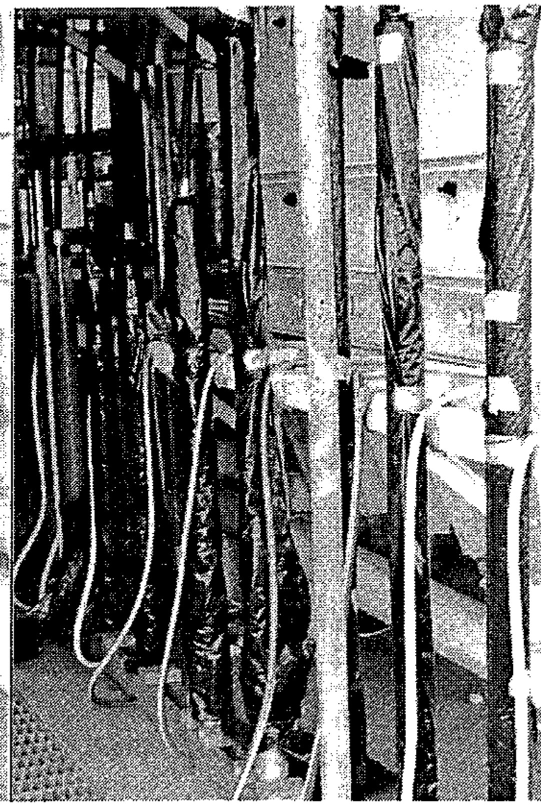
Additives: Additives used to treat the scum were the same as for the field study, designated 'A', 'B' and 'C', untreated controls being designated 'D'.

Column Tests:

Arrangements: Two liters of Westley scum was floated on two liters of Richmond City settled domestic wastewater sealed in a plexiglass column approximately 2-7/8 in. bore. For each of the three additives, two columns were randomly selected from the eight columns available, and two columns were held as controls. Treated columns were spiked with a single dose of their assigned additive immediately after loading scum into the column, by pouring four grams of the additive blended into wastewater into a feed pipe which led to the liquid zone in each column. An outlet pipe draining wastewater from near the base of each column discharged outside the column at the liquid level to be maintained. Black polyethylene covers protected scum in the columns from light. Figures 14-17 show the bank of test columns without and with their polyethylene covers; and the funnel tanks that delivered wastewater feed into the columns; and a typical closeup of a scum layer.

Operation: Two-liter doses of Richmond settled wastewater were introduced approximately weekly to the column at the feed pipe, allowing an equal volume of liquid to overflow. These feedings were intended to provide some substrate and to help remove deleterious by-products such as organic





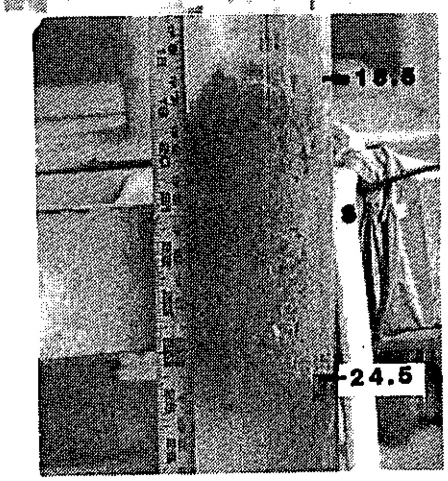


Figure 14: Scum-Filled Test Columns, With Covers Removed. (Top left.)

Figure 15: Scum-Filled Test Columns, With Covers Installed. (Top center.)

Figure 16: Test Columns Feeding Funnels, Each Fabricated from a Garbage Can Connected to a Pipe that Delivered Waste into a Test Column. (Top right.)

Figure 17: Scum Layer in Test Column, Typical. (Right.)

acids. Total solids analyses on the feed and on the overflow liquid near the end of the period of operation showed that the overflow contained more total solids than the feed, as indicated by the following total solids analyses (in mg/L) on one set of samples: feed, 370; additive 'A'-treated column effluent, 980 and 510; 'B'-treated, 640 and 550; 'C'-treated, 820; and control, 810 and 380. The increase in effluent solids is ascribed to attrition of the scum layer, as the thickness of the scum layer decreased rather steadily in each column. Presumably solid particles tended to sink after they detached from buoyant gas bubbles. Any such attrition of scum in the Westley SRRA septic tanks is likely to have been masked by the higher rate of accretion of the scum layers in the field. The columns were set up on September 18, 1985, and operated outdoors for 72 days until November 29.

<u>Results:</u> Table 13 lists data from which scum layer thickness data were determined, namely the levels of the top and bottom of the scum, and also of any air gap that developed to break the scum layer into sections perhaps on account of stress induced by feeding the columns. Scum level readings were made on a scale of inches increasing downwards to 60 inches at the base of the columns. As the scum surfaces were sometimes irregular or diffuse, readings were rounded to the nearest half-inch.

Table 13: Scum and Sludge Layer Thicknesses in Laboratory Test Columns.

Days from setup	15	22	29	37	44	51	58	72
Column 1: Treated with Additive 'B', 4 g/4 L.								
Top of scum, in.	20.5	19.0	19.0	17.0	17.5	18.5	18.5	18.5
Bottom scum, in.	31.0	29.5	27.5	24.0	24.0	24.5	24.5	24.5
Scum depth, in.	10.5	10.5	8.5	7.0	6.5	6.0	6.0	6.0
Sludge depth, in.	--	--	--	--	4.0	--	3.5	4.0
Column 2: Untreated Control.								
Top of scum, in.	15.0	14.5	15.0	15.5	15.0	15.5	15.5	15.5
Top air gap, in.	--	--	19.0	19.0	19.0	19.5	19.5	19.5
Bottom gap, in.	--	--	21.0	21.0	23.0	24.0	22.5	22.0
Bottom scum, in.	24.5	23.5	25.0	26.0	26.5	27.5	25.5	24.5
Scum depth, in.	9.5	9.0	8.0	8.5	7.5	7.5	7.0	6.5
Sludge depth, in.	--	--	--	--	3.0	--	2.5	2.5
Column 3: Treated with Additive 'A', 4 g/4 L.								
Top of scum, in.	22.5	16.5	14.5	13.0	14.0	15.5	16.0	17.5
Top air gap, in.	--	--	17.5	--	--	--	--	--
Bottom gap, in.	--	--	18.5	--	--	--	--	--
Bottom scum, in.	33.0	25.5	23.0	20.5	21.0	22.5	22.5	23.5
Scum depth, in.	10.5	9.0	7.5	7.5	7.0	7.0	6.5	6.0
Sludge depth, in.	--	--	--	--	3.0	--	3.0	3.0
Column 4: Untreated Control.								
Top of scum, in.	22.5	16.5	10.0	12.0	.5	-5.0	.0	-4.0
Bottom scum, in.	32.5	25.0	17.5	19.0	7.0	1.5	6.5	2.5
Scum depth, in.	10.0	8.5	7.5	7.0	6.5	6.5	6.5	6.5
Sludge depth, in.	--	--	--	--	3.0	--	2.5	2.5
Column 5: Treated with Additive 'C', 4 g/4 L.								
Top of scum, in.	22.0	39.0	35.0	21.0	19.5	--	--	--
Bottom scum, in.	32.0	49.0	41.0	24.0	22.0	--	--	--
Scum depth, in.	10.0	10.0	6.0	3.0	2.5	.0	.0	.0
Sludge depth, in.	--	--	--	--	5.5	6.0	5.5	5.0
Column 6: Treated with Additive 'C', 4 g/4 L.								
Top of scum, in.	14.5	29.0	30.0	30.5	31.0	32.0	31.0	30.5
Bottom scum, in.	23.0	37.0	38.0	38.0	38.0	38.5	37.5	37.0
Scum depth, in.	8.5	8.0	8.0	7.5	7.0	6.5	6.5	6.5
Sludge depth, in.	--	--	--	--	7.0	--	5.0	5.0
Column 7: Treated with Additive 'B', 4 g/4 L.								
Top of scum, in.	15.0	15.0	15.0	15.5	15.0	15.5	15.5	15.5
Bottom scum, in.	28.0	26.0	25.5	25.0	24.5	25.0	25.0	24.5
Scum depth, in.	13.0	11.0	10.5	9.5	9.5	9.5	9.5	9.0
Sludge depth, in.	--	--	--	--	3.0	--	3.0	3.0
Column 8: Treated with Additive 'A', 4 g/4 L.								
Top of scum, in.	22.5	20.0	19.0	16.5	18.0	18.5	18.5	18.5
Bottom scum, in.	30.5	26.0	25.0	22.5	24.0	24.5	24.0	24.0
Scum depth, in.	8.0	6.0	6.0	6.0	6.0	6.0	5.5	5.5
Sludge depth, in.	--	--	--	--	3.0	--	2.5	3.0

Rates of Change of Scum Thickness: Figure 18 plots the thickness of the scum mat versus time on a log-log scale, and Table 14 presents the associated regression analyses. Figure 18 also shows 95% confidence limits for the slope of each regression line, computed from the Table 14 listing of the standard error of the regression slopes and their standard errors. Table 14 further tests the statistical significance of each slope and the differences between the slopes, on the log-log plots of scum thickness versus time in Figure 18. All slopes differed statistically significantly from zero (no slope) at the 95% level. Slopes from the two control columns and from one each of the three treated columns did not differ significantly from one another (Figure 18, Frames A, B, D, F and H). However, these five slopes (from two control columns and one each of the treated columns) were significantly flatter than the other three slopes (Figure 18, Frames C, E and G). According to probability theory, if five 'flat' and three 'steep' slopes were randomly distributed over all eight columns, the probability of at least one 'steep' slope in the two random selections for the control columns is (3/8) + (5/8) x (3/7) = 64%, so the chance of no 'steep' slopes in two random control columns is 100% - 64% = 36%. Thus, the occurrence of 'steep' slopes only in the treated columns is not in itself statistically remarkable, under a null hypothesis of a random distribution of 'flat' and 'steep' slopes among all of the columns.

