PB81-198160

Lime Stabilization and Ultimate Disposal of Municipal Wastewater Sludges

Camp, Dresser and McKee, Inc.
Boston, MA

Prepared for

Municipal Environmental Research Lab
Cincinnati, OH

May 81

U.S. Department of Commerce
National Technical Information Service
NTIS

PB81-159196

EPA 600/2-81-076
May 1981

LIME STABILIZATION AND ULTIMATE DISPOSAL OF MUNICIPAL WASTEWATER SLUDGES

by

Camp Dresser & McKee Inc.
Boston, Massachusetts 02108

Contract No. 68-03-2803

Project Officer

Roland V. Villiers
Wastewater Research Division
Municipal Environmental Research Laboratory
Cincinnati, OH 45268

MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/2-81- 076	2. ORD Report	3. RECIPIENT'S ACCESSION NO. PB81 198160
4. TITLE AND SUBTITLE LIME STABILIZATION AND ULTIMATE DISPOSAL OF MUNICIPAL WASTEWATER SLUDGES		5. REPORT DATE May 1981
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Camp, Dresser, and McKee, Inc.		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Camp, Dresser, and McKee, Inc. One Center Plaza Boston, MA 02108		10. PROGRAM ELEMENT NO. CAZB1B, D.U. B-113
		11. CONTRACT/GRANT NO. 68-03-2803
12. SPONSORING AGENCY NAME AND ADDRESS Municipal Environmental Research Laboratory - Cin.,OH Office of Research and Development U.S. Environmental Protection Agency Cincinnati, Ohio 45268		13. TYPE OF REPORT AND PERIOD COVERED Final 6/79 to 3/80
		14. SPONSORING AGENCY CODE EPA/600/14

15. SUPPLEMENTARY NOTES

Project Officer: Roland V. Villiers (513) 684-7664

16. ABSTRACT

Twenty-eight lime stabilization facilities were visited. None of these plants were originally designed for sludge lime stabilization. Lime stabilization was instituted either as a permanent sludge handling mechanism to replace a more costly process, as an interim sludge handling technique, as a back-up process, or as a seasonal practice. Three general techniques of lime stabilization were observed. Lime addition to a liquid sludge before land application. Lime addition to a liquid sludge before cake dewatering. Lime addition to a dewatered sludge cake. Bacterial analyses performed at some of the facilities demonstrate that liming a sludge to a pH of 12 is an effective means of total and fecal coliform inactivation. The lime stabilized sludge product is either landfilled, land applied as a liquid sludge, applied to land as a cake, or stockpiled prior to landfilling or land application. Stockpiling of sludge has in some cases resulted in odors upon pile breakdown. Indications are that with pH drop in stockpiles regrowth of organisms can occur. Lime stabilized liquid sludge and cake sludge are land applied to farms and to test areas. According to operators at several facilities, farmers willingly accept the product reporting reduced soil liming requirements and satisfactory crop growth. Despite this, some facilities encountered difficulties in acquiring suitable land application sites.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Sludge Treatment Sludge Disposal	Lime stabilization Sludge stabilization Sludge treatment Land application	13b

18. DISTRIBUTION STATEMENT Release unlimited	19. SECURITY CLASS (This Report) Unclassified	21. NO. OF PAGES 191
	20. SECURITY CLASS (This page) Unclassified	22. PRICE

EPA Form 2220-1 (9-73)

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FOREWORD

The U.S. Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimonies to deterioration of our natural environment. The complexity of that environment and the interplay of its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

In order to acquire data for this report, 28 municipal wastewater treatment facilities practicing lime stabilization of sludge were visited. In these visits, various lime stabilization techniques were observed. Additionally, data regarding bacterial kill and costs were collected. Three general techniques of lime stabilization practiced at the visited sites are: (1) lime addition to a liquid sludge in a batch operation prior to land application; (2) lime addition, in dosages higher than that needed for sludge conditioning alone, to liquid sludge prior to dewatering; and (3) lime addition to a dewatered sludge cake. Bacterial data shows that lime stabilization can be an effective means of reducing coliform bacteria concentrations when the pH of operation is 12.0 or greater. Of course, the effectiveness in bacterial reduction depends on the technique being used. The lime stabilized sludge is being landfilled or land applied in a liquid or cake form.

Francis T. Mayo, Director
Municipal Environmental Research Laboratory

ABSTRACT

Lime stabilization, the addition of sufficient lime to sludge to produce a pH of 12 after two hours of contact, has been accepted by EPA as a method of significantly reducing pathogens in sludge. It has gained popularity as a replacement for both incineration and heat conditioning. Rising costs and uncertain availability of fuel have caused facilities, many of which are in Connecticut, to seek alternatives like lime stabilization.

Twenty-eight lime stabilization facilities were visited. Fifteen of these plants are located in Connecticut; twelve are in other New England states; and one is in New York. None of these plants was originally designed for sludge lime stabilization. Lime stabilization was instituted either as a permanent sludge handling mechanism to replace a more costly process, as an interim sludge handling technique, as a back-up process, or as a seasonal practice.

Bacterial analyses performed at some of the facilities demonstrate that liming the sludge to a pH of 12 is an effective means of total and fecal coliform inactivation. Survival of pathogens and other indicator organisms was not tested at the sites visited. The data collected indicate that to provide for a pH of 12, a lime dose (as CaO) of 20 to 30 percent should be planned for if no sludge samples are available for testing. A dose of greater than 30 percent might be expected for sludges thinner than two percent solids.

Three general techniques of lime stabilization were observed. These techniques are: (1) lime addition to a liquid sludge before land application; (2) lime addition to a liquid sludge before sludge dewatering; and (3) lime addition to a dewatered sludge cake.

Lime addition to a liquid sludge prior to land application is typically a batch process in which lime is added to a tankful of sludge. The lime-stabilized sludge is then pumped to a land application vehicle for removal from site.

At those sites practicing lime addition to a liquid sludge prior to sludge dewatering, stabilization is accomplished by simply increasing the lime dose required for sludge conditioning to obtain the required pH. Conventional sludge conditioning equipment is used. Equipment provided for in original facility design has been sufficient to handle increased dosages needed for stabilization.

Cake sludge is lime stabilized by the addition of hydrated lime directly to a sludge cake screw conveyor. The mixing action of the conveyor is used to mix the lime and sludge.

The following three types of lime were purchased at the sites visited: (1) quicklime (CaO); (2) bagged hydrated lime ($Ca(OH)_2$); and (3) lime slurry. The lime slurry used most frequently is carbide lime or chemical lime, a by-product of acetylene production.

Bagged hydrated lime and carbide lime slurry are the economical forms to use in plants smaller than 5 mgd. At larger facilities, the slaking of quicklime becomes economical. With facilities larger than 5 mgd, high manpower requirements make the handling of bagged hydrated lime more costly and inconvenient than carbide lime slurry or quicklime. With larger plant size, quicklime becomes more economical because of the chemical's low cost.

The lime-stabilized sludge product is either landfilled, land applied as a liquid sludge, applied to land as a cake, or stockpiled prior to landfilling or land application. Stockpiling of sludge has, in some cases, resulted in odors upon pile breakdown. Indications are that, with the pH drop in stockpiles, regrowth of organisms can occur.

Lime-stabilized liquid sludge and cake sludge are land applied to farms and to test areas. According to operators at several facilities, farmers willingly accept the sludge product, reporting reduced soil liming requirements and satisfactory crop growth. Despite this, some facilities encountered difficulties in acquiring suitable land application sites.

This report was submitted in fulfillment of Contract No. 68-03-2803, Work Effort 3, by Camp, Dresser and McKee, Inc., under sponsorship of the U.S. Environmental Protection Agency. This report covers the period 6/79 to 3/80, and work was completed as of 12/80.

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ACKNOWLEDGMENTS

"Review of Techniques for Stabilization of Municipal Wastewater Sludges with Lime and Their Ultimate Disposal" was prepared under the direction of Mr. Paul W. Prendiville, officer-in-charge, and Dr. Albert B. Pincince, project manager. Principal investigators were Mr. Robert M. Otoski (project engineer) and Mr. David F. Young. The assistance of Ms. Juliette L. Brown, Mr. John F. Donovan, Ms. Ellen M. Connors, and Ms. Suzanne M. Belleville is gratefully acknowledged.

EPA project officer was Mr. Roland V. Villiers, who provided valuable direction and guidance.

SECTION 1

INTRODUCTION

GENERAL

In wastewater treatment, it is often desirable to stabilize sludge, making it less odorous and putrescible and decreasing its pathogen concentration. The level of pathogens in sewage sludge must be reduced if it is to be applied to the land surface or incorporated into the soil. Several processes are available to satisfy this requirement, although they achieve varying levels of pathogen reduction. These processes include aerobic digestion, air drying, anaerobic digestion, composting, and lime stabilization.

Lime stabilization has gained popularity as a replacement for incineration and heat treatment, processes which have been affected by rising costs and uncertain availability of fuel. In some locations, lime stabilization further processes aerobically digested sludge that would not otherwise have achieved stabilization because of inadequate solids destruction.

Adding lime to sludge increases its pH and thus discourages the growth of organisms that might be harmful or promote odors. It does not, however, decrease the content of volatile material. According to EPA, sludge is lime-stabilized when the addition of lime increases the sludge's pH to at least 12, two hours or more after the liming occurs. The addition of more lime is normally required for sludge to reach pH 12 than is required for it to achieve conditioning, i.e., an alteration of sludge properties to improve dewatering characteristics. This is an important point, especially in view of the fact that some plant operators purporting to be stabilizing sludge are not adding sufficient lime to increase the pH to 12, and therefore are only conditioning it. Some sludges require such large quantities of lime for conditioning that stabilization occurs simultaneously.

Because of the concentration of lime stabilization facilities in Connecticut, EPA asked Camp Dresser & McKee to investigate the Connecticut facilities and, at the same time, those in other areas of New England. (Because of its proximity, Rochester, New York's Northwest Plant was also included in the survey.)

This guide was prepared based on information obtained from visits to 28 plants, previously published information, suggestions from manufacturers, and our past technical experience. It is intended to serve as a practical source of information for designers, operators, and others, providing information on design and operation of lime stabilization facilities, describing the effectiveness of lime stabilization for pathogen kill, and comparing lime stabilization with other stabilization processes. The work was carried out under contract No. 68-03-2803 issued by EPA's Municipal Environmental Research Laboratory, Office of Research and Development.

PLANTS VISITED

We identified facilities practicing lime stabilization in New England by contacting the regulatory agency of each state. Because of the concentration of lime stabilization plants in Connecticut, we also called each wastewater treatment plant in that state. We visited all the lime stabilization plants identified except for two that were not available for study.

Our visits revealed that some plants reported to be using lime stabilization were in fact only conditioning because the pH in the sludge was less than 12. Some information on those plants and their lime conditioning was useful to this study, however, and for that reason has been retained in this report.

During the site visits we interviewed the plant superintendent or the chief plant operator to obtain information concerning the entire treatment plant, the selection and history of the lime stabilization process, and details regarding the sludge management program. We solicited comments; examined plant records concerning equipment reliability, system costs, and the final sludge disposal operation; and collected data from any special studies on the lime stabilization process or system. With plant personnel, we inspected lime and sludge handling areas and equipment. We also visited landfill and land application sites. We did not take our own measurements, relying instead on plant records and statements of the operator.

Table 1 summarizes the data collected, including general information on the plants and their lime stabilization systems. Detailed plant-by-plant compilations of all pertinent data collected through the plant visits are found in the Appendix which contains information regarding equipment materials and sizes, techniques, and manpower used in lime handling and loading, cost data, and results of special studies.

The present average flow of the facilities studied ranges from 0.2 to 20 million gallons per day (mgd).** Fourteen (50 percent) of these plants have present average flows of less than 3.0 mgd, and twenty (71 percent) have flows of 6.0 mgd or less. Of those five having a present average flow of greater than 10 mgd, only the Lewiston-Auburn, Maine and the Rochester, New York facilities are truly lime stabilization facilities on a full-time basis. Two of the four plants use lime only in a back up capacity: New Haven, Connecticut (as a back up to incineration) and

** For convenience of the reader, the English system is mainly used in this report. A metric conversion table is given in the Appendix.

TABLE 1

DATA FROM LIME STABILIZATION FACILITIES (page 1 of 4)

	(1) Enfield CT	(2) Glastonbury CT	(3) Groton (Town) CT	(4) Killingly CT	(5) Middletown CT	(6) Naugatuck CT	(7) New Haven (East St.) CT
PLANT DATA							
Plant Size (mgd)	10.5	3.6	5.0	8.0	6-10	10.3	22.5
Average Flow (mgd)	4.5	1.1	2.5	2.0	4	5.0	15.5
Digestion	Aerobic Digestion	None	None	None	None	None	None
Type of Dewatering	Vacuum Filter	Centrifuge	Centrifuge	Vacuum Filter	Vacuum Filter	Vacuum Filter	Vacuum Filter
Storage of Limed Sludge	Stockpile	Stockpile	Concrete Tank	None	None	None	None
Disposal of Limed Sludge	Stockpile/ apply	Pile/Compost/ Landfill	Landfill	Landfill	Landfill	Landfill	Landfill
LIME STABILIZATION SYSTEM							
Sources of Sludge Limed	Primary/ Secondary	Primary/ Secondary	Primary/ Secondary	Primary/ Secondary	Primary/ Secondary	Primary/ Secondary	Primary
Type of Sludge Limed	Mix of Raw/ Digested	Cake	Cake	Thickened	Thickened	Thickened	Thickened
Percent Solids of Sludge Limed	4-8	17-18	16	4.5 - 6.5	3-4	5	10
Lime Dose (percent of dry sludge solids as CaO)	25-30	6	30	19	23	14-25	No Data
Other Chemicals Added	Ferric Chloride	Polymer	Polymer	Ferric Chloride	Ferric Chloride	Ferric Chloride or Polymer	None
Method of Liming	At Vacuum Filter	Sprinkle Dry	Bags to Pit	At Vacuum Filter	At Vacuum Filter	At Vacuum Filter	At Vacuum Filter
Reported pH	12	11-12	11.5 - 12	11.5 - 12	12	11.8 - 12.5	12
Type of Lime Purchased	Slurry	Hydrated	Hydrated	Hydrated	Hydrated	Quicklime	Hydrated
Percent Solution of Lime Applied (as $Ca(OH)_2$)	20	Dry	Dry	11	5	11	17
Use of System	Permanent	Interim	Interim	Permanent	Permanent	Permanent	Back-up

TABLE 1 (Cont.)

DATA FROM LIME STABILIZATION FACILITIES (page 2 of 4)

	(8) North Canaan CT	(9) So. Windsor CT	(10) Stafford CT	(11) Stamford CT	(12) Stratford CT	(13) Thompson CT	(14) Vernon CT
PLANT DATA							
Plant Size (mgd)	0.35	3.75	2	20	11.5	1.5	6.4
Average Flow (mgd)	0.2	1.3	2.5	20	8.0	0.2	3.5
Digestion	Aerobic Digestion	Aerobic Digestion	None	None	Aerobic Digestion	Aerobic Digestion	None
Type of Dewatering	None	Drying Beds	Vacuum Filter	Belt Filter Press	Vacuum Filter	None	Vacuum Filter
Storage of Limed Sludge	Unmixed Tank	None	None	None	None	Digester	None
Disposal of Limed Sludge	Apply	Stockpile	Stockpile/ Landfill	Landfill	Stockpile/ Landfill	Apply	Landfill
LIME STABILIZATION SYSTEM							
Source of Sludge Limed	Secondary	Primary/ Secondary	Secondary	Primary/ Secondary	Primary/ Secondary	Secondary	Primary
Type of Sludge Limed	Digested	Digested	Thickened	Cake	Mix of Raw/ Digested	Digested	Thickened
Percent Solids of Sludge Limed	2	1.2	5	23	3.1	2	9
Lime Dose (percent of dry sludge solids as CaO)	5	21	16	18-20	18	16	22
Other Chemicals Added	None	None	Ferric Chloride	Polymer	Polymer	Polymer	Ferric Chloride
Method of Liming	Add to Storage	Add to Digester	At Vacuum Filter	Sprinkle Dry	At Vacuum Filter	Add to Digester	At Vacuum Filter
Reported pH	12	12	11.5	12.1	11.8 - 12.0	12	11.8 - 12.0
Type of Lime Purchased	Hydrated	Slurry	Hydrated	Hydrated	Slurry	Hydrated	Slurry
Percent Solution of Lime Applied (as $Ca(OH)_2$)	Dry Hydrate	As Received	11	Dry Hydrate	As Received	19	35
Use of System	Seasonal	Interim	Permanent	Backup	Interim	Permanent	Interim

TABLE 1 (Cont.)

DATA FROM LIME STABILIZATION FACILITIES (page 3 of [illegible])

	(15) Willimantic CT	(16) Bath ME	(17) Falmouth ME	(18) Kennebec (Waterville) ME	(19) Lewiston-Auburn ME	(20) Portland (Westbrook) ME	(21) Scarborough ME
PLANT DATA							
Plant Size (mgd)	5.5	1.6	1.5	12.7	14.2	4.5	0.4
Average Flow (mgd)	2.4	2.6	0.5	8.4	11.0	2.0	0.3
Digestion	None	None	Aerobic Digestion	None	None	None	Aerobic Digestion
Type of Dewatering	Vacuum Filter	Vacuum Filter	None	Vacuum Filter	Vacuum Filter	Vacuum Filter	None
Storage of Limed Sludge	None	None	Aerated	None	None	None	None
Disposal of Limed Sludge	Stockpile/ Apply	Landfill/ Apply	Apply	Landfill/ Apply	Landfill	Landfill	Apply
LIME STABILIZATION SYSTEM							
Source of Sludge Limed	Primary/ Secondary	Secondary	Secondary	Primary/ Secondary	Primary/ Secondary	Secondary	Secondary
Type of Sludge Limed	Thickened	Thickened	Digested	Thickened	Thickened	Thickened	Digested
Percent Solids of Sludge Limed	3-4	7	1-3	4	5-8	5-6	2
Lime Dose (percent of dry sludge solids as CaO)	15	10	5	15	16-18	25	4
Other Chemicals Added	Ferric Chloride	Ferric Chloride	None	Ferric Chloride	Ferric Chloride	Ferric Chloride	None
Method of Liming	At Vacuum Filter	At Vacuum Filter	Add to Storage	At Vacuum Filter	At Vacuum Filter	At Vacuum Filter	To Sludge Pipeline
Reported pH	10.5 - 11.0	11.5 - 12.0	11.5 - 12.5	11.5	11.5 - 12	11.5 - 12.5	11.5 - 12.0
Type of Lime Purchased	Slurry	Hydrated	Hydrated	Quicklime	Quicklime	Hydrated	Hydrated
Percent Solution of Lime Applied (as $Ca(OH)_2$)	10	8	11	11	5	10	Dry
Use of System	Permanent	Permanent	Permanent	Permanent	Permanent	Interim	Seasonal

TABLE 1 (Cont.)

DATA FROM LIME STABILIZATION FACILITIES (page 4 of 4)

	(22) Somersworth NH	(23) Rochester NY	(24) Buckman Pt. RI	(25) E. Providence RI	(26) Woonsocket RI	(27) Burlington (Main) VT	(28) Burlington (Riverside) VT
PLANT DATA							
Plant Size (mgd)	2.4	15	31	10.4	16	5.0	1.0
Average Flow (mgd)	1.6	12	23	6	8	4.5	0.7
Digestion	None	None	Anaerobic	None	None	Anaerobic	Anaerobic
Type of Dewatering	Vacuum Filter	Vacuum Filter	Vacuum Filter	Vacuum Filter	Vacuum Filter	Vacuum Filter	Vacuum Filter
Storage of Limed Sludge	Stockpile	None	None	None	None	None	None
Disposal of Limed Sludge	Apply	Apply	Landfill	Landfill	Landfill	Landfill	Landfill
LIME STABILIZATION SYSTEM							
Source of Sludge Limed	Secondary	Primary/ Secondary	Primary/ Secondary	Primary/ Secondary	Primary/ Secondary	Secondary	Secondary
Type of Sludge Limed	Thickened	Thickened	Digested	Thickened	Thickened	Thickened	Thickened
Percent Solids of Sludge Limed	3-4	5	3	5	5	4.5	4.5
Lime Dose (percent of dry sludge solids as CaO)	18-25	30-40	18-19	20-22	10-12	20-30	20-30
Other Chemicals Added	Polymer/ Ferric Chloride	Polymer	Ferric Chloride	Ferric Chloride	Ferric Chloride	Ferric Chloride	Ferric Chloride
Method of Liming	At Vacuum Filter	At Vacuum Filter	At Vacuum Filter	At Vacuum Filter	At Vacuum Filter	At Vacuum Filter	At Vacuum Filter
Reported pH	11-12	12.2	11	12	11	11.5	11.5
Type of Lime Purchased	Hydrated	Quicklime	Slurry	Hydrated	Quicklime	Hydrated	Hydrated
Percent Solution of Lime Applied (as $Ca(OH)_2$)	7	Up to 45	33	19	12	17	17
Use of System	Permanent	Seasonal	Permanent	Interim	Interim	Interim	Interim

Stamford, Connecticut (to coincineration). At Bucknam Point, Rhode Island, lime is used primarily as a conditioning agent and for odor control.

At no facility had lime stabilization been the original design intent. At two facilities, lime was used as a back-up to sludge incineration; ten plants are using lime as an interim procedure prior to institution of composting or incineration; thirteen are permanently using lime as a replacement for incineration or heat treatment; and three are using lime on a seasonal basis.

In addition to these plants using lime on a planned basis, two plants in Connecticut reported using lime in emergency situations. In both cases, anaerobic digesters had to be emptied and their contents were lime stabilized.

FINDINGS

1. Lime stabilization can be simple and inexpensive. Required equipment is typically a dry storage area for bagged lime or a storage tank with a mixer for slurry storage, a steel tank with a mixer and a dust collector for slurry makeup (or without dust collection if only for slurry dilution), a slurry metering pump, and a mixed tank to provide the sludge/lime detention period. This system is followed with a dewatering system, or sludge can be pumped directly to a land application truck.

   In the simplest of systems, only a sludge/lime mixing tank and a land application truck is required. Lime slurry is purchased when needed and used immediately. Running the system requires little training and little technical knowledge.

2. Lime stabilization is effective as a back-up or as an interim system. Lime is widely available, can be stored, and may already be in use at the plant in another capacity. When used as back-up, a lime stabilization system may be put on-line on short notice and has a simple start-up procedure. In addition, the capital cost of the equipment selected can be very economical, especially in a labor-intensive, back-up system design.

   If an interim sludge handling system is required, lime stabilization may be inexpensively accomplished using equipment already available at the plant site. At a number of plants visited, lime stabilization took place in available sludge conditioning tanks, in existing aerobic digesters, in unused sludge tanks, and by direct application to sludge conveyance systems.