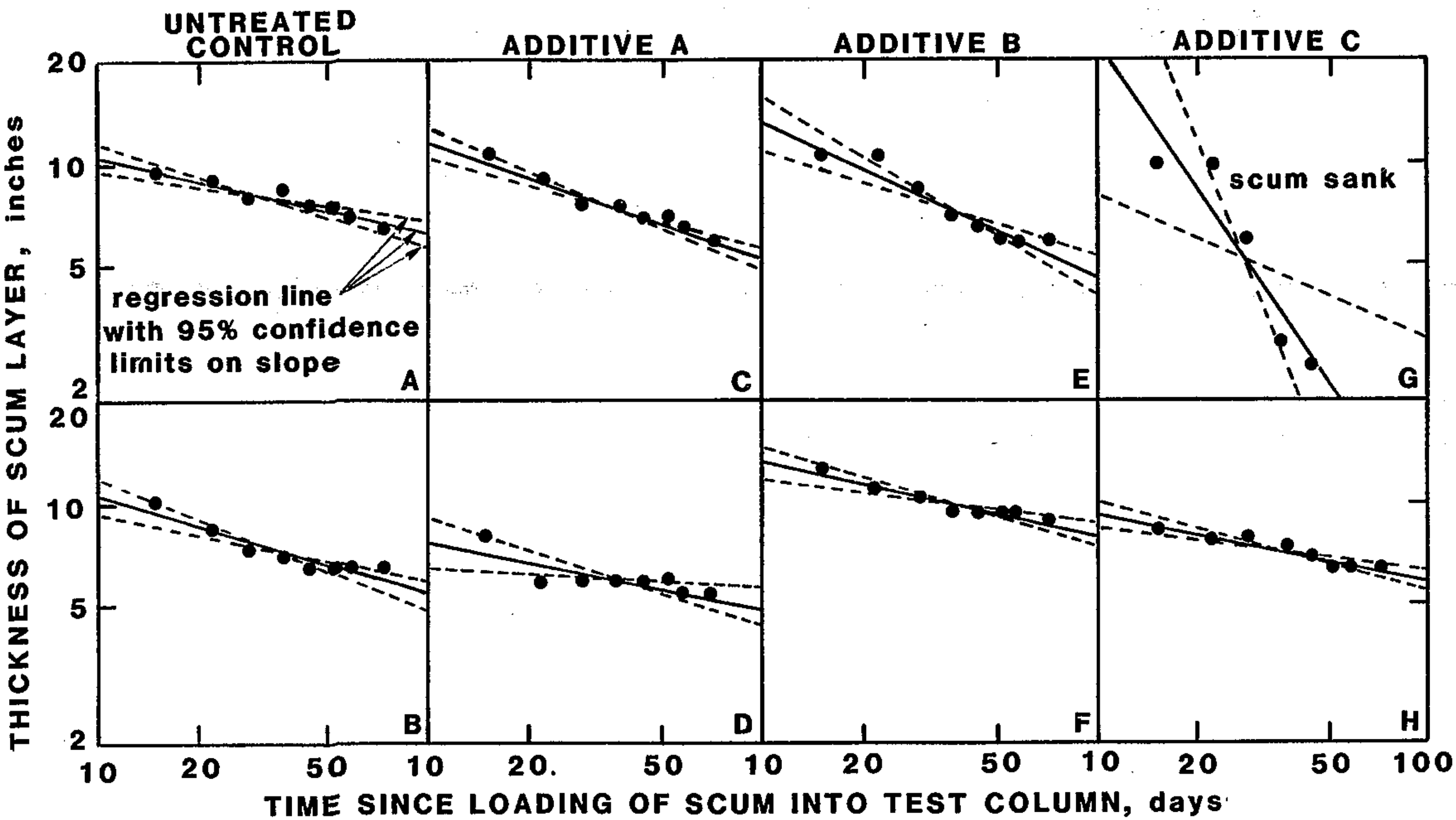


Figure 18: Scum Thickness Versus Time in Laboratory Test Columns.

Table 14: Statistical Analysis of Rates of Change of Scum Layer Thickness in Laboratory Test Columns.

Additive initially introduced to column	No additive		Additive 'A'		Additive 'B'		Additive 'C'	
Frame of Figure 18 in which data plotted	A	B	C	D	E	F	G	H
Code number of laboratory test column	2	4	3	8	1	7	5	6
Table column number	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Statistical significance of correlation	**	**	**	*	**	**	*	**
Correlation, ln(thickness) vs. ln(time)	-.9533	-.9502	-.9787	-.8273	-.9563	-.9455	-.9334	-.9565
Regression, ln(thickness) vs. ln(time)	-.2327	-.2896	-.3357	-.1851	-.4447	-.2165	-1.4292	-.1984
Standard error of regression coefficient	.0301	.0388	.0287	.0513	.0555	.0304	.3172	.0247
Intercept = scum thickness, in., at 1 day	18.2298	20.6953	25.1926	11.8602	36.8638	22.0800	611.735	14.8718
Number of experimental points plotted	8	8	8	8	8	8	5	8
Tests for statistical significance of differences between regression coefficients:								
Versus column (1) values, t-test parameter	.0000	-1.1588	-2.4755	.7995	-3.3580	.3795	-5.4362	.8806
Direction and significance of difference	-	-	<	-	<<	-	<<	-
Versus column (2) values, t-test parameter		.0000	-.9557	1.6236	-2.2913	1.4832	-5.1019	1.9823
Direction and significance of difference		-	-	-	<	-	<<	-
Versus column (3) values, t-test parameter			.0000	2.5597	-1.7439	2.8483	-4.9779	3.6214
Direction and significance of difference			-	>	-	>	<<	>>
Versus column (4) values, t-test parameter				.0000	-3.4337	-.5249	-5.4225	-.2331
Direction and significance of difference				-	<<	-	<<	-
Versus column (5) values, t-test parameter					.0000	3.6056	-4.2473	4.0534
Direction and significance of difference					-	>>	<<	>>
Versus column (6) values, t-test parameter						.0000	-5.5070	.4602
Direction and significance of difference						-	<<	-
Versus column (7) values, t-test parameter							.0000	5.6336
Direction and significance of difference							-	>>

** and * indicate 99% and 95% statistical significance levels against null hypothesis of zero correlation.

Sludge Formation: Also shown in Table 13 are a few measurements of the thickness of a layer of sludge that developed in the columns, evidently mostly from scum that sank. In one column the entire floating scum mat sank during operation of the columns. The reason for sinking of scum is suggested by batch reactor experimental results (described shortly), that showed the density of scum to vary closely about the density of water. Rest area septic tank scum is a loose conglomerate of water and solids, probably with bubbles of gas from digestion of solids in the septic tank. Scum may owe the buoyancy that accounts for its existence to the small, loosely bound gas fraction, which when liberated from a solid particle, may allow the particle to sink and become sludge.

Statistical Significance of Treatment by Additive: Another approach was taken to identifying any effect of additive on the slope of the plot of scum thickness versus time. This involved the use of multiple regression analysis of scum thickness versus time data for each additive, and adding a dummy variable to indicate the presence or absence of the additive by 1 or 0 values for the dummy variable respectively. Use of the dummy variable permitted including data from columns treated with that additive together with data from untreated control columns, thereby providing for evaluation of the effect of treatment by the statistical significance of the dummy variable. Scum thickness data were normalized by dividing each thickness measurement by the initial (Day 15) value of thickness measurements for that column, so the regression would take in account only differences in slope between the plotted lines and not differences in ordinate. With generally 8 data points of scum thickness vs. time, and 2 columns per additive together with 2 control columns in each analysis, 32 data points were obtained. Table 15 lists partial correlation coefficients obtained.

Table 15: Coefficients of Partial Correlation Between Log-Transformed Normalized Scum Thickness, Log-Transformed Time, and the Additive Dummy Variable.

Additive	Partial correlation of log-transformed normalized scum thickness with: Log-transformed time	Additive dummy variable[a]	Degrees of freedom	Partial correlation coefficient that is significant at 95% level	99% level
(1)	(2)	(3)	(4)	(5)	(6)
'A'	-0.866	-0.335	28	0.361	0.463
'B'	-0.858	-0.262	28	0.361	0.463
'C'	-0.461	-0.203	25	0.381	0.487

[a] Assigned to 1 or 0 for presence or absence of additive.

In no case was the additive dummy variable significantly correlated with scum thickness. Statistical evidence is lacking to reject the null hypothesis that the slope of the logarithmic plot of scum thickness versus time does not differ significantly between the pair of control columns and any of the three pairs of additive-treated columns.

Batch Tests:

Methods: One-half liter batches of scum, some spiked with a known dose of additive, and others untreated as controls, were held in batch reactors, namely 500 milliliter Erlenmeyer flasks. Various measurements were made, including the extent to which liquid drained from the scum over a period of observation. These measurements were compared between additive-treated and untreated controls, and also between different doses of each additive. Also, during the experiments the reactors were periodically photographed to document the progression of visible changes, with typical photographs appearing as Figure 19.

Series A Batch Tests: These reactors were filled with scum collected on an earlier occasion than for scum used in the column tests or the Series B and C batch tests. Quadruplicate untreated control reactors were filled, and duplicate treated reactors spiked with additives 'A', 'B' and 'C' at concentrations of 0.01, 0.1 and 1 grams per liter (g/L). The filled reactors were held outdoors for five days, during which time the contents remained essentially unchanged. As a result of discussions in which it was suggested that the batch reactors should better be operated in the dark, Series A batch tests were terminated.

Unlimed (Series B) Batch Tests: This series was conducted concurrently with Series C. Forty reactors were loaded with

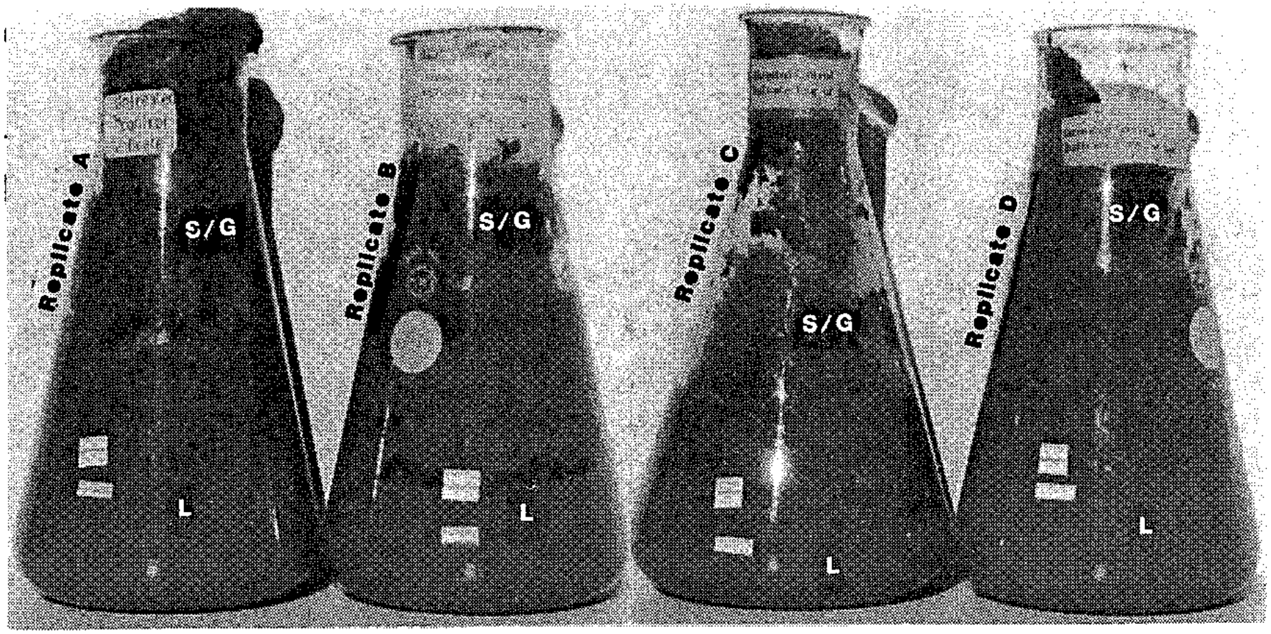


Figure 19: Batch Reactors, Typical.

Zones: S = solid, L = liquid, G = gas.

0.5 liters of scum, four untreated controls, and three quadruplicate treated sets dosed with 0.1, 1 or 10 g/L of additive 'A', 'B' or 'C'. Operation of the experiment involved holding the reactors for 28 days in a dark chamber out of doors, and photographing and weighing the reactors periodically.

After about a week scum in some of the reactors expanded, apparently due to production of gas from the scum, then water drained from the scum to form a pool of leachate in each reactor. At the end of the test, measurements were made of the volume of liquid that could be poured from each reactor, and the volume of residual scum. From these volumes, together with weighings of the reactors, the density of the residual scum was calculated, assuming unit density for the liquid fraction.

Results: In Figure 20, histogram plots of scum paste volumes, liquid volumes and scum densities are shown, with each bar of the histogram showing results from quadruplicate reactors. Each group of four bars shows data from one of the three additives investigated, at dosages of 0, 0.1, 1 and 10 g/L (0, 0.01, 0.1 and 1 % by weight). Table 16 lists experimental data, with parameter statistics and results of statistical t-tests on differences between the means of various parameter values. In view of the objective of the study to reduce the volume of scum, primary interest focuses on minimizing the volume of residual scum, that averaged 52%

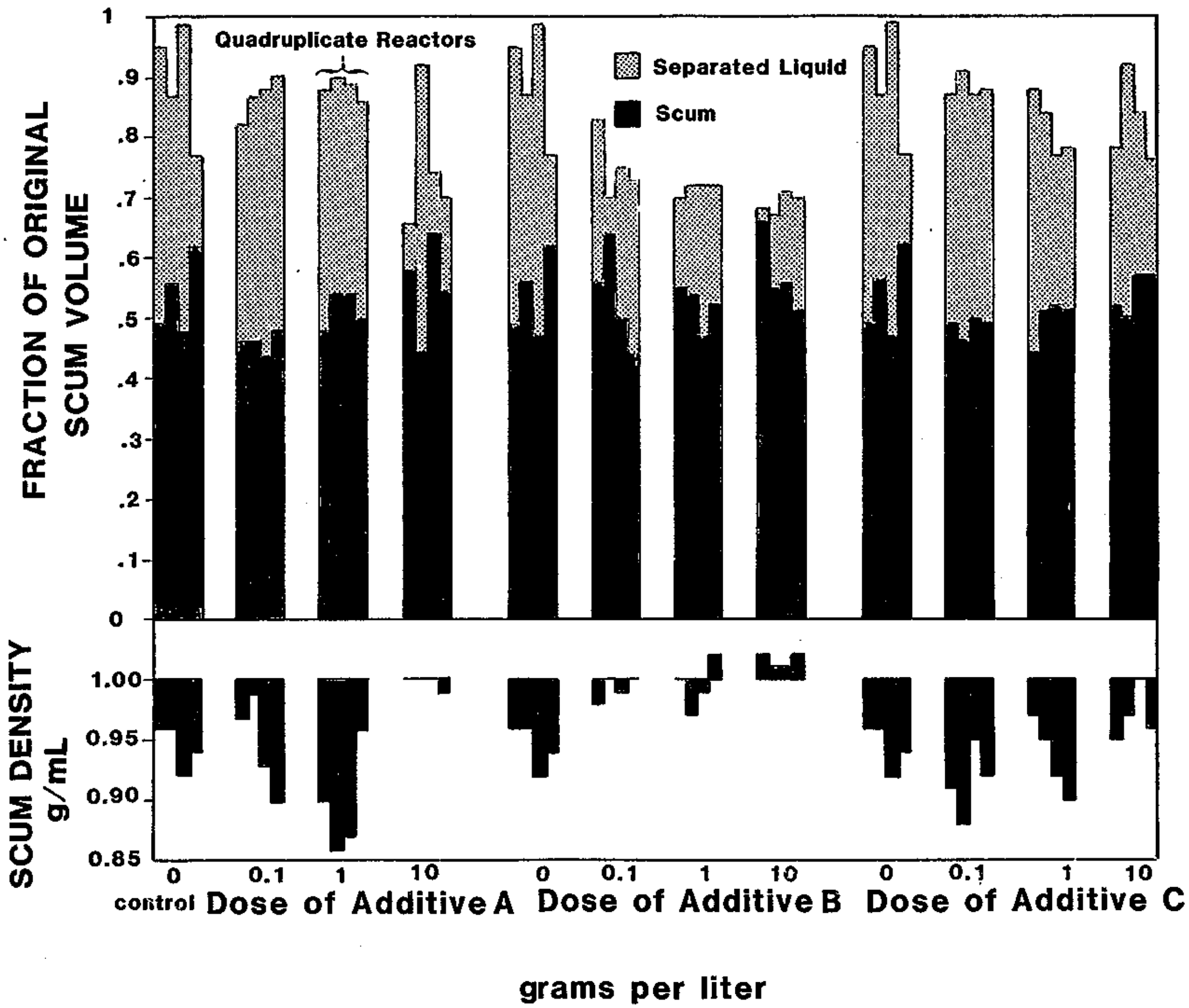


Figure 20: Final Scum Volume and Density in Series B Unlimed Batch Reactors.