3. Present systems can be upgraded by applying lime stabilization. At the sites visited, lime was used to upgrade the previous systems in three ways. It was used to improve the degree of stabilization

achieved by aerobic and anaerobic digesters; applied to systems that had been disposing conditioned, but unstabilized sludge; and applied as an odor control device. Typically, equipment required was either available onsite or required little expense.

4. Lime stabilization has been instituted as a less costly alternative both to incineration and to heat treatment. A number of treatment facilities visited had instituted lime stabilization to replace sludge incineration or heat treatment, largely because of the effects rising fuel costs have had on the costs of these two processes. In addition, the treatment plant facilities utilizing lime stabilization were generally small and had difficulty keeping incinerators loaded. Fuel is wasted keeping the incinerator temperature up during low load periods.

5. Lime stabilization is well-suited for smaller plants. Twenty of the 28 plants visited (71 percent) have present average flows of 6.0 mgd or less. Of the five plants receiving more than 10.0 mgd, only one is truly lime stabilizing on a full-time basis.

   Lime stabilization costs are typically operation and maintenance intensive. The costs of chemicals, which are a major portion of the total cost, show little economy of scale.

6. The economical form of lime depends on plant size and location. Bagged hydrated lime or lime slurry are the least expensive forms for smaller plants (up to about 5 mgd), and quicklime is appropriate for larger plants. If carbide lime (which is a waste product) can be economically delivered, its use is appropriate for a wide range of plant sizes.

7. Stockpiling may adversely affect the bacteriological quality of a lime-stabilized sludge. Although lime stabilization of sludge results in a high coliform kill, sludge organics are not destroyed and viable organisms do remain. Surviving pathogens can "regrow" or can recover from inactivation if sludge pH drops, causing the sludge to become "unstabilized". Evidence of this was noted at various sites. Stockpiles of a few months to a year old, when broken down, emitted an odor signifying bacteria infestation.

   Stockpiling of sludge that has been lime stabilized, dewatered, and allowed to dry on sandbeds has shown significant improvement over the stockpiling of wet cake.

8. A program for applying lime stabilized sludge to land can be successful.

   a. Treatment plant operators have reported that farmers initially skeptical have come to look forward to receiving the sludge as their crop growth has improved. In the study area, lime is normally applied to the land to maintain soil pH. The addition of lime-stabilized sludge reduces or eliminates the need for this lime addition.

   b. The sludge has successfully been used as a soil builder. Stripped lands are improved by the organic content and moisture holding capacity of the sludge.

   c. Lime-stabilized sludge application operations have had few problems with odors. The odors emitted have been described as being less offensive than those emitted when manure is spread. Odor problems have developed only when stockpiled sludge was applied on warm days.

9. Lime stabilization systems may be subject to poor operational procedures. Because the effects of incomplete stabilization are not immediately apparent and do not occur onsite, an improper lime dose may not be recognized. In addition, where lime is added prior to dewatering, the lime dose required for stabilization may be confused with the dose required for sludge conditioning. This may result in attainment of lower sludge pH than required for stabilization. Cutting lime dose is an easy, but improper, means of cutting chemical costs.

10. Treatment plant operators should be educated on the goals of lime stabilization. Operators need to be made more aware of the importance of adding an appropriate quantity of lime to the sludge and supplying adequate mixing and detention time. This effort would help reduce problems caused by poor operation and could reduce the cases of incomplete stabilization. Additionally, it is important for the operators to understand that the primary goal of stabilization is not for aesthetic odor control, but to protect public health.

RECOMMENDATIONS FOR FURTHER STUDY

1. A study should be performed to determine the effectiveness of lime addition to conventionally designed dewatering systems. As shown in this report, existing plants presently dewatering sludge are converting to lime stabilization with little additional capital expense. Existing sludge conditioning drums are being used for lime addition. The mixture of sludge and lime remains in a liquid form for about 15 minutes in the vacuum filter sludge vat prior to dewatering. Initial mixing is good and pH values are kept at sufficient values for the required time, but during the detention period the sludge is sitting

in a cake form. It is unknown whether a 15-minute detention of the liquid is sufficient. A study should be conducted to determine the required detention time. Cake samples taken at various detentions would be analyzed for pathogen numbers.

2. Lime stabilization of a cake sludge should be evaluated. A study should be performed to determine if sludge can be stabilized by adding lime to a cake form of sludge. The initial mixing of sludge and lime and the effects of having only a low proportion of free water to convey the hydroxyl ions must be determined. Such systems are worth evaluating. Operating systems have been low capital, providing inexpensive stabilization techniques.

3. Regrowth in stockpiles of lime stabilized sludge cake needs to be quantified. If sludge cake is to be land applied, stockpiling allows for flexibility in application schedules. Sometimes stockpiled, lime-stabilized sludge gives off odors when piles are broken down, depending on stockpile age. These odors may signify bacterial regrowth. In order to evaluate whether or not stockpiling impacts the efficiency of lime stabilization, tests should be performed to determine bacterial regrowth over time.

4. The effects of sand bed drying of sludge prior to stockpiling should be evaluated. Allowing sludge to dry prior to stockpiling appears to be effective in reducing odors that occur when piles are broken down. A bacterial analysis of the results is recommended.

5. Fecal streptococci should be tested in future studies. The bacterial analyses performed at the sites visited were for total coliform or for fecal coliform. Fecal streptococci is an indicator that is more resistant to inactivation by lime. Researchers should consider studying fecal streptococci, and possibly actual pathogens as well, in future studies.

SECTION 2

LIME REQUIREMENTS AND THE EFFECT OF LIME STABILIZATION

LIME REQUIRED TO REACH pH 12

We were able to determine required lime dosages for most of the plants visited, either through interviews with the operators, or by calculating the dosage from information available. We found a large variation in lime dosage -- 5 to 35 percent as CaO -- for plants reported to reach pH 12. The average dosage was between 20 and 25 percent.

We found little correlation with either sludge type or solids concentration. Table 2 shows the lack of correlation for sludge type, and the scatter in Figure 1 shows no correlation with sludge solids for the plants surveyed. A weak trend develops when data from other sources are added. The additional data suggest that sludges thicker than 2 percent can be expected to require between 10 and 25 percent lime; provision for 20 to 30 percent should be sufficient if sludge samples cannot be tested. For sludge thinner than 2 percent, lime dosages of 30 percent or more would be required.

PATHOGEN KILL

None of the plants surveyed had conducted extensive studies to assess the effects of lime stabilization on pathogen concentrations. Only five plants reported testing: Falmouth, Bath, and Kennebec, Maine; Enfield, Connecticut; and Rochester, New York. With the exception of a single test on viruses at Rochester, all tests were on bacteria. Most tests were with coliform bacteria. There were no attempts to assess quantities of parasites.

At the Falmouth, Maine treatment facility, bacterial analysis performed on a single, liquid sludge sample, lime-stabilized at a pH of 12.5, showed that no fecal coliform, total coliform, or fecal streptococci were present.

Tests at the other four plants were conducted on vacuum filter cake. Enfield cake, at pH 12, and Rochester cake, at pH 12.2, yielded negative results in tests for total coliform bacteria. Tests on Rochester sludge were also negative for fecal coliform.

Tests on cakes at lower pH values yielded positive results for indicator organisms. At Bath, Maine, sludge cake at a pH of 11.5 contained 100 fecal coliform per 100 ml. While Kennebec, Maine, cake at pH 11.7

TABLE 2

LIME DOSES USED AT SITES VISITED

(Sites with Complete Record Attaining pH 12)

Sludge Type	Number of Sites	Average Sludge Solids (percent)	Sludge Solids Range (percent)	Average Lime Dose (percent as CaO)	Lime Dose Range (percent as CaO)
Raw Sludges	10	5.7	3.1 - 9.0	22	10 - 35
Primary and Secondary	7	5.7	3.1 - 9.0	22	17 - 35
Secondary	3	5.6	4.0 - 7.0	20	10 - 25
Aerobically Digested Sludges	4	3.3	2.0 - 6.0	17	5 - 27
Primary and Secondary	2	4.5	3.1 - 6.0	23	18 - 27
Secondary	2	2.0	2.0	11	5 - 16

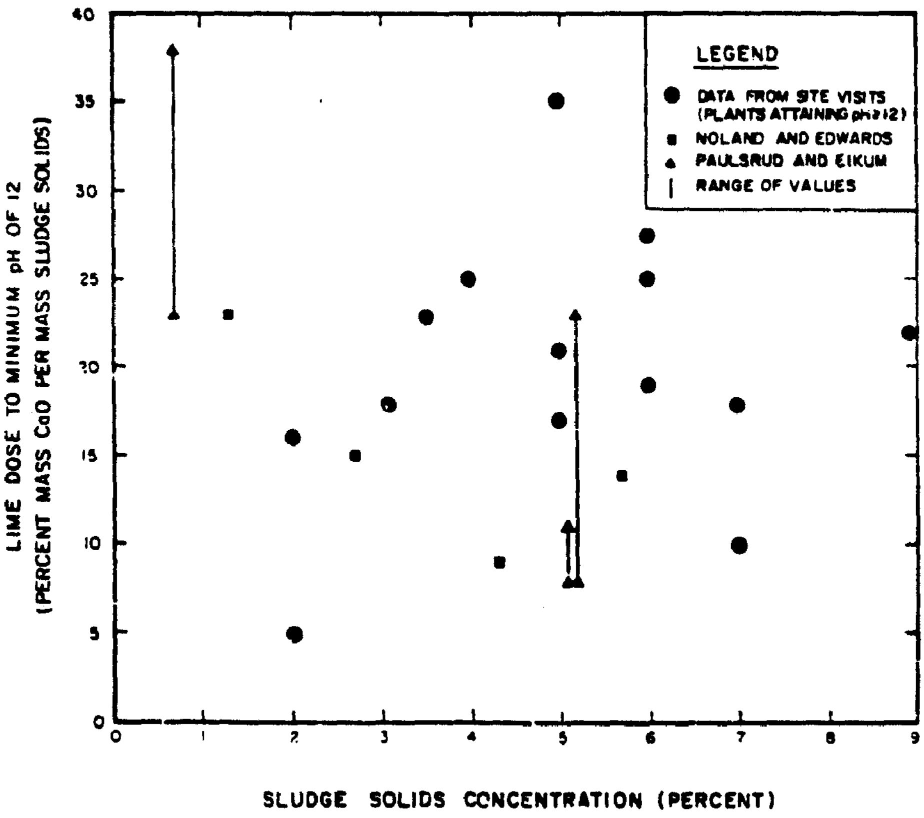


FIG. 1 LIME DOSAGES AT VARIOUS SLUDGE SOLIDS CONCENTRATIONS

contained 150 fecal coliforms per gram and 460 total coliforms per gram, the same plant's cake at pH 12 showed no coliform. (Fecal coliform content of cake without stabilization is roughly 4 x 10^6 per gram (2)).

The limited tests on vacuum filter cake at the facilities surveyed suggest that substantial coliform bacterial kills can be obtained at pH 12 using conventional vacuum filter conditioning drums and vats. Nevertheless, further study, including studies using other organisms, should be conducted. The detention time of the liquid sludge in the vacuum filter vat is only about 15 minutes, but published studies demonstrating the effectiveness of lime stabilization deal with a liquid sludge limed to a pH of 12 or greater for a detention period of 30 minutes or more.

Farrell et al (2) showed the importance of holding the sludge in a liquid state for a contact period prior to sludge filtering. In their study, a liquid sludge was lime stabilized and held in a liquid state. A second sample was filtered two minutes after lime addition. One-half hour after lime addition, the fraction of original bacteria remaining in the liquid sludge was lower than that in the cake. Coliform and fecal streptococci were monitored in this test.

Studies conducted by Counts and Shuckrow (1), Farrell et al (2) and Noland et al (4) tested for the inactivation of fecal coliform and fecal streptococci indicators. The results show fecal streptococci to be more resistant to inactivation by lime than the coliform species. The study of fecal streptococci, which was not conducted at the vacuum filter plants, would be a more stringent test of the effectiveness of this lime stabilization technique.

The literature is lacking in results with respect to viruses and parasites. We found no citations on the effect of lime addition on virus concentrations in sludge. While a single test at Rochester found no viruses in vacuum filter cake, this result needs to be verified to determine if the finding is universally true. Other studies (2, 4) concluded that lime stabilization had little effect on parasites such as hookworms, amoebic cysts, and ascaris ova. In one study (6), salmonella and intestinal parasites were killed within two hours after quicklime addition to pH 13 to a cake sludge. In that study, the sludge temperature had reached 176°F.

At two of the facilities, Glastonbury and Stamford, Connecticut, lime stabilization was accomplished by the addition of hydrated lime directly to a dewatered sludge cake. These facilities reported that odors were effectively controlled in cake to which lime had been added after dewatering.

While the absence of odors is an indirect indicator of stabilization, there is no direct evidence available regarding the effectiveness of this method for destroying pathogens. Inadequate mixing of the lime and cake might produce inconsistent kills. We suggest that kill of organisms obtained when mixing lime with cake be studied inasmuch as it is inexpensive and readily adaptable to existing facilities.

REGROWTH OF ORGANISMS

When organisms remain after stabilization, or when the sludge becomes reinfected, the organisms will increase in number or recover from inactivation as the pH of the sludge decreases with time. Because these sludges could become hazards or nuisances if improperly handled, prompt disposal or application of lime-stabilized sludges is a desirable precautionary measure.

Of the plants studied, only the Stratford, Connecticut, plant had conducted tests on bacterial regrowth. Some had experience with odors generated in sludge piles that had been standing for various periods of time. In general, however, fresh limed sludge and limed sludge that has been stockpiled for a long period of time (three to four years at Enfield) is inoffensive. There is some intermediate period when odors can be expected if stockpiles are broken. This period might be variable, depending on sludge characteristics, amount of lime added, and weather. Stockpiles at least a week old at Kennebec, Maine and Stratford, Connecticut, and a month old at Somersworth, New Hampshire, produced offensive odors when they were broken down, but stockpiles less than a month old were moved without serious odors at Glastonbury and Enfield, Connecticut.

The odor generation can be correlated with the drop in pH that occurs with time. At Enfield, odors were not emitted when stockpiles of less than seven weeks were broken. The pH values of stockpiles had remained at about 11 or more until about seven weeks, when they began to drop.

Testing at Stratford suggests that regrowth of organisms is caused by organisms already in the sludge, rather than by reinfestation from external sources. The tests consisted of monitoring covered and uncovered stockpiles of sludge cake for two months, testing for coliform bacteria. Both types of stockpiles showed similar rates for pH decay and similar bacterial numbers.

Air drying of limed sludge before stockpiling can help decrease odors when the piles are later broken down. This finding is based on experience at Stratford with sludge air dried for one week on sand beds.

Since stockpiling sludge cake allows organisms to regrow, there might be some hazard, in addition to nuisance, associated with handling sludge whose pH has dropped. Studies should be conducted to recommend the handling of such sludges.

SECTION 3

DETAILED DESCRIPTION OF LIME STABILIZATION

This section describes equipment and techniques used for lime stabilization at the plants surveyed.

PREPARATION OF LIME SLURRY

The plants surveyed purchase lime in the two available chemical forms: quicklime (CaO) and slaked lime ($Ca(OH)_2$). Quicklime is slaked before use. Plants buying slaked lime normally prepare a slurry from the hydrate or purchase the lime in a liquid form. A few add unslurried hydrated lime, however. Some dilute lime purchased in a liquid form to an even thinner consistency before applying it to sludge.

Quicklime

Five plants receive quicklime: Kennebec and Lewiston-Auburn, Maine; Naugatuck, Connecticut; Rochester, New York; and Woonsocket, Rhode Island. They purchase high-calcium quicklime (95 percent as CaO), which is delivered by truck in 24-ton loads.

Unloading to conventional lime silos at all the facilities is accomplished by pneumatic systems with blowers on the delivery vehicles. The loading line is typically a four-inch, carbon-steel line running vertically up the outside of the silo to the top, with long-radius elbows at bends. Bag filters at the top are used to clean the air which conveys the lime.

The silos themselves are made of carbon steel, without coating, unless one had been applied to protect the steel before the tank was placed in service. The silo bottoms are sloped at about 60 degrees. All silos have external vibrators for improving the flow of quicklime, and the silo at Woonsocket, Rhode Island has a bin activator. Rotary air locks at the bottom control the flow of lime and discharge directly to slakers at Kennebec, Maine, and at Rochester, New York. At other plants, lime is conveyed to day bins located above the slakers.

Flow from the silos to the day bins is pneumatic at Naugatuck, Connecticut, and at Lewiston-Auburn, Maine; at Woonsocket, Rhode Island, a screw conveyor is used. The pneumatic systems separate lime from air by two different methods: a cyclonic separator (at Naugatuck) and diverter plates, which direct the lime into the day bins (at Lewiston-Auburn). At Lewiston-Auburn, the conveying air continues to the lime slurry tank on the way to bag filters. Most of the lime passing the diverter plate falls into the slurry tank.

At Naugatuck, Connecticut, slurry slakers are used. Paste slakers are used at the other four sites. At all of the installations, lime slurry tanks are adjacent to the slakers. At the Kennebec plant, the slakers sit directly on the slurry holding tanks, eliminating the need for a pipeline. The slurry tank sits below the slaker at Naugatuck, and the lime slurry flows by gravity to the holding tank through a clear, flexible, plastic hose, which can be shaken to break up precipitate. Pumping of slurry from a slaker is required at only one of the plants visited.

The slurry holding tanks at the plants visited are roughly as wide as they are high, and they are either cubical and concrete or cylindrical and steel. Some tanks have high-speed propellers, others have low-speed turbines, and some have baffles to prevent vortexing. There was no clear evidence to suggest that one type of material or mixing would be inherently better than the others.

All holding tanks had level probes to control slaker operation. At Woonsocket, which has a high-speed mixer, the probe is protected from turbulence by a baffle. Probes at all plants are set so that there will always be sufficient slurry to enable the mixers to work efficiently.

The silos and the slakers do not provide the only way to process lime at facilities with quicklime. For example, at Lewiston-Auburn, Maine, the slurry tanks have large openings to allow use of bagged hydrated lime for slurry preparation.

Hydrated Lime

The treatment plants visited using hydrated lime receive a high-calcium grade lime containing 72 to 74 percent calcium oxide and 23 to 24 percent water in chemical combination with the calcium oxide.

Hydrated lime is normally delivered packed in 50-lb bags. The heavy-duty paper bags are stacked about 10 high on 4-ft by 4-ft pallets holding about 50 bags. Plants requiring lime delivery on a regular basis receive about 900 bags per delivery. Other common delivery loads are 500 and 200 bags.

At plants receiving lime in intervals of five weeks or less, a fork-lift truck is typically used to unload the pallets of bagged lime. This operation takes about 2 labor hours. At the smaller plants, where bags are typically unloaded manually one at a time, unloading takes 4 to 12 labor hours, depending on delivery size.

The bagged lime storage area is conveniently located near the loading dock at most of the facilities visited. At one large facility, however, bags are unloaded one at a time, by hand, onto a conveyor taking the bagged lime down into a basement storage area. With this arrangement, 16 labor hours are required to unload one truckload of lime. Not only is labor excessive, but some bags fall off the conveyor and break.

Manually Operated Systems for Preparing Slurry: Equipment --

Lime slurry is typically made up from hydrated lime using a manually operated batch system. The equipment consists of: a bagged-lime storage area, a slurry makeup tank, a mechanical mixer, dust control equipment, a water meter, and a platform from which bags of hydrated lime can be unloaded. As shown in Figure 2, the bag storage area of a typical system is conveniently located next to the makeup tank. Lime slurry is pumped directly from the makeup tank to the next treatment process, except at East Providence, Rhode Island, where day tanks are used.

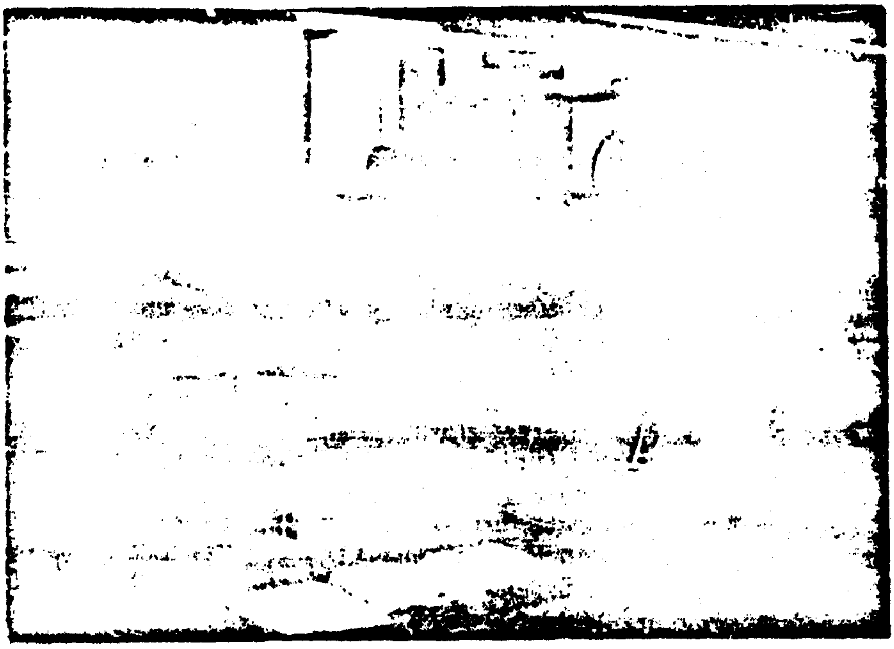


Figure 2. Hydrated lime slurry makeup system
Bath, Maine

The lime slurry makeup tanks are constructed of unlined carbon steel. They are usually cylindrical with a height-to-diameter ratio of about 1 to 1 and an average volume of 500 to 600 gallons. The tanks include hatches for lime addition. All had a gravity drain to allow rinsing and easy removal of any settled grit.

The tanks are mixed to prepare the slurry and then to keep it in suspension. Two types of mechanical mixers are used: a small-diameter, high-speed, propeller-type mixer which operates at 150 to 300 rpm; and a large-diameter, low-speed, paddle or turbine-type mixer which operates at about 15 rpm. For a 500-gallon tank, a motor of approximately three-quarter horsepower is provided. Operators at the sites visited have reported that both types of mixers work well.

Another method, mixing with air, is used at the Falmouth, Maine wastewater treatment facility. Not included in the original design, the lime slurry makeup tank was later installed outdoors. By simply running an air line to the tank, mixing was provided without exposing any electrical equipment to the elements.

Most systems have at least two slurry makeup tanks. In operation, slurry is usually being pumped from one tank as it is being prepared in the other. Some operators choose to pump from both tanks simultaneously. In some instances, only one tank is used with the second tank acting as a back-up. In the latter two operations, lime slurry is being pumped and prepared simultaneously. The operator starts making up additional slurry while the tank is still one-quarter to one-half full.