Table 16: Batch Reactor Data, Dark Reactor, pH Unadjusted, Series B.

Additive designation	Additive dose	Replicate code	Scum weight,g 10/2/85	Scum weight,g 10/9/85	Scum weight,g 10/16/85	Weight change, grams	Liquid volume, mL	Paste volume, mL	Paste density, g/mL
No additive (control)	none	A	481	469	464	17	230	245	0.96
		B	431	427	425	6	155	280	0.96
		C	486	479	477	9	260	235	0.92
		D	372	367	365	7	75	310	0.94
'A'	0.1 g/L	A	417	408	403	14	180	230	0.97
		B	439	434	431	8	203	230	0.99
		C	440	429	424	16	220	220	0.93
		D	439	430	425	14	210	240	0.90
	1 g/L	A	431	421	417	14	200	240	0.90
		B	426	417	411	15	180	270	0.86
		C	424	416	411	13	175	270	0.87
		D	433	425	420	13	180	250	0.96
	10 g/L	A	338	331	328	10	39	290	1.00
		B	472	464	461	11	238	223	1.00
		C	378	372	369	9	50	320	1.00
		D	359	353	350	9	82	272	0.99
'B'	0.1 g/L	A	414	412	409	5	135	280	0.98
		B	355	352	351	4	30	320	1.00
		C	375	373	373	2	125	250	0.99
		D	369	366	365	4	145	220	1.00
	1 g/L	A	360	353	350	10	75	275	1.00
		B	357	355	353	4	90	270	0.97
		C	365	360	358	7	125	235	0.99
		D	362	358	355	7	90	260	1.02
	10 g/L	A	350	346	345	5	10	330	1.02
		B	343	340	339	4	60	275	1.01
		C	362	360	358	4	75	280	1.01
		D	364	357	354	10	95	255	1.02
'C'	0.1 g/L	A	426	417	413	13	190	245	0.91
		B	438	431	428	10	225	230	0.88
		C	435	426	423	12	185	250	0.95
		D	441	434	431	10	205	245	0.92
	1 g/L	A	441	436	434	7	220	220	0.97
		B	432	422	418	14	175	255	0.95
		C	371	366	365	6	125	260	0.92
		D	373	367	364	9	135	255	0.90
	10 g/L	A	392	385	382	10	135	260	0.95
		B	462	456	453	9	210	250	0.97
		C	439	425	420	19	135	285	1.00
		D	374	370	368	6	95	285	0.96

Scum wt stats 10/16/85	Weight change stats	Liquid volume stats	Paste volume stats	Paste density stats	Statistics
394.75	9.40	144.18	260.37	0.961	Overall mean
39.48	4.11	64.97	28.15	0.044	Overall S.D.
432.75	9.75	180.00	267.50	0.945	Control, mean
50.28	4.99	82.76	34.28	0.019	Std deviation
					Additive 'A'
420.75	13.00	203.25	230.00	0.946	Dose=0.1, mean
12.23	3.46	17.00	8.16	0.043	Std deviation
-0.46	1.07	0.55	-2.13<	0.11	vs. control
414.75	13.75	183.75	257.50	0.898	Dose=1, mean
4.50	0.96	11.09	15.00	0.046	Std deviation
-0.71	1.57	0.09	-0.53	-1.94	vs. control
-0.92	0.42	-1.92	3.22>	-1.66	vs. dose=0.1
377.00	9.75	102.25	276.25	0.995	Dose=10, mean
58.45	0.96	92.32	40.65	0.006	Std deviation
-1.45	0.00	-1.25	0.33	5.31>>	vs. control
-1.47	-1.81	-2.15<	2.23>	2.46>	vs. dose=0.1
-1.29	-5.91<<	-1.75	0.87	4.42>>	vs. dose=1
					Additive 'B'
374.50	3.75	108.75	267.50	0.993	Dose=0.1, mean
24.73	1.26	53.13	42.72	0.011	Std deviation
-2.08<	-2.33<	-1.45	0.00	4.44>>	vs. control
354.00	7.00	95.00	260.00	0.996	Dose=1, mean
3.37	2.45	21.21	17.80	0.019	Std deviation
-3.13<	-0.99	-1.99<	-0.39	3.54>>	vs. control
-1.64	2.36>	-0.42	-0.28	0.221	vs. dose=0.1
349.00	5.75	60.00	285.00	1.014	Dose=10, mean
8.60	2.87	36.29	31.89	0.002	Std deviation
-3.28<	-1.39	-2.66<	0.75	7.00>>	vs. control
-1.95<	1.28	-1.52	0.66	4.02>>	vs. dose=0.1
-1.08	-0.66	-1.67	1.37	1.85	vs. dose=1
					Additive 'C'
423.75	11.25	201.25	242.50	0.917	Dose=0.1, mean
7.89	1.50	17.97	8.66	0.029	Std deviation
-0.35	0.58	0.50	-1.41	-1.73	vs. control
395.25	9.00	163.75	247.50	0.937	Dose=1, mean
36.11	3.56	43.28	18.48	0.033	Std deviation
-1.21	-0.24	-0.35	-1.03	-0.55	vs. control
-1.54	-1.17	-1.60	0.49	0.94	vs. dose=0.1
405.75	11.00	143.75	270.00	0.970	Dose=10, mean
38.40	5.60	48.02	17.80	0.022	Std deviation
-0.85	0.33	-0.76	0.13	1.73	vs. control
-0.92	-0.09	-2.24<	2.78>	3.05>	vs. dose=0.1
0.40	0.60	-0.62	1.75	1.85	vs. dose=1

Note: 'vs. . . .' on right side of table are t-test statistics. With 6 df, t=1.943 is significant at the 95% level, t=3.143 is significant at 99%.

of the original volume of scum, with a relative standard deviation of 6%. In general, residual scum volume and liquid volume varied little with additive dose (including the zero dose control) at the 95% level of statistical significance. However, with Additive 'A' at a dose of 0.1 g/L, residual scum volume was only 85% of that in the control reactor. Also, residual scum densities were fairly constant, although with Additive 'A' at 10 g/L, or with 'B' at all dosages, the scum density was significantly higher than in the control. Thus the relatively sensitive batch reactor experiments provide some evidence of interaction between scum and additive. Also, Figure 20 shows a loss in volume of liquid plus residual scum from the original volume of scum, possibly due to elimination of gas voids initially present. However, no initial weighings were made that might otherwise explain the volume loss.

Limed (Series C) Batch Tests: The pH of the scum was first adjusted from 5.8 to 8.4 by the addition of slaked lime. Thirty reactors were loaded with 0.5 liters of scum, three control reactors and three triplicate sets dosed with 0.1, 1 and 10 g/L of with additive 'A', 'B' or 'C'. Operation of the experiment involved holding the reactors for 28 days in a dark chamber out of doors, and photographing and weighing the reactors periodically. The final pH in a control reactor was 6.4.

Results: Figure 21 and Table 17 present Series C experimental data in a manner similar to that for Series B data. Limed scum did not form a drainage pool as had unlimed scum, but was apparently almost unchanged through the experiments. The volume of residual limed scum averaged 92% of the original volume of scum (compared to 52% for unlimed scum), with a relative standard deviation of 5%. Limed scum did not form a drainage pool because it tended to be denser than water, with a mean unit weight of 1.01 g/L, compared to 0.96 g/L for unlimed scum. A little liquid generally formed on the surface of limed scum. (If liming of scum were practical in the field, scum might be sunk and eliminated.)

But apart from the effect of liming, the effects of additives on Series C reactors was minor. With Additive 'A' at 0.1 g/L, or 'B' at 10 g/L, or 'C' at 1 g/L, the volume of scum paste was higher than for the control, but with 'C' at 10 g/L it was lower. Additive-treated scum tended to be slightly less dense than the control, but not statistically significantly. These observations are tentative and may be spurious.