Because the hydrate is a very fine powdery material, dust control is provided at most facilities. One facility visited had no dust control, and the entire area surrounding the lime/slurry makeup tank was covered with dust. An effective dust control system is shown in Figure 2. In Figure 3, this dust control system is in operation while lime is being added. Dusty air is drawn into the tank by a fan and cleaned by a bag filter sitting in the housing on top of the tank lid. At some facilities, the air cleaned in this way is vented to the outdoors because some fine materials could escape the bag filter. The bag filter is a low maintenance item requiring bag replacements only one to two times per year. Although this dust control method is effective, the area still acquires dust and should be cleaned regularly.

A makeshift dust control system is in operation at the Stafford, Connecticut, wastewater treatment facility. This system, shown in Figure 4, consists of an 8-inch vertical vent pipe and a fan to draw the dusty air, with the entrance port of the pipe located just over the mixing tank lid. This system works quite well.

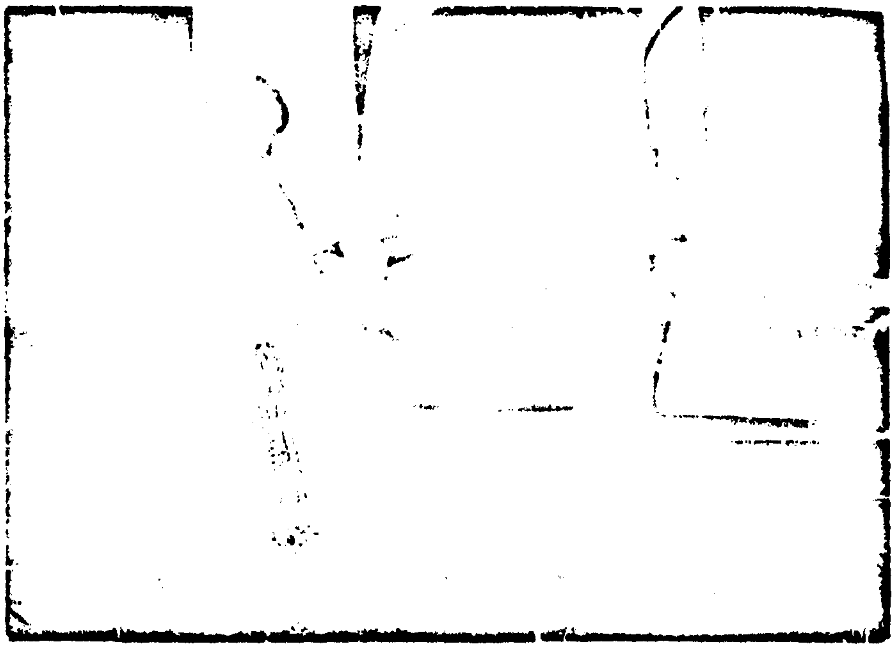


Figure 3. Addition of bagged hydrated lime to slurry makeup tank, Bath, Maine

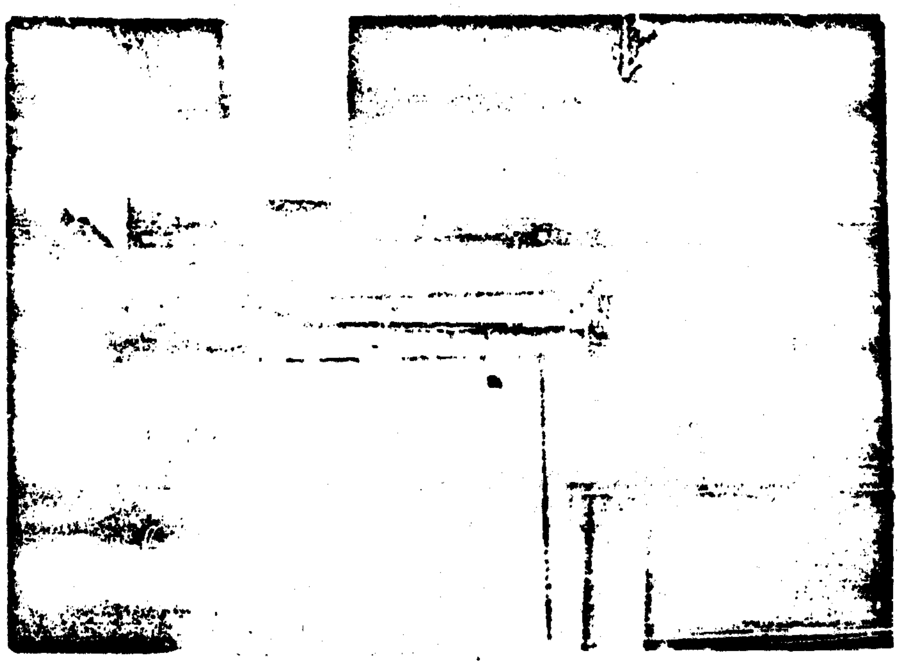


Figure 4. Dust control added to existing system, Stafford, Connecticut

A platform, as was shown in Figure 2, is usually provided to allow the operator to pour in bags of lime from waist level. At New Haven, Connecticut, the lime slurry makeup tank is taller than those shown in the figures, having a capacity of about 1,000 gallons. A bag elevator has been provided to raise the bags to platform height so the operator does not have to carry them up the stairway.

In the system shown in Figure 5, the base of the slurry makeup tank is depressed two to three feet below the steel grating floor. With this system, the operator does not have to walk up steps with a 50-lb bag of lime. Any dust escaping the dust control system falls through the grating to the concrete slab below.

Figure 5. Slurry makeup tank depressed into floor, Middletown, Connecticut

Manually Operated Systems for Preparing Slurry: Procedures --

The operator determines the available capacity in the lime slurry makeup tank by measuring the water depth with a ruler. The operator then turns on the water flow and, as the water fills the tank, manually adds a predetermined number of bags of lime. Most plants use plant water, although some plants use city water in preparing the slurry. One 50-lb bag of hydrated lime is typically added to 50 gallons of water to make an 11 percent lime/slurry solution. The volume of water added to the slurry makeup tank is measured by one of two means. A water meter is normally supplied for accurate measurement. When used, the meter should sit clearly visible to the operator on the top of the tank lid. If no meter is supplied, the operator uses tank depth as a gauge of water volume.

The makeup of one batch of slurry takes about 15 minutes. The slurry makeup operation requires regular attention. A low-level probe, not used at any of the sites visited, could be used to allow the operator to perform other tasks between makeups of batches.

After a day's operation, the tanks should be emptied and rinsed. At some facilities, the tank is filled with water which is held until the next operating shift.

Automatically Fed Systems for Preparing Slurry --

An automatic slurry makeup system can be used with hydrated lime. Only at Portland-Westbrook, Maine, was such a system used. The system, pictured in Figures 6-7, consists of a bagged-lime feed hopper, a silo (with vibrator below), a dry-lime feeder, and a slurry mix tank. The use of a bag-fed silo and automatic feeder can limit bag handling to once per shift. The fine-textured hydrated lime can be difficult to handle and may clog in the silo. This problem may be solved by the use of properly operated vibrators or air pads on the silo. Another option is to outfit the silo with a live-bin bottom.

Automatically fed hydrated lime systems are best applied at plants too large for manual batch slurry makeup and too small to efficiently handle bulk quicklime.

Slurried Lime

Six of the plants surveyed purchase lime slurry. Five of these purchase slurry produced as a by-product in acetylene production. This product, known as carbide lime or chemical lime, is available in many areas and is readily obtainable in the study area. One treatment facility receives slurried lime commercially prepared by slaking quicklime. This product is more expensive than the acetylene by-product, but its concentration is more consistent.

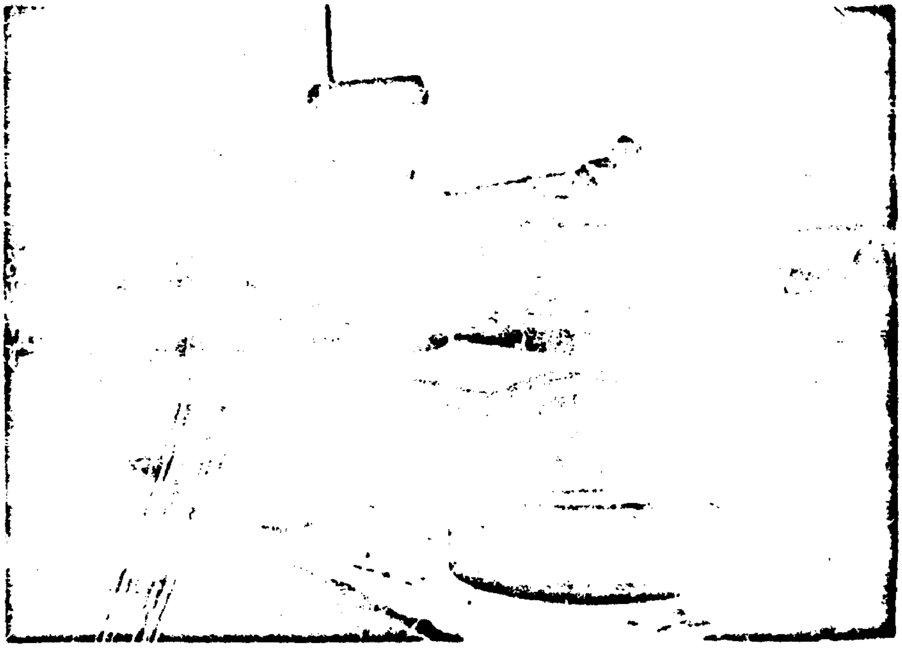


Figure 6. Automatic hydrated lime slurry makeup system, hatches to day bins, Portland-Westbrook, Maine

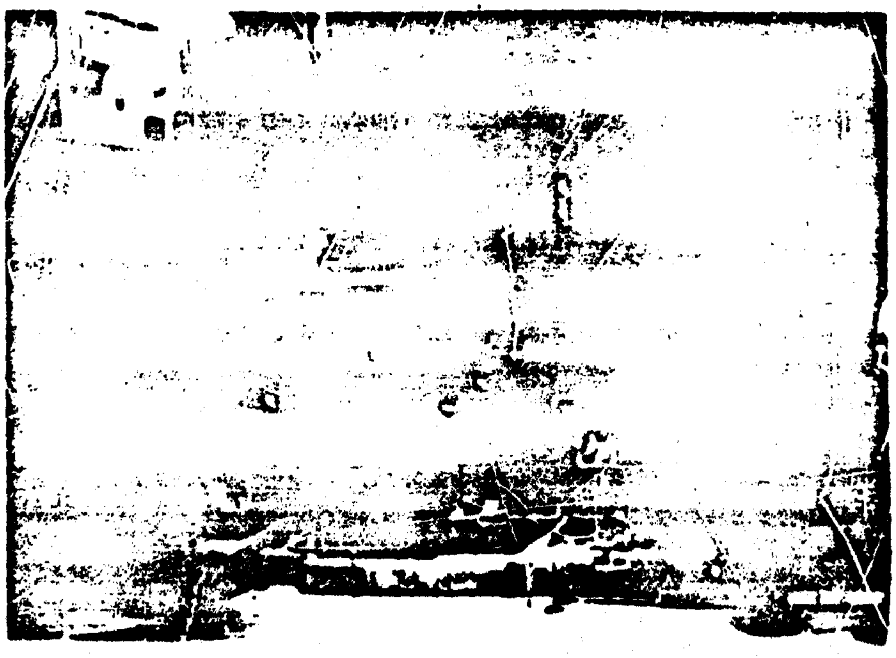


Figure 7. Automatic hydrated lime slurry makeup system, day bins and feeders, Portland-Westbrook, Maine

Table 3 gives a typical chemical analysis of carbide lime as reported by a supplier. The data show that the calcium concentration is similar to that of high-calcium lime. Carbide lime is normally delivered at a 35 percent solids concentration. Because operators report that delivery concentrations can range from 20 to 35 percent, however, storage facilities should be sized to handle a 20 percent slurry.

Storage and Delivery of Slurried Lime --

Slurried lime is delivered by tank truck in 4,800-gallon loads. Lime can be delivered from the delivery truck to storage by gravity. If a pump is needed, an abrasive handling transfer pump can be used. A hose should be provided to allow for rinsing settled lime out of the truck. The slurry usually contains grit. To prevent grit from entering the treatment plant's lime handling system, the Willimantic, Connecticut plant has a screen on the storage tank entry port. Figure 8 shows the type of screen used.

The lime slurry storage tanks at Stratford and Willimantic, Connecticut, are constructed of concrete. Unlined carbon steel is used at other Connecticut plants in Enfield and Vernon, and at Bucknam Point, Rhode Island. No storage is required at South Windsor, Connecticut, where the lime delivery is dumped in one batch to a sludge/lime mixing tank. At Stratford, Enfield, and Bucknam Point, the tanks are indoors. The Vernon facility has a 15,000-gallon outdoor storage tank. Underground tanks are also used, as at Willimantic.

The storage tanks must be mixed constantly. Large storage tanks at Enfield and Stratford use a large-diameter, slow-speed paddle mixer. A high-speed mixer is used at Bucknam Point, Stratford, and Willimantic.

The five plants storing slurry keep a minimum inventory of one to two weeks' supply and schedule deliveries weekly. The facilities have either one or two lime slurry storage tanks. Three plants have two storage tanks, each with the capability of holding one truckload of lime. Two plants have only one storage tank. In each case, this tank has capacity of three truckloads.

Day Tanks for Lime Slurry --

All of the five facilities storing lime slurry utilized day tanks in addition to bulk storage. This is done for two major reasons:

(1) to locate a storage tank close to the application point of the lime slurry

(2) to provide for dilution of slurry, if desired.

TABLE 3

TYPICAL ANALYSIS OF CARBIDE LIME

Typical Chemical Analysis	
$Ca(OH)_2$	95
CaO Equiv.	72
$CaCO_3$	1.5
MgO	0.25
R_2O_3 (Fe_2O_3 & Al_2O_3	1.6
Insolubles	1.1

Screen Size Distribution	
Thru 20 Mesn	99.9%
Thru 48 Mesh	99.2
Thru 100 Mesh	97.0
Thru 325 Mesh	85.0

Source: Chemline Corporation, 1979

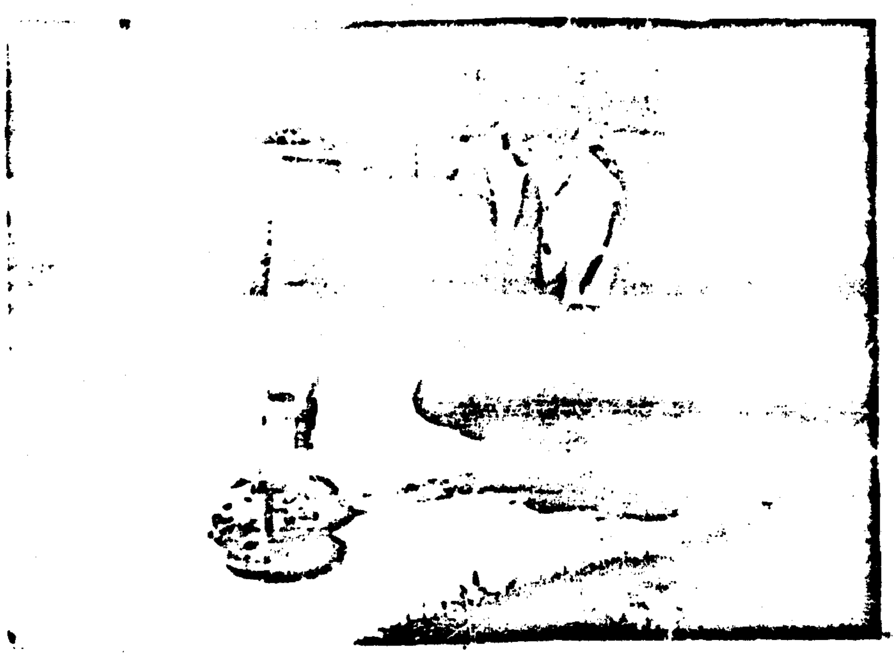


Figure 8. Lime slurry storage tank with grit screen, Willimantic, Connecticut

If the slurry, as received, is of a concentration higher than desired for use, it may be diluted. Additionally, dilution to a constant slurry concentration simplifies volumetric metering. Although day tanks at all of the facilities visited are equipped to provide dilution, it is regularly practiced only at Enfield. Here, dilution is a batch operation. The desired concentration is obtained by adding a metered quantity of water to a concentrated slurry.

Day tanks are typically constructed of carbon steel with no lining. The tanks are usually sized to hold the capacity for one shift, but may be sized for some other convenient time interval. During this time, the tanks must be mixed. The same type of turbine and propeller mixers used in lime slurry makeup tanks are available for day tanks. The tank should be fitted with a drain and flushed when empty. At the Vernon, Connecticut wastewater treatment facility, flexibility has been built in by designing the day tanks so that they can be used to make up lime slurry from bagged hydrated lime. With this capability, the plant is protected in the event that the source of lime slurry is temporarily interrupted.

PUMPING AND CONVEYANCE OF LIME SLURRY

The types of pumps, types and configurations of pipelines, and valves used in the conveyance of lime slurry are discussed in this section.

Applications of Lime Slurry Transfer Pumps

Lime slurry transfer pumps are used to transfer lime slurry to a day tank or to a batch lime stabilization tank. Slurry is pumped to a day tank with a slurry pump at Enfield, Stratford, and Vernon, Connecticut; East Providence and Bucknam Point, Rhode Island; and Rochester, New York. At Thompson, Connecticut, lime slurry is pumped to a batch stabilization tank. A portable lime slurry transfer pump is used at Thompson, employing a procedure described in a later section, when bulk lime stabilization is practiced. The transfer pumps are only required to operate at a single speed. They operate in an on/off cycle, delivering lime slurry as required.

Whenever possible, it is recommended that lime slurry be transferred from storage by gravity. Such a configuration is utilized at the Willimantic facility. Lime slurry is transferred from the bulk lime slurry storage tank to the lime slurry day tank through a 3-inch-diameter, 3-foot-long pipeline fitted with a manually controlled gate valve.

Lime slurry is non-corrosive but abrasive, and transfer pumps must be specially designed. Positive displacement pumps are used at Enfield, Connecticut and at Rochester, New York, but a closed-impeller centrifugal pump is normally selected.

The centrifugal pump selected is either hard metal (not simply all iron) or rubber-lined. A hard-metal pump is very resistant to abrasion. While more resistant than rubber-lined pumps, they are also more expensive. Rubber-lined pumps do resist abrasion quite well, and are sufficient in many applications. Abrasive particles simply bounce off or become embedded in the rubber lining. With heavier slurries, the rubber will wear and shred over time.

To decrease wear due to abrasion, the pump selected should operate at low speeds -- conventionally about 1,100 rpm or less. Pumps should be supplied with a maximum size impeller to ensure efficient passage of solids, reducing the possibility of solids build-up within the pump.

Applications of Lime Slurry Metering Pumps

Lime slurry metering pumps dispense appropriate lime dosages to continuously operated systems. The pump output is usually controlled by adjusting pump speed from a control panel located close to the point of lime application, but output can be manually controlled.

Three types of metering pumps were in use at the treatment plants visited: plunger or piston pumps; diaphragm pumps; and progressive cavity pumps.

Plunger pumps were used at nine of the twenty treatment plants using slurry metering pumps. Operators were generally satisfied with their operation, citing low maintenance requirements. In one instance these pumps were used to replace diaphragm pumps that repeatedly failed.

Eight of twenty plants were using diaphragm pumps to meter the lime slurry. Most plants use the mechanical type of diaphragm pump. Operators reported that regular maintenance was required; the rubber diaphragms reportedly had to be replaced every few months. While replacement of the rubber diaphragm is a relatively simple operation and most operators do not complain of this regular maintenance requirement, some operators were upset by inopportune diaphragm breakage.

Progressive cavity pumps were used at three of the facilities visited. At one facility the operator reported that rotors and stators were wearing excessively.

Piping Systems For Lime Slurry

The major problem in the conveyance of lime slurry is that of scaling. Water carrying the lime undergoes a softening action and calcium carbonate ($CaCO_3$) precipitate is formed. This results in the formation of a dense hard scale on the conveying line. An example of this is shown in Figure 9 from Middletown, Connecticut. Eventually a pipe has to be either cleaned or replaced.

Figure 9. Lime scaling of pipeline, Middletown, Connecticut

As lime slurry is noncorrosive, a wide range of pipe materials can be used. Carbon steel pipes, plastic pipes, and flexible rubber hoses are used at the sites visited. At Thompson, Connecticut, a flexible fire hose conveys lime slurry to the stabilization tank.

When using rigid pipe, a provision for pipe cleaning should be made at each pipe bend. Tees or wyes were used in place of bends at many sites. These allow access to the pipes' interior for cleaning with either a rod or a pipeline reamer "pig". Long-radius, removable elbows also provide access for cleaning, and are in use at Kennebec, Maine.

Flexible hoses are used at Enfield, Naugatuck, Stratford, and Vernon, Connecticut, and at Kennebec, Maine. The hose can be flexed and shaken to break up any calcium carbonate build-up on the interior of the pipe walls.

The system at Kennebec, Maine, is shown on Figure 10. The hose is laid in overhead troughs or trays. With this system, a stick can be poked through the bottom of the trough, allowing the pipe to be shaken from below. At Stratford and Vernon, Connecticut, the pipeline was simply tied into place. At these two plants, flexible hose replaced a rigid pipe installed initially.

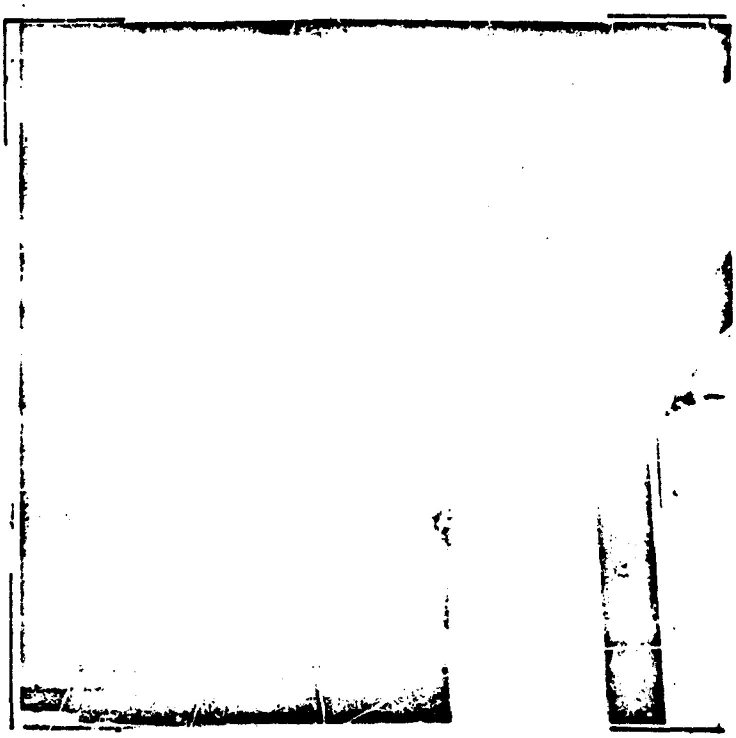


Figure 10. Troughs holding flexible lime hoses, Kennebec, Maine

Another technique of controlling lime build-up is the use of an inhibitor, such as sodium hexametaphosphate. Inhibitors are used in areas with hard water to protect dewatering equipment, such as vacuum filters, from build-up of lime.