Recapitulation:

Two sets of laboratory experiments were designed to define how any of the three additives examined affected the volume of septic tank scum initially placed in the experimental laboratory process units. These process units were referred

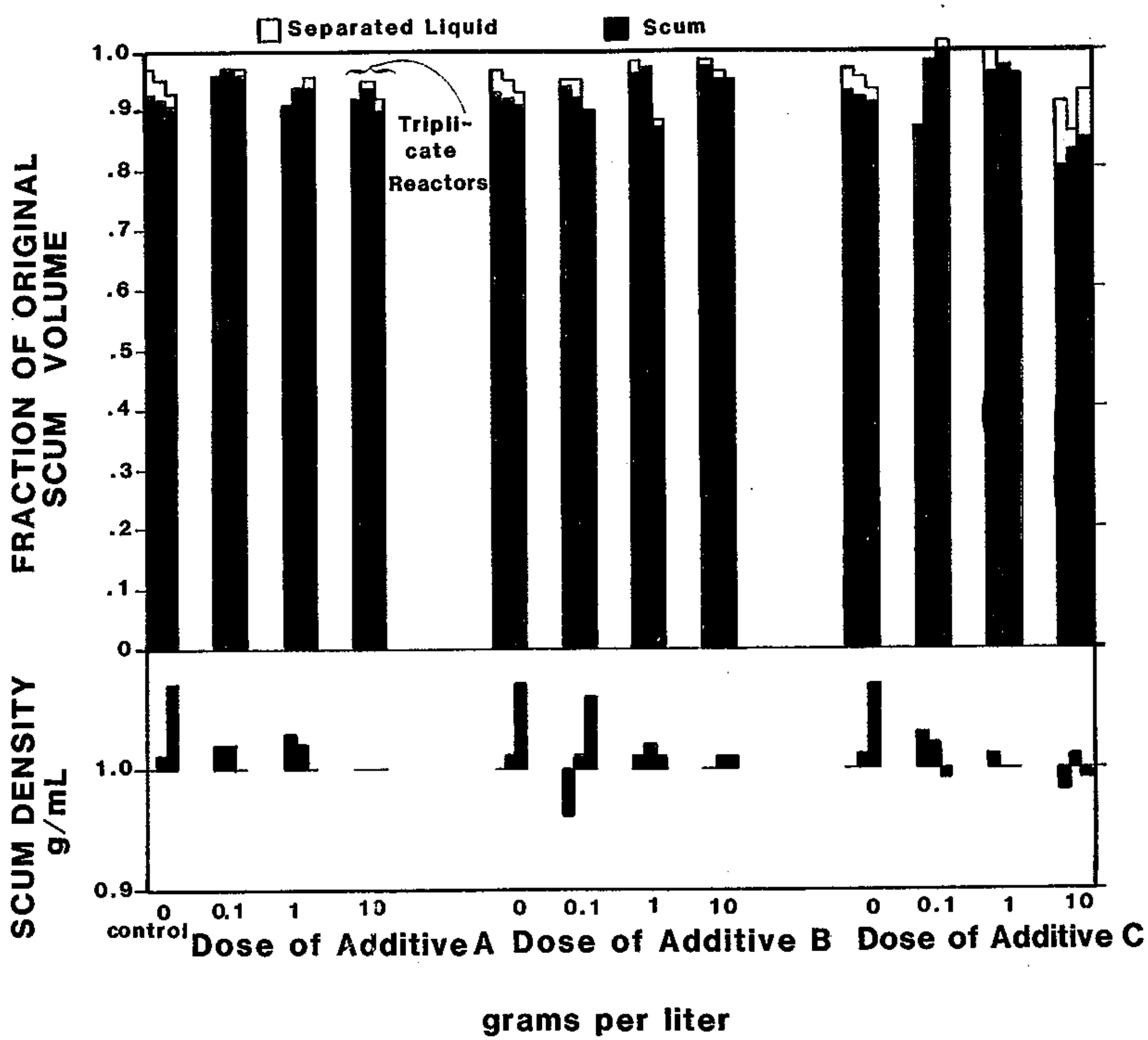


Figure 21: Final Scum Volume and Density in Series C Limed Batch Reactors.

Table 17: Batch Reactor Data, Dark Reactor, pH Adjusted, Series C.

Additive designation	Additive dose	Replicate code	Scum weight,g 10/2/85	Scum weight,g 10/9/85	Scum weight,g 10/16/85	Weight change, grams	Liquid volume, mL	Paste volume, mL	Paste density, g/mL
No additive (control)	none	A	--	--	487	--	20	465	1.00
		B	--	--	479	--	15	460	1.01
		C	--	--	497	--	10	455	1.07
'A'	0.1 g/L	A	--	--	489	--	0	480	1.02
		B	--	--	493	--	0	485	1.02
		C	--	--	487	--	5	480	1.00
	1 g/L	A	--	--	468	--	0	455	1.03
		B	--	--	478	--	0	470	1.02
		C	--	--	475	--	5	470	1.00
	10 g/L	A	--	--	460	--	0	460	1.00
		B	--	--	475	--	5	470	1.00
		C	--	--	462	--	10	450	1.00
'B'	0.1 g/L	A	--	--	458	--	5	470	0.96
		B	--	--	478	--	15	460	1.01
		C	--	--	479	--	0	450	1.06
	1 g/L	A	--	--	497	--	10	480	1.01
		B	--	--	495	--	0	485	1.02
		C	--	--	446	--	5	435	1.01
	10 g/L	A	--	--	491	--	5	485	1.00
		B	--	--	479	--	0	475	1.01
		C	--	--	486	--	5	475	1.01
'C'	0.1 g/L	A	--	--	449	--	0	435	1.03
		B	--	--	499	--	0	490	1.02
		C	--	--	498	--	5	500	0.99
	1 g/L	A	--	--	505	--	20	480	1.01
		B	--	--	485	--	0	485	1.00
		C	--	--	480	--	0	480	1.00
	10 g/L	A	--	--	446	--	55	400	0.98
		B	--	--	434	--	15	415	1.01
		C	--	--	462	--	40	425	0.99

Scum wt stats 10/16/85	Weight change stats	Liquid volume stats	Paste volume stats	Paste density stats	Statistics
477.23	--	8.33	464.17	1.010	Overall mean
18.14	--	12.48	23.27	0.021	Overall S.D.
487.67	--	15.00	460.00	1.028	Control, mean
9.02	--	5.00	5.00	0.037	Std deviation
					Additive 'A'
489.67	--	1.67	481.67	1.013	Dose=0.1, mean
3.06	--	2.89	2.89	0.008	Std deviation
0.36	--	-4.00<<	6.50>>	-0.58	vs. control
473.67	--	1.67	465.00	1.015	Dose=1, mean
5.13	--	2.89	8.66	0.014	Std deviation
-2.34<	--	-4.00<<	0.87	-0.42	vs. control
-4.64<<	--	0.00	-3.16<	0.30	vs. dose=0.1
465.67	--	5.00	460.00	1.001	Dose=10, mean
8.14	--	5.00	10.00	0.003	Std deviation
-3.14<	--	-2.45<	0.00	-1.22	vs. control
-4.78<<	--	1.00	-3.61<	-2.00	vs. dose=0.1
-1.44	--	1.00	-0.65	-1.89	vs. dose=1
					Additive 'B'
471.67	--	6.67	460.00	1.012	Dose=0.1, mean
11.85	--	7.64	10.00	0.050	Std deviation
-1.86	--	-1.58	0.00	-0.46	vs. control
479.33	--	5.00	466.67	1.016	Dose=1, mean
28.88	--	5.00	27.54	0.004	Std deviation
-0.48	--	-2.45<	0.41	-0.60	vs. control
0.43	--	-0.32	0.39	0.11	vs. dose=0.1
485.33	--	3.33	478.33	1.008	Dose=10, mean
6.03	--	2.89	5.77	0.005	Std deviation
-0.37	--	-3.50<	4.16>>	-0.90	vs. control
1.78	--	-0.71	2.75>	-0.11	vs. dose=0.1
0.35	--	-0.50	0.72	-1.41	vs. dose=1
					Additive 'C'
482.00	--	1.67	475.00	1.012	Dose=0.1, mean
28.58	--	2.89	35.00	0.024	Std deviation
-0.33	--	-4.00<<	0.73	-0.53	vs. control
490.00	--	6.67	481.67	1.003	Dose=1, mean
13.23	--	11.55	2.89	0.006	Std deviation
0.25	--	-1.15	6.50>>	-1.06	vs. control
0.44	--	0.73	0.33	-0.80	vs. dose=0.1
447.33	--	36.67	413.33	0.993	Dose=10, mean
14.05	--	20.21	12.58	0.016	Std deviation
-4.18<<	--	1.80	-5.97<<	-1.41	vs. control
-1.89	--	2.97>	-2.87<	-1.34	vs. dose=0.1
-3.83<<	--	2.23>	-9.17<<	-1.06	vs. dose=1

Note: 'vs. . . .' on right side of table are t-test statistics. With 4 df, t=2.132 is significant at the 95% level, t=3.747 is significant at 99%.

to as the columns and the batch reactors. Scum used in the process units was obtained from the Westley southbound SRRA east and west septic tanks. Additive-treated process units were dosed with one of three additives at various dosages, while untreated process units served as controls.

For the column laboratory experiments, several process units were set up, each containing a layer of scum floating on domestic wastewater. The rate of decrease of thickness of each mat as it disintegrated into the wastewater was determined, and these rates were compared between process units. No significant difference was found between the rates of decrease of thickness of scum mats treated with any of the three additives and the rates in the untreated control process units.

In the batch reactor laboratory experiments, measurements were made of scum density, and of volume changes as water was allowed to drain from the scum by gravity. These experiments were conducted on scum as received, and also on scum that had been limed to counteract acidity (pH 5.8). During four-week tests, the volume of unlimed scum decreased by an average of 48% of the original volume, compared to 8% for limed scum. Unlimed scum remained generally lighter than water, but limed scum was heavier and would have sunk. The relatively sensitive batch reactor experiments provided some evidence of interaction between scum and additive that had not been observed in field or column studies.