A regular flushing schedule should be developed for the entire lime handling system, including valves, pumps, tanks and mixers as well as pipelines. At most of the sites surveyed, flushing is done at the end of every lime use. Flushing can be controlled manually or automatically. Automatic controls are activated upon lime system shut-down, and should always be used when the lime system is automatically controlled.

Valving in Lime Slurry Pipeline Systems

There are two general types of lime piping system layouts: direct and loop. In direct systems, lime is pumped directly from one point to another. All of the plants visited used this system of piping. The use of loop systems is more popular at large facilities.

When pumping lime slurry directly from one point to another, the use of one pump and one pipeline is insufficient. Most plants visited are designed with flexibility, with each slurry tank serviced by more than one pump. A number of valves are required to achieve flexibility. At the plants visited, gate valves were commonly used in steel pipelines. At Willimantic, Connecticut, ball valves were used with the PVC pipes. These types of valves should not be operated partially opened. In this position, lime particles would settle out and build up in front of them.

APPLICATION OF LIME

The points of application can be divided into three major groupings:

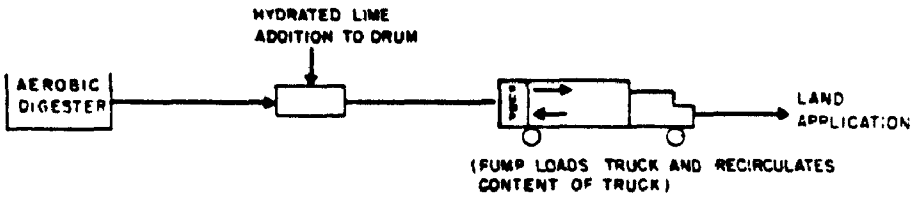
(1) to a liquid sludge before land application;
(2) to liquid sludge before dewatering; and
(3) to a cake sludge after dewatering.

Lime Application to a Liquid Sludge Prior to Land Application

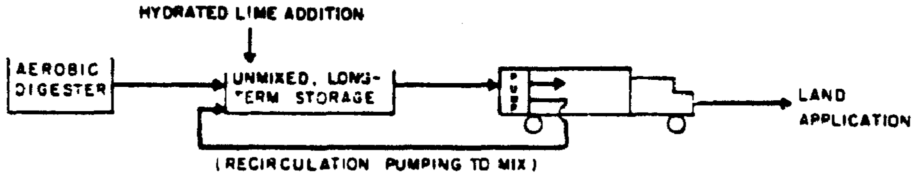
At five treatment facilities, aerobically digested liquid sludge was lime stabilized prior to land application. The sludge was stored in an aerobic digester or in a separate storage tank prior to batch lime addition and lime stabilization. Four basic systems developed.

1. Lime Addition to Sludge Transfer Line. At Scarborough, Maine bagged, hydrated lime is added to a pipeline transferring aerobically digested sludge to a land application truck. The treatment plant was initially designed so that the sludge could flow by gravity from the digester to sand drying beds. Because of low volatile solids reduction in the digester, the stabilization of the sludge had to be upgraded. Lime stabilization was selected.

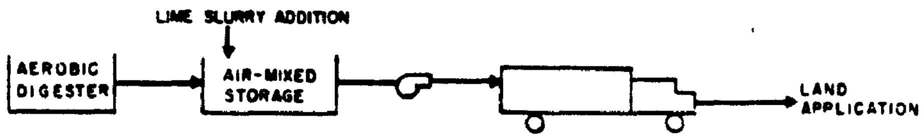
   The system used at Scarborough is shown in Figure 11. The gravity line from the aerobic digester goes into the bottom of a tee section. The right hand of the tee section is connected to an open barrel (see Figure 12); the left hand of the tee is connected to a line leading to a pump on the land application truck. When sludge is to be removed, the valve to the truck is first closed and all other valves are opened. The barrel fills with sludge by gravity while the operator adds a few shovels of lime to the barrel. When the barrel is full, the valve to the truck is opened and the pump on the truck is activated. Sludge with lime is pulled from the barrel. At the same time, sludge is being



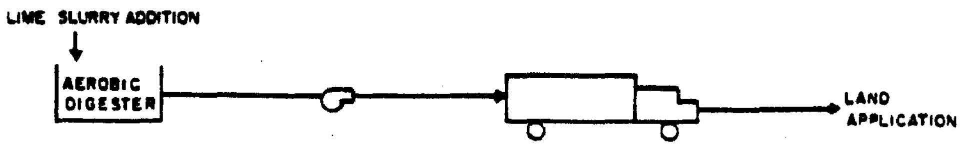
A. LIME ADDITION TO SLUDGE TRANSFER LINE (SCARBOROUGH, ME.)



B. LIME ADDITION TO UNMIXED STORAGE TANK (NORTH CANAAN, CT)



C. LIME ADDITION TO MIXED STORAGE TANK
(THOMPSON, CT. AND FALMOUTH, ME.)



D. LIME ADDITION TO BATCH AEROBIC DIGESTER
(SOUTH WINDSOR, CT.)

FIG. 11 LIME ADDITION TO LIQUID SLUDGE PRIOR TO LAND APPLICATION

pulled from the aerobic digester. When the barrel is emptied, the valve to the barrel is closed. After the truck is nearly full, the valve to the barrel is reopened, more lime is added, and the startup operation is repeated. After the truck is filled, the pump is temporarily stopped and all valves are closed.

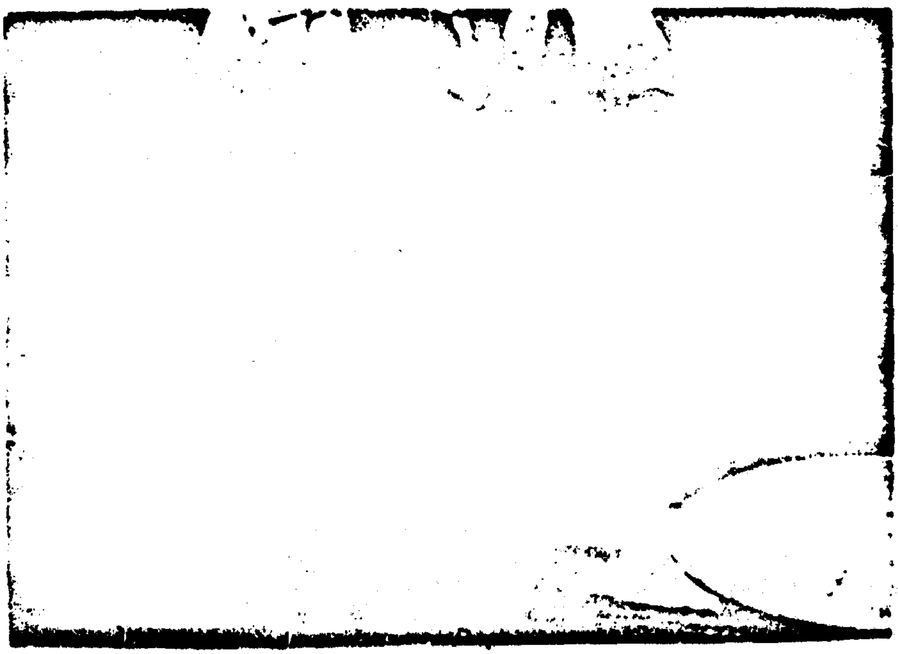


Figure 12. Hydrated lime addition to sludge transfer line, Scarborough, Maine

The land application vehicle is a converted oil delivery truck. In the rear of the truck the pump is valved so that it can pull sludge from the digester, mix the contents of the truck by recirculation pumping, and be used to spray liquid sludge onto fields. While the truck is being driven to the land application site, the proper valves are opened and the contents of the truck are mixed by recirculation pumping.

The technique used at Scarborough obviously requires little capital investment. It does have some severe limitations, however. The pH of the lime-stabilized sludge can only be accurately determined after the truck is filled and the recirculation pumping has completely mixed its contents. Whether or not there is complete mixing is questionable. After pH is determined, it is too late to add more lime to correct insufficient pH unless it is added directly to the truck. Because no provision for this has been made, pH control is limited.

2. Lime Addition to Unmixed Storage Tank. At North Canaan, Connecticut, aerobically digested sludge is stored all winter in two unmixed storage tanks. The tanks are primary clarifiers abandoned by a previous treatment facility. All sludge collection equipment has been removed. Lime stabilization is required at this facility because of low volatile solids reduction in the aerobic digester.

At North Canaan, lime stabilization is practiced once a year in the spring. A sludge truck equipped with a pump is parked beside the storage tank (see Figure 11). The pump on the truck is used to mix the contents of the storage tank by recirculation pumping while bagged lime is poured directly into the sludge. pH is monitored and lime is added until the desired level is reached. After the proper pH is attained, mixing continues for a while. The truck is then loaded. The truck must make a number of trips to completely empty the contents of the sludge storage tank.

This system required no capital expenditure, except the purchase of the sludge truck. The application is unique in that a tank with sufficient capacity to store all sludge created in the winter was available on site. The acceptability of this type of system is dependent upon operational procedure. The operator must be sure that the lime is well-mixed with the sludge and that the contents of the entire tank has reached the required pH. At each truck loading, pH should be checked and more lime added if pH decay has occurred.

3. Lime Addition to Mixed Storage Tank. Lime is added to mixed storage tanks at Falmouth, Maine and at Thompson, Connecticut. At Falmouth, aerobically digested sludge is stored in the digester. The digester mixer is periodically stopped to allow the sludge to settle and the supernatant to be decanted. With this technique, the digester has sufficient capacity to store sludge produced during the entire winter. By spring, the sludge builds up to a solids concentration of three percent. When weather permits, batches of winter sludge are lime-stabilized in a separate tank prior to land application (see Figure 11) Sludge collected during the remainder of year is also lime-stabilized after aerobic digestion and land-applied as quickly as possible.

Lime stabilization at Falmouth occurs in a bulk storage tank capable of storing 16,000 gallons of sludge. The tank is equipped within an air mixer that completely mixes its contents. The outlet is fitted with a screen to capture fibers and other materials that would be unsightly if land applied.

Sludge is stabilized once per day. In the afternoon, after the sludge storage tank has been emptied, the digester is shut off and the sludge is allowed to settle. The liquid is decanted and the settled sludge is pumped to the storage tank. Lime slurry is then added to increase the pH to the proper level. The operator reports that there is an ammonia odor. After overnight storage with the air mixer kept on, the pH is checked to make sure that it is sufficiently high. If required, lime is added to adjust the pH. The sludge is then pumped to a 2,000-gallon land application vehicle for disposal. Daily operation simplifies operation, and provides flexibility in scheduling land application.

The Falmouth plant was originally equipped with the sludge storage tank and the air mixer. A lime slurry preparation tank, a pump and pipeline to carry the sludge to the land application truck, and the land application truck itself were required to convert this plant to lime stabilization. The land application truck was fabricated by treatment plant personnel who affixed a tank to the bed of a truck already owned by the town.

At Thompson, two aerobic digesters were provided in the original plant design. These tanks are shown in Figures 13 and 14. One of these tanks is operated as an aerobic digester; the other is operated as an aerated storage tank. The air to the digester is periodically stopped, supernatant is decanted, and the settled sludge solids are pumped with a portable "mud sucker" pump to the storage digester. The storage digester is also occasionally decanted.

Two to four times per year, the contents of the storage tank are lime stabilized. Lime slurry is prepared from bagged hydrated lime. The slurry makeup system was included in the original plant design to prepare lime for conditioning prior to sludge vacuum filtration. Prepared slurry is pumped with a portable pump through a flexible fire hose to the storage digester. The pH of the tank is monitored and lime is added until the desired pH is maintained. The contents of the storage tank are kept completely mixed until the tank is emptied, one load at a time, to a land application truck. The lime stabilized sludge is transferred using the same "mud sucker" pump used to transfer the aerobically digested sludge to the storage tank. It takes about one week of land application to empty a tank full of lime stabilized sludge, during which time pH in the tank is monitored and maintained.

The systems at Falmouth and Thompson work very well. The sludge is completely mixed and held at high pH while still in the liquid form, ensuring the greatest pathogen kill. pH control is very good. The sludge pH can be accurately measured and adjusted as the sludge is completely mixed and held to the proper detention time.

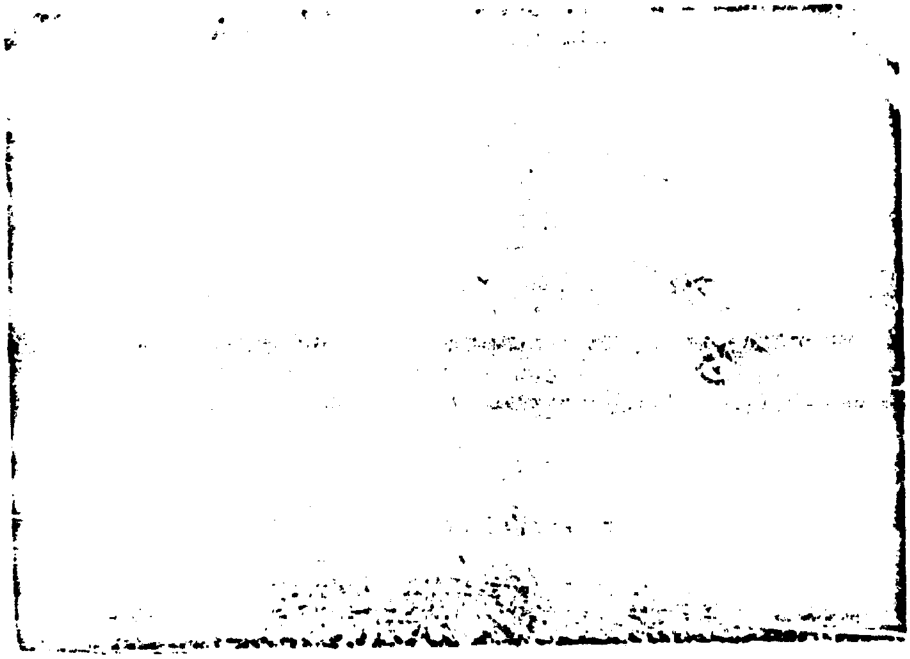


Figure 13. Aerobic digester, digestion mode, Thompson, Connecticut

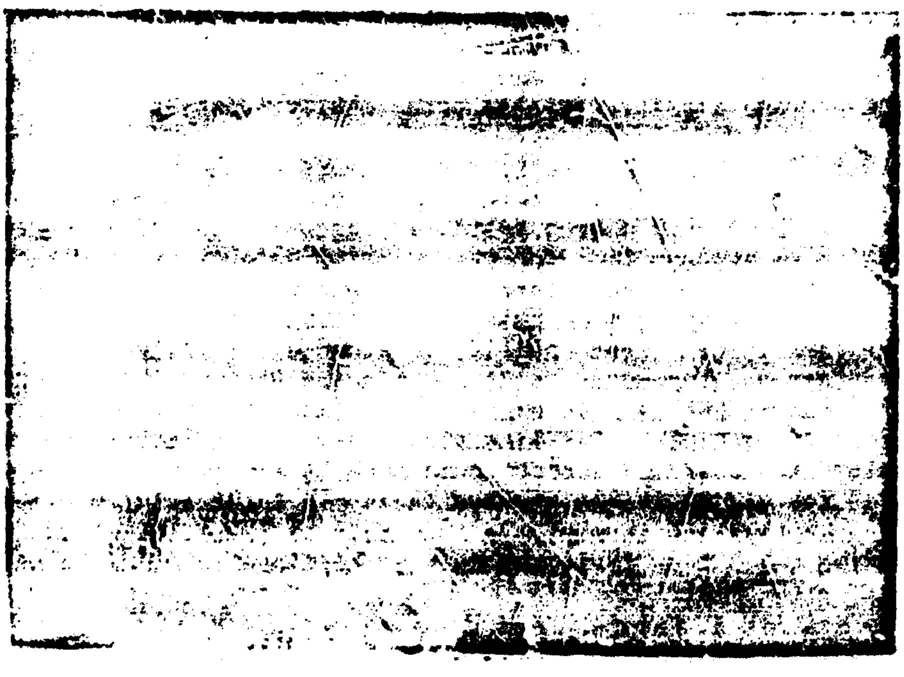


Figure 14. Aerobic digester, used for lime stabilization, Thompson, Connecticut

The system at Thompson required little capital investment. The plant simply purchased two portable pumps and fabricated a land application truck by fixing a tank onto a dump truck bed.

4. Lime Addition to Batch Aerobic Digester. At South Windsor, Connecticut, sludge is lime stabilized by adding lime directly into an aerobic digester. A diagram of the system is provided in Figure 11.

   At South Windsor, sludge solids are allowed to build up in an aerobic digester. After about one month, a truckload of carbide lime slurry is ordered and dumped into the digester. Experience has shown that one truckload is sufficient to lime-stabilize. After mixing for a short while, the sludge is pumped to sand drying beds. No data have been kept to show whether or not lime addition has improved the dewaterability of the sludge on the beds. The operation at South Windsor is used only in the summer months. In the winter the sludge is incinerated.

   This system required no capital investment and positive ph control is provided. With the South Windsor system, it is recommended that a few spare bags of hydrated lime be kept on hand in the event that the truckload of carbide lime ordered is not sufficient to lime-stabilize the sludge.

   Lime addition to batch aerobic digesters can provide proper mixing and detention time for lime stabilization. The technique has the advantage of utilizing existing plant equipment. Because of the volume of sludge that must be lime-stabilized at one time, land application scheduling may be restrictive. Unless pH is monitored, the long storage time for the lime-stabilized sludge could result in pH decay prior to sludge removal.

Lime Addition to Liquid Sludge Prior to Dewatering

At the 20 treatment plants using vacuum filters, lime was added for stabilization in the sludge conditioning drum prior to dewatering. Adding conditioning agents to conditioning drums is conventional, of course. All of the plants had been designed for lime conditioning sludge. In each instance, the quantity of lime dose is the only difference between lime conditioning and lime stabilization.

Even though more lime is usually required for sludge stabilization than for lime conditioning, the lime handling equipment included in the original plant design at all of the facilities visited was found to be of sufficient size.

Because they were designed for lime conditioning, not lime stabilization, the conditioning drums have a small capacity, resulting in a detention time of only a minute or less. If a system were initially designed to provide lime stabilization, the detention time would be at least 30 minutes. A lime conditioning tank design is concerned not with detention time but only with mixing of lime slurry and sludge.

The vat containing liquid sludge beneath the vacuum filter does provide some detention time, but detention time is not a designed parameter for selection of this vat. The vat detention time is a function of filter submergence, vat geometry, sludge solids concentration, and the sludge filter rate. Under normal conditions, the detention time that occurs can be 15 minutes or more.

Because of the addition of lime, filtrate has a high pH. The operators of the treatment facilities reported that the increased dose from lime stabilization caused no adverse effects on the treatment facility from changed sidestream characteristics. While a few operators did note that there was an increase in pH of the wastewater being treated, it seemed to have no effect on wastewater treatment efficiency. Operators also noted that the solids capture of the vacuum filters and the solids filtering rate neither degraded nor improved noticeably with the increased doses of lime. Operators at some facilities reported an ammonia odor at the vacuum filters.

In most instances, operators commented that the increased dose resulted in no effect on maintenance. Two operators commented that vacuum filters had to be cleaned quite frequently, but that this had also been the case prior to the institution of lime stabilization.

For proper operation of the lime stabilization system, the dose of lime must be sufficient to reach a specified pH and not simply to achieve efficient sludge dewatering. pH was monitored by using either litmus paper, or a pH probe, or by using litmus paper regularly and occasionally checking its reliability by using a pH probe. pH was typically measured in one of three places: on the liquid sludge in the vacuum filter vat; on the freshly dewatered sludge while still on the vacuum filter or conveyor; or on sludge cake that had been allowed to sit for a while.

Lime stabilization is typically defined as liming the sludge so that it has a pH of 12 after two hours detention time. In view of this, the system should be operated so that the vacuum filter sludge cake has a pH of 12 after one and three-quarters hours (allowing 15 minutes detention in the vacuum filter vat). To achieve this goal, some operators operated the system so that sludge in the filter vat or freshly dewatered sludge was limed through a pH of slightly greater than 12, say 12.1 or 12.2. This method was based on individual experience showing that such a procedure would result in the sludge maintaining a pH of at least 12.0 after the two-hour detention period.

The lime dose was typically controlled by adjusting lime metering pump speed from a control panel located near the vacuum filter. At some treatment plants, the operators commented that they selected the lime dose "by eye". Others claimed that, based on past experience, they could simply add enough lime to achieve good dewaterability as this dosage was sufficient to achieve the desired pH. Such shortcuts are not acceptable, however. The pH must be checked with regularity and the lime dose adjusted as necessary.

At 16 out of 20 plants dewatering with a vacuum filter, ferric chloride is normally used in conjunction with lime for conditioning purposes. One plant used lime alone. At three facilities, operators chose to use polymer instead of ferric chloride as a conditioning aid with lime. The operators commented that they had a difficult time finding a polymer that could work well with the high pH of the lime sludge. Those plants now successfully using polymer are satisfied that there was some decrease in the required lime dose.

Lime Addition to Dewatered Sludge Cake

Sludge cake is lime-stabilized at three facilities. Two plants add lime to a sludge screw conveyor; one plant adds lime to sludge cake stored in a pit.

Lime Addition to Sludge Screw Conveyor --

At two plants, Glastonbury and Stamford, Connecticut, powdered hydrated lime is added to sludge in a screw conveyor. The conveyor mixes the sludge with the lime while conveying it to a truck for ultimate disposal.

The system used at Glastonbury is shown in Figure 15. Bags of lime are lifted by an elevator and stored on a platform raised about six feet off the floor. The lime is poured, one bag at a time, into a 55-gallon drum, at the bottom of which is fixed a conventional lawn spreader. The lawn spreader is turned by a belt conveyor that carries sludge from the centrifuge to the screw conveyor. The sludge falls off the belt and onto the screw conveyor just below the lawn spreader. The spreader sprinkles lime onto the screw conveyor, which mixes the lime with the sludge while conveying it to a truck for ultimate disposal.

Lime dosage is controlled by making an adjustment to the dosing rate of the lawn spreader. pH was checked by using litmus paper when lime stabilization had been the goal of this facility. At present, lime addition is being practiced only for odor control, as the sludge is being brought to a landfill where composting is being set up.

When the system at Glastonbury was initially set up, the platform that holds the system had to be built and the lawn spreader acquired. The other equipment was available onsite. The screw conveyor was initially used as an ash conveyor in the incinerator which has since been abandoned.

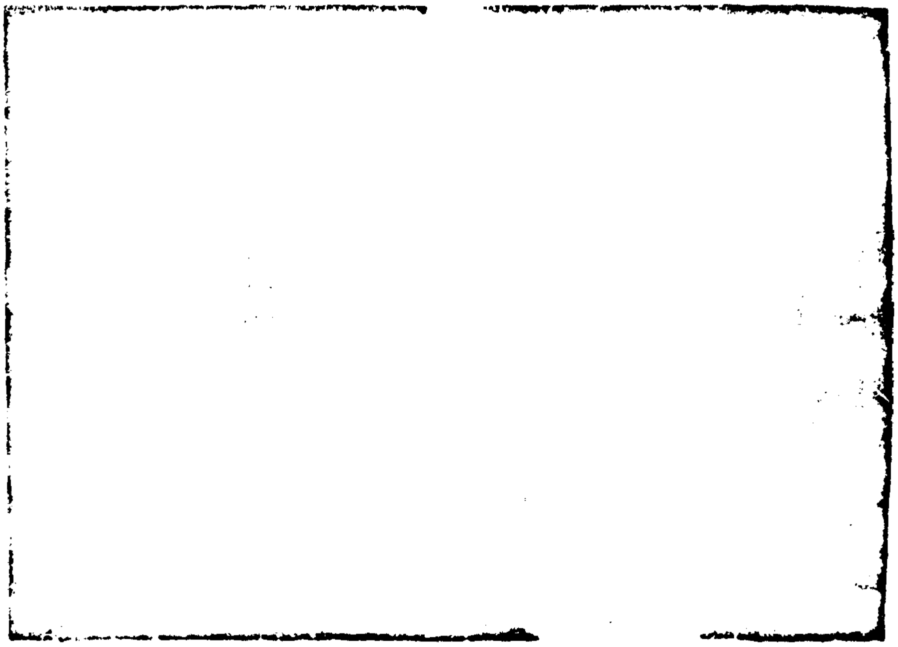


Figure 15. Hydrated lime addition to cake sludge, Glastonbury, Connecticut

Stamford, Connecticut's system is also unique. Hydrated lime is poured one bag at a time into a hopper (Figure 16). A flexible screw conveyor conveys the hydrated lime from the hopper into a storage silo, shown in Figure 17. Hydrated lime from the silo is conveyed by a screw conveyor to a second screw conveyor moving sludge cake from a belt press to a truck. The configuration of conveyors is shown in Figure 18.

The pH is occasionally checked by using litmus paper on the sludge-cake. While the operator aims for a pH of 12.1, actual operation usually results in a pH after two hours of 11.8. Lime dose is controlled by setting the ratio of the speed of the lime conveyor versus that of the sludge conveyor, using a control panel located on an upper level beside the belt filter.

The system at Stamford, Connecticut is simply a back-up to coincineration. All equipment was purchased when the system was installed.

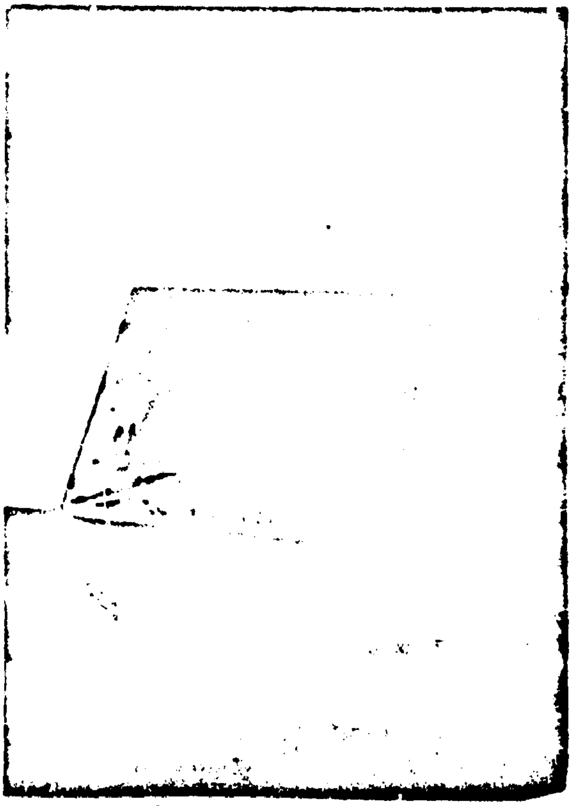


Figure 16. Hydrated lime addition to cake sludge, lime hopper, Stamford, Connecticut

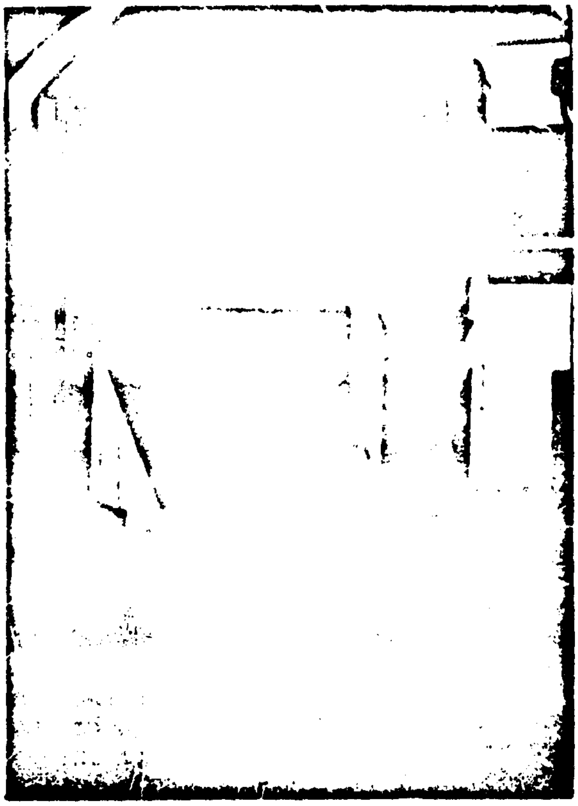


Figure 17. Hydrated lime addition to cake sludge, lime day bin, Stamford, Connecticut

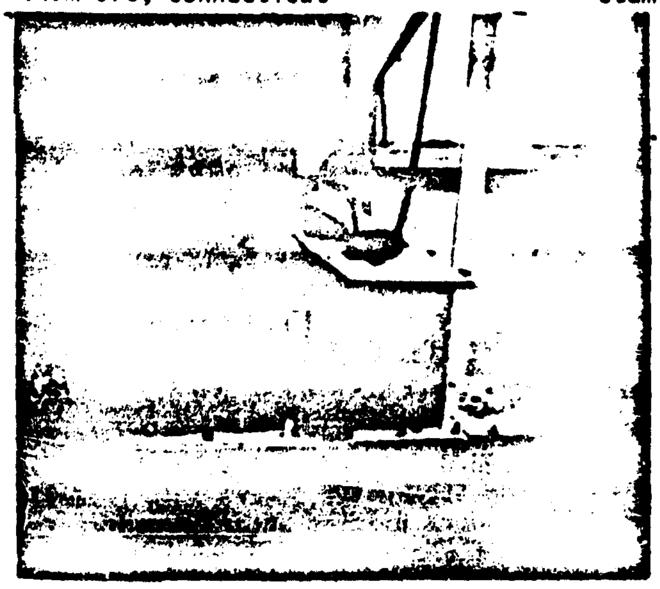


Figure 18. Hydrated lime addition to cake sludge, lime and sludge conveyors, Stamford, Connecticut

No biological tests have been made to determine whether mixing of cake and lime is effective. The odor control is so far the only indication that bacterial activity is inhibited.

Lime Addition to Sludge Cake Storage --

At Groton Town, Connecticut, dewatered sludge cake is stored in an open tank abandoned from a previous treatment plant. In a batch operation, wood chips and bags of lime are added to the pit (the wood chips are used to increase the solids content prior to landfilling). The sludge is then mixed with a front end loader and loaded onto a truck for removal from the site. This method results in poor pH control and poor mixing, and is being replaced by static composting at the landfill.

DISPOSAL AND REUSE ALTERNATIVES

Sludge Removal From Site

Liquid sludge is disposed of by land application, using trucks described later in this chapter. Cake sludge is carried by a conveyor to a container that can be lifted and removed by truck; to a bin that is unloaded to a dump truck by a front end loader; or to a hopper or chute discharging directly to the sludge hauling dump truck. This hopper can also temporarily store the cake sludge while the truck is in transit. At two facilities using a hopper to temporarily store sludge, operators commented that the sludge would not flow readily from the hopper to the awaiting truck by gravity alone, but had to be washed or poked through.

Stockpiling

At a number of the sites visited, cake sludge was trucked to a land application or landfill site and simply dumped in a stockpile. Sludge was allowed to sit in piles, to be spread or landfilled at a later time. Sludge can sit in a stockpile without odors occurring. If piles are disturbed after short-term stockpiling, they do not emit highly offensive odors. When somewhat older stockpiles are broken into, however, a very offensive odor is emitted. Because of this, operators at Kennebec, Maine and Rochester, New York commented that they would not allow sludge cake to sit in piles for more than a day. At Somersworth, New Hampshire, the term of stockpile storage is also limited.

At Enfield, Connecticut, sludge has been successfully stockpiled for periods of months and even years. Experience at this facility has shown that the pH drop in the stockpiles occurs only gradually. The operator has commented that odors emitted after breakdown from stockpiles a few months old are somewhat offensive, but shortlived. Some sludge stockpiles at Enfield and at Glastonbury had been allowed to sit for a number of years. When broken into, only a slight musty odor is emitted from these piles. The sludge in the center of the pile has been broken down and has the appearance of an organic topsoil.

At Stratford, sludge was at one time simply trucked to the landfill site and stored in stockpiles. Because of odors emitted when the stockpiles were broken down, the operator decided to change the stockpiling procedure. At present, freshly dewatered sludge is trucked to the landfill site and spread on sand beds. The sludge is allowed to sit on these beds for a week or so to dry before being scooped up and stored in a stockpile (see Figure 19). As a result of the drying procedure prior to stockpiling, the operator reports that only a slight odor is emitted when stockpiles are broken down and taken to the landfill.

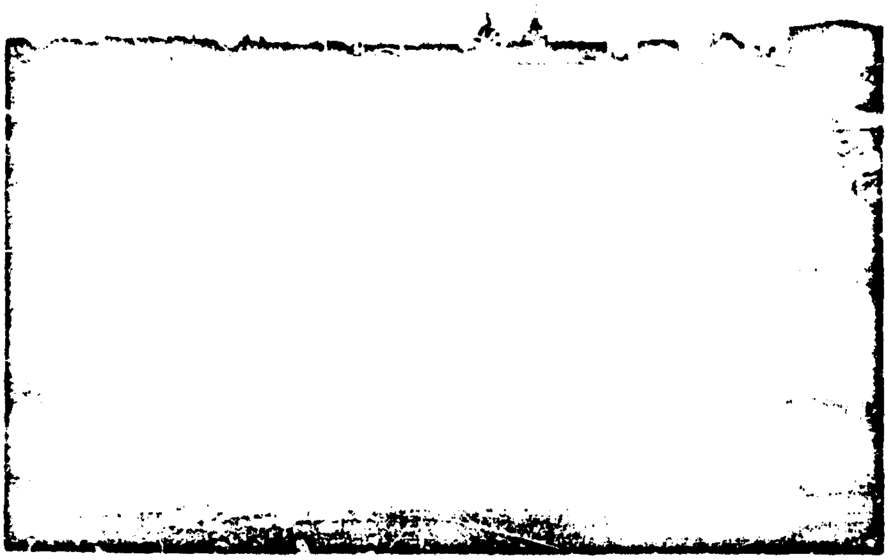


Figure 19. Sand bed dried sludge in stockpiles, Stratford, Connecticut

Landfilling

Landfilling is the means of sludge disposal at 18 of the 28 plants visited. At 12 of the facilities, the sludge is simply buried. Landfill operators at the six other sites take advantage of the fertilizer and moisture holding value of the sludge and use it as a cover material. It was reported that a grass cover grew quite well on the sludge used as a landfill cover.

The only report of odor problems associated with landfilling of the sludge was the result of breaking down old stockpiles. At none of the sites visited was any special monitoring done.

Land Application

At ten of the plants visited, lime stabilized sludge is land-applied. A liquid sludge is applied at four of these plants, and the remainder land-apply a sludge cake. The sludge is used for its fertilizer value and for its ability to increase the moisture holding capacity of the soils.

In many instances, farmers were initially reluctant to accept the sludge. A report based on the land application program at Falmouth, Maine shows how the sludge was gradually accepted by the public. This was a result of careful planning. The public was invited to visit sites where sludge had been applied, to tour treatment plant facilities, and to ask any questions concerning the land application process. Responses to questionnaires sent out to those receiving the sludge were exceptionally favorable.

Uses of the Sludge --

Wastewater treatment plant operators selected application techniques and reuse options, and made the arrangements with those accepting the sludge.

At Falmouth, liquid sludge is applied at no charge to fields where grass is grown. The sludge has been well-accepted and there is a waiting line for recipients. At Thompson, Connecticut, a similar arrangement has been made with those receiving the sludge. Lime-stabilized sludge is applied to fields where silage corn and hay are grown. Lime-stabilized sludge from the Scarborough, Maine, treatment facility is applied to lawns and hay fields, and is also used to reclaim land that has been stripped of loam. The treatment plant receives $6.00 per load of sludge. In addition, the farmers sometimes supply the lime required for stabilization. At North Canaan, Connecticut, a farmer removes the sludge from the treatment plants with his own truck. It is mixed with animal wastes and used on fields where silage corn and hay are grown. Cake sludge from the Enfield, Connecticut, wastewater treatment plant is spread on town land where silage corn is grown. A number of experiments have been run at this site, and will be discussed later in this chapter. Willimantic, Connecticut, sludge is mixed with soil and used as a loam on which grass is grown. Sludge from the Bath, Maine, wastewater treatment plant is used to reclaim land stripped of loam. The organic content of the sludge improves the moisture holding capacity of poor subsoils.

At Rochester, New York, and at Somersworth, New Hampshire, the cake sludge is applied to fields. Treatment plant personnel truck the sludge to the site, spread it on the fields, and harrow it, all at no charge. A portion of the sludge from the Kennebec, Maine, wastewater treatment plant is applied to farmlands. The farmers report that they are very pleased to receive the sludge. Odors are reported to be similar to those when manure was spread, as long as sludge is not stockpiled.

At Somersworth, only 20 percent of the sludge is land-applied as there is difficulty finding additional land. Much of the sludge from Rochester and Enfield is applied to lands owned by the towns. Operators from these three sites expressed a desire to spread more sludge on privately owned lands. The difficulty in locating sites is not one of public acceptance, but of finding land appropriate for landspreading of sludge. Such spreading is regulated when land will have high human contact.

Techniques Used to Apply Liquid Sludge --

The trucks used to land-apply liquid sludge at the sites visited were fabricated from various types of vehicles.

An army surplus truck equipped with a pump and tank was used by the farmer who removed sludge from the North Canaan plant. The truck used at Scarborough, Maine is a converted oil delivery truck. The pump at the rear of this truck was revalved so that it could pump sludge to the truck, mix the contents of the tank on the truck by recirculation pumping, and pump sludge from the truck. The truck is also equipped with a nozzle and splash plate on the rear of the tank so that it can discharge sludge by gravity.

The trucks used at the Thompson and Falmouth facilities were also fabricated. The Thompson truck was converted from an old dump truck. The suspension was built up and a tank fitted to the bed of the truck. A nozzle was fixed to the rear of the tank so that the sludge could be discharged by gravity. The truck used at Falmouth, Maine is shown in Figure 20. Plant personnel completely fabricated this truck from an old flatbed truck. Sludge is discharged by gravity through the nozzle shown at the rear of the tank.

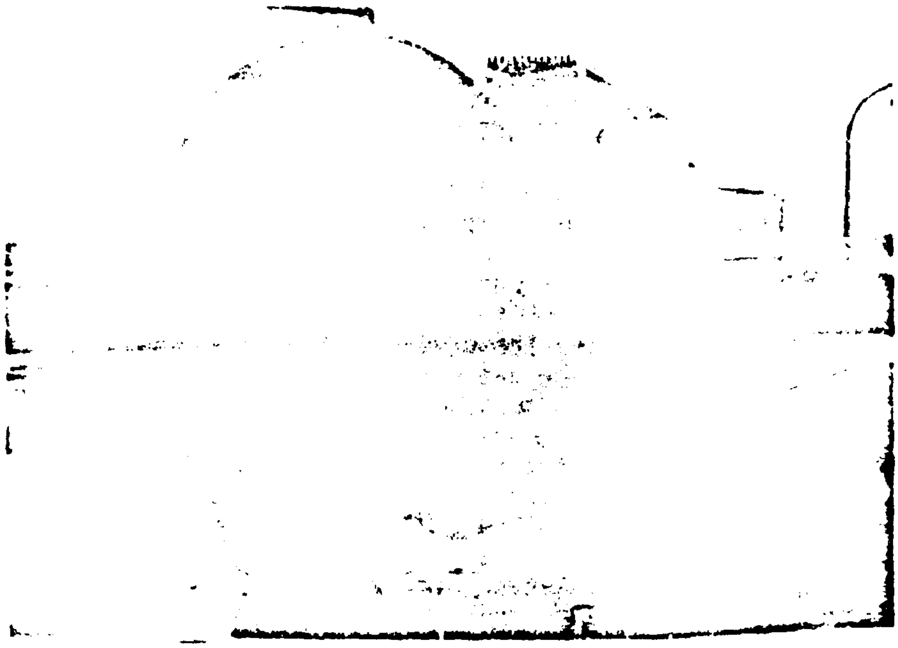


Figure 20. Liquid sludge land application truck, Falmouth, Maine

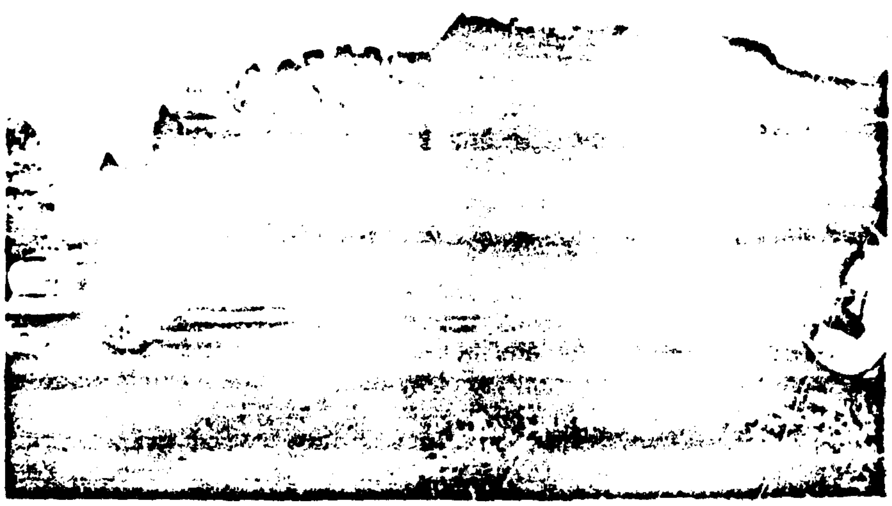


Figure 21. Manure spreader for land applying sludge cake, Somersworth, New Hampshire

The operator at Falmouth, Maine commented that the sludge disposal vehicle could be improved by fitting the truck with a pump and long hose, as used at Scarborough, Maine. This would allow more even spreading of the sludge and would provide access to areas inaccessible to the truck.

Equipment Used to Land-Apply Cake Sludge --

Farm equipment was usually used to handle the land application of the cake sludge. Figure 21 is a picture of a manure spreader used at Somersworth. The blades at the rear of the spreader throw sludge out of the back of the vehicle. A harrow follows the manure spreader, mixing the soil with the sludge.

Attempts to use a manure spreader at the Rochester facility were unsuccessful because the cake was sticky. Figure 3-17 shows the cake sludge application system developed by Rochester treatment plant personnel. Figures 22 and 23, show the hopper that holds the sludge. A sliding gate at the bottom of the hopper opens completely and the cake sludge falls to the ground. The hopper, which rests on skids, is pulled along by a tractor. Sludge falling out of the hopper is left behind in a mat. Mat depth is controlled by an adjustable plate on the rear of the hopper. As shown in Figure 23 , the mat is broken up by blades that follow the hopper. Figure 24 shows the harrows that complete the mixing of sludge with the soil.

Results of Land Application --

It was earlier explained that a number of farmers have willingly accepted lime-stabilized sludge, and some are willing to reimburse the treatment plant for the expense of spreading the sludge. The sludge's lime content has been welcomed by New England farmers who normally have to lime their soil. By using the sludge, the need for liming the soil is reduced or eliminated. The operator at Falmouth, Maine monitors pH of lands to which sludge was applied. If pH were to drop to less than 6.6, lime would be added, but this has never been necessary.

A controlled test was performed at Enfield to analyze the effects of lime-stabilized sludge on crops. The experiment, conducted on town-owned lands located about 5 miles from the treatment plant, lasted from July 1976 to September 1979. Much of the data were collected by staff and students from the University of Connecticut at Storrs. Two separate field areas were established, each divided into sections receiving six different application rates. The sludge was plowed into the soil. One area received sludge only the first year, and the other received sludge each year for three years. The application rates used on each area were 0, 13, 33, 66, 99, and 132 metric tons of sludge per hectare per year. Field areas also received annual additions of potassium fertilizer (112 kilograms per hectare) to supplement the low potassium content of the sludge.