APPENDIX I

Westley and Turlock SRRA Waste Disposal Systems

Construction Drawings (Reduced)

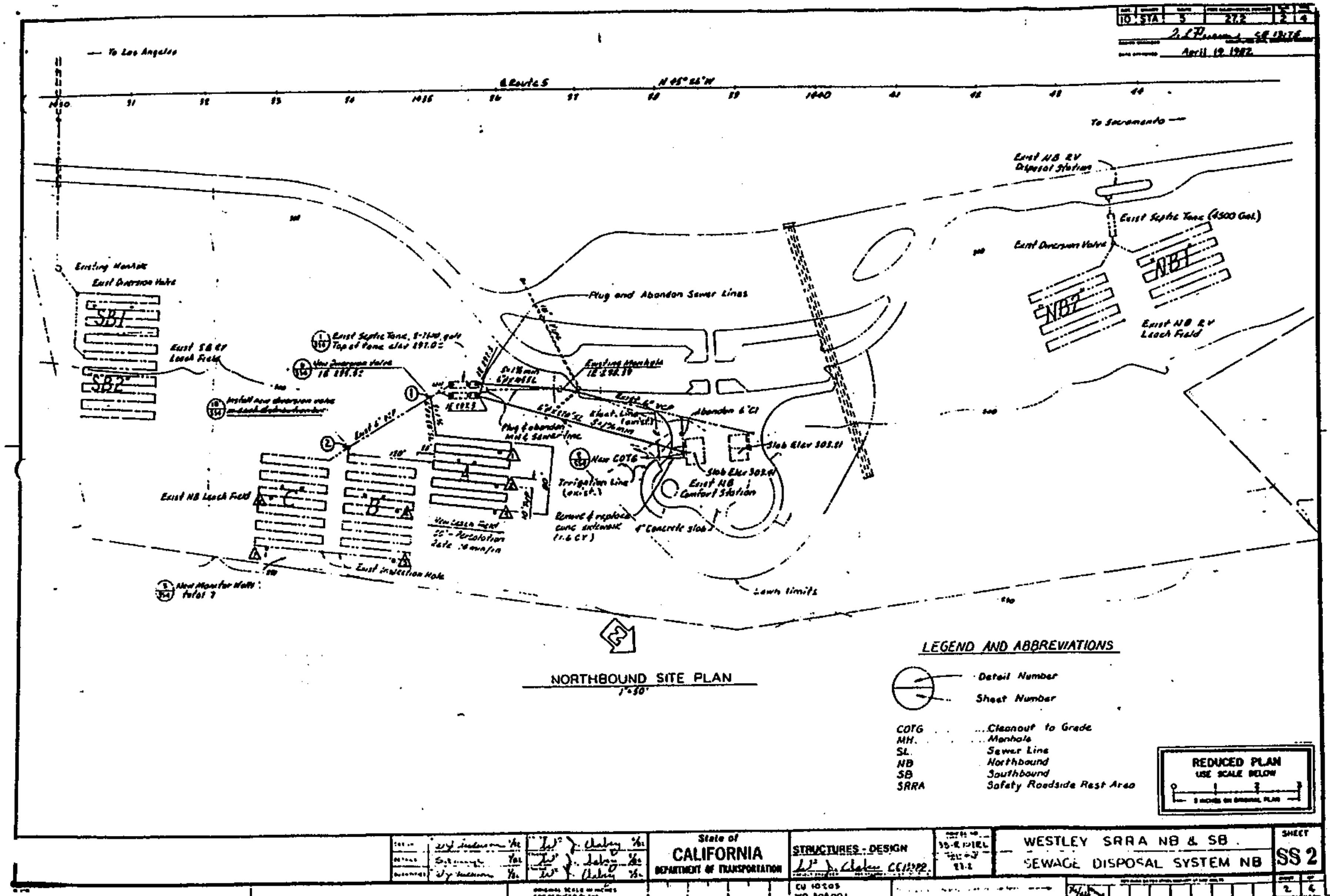


Figure 22: Westley Northbound SRRA Sewage Disposal System.

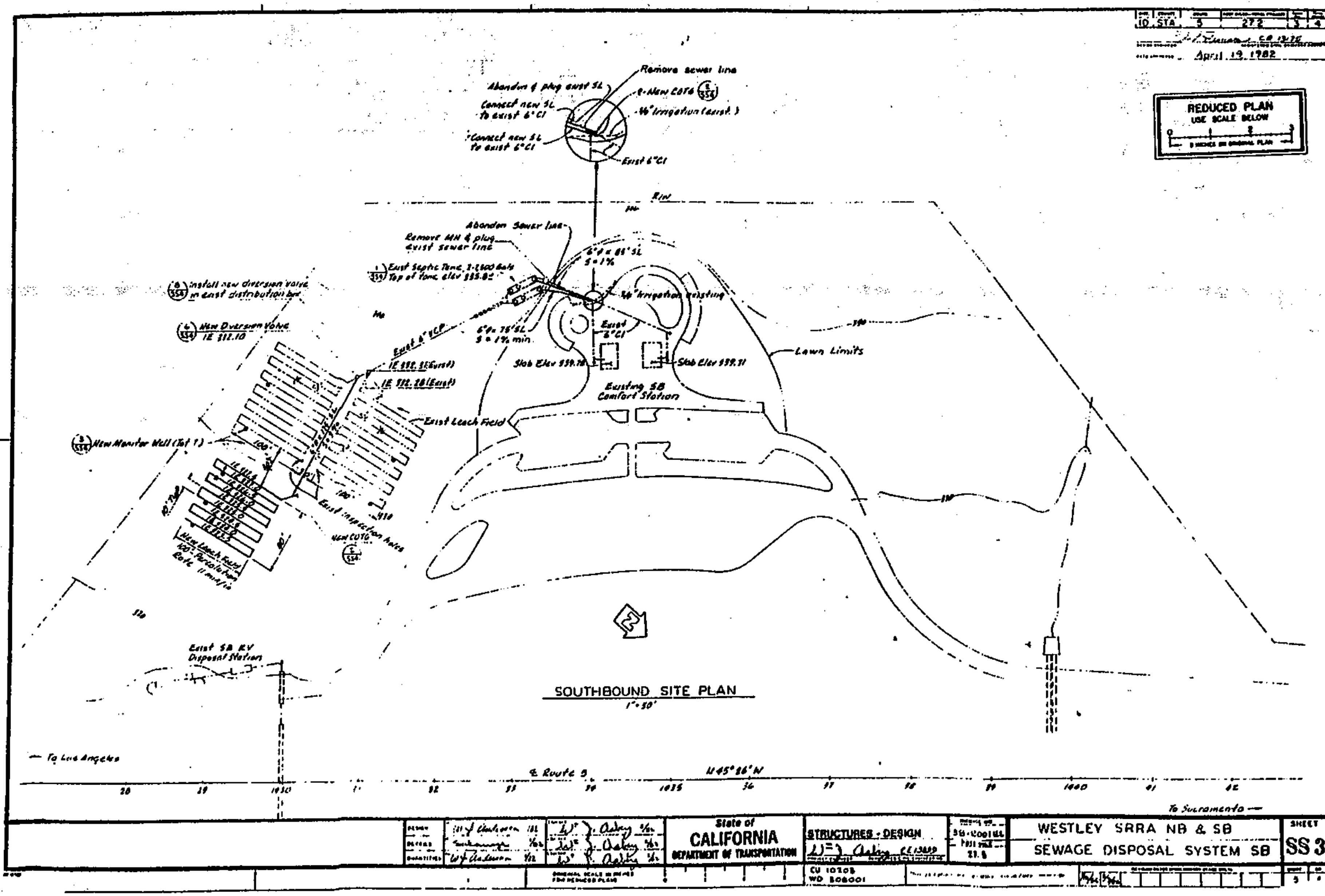


Figure 23: Westley Southbound SRRA Sewage Disposal System.