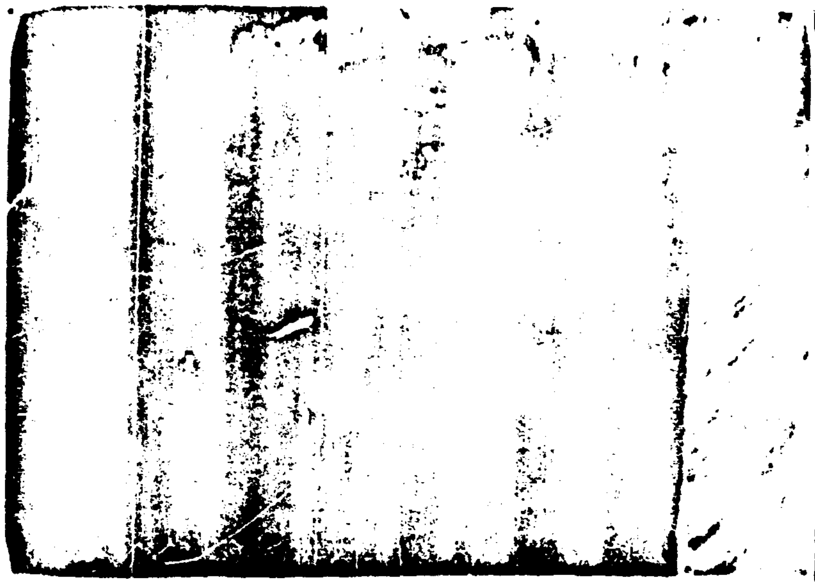


Figure 22. (left) Sludge cake land application equipment, sludge hopper, Rochester, New York

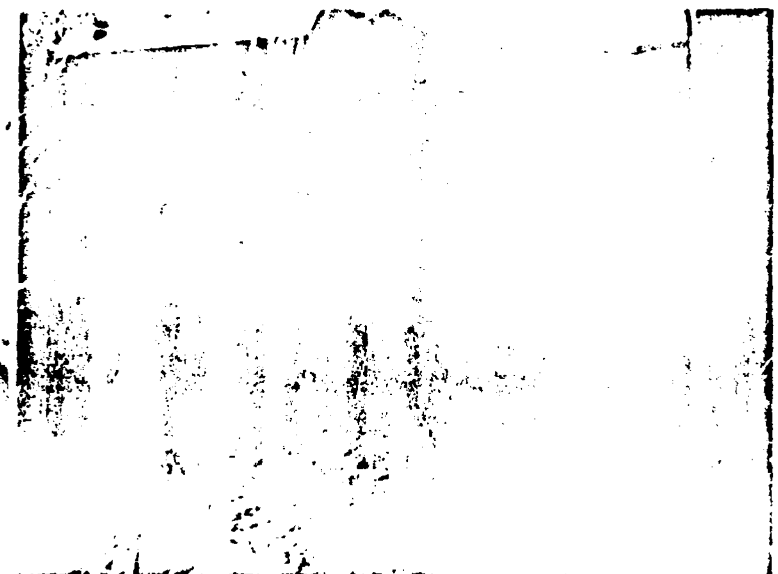


Figure 23. (above) Sludge cake land application equipment, rear of hopper, Rochester, New York

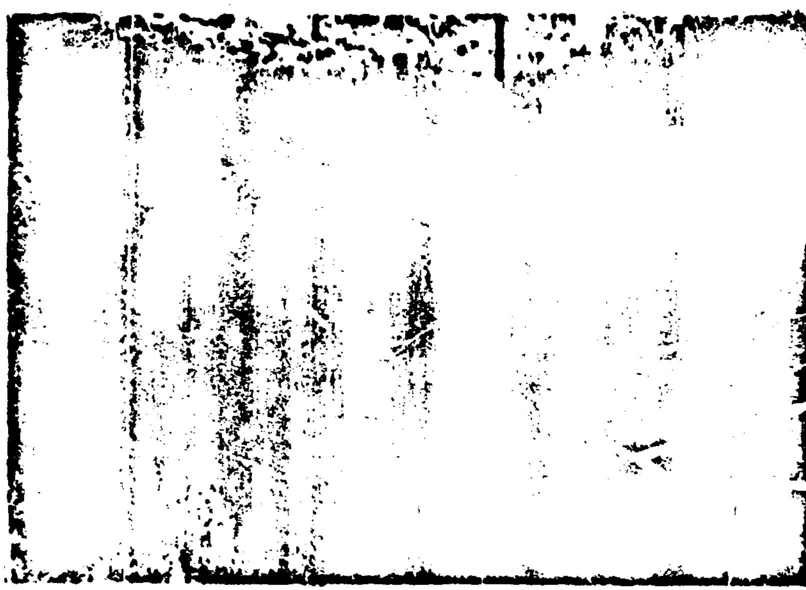


Figure 24. (left) Sludge cake land application equipment, harrows, Rochester, New York

Each May, corn was planted on both fields, to be harvested in September or October. In the first year, yields were higher from those fields receiving the high application rates of sludge. In following years, the plots of land receiving the highest dosage of sludge, and receiving a dose only in the first year of study, continued to have the highest yield of corn. Among those plots receiving annual applications of sludge, however, yields in succeeding years peaked on plots receiving lower application rates of sludge. This response may be attributable to residual sludge nutrient release.

Every year, samples of corn were analyzed for nitrogen, phosphorus, potassium, and heavy metals. Soil samples were obtained to a depth of 244 centimeters and analyzed for nitrate, chloride, pH, cadmium, copper, nickel, lead, zinc, organic nitrogen, and organic matter. The results of this study, taken from an unpublished report (7), were as follows:

1. Annual applications of more than 33 metric tons per hectare of Enfield sewage sludge over a three-year period led to nitrate accumulation in the soil profile. At lower application rates, the corn crops removed a greater proportion of the nitrogen applied, leaving less nitrate to be leached. By decreasing rates of sludge application each year, it appears that minimal nitrate leaching could be achieved, yet satisfactory yields of corn silage could be attained without the need for supplementary nitrogen fertilizer. With the sludge, the best rate of application should be chosen to meet the needs of the crop and minimize nitrate leaching towards the groundwater.

2. Concentrations of cadmium, copper, lead, nickel and zinc in the top 30.5 centimeters of soil increased with increasing application rate and accumulated with the number of sludge applications. No statistically significant increase in concentrations was found below the 30.5 centimeter depth. Soil pH was probably the single factor most responsible for inhibiting downward movements of heavy metals. The limed sewage sludge increased soil pH significantly, which resulted in low metal solubility.

3. The use of limed, dewatered sewage sludge raised soil pH in proportion to the quantity of sludge applied. Soil with an initial pH of 6.1 to 6.4 had a pH of 7.7 after three years of annual applications of 132 metric tons per hectare. The control plot (receiving no sludge) had a pH of 6.8 after three years.

4. Heavy-metal uptake by the corn silage crop was in proportion to the quantity of sludge applied. Heavy-metal concentrations in the harvested crop did not exceed the normal ranges of these metals found in this crop without sewage sludge applied on soil, however. Crop removal of the heavy-metals studied was negligible with respect to the amounts contained in the sludge applied. The uptake of these metals by the crop was less than one percent.

Sludge from the Kennebec, Maine, treatment plant was used to fertilize hay and corn fields. Samples of these crops and samples of the same crops taken from fields fertilized only with conventional fertilizer were analyzed for heavy-metal uptake. Metal uptake was found to be greater in the fertilized fields than in the fields treated with the lime-stabilized sludge. A conclusion drawn was that the lime-stabilized sludge increased the soil pH, ultimately decreasing the availability of soluble metals that could be taken up by the plants. It was recognized that extensive testing in the future will have to be performed to determine the long-term effects of using the sludge.

Other plants have checked heavy-metals in crops, soils, and groundwater, but results have not been documented.

SECTION 4

INNOVATIVE TECHNIQUES

The lime stabilization systems used were generally developed by treatment plant personnel. A number of innovative tecnniques were developed for the stabilization, handling, and disposal of the sludge.

The plants use screw conveyors to mix centrifuge cake and lime. At Glastonbury, Connecticut, a common lawn spreader is used to sprinkle the lime onto a screw conveyor that was taken from an abandoned sludge incinerator. At Stamford, Connecticut a screw conveyor carries lime from a storage silo and meters it to cake sludge in a second screw conveyor.

Two other plants add lime to batch aerobic digesters. At South Windsor, Connecticut, a truckload of liquid carbide lime is ordered when sludge is to be lime-stabilized. The lime is simply dumped into the batch digester and mixed with sludge by the mixer provided with the digester. A truckload of lime is sufficient to lime-stabilize the contents of the digester. No lime handling equipment had to be installed at the plant.

At Thompson, Connecticut, a lime slurry makeup system was already available because lime conditioning prior to vacuum filtration had once been practiced. This system is used to prepare slurry which is then pumped, by portable pump, to an aerobic digester for lime stabilization. Lime-stabilized sludge is pumped from the digester to a land application truck by another portable pump. The land application truck was fabricated by treatment plant personnel. The conversion to lime stabilization required little capital expenditure.

At Scarborough, Maine, no lime system was included in the original plant design. Treatment plant personnel devised a system to add bagged, hydrated lime directly to a sludge line transferring aerobically digested sludge from the digester to a land application truck (Section 3). The land application truck was converted from an old oil delivery truck. The pump on the back of the truck was valved so that it could mix the contents of the truck's tank by recirculation pumping.

At Falmouth, Maine, lime slurry from bagged, hydrated lime is prepared in a slurry makeup tank located just outside of the building housing the sludge storage tank. An air line was run from the building to the slurry makeup tank to provide air mixing for the slurry. The air system was already in use at the plant for another process. No electrical equipment or lines had to be run outdoors to the lime slurry makeup. Lime slurry flows by gravity from the slurry makeup tank to the indoor sludge storage tank, which is used for lime stabilization.

Treatment plant personnel at Rochester, New York had difficulty land applying the stabilized sludge cake with conventional farming equipment. Because the sludge is sticky, they installed a sludge holding hopper on skids (Section 3) Sludge flows readily by gravity from the hopper as it is pulled along a sludge application site.

At Stratford, Connecticut, the use of stockpiles resulted in odor problems at the land application site when the stockpiles were broken down. To solve this problem, sludge was spread on sand beds at the land application site and allowed to sit for about one week to dry. After drying, the sludge was scraped up and placed in stockpiles. By drying the sludge prior to stockpiling, it was found that no odors were emitted when the piles were later broken down.

SECTION 5

COST OF LIME STABILIZATION

COSTS REPORTED AT THE SITES VISITED

The general consensus of treatment plant operators is that lime stabilization offers them the least expensive sludge stabilization alternative. Only three plants have made rough estimates comparing the actual cost of lime stabilization with the cost of incineration, however. At Rochester, New York, savings realized from lime stabilizing instead of incinerating sludge amount to $10 to $20 per ton dry sludge solids. At Stratford, Connecticut, savings of almost $60 per ton dry sludge solids resulted from the conversion to lime stabilization because sludge production is too low for efficient operation of the incinerator. Annual savings of $200,000 reported by the operator at Enfield, Connecticut are also attributable to an oversized incinerator.

ANALYSIS OF COSTS FOR LIME STABILIZATION

This section includes estimates of capital and annual costs which were prepared to facilitate rough budgeting of lime stabilization systems. The costs presented here should not be used as a basis for comparison of lime stabilization costs versus those of alternative processes. Such an analysis would require the simultaneous estimation of costs of all systems being compared to ensure that balanced assumptions and designs are used.

Using data collected from the plant visits we have estimated costs for the following alternatives:

(1) providing a lime slurry system (such as for an existing vacuum filter facility using heat conditioning),

(2) converting a vacuum filter plant capable of lime conditioning to one capable of stabilizing by either

  (a) providing for increased lime dosage in existing facilities, or

  (b) providing for increased lime dosage plus constructing a new sludge conditioning tank with 30-minute detention;

(3) constructing and operating new vacuum filters with lime stabilization; and

(4) stabilizing liquid sludge in a batch operation.

The costs for each alternative were estimated using capacities representative of the plants surveyed. Costs for vacuum filter plant studies were estimated for 1- to 20-mgd plants, and costs for batch lime stabilization were based on capacities of 1 to 5 mgd. Because costs for sludge transportation and disposal are site-specific, they are not included in this study.

Table 5-1 presents the criteria used to determine sludge production, lime usage, and cost for various plant sizes. The capital cost base and salary and electricity costs used are representative of April 1980 costs. Operation and maintenance costs include power, chemicals, labor, system maintenance, receipt of lime, and slurry makeup, where appropriate.

TABLE 4

CRITERIA USED FOR COST STUDY

Sludge Production	2000 pounds sludge per million gallons wastewater treated
Lime Dose for Stabilization	20 percent (as CaO)
Capital Cost Base	3135 (ENR, April 1980)
Capital Cost Amortization	20 years; 7 percent
Salary	\$13.50 per hour (including benefits)
Electrical Cost	\$ 0.06 per Kwh
Maintenance	3 percent of equipment capital cost (annually)
Cost of Lime:	
Bagged Hydrated Lime	\$125 per ton CaO delivered
Carbide Lime	\$ 85 per ton CaO delivered
Quicklime	\$ 65 per ton CaO delivered

The estimated capital costs, in some cases, do not change with plant size. This is the result of using the same equipment, but with different operating schedules. Schedules for operation were selected by analyzing data from the plants visited.

COSTS OF PROVIDING A LIME SLURRY SYSTEM FOR EXISTING VACUUM FILTERS

We developed and compared costs for three methods of procuring a lime slurry for use prior to vacuum filtration: (1) preparation of slurry from bagged hydrated lime; (2) purchase of carbide lime slurry; and (3) preparation of slurry by slaking quicklime. Costs include the following variables: chemical purchase, delivery and storage; slurry makeup; and building space. Because the cost of pumping slurry to vacuum filter conditioning and the cost of a ferric chloride system do not vary among the systems under study, they are not included.

Figure 25-a shows the capital costs, Figure 25-b shows the operation costs, and Figure 25-c shows the total annual costs. As illustrated by Figure 25-c, bagged hydrated lime and prepared carbide lime slurry are less expensive than slaked quicklime in smaller plants. As seen in that figure, capital costs for quicklime slaking systems are so high that their use in small plants would not be considered. At treatment plants with capacities of about 5 mgd, slaking quicklime becomes economical. At plants larger than 5 mgd, high manpower requirements make handling bagged hydrated lime more expensive and inconvenient than purchasing carbide lime slurry. At larger plants with greater lime consumption, the use of slaked quicklime becomes the least expensive alternative because of the low cost of quicklime.

The costs associated with a hydrated lime system include a fork-lift truck for moving bagged lime; storage; and a slurry makeup system comprised of tanks, a dust control system, mixers, and loading platforms. The carbide lime system costs include those of storage tanks with mechanical mixers, transfer pumps, and dilution/day tanks. The quicklime system costs are based on silo storage, pneumatic conveyance to day silos, slakers, and slurry tanks.

COST OF CONVERSION TO LIME STABILIZATION AT A FACILITY WITH VACUUM FILTRATION

Figure 26 reports the costs estimated for institution of lime stabilization at a plant with vacuum filtration by (a) simply increasing the dose of lime to the existing conditioning drum or (b) both increasing doses and constructing a larger sludge conditioning/stabilizing tank with a 30-minute detention time. For this analysis, it was assumed that the increase in lime dose between sludge conditioning and sludge stabilization was from 12 percent to 20 percent CaO per dry sludge solids. At the particular sites visited, no capital investment was required as lime handling equipment included in the original design was sufficiently large to handle the increased dosages needed for lime stabilization. Therefore, Figure 5-2 does not include costs for lime handling systems. Costs for a system requiring installation of a larger conditioning tank are reported in case a longer liquid sludge detention time is desired.

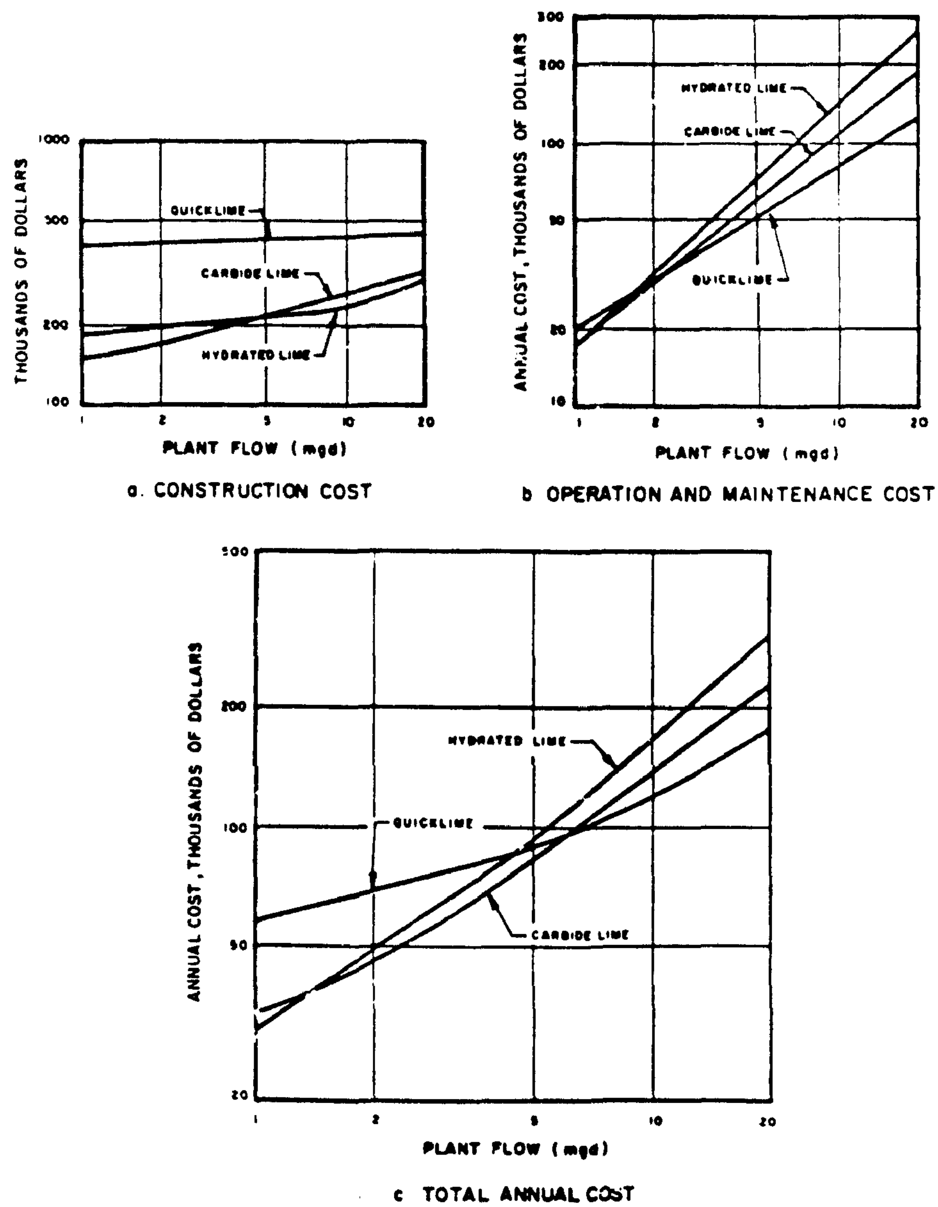
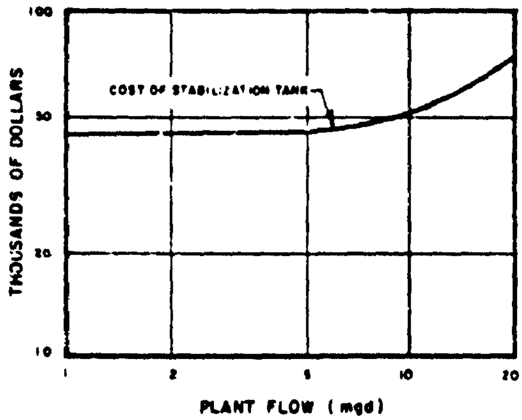
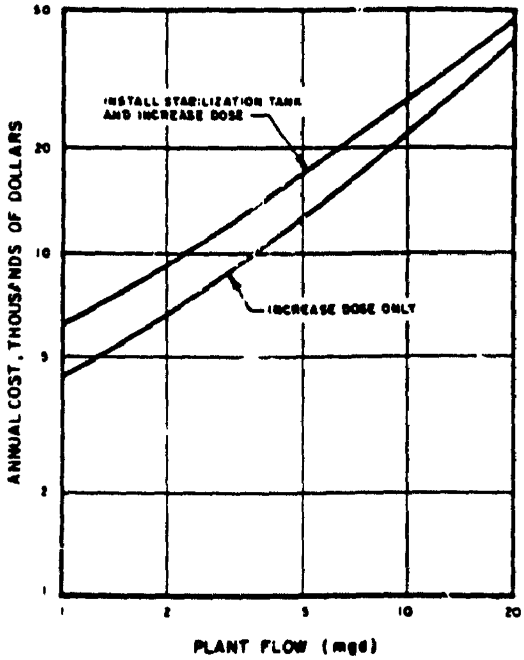


FIG. 25. COSTS OF PREPARING LIME SLURRY FOR ADDITION PRIOR TO VACUUM FILTRATION



a. CONSTRUCTION COST



b. OPERATION AND MAINTENANCE COST

FIG. 26. COST OF CONVERSION TO LIME STABILIZATION AT A FACILITY WITH VACUUM FILTRATION

The costs of stabilizing lime by simply increasing lime dosage are essentially determined by the increased chemical cost and the increased labor costs associated with handling lime and monitoring pH. The cost of a system with a new, larger conditioning tank includes the costs of lime; labor for lime handling and pH monitoring; labor and parts for conditioning tank maintenance; power for conditioning tank mixing; and the capital cost of conditioning tank, mixer, and building space.

COST OF NEW VACUUM FILTERS WITH LIME STABILIZATION

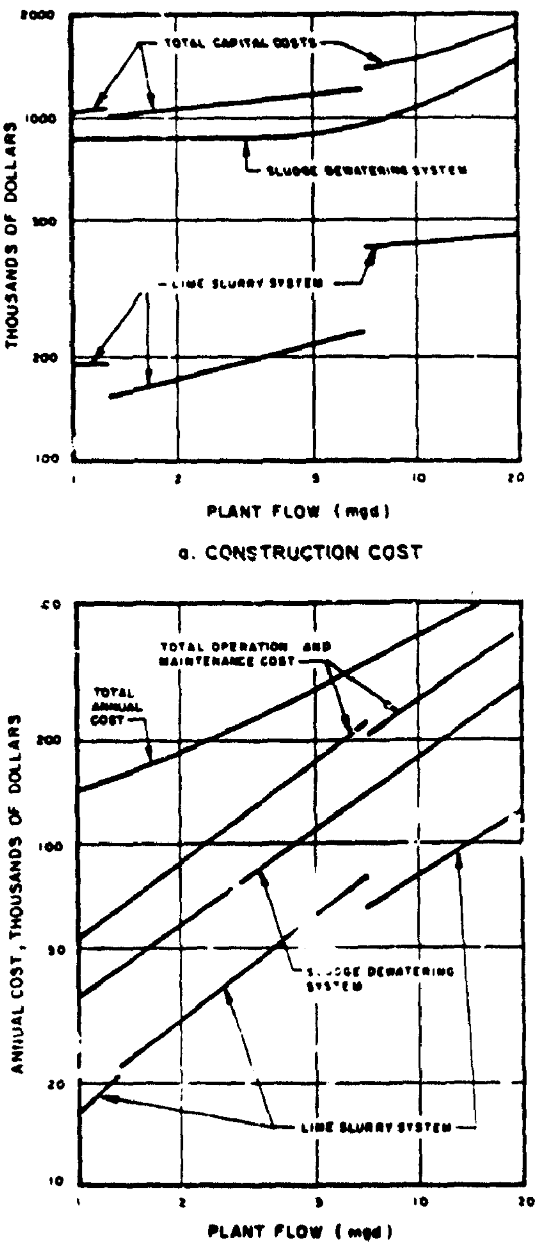
Costs for constructing and operating a complete lime stabilization system with vacuum filtration were developed and are reported on Figure 27. The slurry systems selected for use are each the least costly system for a given plant size, as shown in Figure 25. The flat curve representing capital costs for 1- through 5-mgd facilities reflects the selection of the same number of vacuum filters (two) with different operating schedules, vacuum filter sizes, and back-up requirements to handle the various sludge loads.

Costs for the dewatering system include slurry metering pumps; piping; 30-minute, mechanically mixed stabilization tanks; vacuum filters (with 4 lb/sf/hr loading); sludge conveyors; control panels; and building requirements. The cost of constructing and operating a ferric chloride system and the cost of purchasing the chemical are also included.

COST OF LIME STABILIZATION OF LIQUID SLUDGE IN A BATCH OPERATION

Costs associated with constructing and operating a system to lime stabilize a liquid sludge prior to land application were also developed and are reported in Figure 28. Sludge would be stored in the winter and lime stabilized during a seven-month period. Sludge storage costs are not included. Those plants studied which lime-stabilize liquid sludge in a batch operation either had sufficient winter sludge storage capacity in initial plant design or lime-stabilize sludge only on a seasonal basis.

Capital costs are broken into two parts: (1) the cost of equipment to prepare and pump lime slurry and (2) the cost of lime stabilization tanks. The cost of lime slurry preparation and handling equipment is reported separately because some plants, such as South Windsor and Thompson, Connecticut, have aerobic digesters in which stabilization can be accomplished. The capital cost of the total system reflects the cost of constructing a complete system operating in a mode similar to that at Falmouth, Maine.



a. CONSTRUCTION COST

b OPERATION AND MAINTENANCE COST AND TOTAL ANNUAL COSTS

FIG. 27. COST OF NEW LIME STABILIZATION AND NEW VACUUM FILTRATION

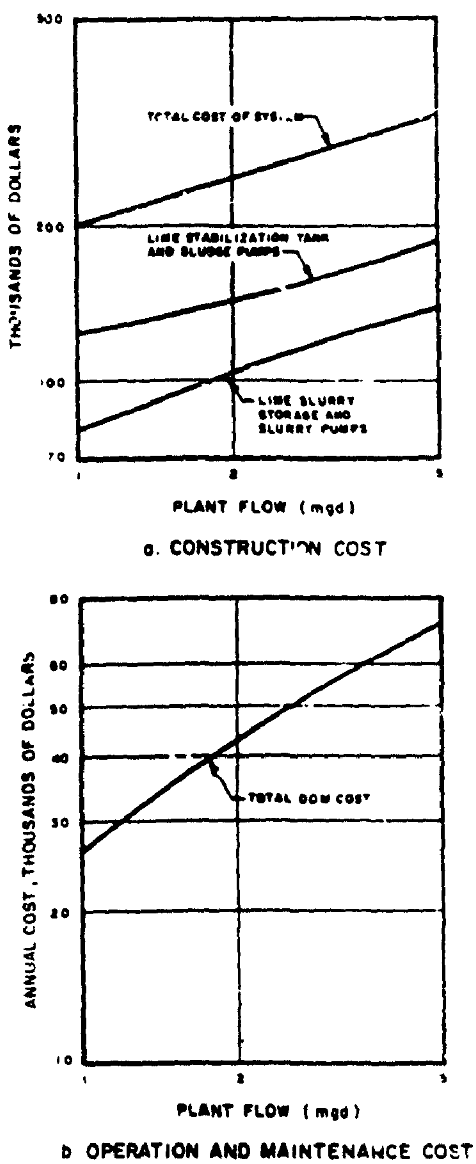


FIG. 28. COST OF LIME STABILIZATION OF LIQUID SLUDGE IN A BATCH OPERATION

The costs reported are for a system using carbide lime slurry because this is the least expensive alternative for batch lime stabilization. Capital costs include slurry storage tanks and mixers, lime slurry transfer pumps, piping, lime stabilization tanks with mechanical mixers, and pumps and pump gallery for transferring stabilized sludge to trucks for land application. Operation and maintenance costs include chemical costs, cost of pumping lime slurry and lime-stabilized sludge, costs of labor and parts for maintenance of slurry system and stabilization tanks, and labor costs for running the entire process.

SECTION 6

ACCEPTABILITY OF METHODS

The degree of pathogen destruction in sludge attained by lime stabilization is affected by the pH reached, the length of time the high pH is maintained, and the completeness of lime/sludge mixing. Data from this study and studies from the literature show that indicator and pathogen numbers are effectively reduced in a liquid sludge limed to a pH of 12.0 and held at that pH for two hours or more. Deviation from these operational variables may adversely change the effectiveness of kill.

Using these variables, we have rated the system observed in the plant visits. The ratings reflect only a system's ability to attain the required pH, its degree of lime and sludge mixing, its lime and sludge mixing detention time, and the detention time over which its pH may be monitored. The ratings (all assuming proper operation of equipment) are:

(1) Acceptable
(2) Conditionally acceptable (acceptable, but requires attentive operation)
(3) Requires further study
(4) Not acceptable.

LIME ADDITION TO LIQUID SLUDGE BEFORE LAND APPLICATION

1. Addition of hydrated lime to sludge being pumped to land application truck (conditionally acceptable). This type of system depends on the sludge truck's pumping action to recirculate the sludge and provide the mixing required. With this technique, mixing throughout the truck might be incomplete. It is acceptable only with careful operation to ensure complete lime/sludge mixing for an adequate period.

2. Lime addition to storage tank mixed by recirculation pumping (conditionally acceptable). This technique requires that sludge and lime be mixed in a storage tank by recirculation pumping. Because complete mixing would be difficult to attain, this method is acceptable only if operation ensures good lime/sludge mixing and testing for pH.

3. Lime addition to mixed batch tanks (acceptable). If this system is designed to provide good mixing, the operation simply requires that the operator maintain a pH level of 12 for two hours. If the pH level is not maintained, more lime can be added and pH retested later. This type of system can be recommended because it ensures the time and degree of mixing needed for lime stabilization.

LIME ADDITION TO LIQUID SLUDGE BEFORE DEWATERING

1. Lime addition to vacuum filter conditioning drum (conditionally acceptable). Indications are that this commonly used technique is effective when operated properly. Spot bacterial analysis performed at some plants demonstrated effective bacterial kill. Odors, a sign of bacterial infestation, were effectively controlled by this technique. Detention of the lime/liquid sludge blend is only 15 minutes, but an excess lime dose can be added to ensure that pH 12 will be maintained in the cake for two hours. A disadvantage is that corrective measures are determined after a sludge is dewatered, with the possible result of improperly stabilized cake.

LIME ADDITION TO DEWATERED SLUDGE CAKE

1. Lime addition to sludge screw conveyor (requires further study). In this method, lime is added to a cake sludge and the two are mixed with a screw conveyor. There has been no testing to show whether there is proper mixing and whether organisms are killed throughout the sludge. It merits study, however, because of its simplicity and because of its effectiveness in controlling odors.

2. Lime addition to sludge cake storage. This method has been rated not acceptable, due to incomplete mixing.

SECTION 7

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APPENDIX

DATA FROM PLANTS VISITED

1. ENFIELD, CONNECTICUT

(Lime Added to Vacuum Filter Conditioning Tank)

A. PLANT DATA

Plant Type: Conventional activated sludge

Plant Flow: 10.0 mgd design
4.5 mgd present average

Quantity Limed: 3.0 dry tpd present average

B. WASTEWATER PROCESSING TRAIN

Pretreatment
- Comminutors
- Grit removal

Primary Treatment

Secondary Treatment
- Conventional activated sludge

Chlorination

Discharge
- Connecticut River

Comments: Influent wastewater is almost all domestic.

C. SLUDGE PROCESSING TRAIN

Primary Sludge
- Combined with secondary sludge in primary clarifier

Secondary Sludge
- Aerobic Digester
- Primary influent wastewater stream

Combined Sludges
- Sludge conditioning/lime stabilization
- Vacuum filtration
- Stockpile/land application

Comments: Lime stabilization is practiced because it is too costly to operate the multiple-hearth furnace.

D. LIME USE

Type of Sludge: Primary sludge and aerobically digested secondary sludge

Solids Concentration of
Sludge Before Lime Added: 4 to 8 percent

Lime Dosage (as CaO per
weight of dry sludge solids): 25 to 30 percent

Quantity of Lime Used: 33 tons per month, $Ca(OH)_2$

pH Attained: 12.0

Other Chemicals: Ferric chloride added in sludge conditioning, 7 percent.

E. DETAIL OF LIME SYSTEM

Lime Delivery/Storage

Type of Lime Purchased: Lime slurry, 40 percent concentration. Concentration varies with truckload but is usually quite consistent. The slurry is a byproduct/waste material from acetylene production.

Delivery: Purchase about one 4800-gallon truckload per week. Lime flows by gravity to storage tanks. Occasionally, there is a problem with gravel in the lime slurry; the operator depends on the supplier to screen the slurry.

The delivery line is 3 inches in diameter. It has a long vertical run and has clogged. About 30-40 minutes are needed to unload the truck.

Storage: Two, 6000-gallon horizontal, cylindrical steel tanks. Constantly mixed with low-speed, rotating paddle mixers.

Inventory: One to two weeks' supply always kept on hand. Delivery schedule is regular, no reported problems.

Lime Slurry Transfer Pumps

Type and Number of Pumps: Two mechanical diaphragm pumps, each with air cushion/standpipe type shock absorption.

Type of Piping: Vertical exit lines are iron; horizontal lines are 2-inch hose sitting in troughs. A flushing system is used daily.

Valving: Can pump from any storage tank, with any pump, to any day tank.

Lime Slurry Dilution/Day Tanks

Type and Number of Dilution Tanks: Two, 2000-gallon steel cylindrical tanks. The bottom of each tank forms a cone; at the cone bottom is the exit port.

Type of Mixing: Low-speed paddle mixers

Method of Dilution: Operator measures quantity of slurry in tank by measuring tank depth. Dilution water is measured with a water meter.

Diluted Slurry Concentration: 20 percent as $Ca(OH)_2$

Type of Water Used in Dilution: Plant water

Comments: Lime slurry is diluted at night. The tanks have sufficient capacity for a day's operation.

Lime Metering Pumps

Type and Number of Pumps: Two mechanical diaphragm pumps (no shock absorption equipment)

Type of Piping: Vertical exit lines are steel. Horizontal lines are hose, sitting in troughs. A flushing system exists and is used daily.

Valving: Can pump from any day tank, with any pump, to any conditioning tank.

Lime Application to Sludge Conditioning Tank

Point of Application: Slurry is added to a conventional horizontal sludge conditioning tank located beside each vacuum filter.

Dosage Control: Operator sets the metering pump speed from a control panel located at the vacuum filters.

Dosage Setting: Dosage is initially set by past experience. pH is then measured.

pH Measurement: Frequently measured on the sludge cake using a pH meter.

pH Holding Time: Detention time in filter vat only. Operator has checked cake pH decay and would expect none over a short period.

Quantity of Slurry Used: 2000 gallons per day

Comments: Ammonia odors are present in the conditioning tank/vacuum filter area.

F. DOWNSTREAM PROCESS

Dewatering

Type: Two vacuum filters (coil medium)

Scheduling: Filter 4 days per week, 7 hours per day, one filter.

Loading Rate: 3.5 lb/sq ft-hr

Cake Solids Concentration (includes weight of lime): 20 percent

Comments: The effects of the high lime dose on the treatment plant operations are negligible. The filtrate (pH 12) is returned to the primary influent causing a higher input solids concentration. No problems have resulted from this. The vacuum filter coils are washed in an acid bath every 5 to 6 months. Also, lime scale is manually chiped from the storage tanks every 6 to 8 months. This is considered to be normal maintenance.

Disposal

Method: Stockpile/land application

Procedure: The stabilized sludge cake is transported by conveyor to a dump truck and hauled to a field at the town landfill site. The sludge is stored in 3-foot-high piles. These maximize drying. Periodically, sludge is taken from these stockpiles and applied to experimental corn fields. Some odors exist when these piles are broken into. This process and its results are described in the text.

Comments: When lime stabilization was instituted, the procedure was to incinerate during the winter and to lime stabilize and stockpile the rest of the year.

G. COST OF LIME STABILIZATION

Equipment

Lime handling equipment was originally installed for chemical conditioning prior to dewatering. The equipment is of sufficient size to handle doses required for stabilization. Provision for loading dewatered cake directly to trucks was included in the original design.

Operation and Maintenance

The only increase in costs noted is the increased cost for additional lime. This cost is much lower than the incineration alternative. A cost study was performed to support this conclusion.

Lime is purchased at \$61 per ton of $Ca(OH)_2$.

Lime cost about \$20 per dry ton of sludge treated.

H. SPECIAL STUDIES

See text, Section 3.

2. GLASTONBURY, CONNECTICUT

(Lime Added to Centrifuge Cake)

A. PLANT DATA

Plant Type: Secondary treatment by activated sludge

Plant Flow: 3.6 mgd design
1.1 mgd present average

Quantity Limed: 2.0 dry tpd present average

B. WASTEWATER PROCESSING TRAIN

Pretreatment

Primary Treatment

Secondary Treatment
- Activated sludge

Chlorination

Discharge
- Connecticut River

Comments: Influent wastewater is essentially all domestic

C. SLUDGE PROCESSING TRAIN

Primary Sludge
- Sludge degritter
- Gravity thickener (with secondary sludge)

Secondary Sludge
- Gravity thickener (with primary sludge)

Combined Sludge
- Centrifuge (polymer added)
- Lime addition to cake
- Compost/Stockpile
- Landfill

Comments: Lime stabilization is practiced because it is too costly to operate the multiple-hearth furnace. Lime is used primarily to control odors.

D. LIME USE

Type of Sludge: Centrifuge-dewatered primary and secondary sludge.

Solids Concentration of
Sludge Before Lime Added: 17 to 18 percent

Lime Dosage (as CaO per
weight of dry solids): 6 percent

Quantity of Lime Used: 4.8 tons per month, $Ca(OH)_2$

pH Attained: 11.0 to 12.0

Other Chemicals: Polymer added prior to centrifuging.

Comment: Now that composting has been instituted, lime is added simply for odor control. A pH of 12.0 is not always attained.

E. DETAIL OF LIME SYSTEM

Lime Delivery/Storage

Type of Lime Purchased: 50-lb bags of high-calcium hydrated lime.

Delivery: 500 bags about 4 times a year. These bags are moved manually. This takes 4 men about 1.5 hours.

Storage: Bags are stored indoors, stacked about 5 feet high on pallets.

Inventory: Operator keeps a minimum of 3 days' supply on hand. One order supplies the plant for about 3 months.

Lime Application to Cake

Point of Application: To dewatered cake conveyor.

Type of Applicator Method of Application: This system is described in detail in the text.
Method of Mixing Lime and Sludge: Screw conveyor.

Lime Dose Control: Spreader can be opened or closed to adjust the dose.

pH Measurement: Measured twice a day on stabilized cake with pH probe.

pH Holding Time: Composites from 3 hours of operation are held Average holding time is 4 hours.

probe.

F. DOWNSTREAM PROCESS

Disposal

Method: Landfill

Procedure: The stabilized sludge cake falls off the screw conveyor into a 20 cubic yard steel container. Once a day a container truck picks up the sludge container and brings it to a landfill site. The sludge is then mixed with leaves and wood chips. This mixture is stockpiled/composted until it is utilized as cover material at the site. No monitoring is done on this sludge.

G. COST OF LIME STABILIZATION

Equipment

Screw conveyor used to mix lime with sludge is a converted ash conveyor taken from the shut-down multiple hearth incinerator. No other equipment purchased.

Operation and Maintenance

Lime is added using the dewatering schedule, 8 hours per day, three days per week. A man must constantly watch the lime system. Lime is purchased at $93 per ton $Ca(OH)_2$. The cost of trucking sludge has increased. The number of loads has doubled since incinerator shut down.

Lime costs about $7.50 per dry ton of sludge treated.

3. GROTON TOWN, CONNECTICUT

(Lime Added to Centrifuge Cake)

A. PLANT DATA

Plant Type: Conventional activated sludge

Plant Flow: 5.0 mgd design
2.5 mgd present average

Quantity Limed: 2.3 dry tpd present average

B. WASTEWATER PROCESSING TRAIN

Primary Treatment

Secondary Treatment
- Conventional activated sludge

Chlorination

Discharge
- Fort Hill Brook

Comments: Influent wastewater is essentially all domestic.

C. SLUDGE PROCESSING TRAIN

Primary Sludge
- Degritter
- Gravity thickener (with secondary sludge)

Secondary Sludge
- Holding tank
- Gravity thickener (with primary sludge)

Combined Sludges
- Centrifuge (polymer added)
- Storage
- Lime addition
- Landfill

Comments: Lime stabilization is practiced because it is too costly to operate the heat treatment system and the multiple-hearth furnace.

D. LIME USE

Type of Sludge: Centrifuge-dewatered primary and secondary sludge.

Solids Concentration of
Sludge Before Lime Added: 16 percent

Lime Dosage (as CaO per
weight of dry solids): [illegible]0 percent

Quantity of Lime Used: 27 tons per month, $Ca(OH)_2$

pH Attained: 12.0

Other Chemicals: Polymer added prior to centrifuging, 2-3 percent.

E. DETAIL OF LIME SYSTEM

Lime Delivery/Storage

Type of Lime Purchased: 50-lb bags of high-calcium hydrated lime.

Delivery: 800 bags approximately twice a month. The bags are delivered on pallets and moved around with heavy equipment.

Storage: Stacked 10 bags high on pallets, outdoors. Covered with plastic only.

Inventory: Operator keeps a minimum supply of 100 bags on hand.

Comments: The lime hardens when it is stored outside. The operator reports that it is broken apart when it is mixed with the wood chips and sludge.

Lime Application to Cake

Point of Application: Cake storage pit (abandoned trickling filter)

Method of Application: Sludge cake is stored in a pit. Once a month, a predetermined number of lime bags are mixed (crushed) with wood chips. This mixture is applied to the sludge cake. All of the mixing is done with a rented front-end loader. Some odors exist during this process. Studies to consider other methods of lime application are being conducted.

Method of Mixing Lime and Sludge: Front-end loader.

Lime Dose Control: Laboratory pretest of sludge cake. Lime is added to slurried cake until a pH of 12 is reached in a test to predetermine the proper lime dose.

pH Measurement: A pH probe is used on sludge cake samples.

pH Holding Time: No specific holding time.

F. DOWNSTREAM PROCESS

Disposal

Method: Landfill

Procedure: The stabilized sludge cake is taken from the storage/ mixing pit and loaded with the front-end loader into a dump truck. It is then hauled to the landfill and stockpiled, until it is utilized as cover material. No monitoring is done on this sludge.

G. COST OF LIME STABILIZATION

Equipment

No equipment purchased. All of the necessary equipment was on site or was rented.

Operation and Maintenance

Only the cost of lime and the cost of renting the front-end loader and dump truck. Additionally, there is more sludge to truck.

The rental equipment costs $5000 per month and the lime stabilization process requires 3 persons for about 2 days.

Lime is purchased at $80 per ton $Ca(OH)_2$.

Lime costs about $32 per dry ton of sludge treated.

4. TOWN OF KILLINGLY, CONNECTICUT

(Lime Added to Vacuum Filter Conditioning Tank)

A. PLANT DATA

Plant Type: Conventional activated sludge

Plant Flow: 8.0 mgd design
2.0 mgd present average

Quantity Limed: 2.3 dry tpd present average

B. WASTEWATER PROCESSING TRAIN

Pretreatment
- Aerated grit removal

Primary Treatment

Secondary Treatment
- Conventional activated sludge

Chlorination

Discharge
- Quinebaug River

Comments: Influent wastewater is 25 percent industrial, mostly paper mill wastes, and 75 percent domestic.

C. SLUDGE PROCESSING TRAIN

Primary Sludge
- Sludge blending box
- Gravity thickener
- Mechanically mixed sludge storage tank (5 percent solids)

Secondary Sludge
- Mixed with primary sludge at sludge blending box, or
- Flotation thickener and mixed with primary sludge at storage tank

Combined Sludge
- Sludge conditioning/lime stabilization (ferric chloride also added)
- Vacuum filtraton
- Landfill

Comments: Lime stabilization is practiced because it is too costly to operate the multiple-hearth furnace.

D. LIME USE

Type of Sludge: Mixture of gravity thickened raw primary and secondary sludge (flotation thickening optional).

Solids Concentration of Sludge Before Lime Added: 4.5 to 6.5 percent

Lime Dosage (as CaO per weight of dry sludge solids): 19 percent, average

Quantity of Lime Used: 17 tons per month, $Ca(OH)_2$

pH Attained: 11.5 to 12.0

Other Chemicals: Ferric chloride added in sludge conditioning tank, 1 to 3 percent

E. DETAIL OF LIME SYSTEM

Lime Delivery/Storage

Type of Lime Purchased: 50-lb bags of high-calcium hydrated lime.

Delivery: 900 bags every 5-6 weeks. The bags are stacked on pallets and moved with a fork lift.

Storage: Bags are stacked about 5 feet high. The storage area is dry, indoors, accessible to heavy equipment, and located beside the slurry mixing tanks.

Inventory: A minimum of 200 bags (4 days) is always kept on hand.

Preparation of Lime Slurry

Type and Number of Mixing Tanks: Two 900-gallon unlined steel tanks

Type of Mixing: Low-speed rotating paddle boards.

Mixer Motor Size: 1.5 HP

Dust Control Equipment: Lime is added through a small hatch on top of the tank. Forced ventilation pulls dust into the tank. Air cleaned by bag filters and vented to outdoors. Despite the use of this system, area is still fairly dusty.

Method of Slurry
Preparation: Operator manually adds 100 pounds of lime to 100 gallons of water. The bags are opened and poured manually.

Prepared Lime Slurry Concentration: 10.7 percent as $Ca(OH)_2$

Type of Water Used in Slurry Makeup: Plant water

Frequency of Slurry
Makeup: Lime slurry is continually made up in the mix tanks while filtering is in progress.

Special Equipment: Bag filters are a low maintenance item, but require replacement after two years.

Lime Metering Pumps

Type and Number
of Pumps: Two plunger pumps. Pumps are calibrated to be metering pumps by adjusting pump speed. Air cushion/standpipe type shock absorption.

Type of Piping: Two-inch galvanized pipe with unions but without tees. To clean, pipe system is broken down. Manual full flushing system exists however once every year lines are broken down and cleaned.

Valving: Can pump from any mix tank, with any pump, to any conditioning tank.

Lime Application to Sludge Conditioning Tank

Point of
Application: Slurry is added to a conventional, rotating, horizontal, sludge conditioning tank located beside the vacuum filter.

Dosage Control: Operator sets metering pump speed from control panel located at vacuum filters.

Dosage Setting: Operator tests pH of sludge cake and adjusts lime feed to obtain required pH.

pH Measurement: pH is measured with litmus paper on the vacuum filter cake. Occasionally a pH probe meter test is done.

pH Holding Time: Detention time of filter vat only. Cake sometimes checked for pH after three hours holding.

Quantity of Slurry Used: 4200 gallons per day

Comments: Some ammonia odors exist in the conditioning tank area.

F. DOWNSTREAM PROCESS

Dewatering

Type: Two vacuum filters (coil medium)

Scheduling: Filter 2 days per week, 8 hours per day, both filters.