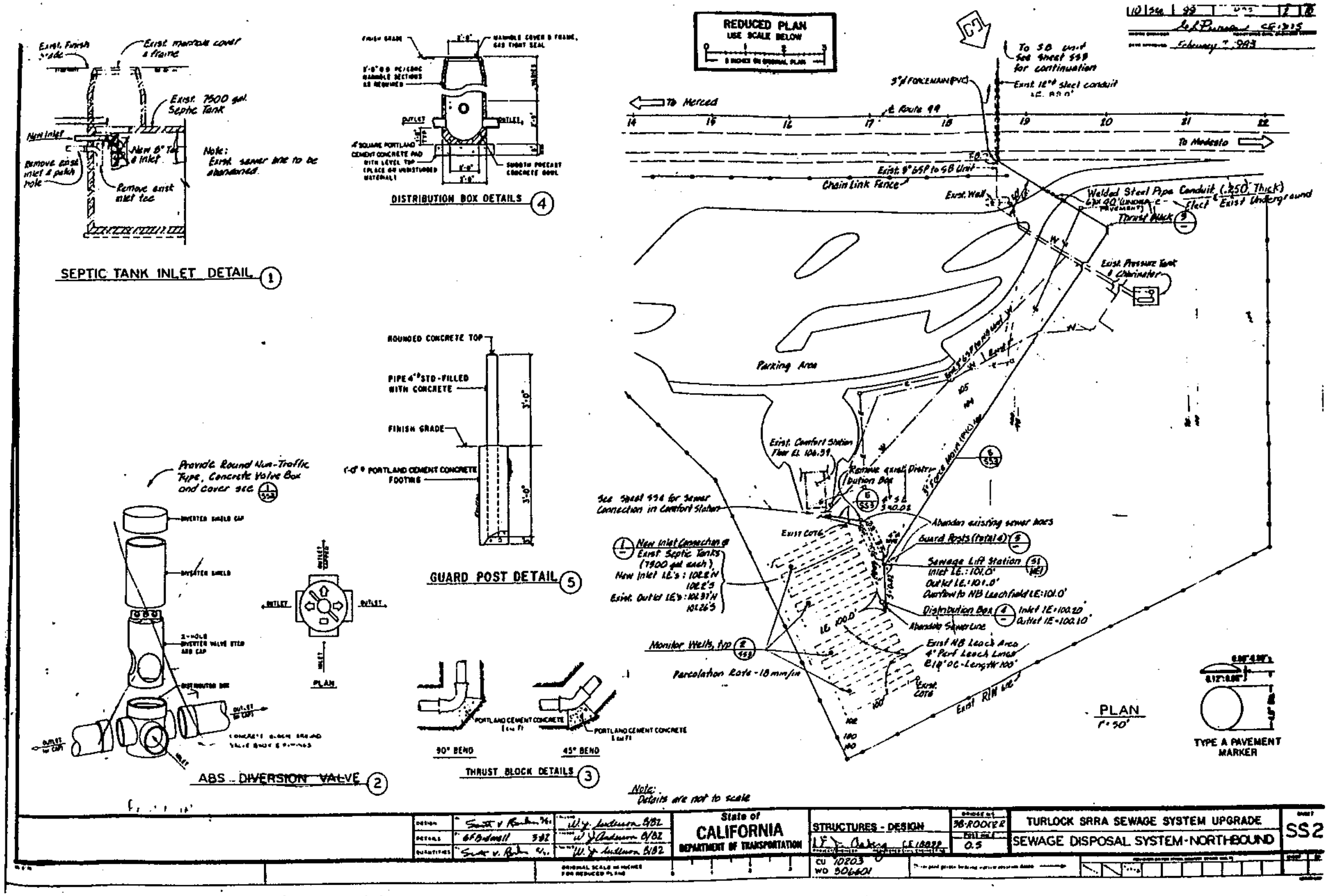


Figure 24: Turlock Northbound SRRA Sewage Disposal System.

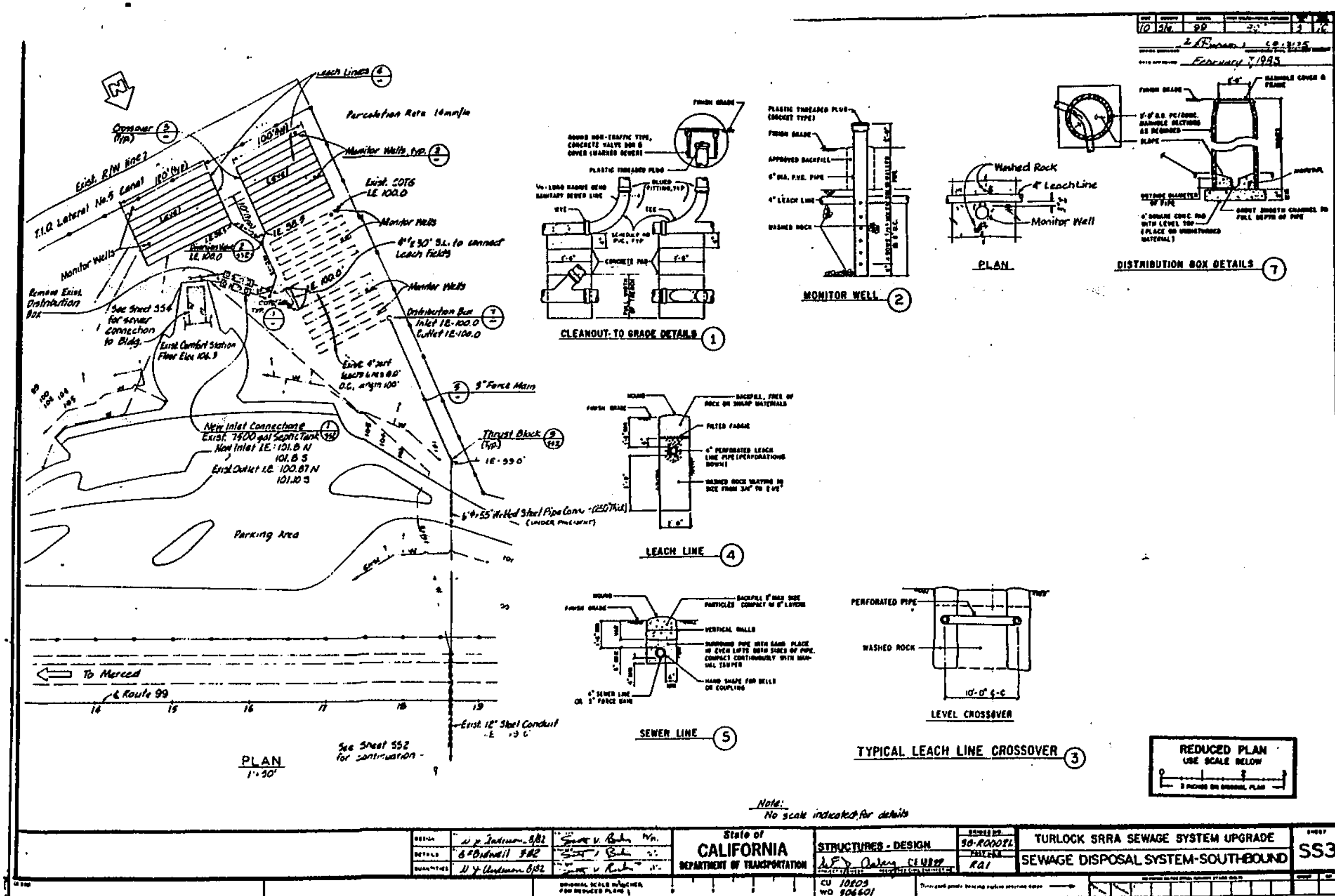


Figure 25: Turlock Southbound SRRA Sewage Disposal System.

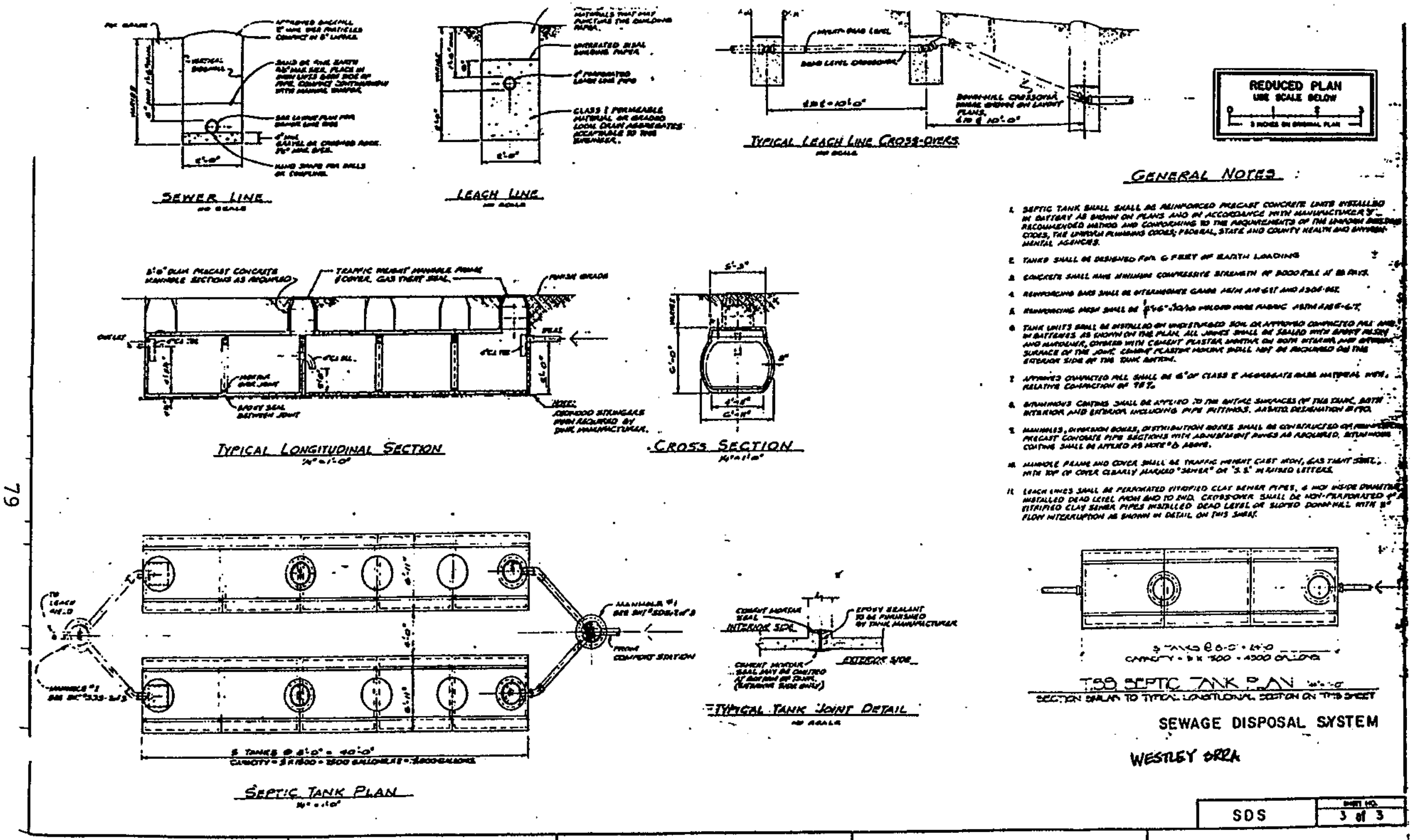


Figure 26: Westley SRRAs Sewage Disposal System Septic Tanks.

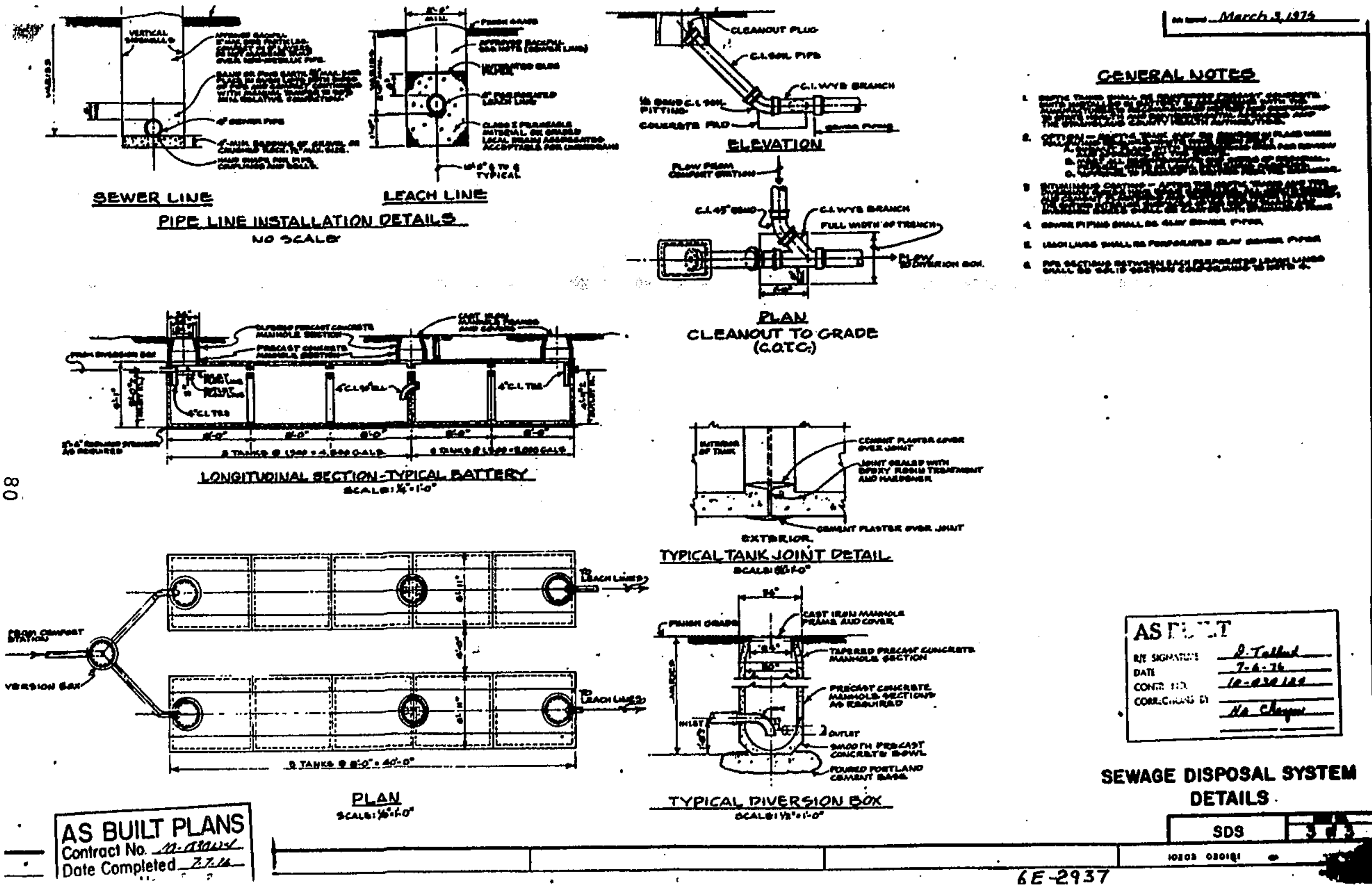


Figure 27: SRRA Sewage Disposal System Details, Septic Tanks.

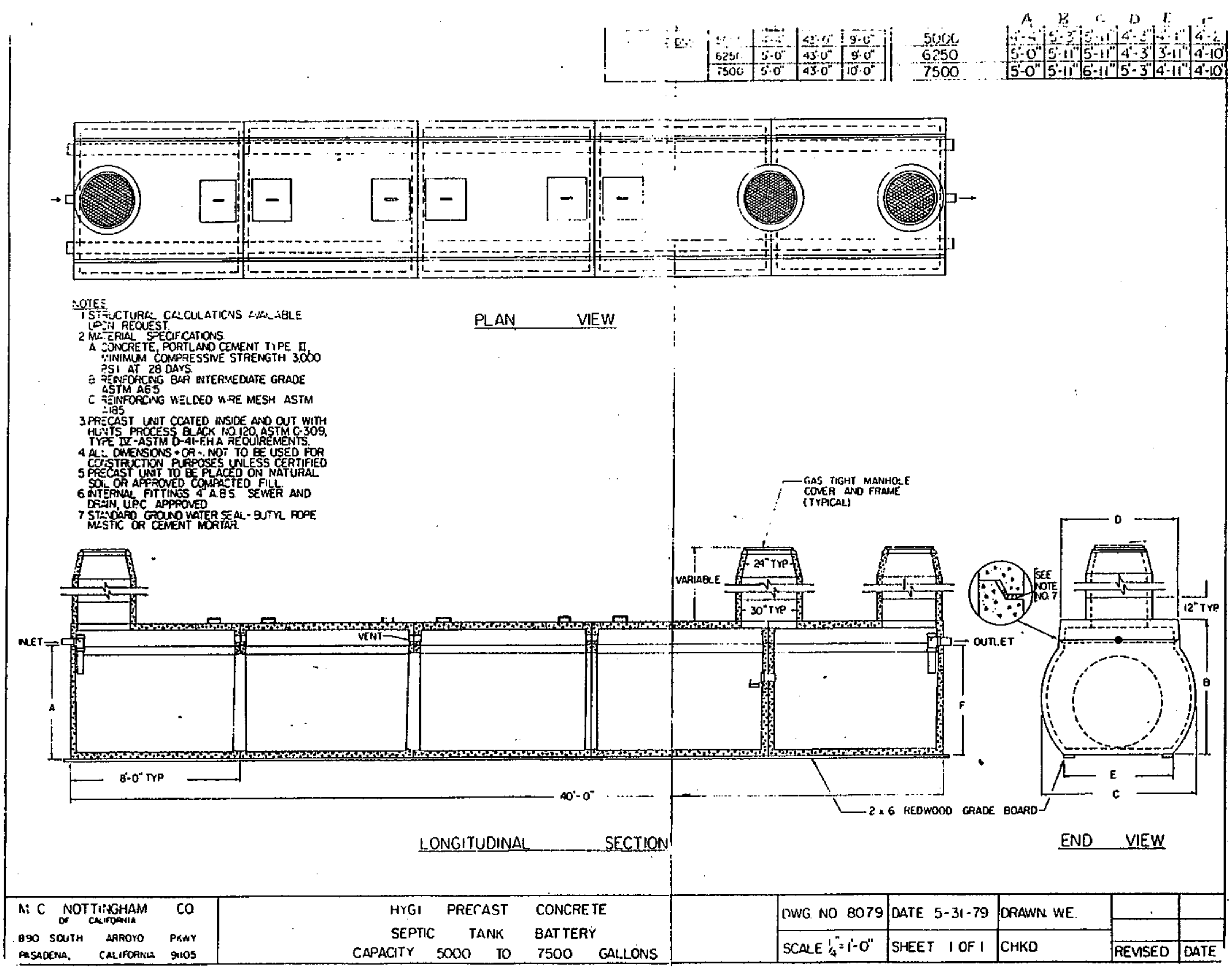


Figure 28: Precast Concrete Septic Tank Battery.