Loading Rate: Average 4 lb/sq ft-hr

Cake Solids Concentration (includes weight of lime): 20 percent

Comments: There have been no major effects reported from using the high lime dose. The filtrate (pH 9.5) is returned to the influent. This raises the pH of the influent but no effect on treatment has been noticed. Lime system is acid washed every 4 months.

Disposal

Method: Landfill

Procedure: The stabilized sludge cake is transported by conveyor to a hopper which deposits it in a 5 cubic yard dump truck. The hopper is designed for short-term storage when the truck is away. The truck hauls the sludge to a landfill where it is mixed with sand and used as a final cover material. No monitoring is done.

G. COST OF LIME STABILIZATION: About \$23 per dry ton of sludge treated.

Equipment

Lime handling system was originally installed for chemical conditioning prior to dewatering. The equipment is of sufficient size to handle the increased dose required for stabilization. Thus, no additional capital expense was incurred.

Operation and Maintenance

No data are available to compare the dose and cost of lime with other alternatives (existing incinerator never used due to projected expense). No major cost effects on operation or maintenance were noted. Lime is purchased at \$91 per ton $Ca(OH)_2$.

5. MIDDLETOWN, CONNECTICUT

(Lime Added to Vacuum Filter Conditioning Tank)

A. PLANT DATA

Plant Type: Conventional activated sludge

Plant Flow: 6.0 - 10.0 mgd design
4.0 mgd present average

Quantity Limed: 1.7 tpd present average

B. WASTEWATER PROCESSING TRAIN

Pretreatment
- Comminutor
- Aerated grit removal

Primary Treatment

Secondary Treatment
- Conventional activated sludge

Chlorination

Discharge
- Connecticut River

Comments: Influent wastewater is less than 1.0 percent industrial flow.

C. SLUDGE PROCESSING TRAIN

Primary Sludge
- Holding tank with secondary sludge

Secondary Sludge
- Gravity thickener or
- Influent wastewater and settled with primary sludge prior to holding tank.

Combined Sludge
- Sludge conditioning/lime stabilization (ferric chloride also added)
- Vacuum filtration
- Landfill

Comments: Lime stabilization is practiced because it is too costly to operate the multiple-hearth furnace.

D. <u>LIME USE</u>

Type of Sludge: Mixture of raw primary and gravity thickened secondary sludge.

Concentration of
Sludge Before Lime Added: 3.0 - 4.0 percent

Lime Dosage (as CaO per
weight of dry sludge solids): 23 percent

Quantity of Lime Used: 15.5 tons per month, $Ca(OH)_2$

pH Attained: 12.1

Other Chemicals: Ferric chloride added in sludge conditioning tank, 4 - 5 percent.

E. <u>DETAIL OF LIME SYSTEM</u>

<u>Lime Delivery/Storage</u>

Type of Lime Purchased: 50-lb bags of high-calcium hydrated lime.

Delivery: 900 bags about every 5-6 weeks. There are 50 bags on a pallet and the pallets are moved with a fork lift.

Storage: Bags are stacked on pallets 5 ft high. The storage area is dry, indoors, accessible to heavy equipment and located beside the slurry mixing tanks.

Inventory: A minimum of 60 bags is always kept on hand.

<u>Preparation of Lime Slurry</u>

Type and Number of Mixing Tanks: Two 650-gallon unlined steel tanks.

Type of Mixing: High-speed, portable propeller mixer.

Mixer Motor Size: 1.5 HP

Dust Control Equipment: Lime is added through a small hatch on top of the tank. Forced ventilation pulls dust into the tank. Air cleaned by bag filters and vented to outdoors.

Method of Slurry Preparation: Operator manually adds 50 pounds of lime to 100 gallons of water.

During vacuum filtration/lime stabilization, more lime slurry must be made up. The slurry is made up in the mix tank while the operation is still in progress.

Prepared Lime Slurry Concentration: 5 percent as $Ca(OH)_2$.

Type of Water Used in Slurry Makeup: City water.

Frequency of Slurry Makeup: A total of 2 man-hours per filtering day are required.

Special Equipment: Flooring around the lime mixing tanks consists of metal grating which is 3 feet from the top of the 5 foot high tank. This makes the manual addition of the lime bags much more convenient.

Lime Metering Pumps

Type and Number of Pumps: One mechanical diaphragm pump is used for metering the lime slurry. No shock absorption system.

Type of Piping: One-and-a-half-inch galvanized pipe, with a built-in flushing system. There are pipe breaks for disasssembly and acid washing.

Valving: The one lime pump can pump from either mix tank.

Lime Application to Sludge Conditioning Tank

Point of Application: Slurry is added to a vertical sludge conditioning tank located beside the vacuum filter. Tank is equipped with a medium speed 3-blade paddle mixer.

Dosage Control: Operator sets metering pump speed from panel located at the vacuum filter.

Dosage Setting: Operator sets lime dose to attain required pH.

pH Measurement: pH is measured daily with litmus paper at the vacuum filter conditioning tank.

pH Holding Time: Detention time of filter vat only.

Quantity of Slurry Used: 3400 gallons per day.

F. DOWNSTREAM PROCESS

Dewatering

Type: One vacuum filter (coil medium).

Scheduling: Filter 5 days per week, 8 hours per day.

Loading Rate: Average 4-5 lb/sq ft - hr

Cake Solids Concentration (includes weight of lime): 20-22 percent.

Comments: There have been no major effects reported from using the high lime dose. Only the normal maintenance of a lime system is required.

Disposal

Method: Landfill

Procedure: The stabilized sludge cake is transported by belt conveyor to a dump truck located outside, hauled to a landfill, and buried. No monitoring takes places.

Comments: Outdoor truck loading has problems with freezing in the winter.

G. COST OF LIME STABILIZATION

Equipment

The lime handling system was originally installed to condition the sludge for vacuum filtering. The system was of sufficient size to handle the increased lime requirements for lime stabilization, thus, no additional capital expense was incurred.

Operation and Maintenance

Lime stabilization was found to be cheaper than incineration. No increased dewatering costs other than that due to an increase in lime use. Lime is purchased at $91 per ton $Ca(OH)_2$.

Lime cost $27.50 per dry ton of sludge treated.

6. NAUGATUCK, CONNECTICUT

(Lime Added to Vacuum Filter Conditioning Tank)

A. PLANT DATA

Plant Type: Two separate wastewater processing systems, one municipal and one industrial. Both are conventional activated sludge. A provision for tertiary clarification has been made in the industrial system.

Plant Flow: 6.7 mgd design to municipal treatment
3.0 mgd present average to municipal treatment
3.6 mgd design to industrial treatment
1.5 to 2.0 mgd present average to industrial treatmenet

Quantity Limed: 4.5 dry tpd present average

B. WASTEWATER PROCESSING TRAIN

MUNICIPAL WASTEWATER TREATMENT

Pretreatment
- Screens

Primary Treatment
- Sludge degritted and screened

Secondary Treatment
- Extended aeration

Chlorination
- Mixed with industrial wastewater effluent prior to chlorination

Discharge
- Naugatuck River

INDUSTRIAL WASTEWATER TREATMENT

Pretreatment
- Neutralized by industry
- Clarified by industry (polymer addition)

Primary Treatment

Secondary Treatment
- Extended aeration

Tertiary Treatment
- Not used at present
- Provision for clarification with alum and/or polymer
- Combined with treated domestic wastewater

C. SLUDGE PROCESSING TRAIN

MUNICIPAL WASTEWATER TREATMENT

Primary Sludge
- Degritting and screening
- Gravity thickened with secondary sludge and with industrial secondary sludge
- Combined with all sludges in mechanically mixed storage mixing tank

Secondary Sludge
- Gravity thickened with primary sludge and with industrial secondary sludge
- Combined with all sludges in sludge storage/mixing tank

INDUSTRIAL WASTEWATER TREATMENT

Primary Sludge
- Gravity thickened
- Combined with all sludges in sludge storage/mixing tank

Secondary Sludge
- Gravity thickened with municipal sludges
- Combined with all sludges in sludge storage/mixing tank

MUNICIPAL AND INDUSTRIAL WASTEWATER TREATMENT

Combined Sludge
- Stored in mixing tank
- Sludge conditioning/lime stabilization
- Vacuum filtration
- Landfill

Comments: Lime stabilization is practiced because it is too costly to operate the multiple-hearth furnace. Lime is sometimes added to sludge storage for odor control. This quantity is not included in the dosage reported for conditioning.

D. LIME USE

Type of Sludge: Gravity thickened industrial and municipal, primary and secondary sludges

Solids Concentration of
Sludge Before Lime Added: 5 percent

Lime Dosage (as CaO per weight of dry sludge solids):
18 to 25 percent when using ferric chloride
14 to 18 percent when using polymer

Quantity of Lime Used: 28 tons per month, CaO, with ferric chloride
22 tons per month, CaO, with polymer

pH Attained: 11.6 to 12.5

Other Chemicals: Added in sludge conditioning tank, ferric chloride, 6.0 percent or polymer 0.1 percent

E. DETAIL OF LIME SYSTEM

Lime Delivery/Storage

Type of Lime Purchased: Quicklime, granular

Delivery: About 24 tons of lime once a month. Truck blows lime into storage silo.

Storage: One 50-ton capacity storage silo, outdoors. Silo has vibrator which is not used. It also has a bag filter to clean conveyor air.

Inventory: Operator orders a load when he is down to a two week (16 ton) inventory.

Conveyance and Slaking

Conveyance System: Originally used a bucket system which worked poorly. A pneumatic conveying system has been installed to move the quicklime from the storage silo to the day bins, from which lime is loaded to the slakers.

The storage silo is fitted with a rotary feed valve which feeds into a 4 inch line. A 15-HP blower conveys the lime to the day bins, which are about 45 feet above the bottom of the silo. The tops of the day bins have a cyclonic device to separate the lime solids from the conveying air. The system works very well.

Type, Size and Number of Slakers: Two, slurry type slakers

Prepared Lime Slurry: 11.5 percent as $Ca(OH)_2$

Type of Water Used in Slurry Makeup: Plant water

Special Equipment: Day bin over slaker has automatic level probes.

Lime Slurry Transfer

Type of Piping: Lime slurry is transferred from the slakers to a storage/day tank by gravity. The tank is located below/beside the slakers. The transfer lines are clear plastic hose, 3-inch diameter.

Lime Day Tank Storage

Type and Number: One, 200-gallon steel tank

Type of Mixing: High-speed propeller mixer

Lime Metering Pumps

Type and Number of Pumps: Five mechanical diaphragm pumps

Type of Piping: The lime is pumped through 2-inch flexible hose to cushion the pipes from the pounding of the diaphragm pumps. Then the lime flows through 1.5 inch aluminum pipe. All lines are flushed after each use.

Originally the lime was transferred through open fiberglass troughs; these would foam and overflow.

Valving: Flexibility is built in.

Lime Application to Sludge Conditioning Tank

Point of Application: Slurry is added to a conventional horizontal sludge conditioning tank located beside each vacuum filter.

Dosage Control: Operator sets metering pump speed from control panel located at the vacuum filters.

Dosage Setting: Operator at first sets dosage to obtain a good cake. The cake is tested for pH. If pH is low, dosage is increased. Conditioning dose is frequently adequate for stabilization.

pH Measurement: Dewatered cake is taken to lab, diluted, and the pH measured with litmus paper.

pH Holding Time: Detention time in filter vat only.

Quantity of Slurry Used: 3000 gallons per filter day with ferric chloride; 2200 gallons per filter day with polymer.

F. DOWNSTREAM PROCESS

Dewatering

Type: Five vacuum filters (coil medium)

Scheduling: Filter 6 days per week, 12 hours per day, 3 vacuum filters.

Loading Rate: 3.0 lb/sq ft-hr, estimate

Cake Solids Concentration (includes weight of lime): 20 percent

Comments: The present lime dose is so close to the dosage needed for dewatering that it has had little effect on plant operations. The filtrate is returned to the industrial primary sludge thickener. This has resulted in better settling in the thickener. The high pH filtrate also helps cut odors in the sludge storage. Only normal maintenance is required.

Disposal

Method: Landfill

Procedure: The stabilized sludge cake is transported by conveyor to 15 cubic yard steel bins located indoors. Container trucks, owned by a trucking company, haul about 17 full bins to a private landfill where the sludge cake is used as cover material. This system allows for flexibility in scheduling sludge removal from the site.

Comments: A slight odor and some flies are present during storage in the steel bins. A $15 disposal charge per full bin is paid by the treatment plant.

G. COST OF LIME STABILIZATION

Equipment

Lime handling equipment was originally installed for chemical conditioning prior to dewatering. The equipment is of sufficient size to handle doses required for stabilization. Thus, no additional capital expense was incurred.

Operation and Maintanance

No increased operation or maintenance costs, versus the cost of simply lime conditioning sludge, were noted other than the cost of the lime. Lime is purchased at $48 per ton CaO.

Lime cost about $12 per dry ton of sludge treated.

H. SPECIAL STUDIES

They are comparing the costs of lime stabilization when using polymer as a filter aid versus using ferric chloride. The lime dose is typically 50 percent higher when using ferric chloride.

7. NEW HAVEN (East Street Plant), CONNECTICUT

(Lime Added as a Backup System Prior to Vacuum Filtration)

A. PLANT DATA

Plant Type: Primary treatment only.

Plant Flow: 22.5 mgd design
15.5 mgd present average

Quantity Limed: 15 dry tpd present average

B. WASTEWATER PROCESSING TRAIN

Pretreatment
- Bar racks
- Screens

Primary Treatment

Chlorination

Discharge
- To ocean.

C. SLUDGE PROCESSING TRAIN

Primary Sludge
- Gravity thickener
- Lime addition (for stabilization when incinerator is down or for conditioning in the winter months)
- Vacuum filtration
- Landfill or incineration

Comments: The plant only uses lime stabilization when the incinerator is not working. Strictly a backup system. Some lime conditioning required in the winter months which is not required at other times of the year.

D. LIME USE

Type of Sludge: Gravity thickened primary.

Solids Concentration of
Sludge Before Lime Added: 10 percent

Lime Dosage (as CaO per
weight of dry solids): No data, used on emergency basis only.

Quantity of Lime Used: No data.

pH Attained: 12.0 to 12.4

Other Chemicals: None.

E. DETAIL OF LIME SYSTEM

Lime Delivery/Storage

Type of Lime Purchased: 50-lb bags of high-calcium hydrated lime.

Delivery: 800 bags every 2-3 months. The bags are delivered 50 to a pallet and handled with a forklift. Takes approximately 2 persons and 2 hours for this procedure.

Storage: Bags are stacked about 5 feet high on pallets and stored indoors in a dry area.

Inventory: An 80 bag minimum inventory is always kept on hand. Maximum storage is about 900 bags. Load orders vary due to the variability in lime usage.

Preparation of Lime Slurry

Type and Number of Mixing Tanks: Two 1100-gallon steel tanks.

Type of Mixing: Low-speed paddle mixer.

Dust Control Equipment: None

Method of Slurry Preparation: Operator manually adds 50 pounds of lime to 30 gallons of water.

Prepared Lime Slurry Concentration: 17 percent as $Ca(OH)_2$

Special Equipment: An elevator is used to lift bags to the tank area. Then the bags are manually lifted into the mix tank.

Lime Metering Pumps

Type and Number of Pumps: Two plunger pumps.

Type of Piping: Galvanized-steel pipes equipped with a flushing system.

Valving: Can pump from any mix tank, with any pump, to any conditioning tank.

Lime Application to Sludge Conditioning Tank

Point of Application: Slurry added to conventional horizontal conditioning tank located beside each vacuum filter.

Dosage Control: Operator sets metering pump speed from control panel.

Dosage Setting: Dosage is set to obtain the required pH.

pH Measurement: Litmus paper to sludge in filter vat, measured hourly.

pH Holding Time: Detention time in filter vat only.

F. DOWNSTREAM PROCESS

Dewatering

Type: Two vacuum filters (coil medium)

Lime Stabilization Data: No lime stabilization data is kept, backup system only.

Disposal

Method: Landfill

Procedure: The stabilized sludge cake is transported by belt conveyor to a dump truck. It is then hauled to a landfill and used as fill.

G. COST OF LIME STABILIZATION

Equipment

No equipment purchased, originally installed as conditioning equipment.

Operation and Maintenance

No data are kept, backup system only. Lime is purchased at $74 per ton $Ca(OH)_2$.

8. NORTH CANAAN, CONNECTICUT

(Lime Added to Liquid Sludge Storage)

A. PLANT DATA

Plant Type: Secondary treatment by activated sludge

Plant Flow: 0.35 mgd design
0.20 mgd percent average

Quantity Limed: 0.06 dry tpd present average

B. WASTEWATER PROCESSING TRAIN

Pretreatment
- Grit channel

Secondary Treatment
- Activated sludge

Chlorination

Discharge
- Blackberry River

Comments: Influent wastewater is essentially all domestic.

C. SLUDGE PROCESSING TRAIN

Secondary Sludge
- Aerobic digester
- Storage in winter and land application in spring after lime stabilization
- Sand drying beds (summer and fall), landfill

Comments: Sludge is aerobically digested. Periodically (1/wk) the digester mixer is stopped and the sludge is allowed to settle. In the winter, the settled sludge is pumped to a storage tank (no mixer) which has sufficient capacity to hold all sludge produced. Supernate is decanted from storage. The stored sludge is lime stabilized in the spring and trucked to a dairy farm. In the summer and the fall, lime is used for odor control and to condition sludge for sand bed drying.

D. LIME USE

Type of Sludge: Aerobically digested secondary sludge

Solids Concentration of
Sludge Before Lime Added: 2 percent

Lime Dosage (as CaO per
weight of dry solids): 5.0 percent

pH Attained: 12

Other Chemicals: None

E. DETAIL OF LIME SYSTEM

Lime Delivery/Storage

Type of Lime Purchased: 50-lb bags of high-calcium hydrated lime

Delivery: 60 bags are picked up by the operator at the local supply store once a year.

Storage: Bags are added almost immediately to the sludge. Little storage time.

Inventory: A few bags, no set amount.

Lime Application to Liquid Sludge Storage

Type, Size and Number of Storage Tanks: Two 15,000 gallon primary concrete tanks from previous facility.

Method of Operation: Sludge is stored in the tanks all winter. When sludge is to be removed, the contents of the tank are pumped to mix it while bagged lime is added. This mixing occurs for one hour after the proper pH is attained.

Method of Lime Addition: Lime is manually poured from the bags into the tank.

Lime Dosage Control: Batch operation, lime added until desired pH is reached.

pH Measurement: By pH probe.

pH Holding Time: One hour.

Removal of Sludge: By tank truck.

Comments: The total liquid sludge storage (including aerobic digester) is 65,000 gallons. This is sufficient capacity to hold the accumulated sludge over the winter until it is lime stabilized in the spring.

F. DOWNSTREAM PROCESS

Disposal

Method: Land application

Procedure: During the spring a farmer uses two converted 2,000 gallon capacity tank trucks to haul the stabilized liquid sludge to his dairy farm. He mixes the liquid sludge with animal wastes and applies this mixture to silage grass and hay fields. No monitoring is done.

During the summer and fall no lime is used. The sludge is dewatered on sand drying beds and landfilled.

Comments: Farmer does the work for free using his own equipment.

G. COST OF LIME STABILIZATION

Equipment

No special equipment purchased by plant personnel. Storage tanks were taken from previous treatment facility and mixing is accomplished by using a pump on farmers' tank truck.

Operation and Maintenance

Lime is purchased at $110 per ton $Ca(OH)_2$.

Cost $700 annually for the complete process of lime stabilization.

H. SPECIAL STUDIES

Farmer had tests done that show a low heavy metals concentration. No bacteriological studies.

9. SOUTH WINDSOR, CONNECTICUT

(Lime Added to Liquid Sludge Storage)

A. PLANT DATA

Plant Type: Conventional activated sludge.

Plant Flow: 3.75 mgd design
1.3 mgd present average

Quantity Limed: 1.0 dry tpd present average

B. WASTEWATER PROCESSING TRAIN

Pretreatment
- Comminutor

Primary Treatment

Secondary Treatment
- Conventional activated sludge

Chlorination

Discharge
- Connecticut River

Comments: Influent wastewater is 85 percent domestic and 15 percent industrial.

C. SLUDGE PROCESSING TRAIN

Primary Sludge: Gravity thickener, combined with secondary sludge in aerobic digester.

Secondary Sludge: Combined with primary sludge in aerobic digester.

Combined Sludge: Aerobic digester (two, operated in parallel), sludge conditioning/lime stabilization, drying beds, stockpile.

Comments: Lime stabilization in summer only, dewater with belt filter and send to landfill remainder of year. Lime stabilization replaced incineration which had mechanical problems. Future plans call for composting.

D. Lime Use

Type of Sludge: Aerobically digested sludges, gravity thickened primary plus secondary sludge.

Solids Concentration of Sludge Before Lime Added: Approximately 1.2 percent.

Lime Dosage (as CaO per weight of dry sludge solids): Sparse data, estimated as 21 percent dose based on 3000 lb of CaO to 14,000 lb of sludge solids. Dose higher than required to attain pH.

Quantity of Lime Used: Estimated, 8 tons per month, $Ca(OH)_2$.

pH Attained: 12.0 or greater.

Other Chemicals: None.

E. DETAIL OF LIME SYSTEM

Lime Delivery/Storage

Type of Lime Purchased: Lime slurry, variable concentrations but always receive 4000 pounds of $Ca(OH)_2$ in each truckload of slurry.

Delivery: Deliveries vary in size. There is no need for lime slurry storage as slurry is added directly from truck to digester.

Comment: Some bags of hydrated lime are kept on hand to help control the pH in the digesters.

Lime Application to Liquid Sludge Storage

Type, Size and Number of Storage Tanks: Two aerobic digesters, 156,000 gallon capacity each, converted aeration basins.

Type of Mixing: Surface aerators (one per digester)

Method of Operation: The capacity of approximately two full digesters is lime stabilized per month. A truckload of lime slurry is added to a digester. The pH is checked after 1.5 hours of mixing time. If the pH is not 12.0 or higher then another load of lime is added. Usually more lime is added than is needed.

Method of Lime Addition: Slurry unloaded by gravity to the digester.

Lime Dosage Control: No control, a full truckload is added.

pH Measurement: A pH probe meter is used to check samples from the digester.

pH Holding Time: 1.5 hours, minimum mixing time.

Removal of Sludge: The lime stabilized liquid sludge is pumped from the digester to the drying beds with a 4 inch trash pump.

F. DOWNSTREAM PROCESS

Disposal

Method: Stockpile or landfill

Procedure: The stabilized liquid sludge is pumped to sand drying beds located on site to be dewatered. About once a month the beds are scraped off with a bulldozer and the sludge is stockpiled in the back of the site.

When lime is not used, the sludge is dewatered with a belt filter and hauled to a landfill.

Comments: The lime stabilization system was designed for temporary use but has been in operation for 3 years.

G. COST OF LIME STABILIZATION

Equipment

Only piece of equipment purchased was the trash pump and this pump is used for other purposes throughout the plant.

Operation and Maintenance

System requires very few manhours. Only temporary system. Lime is purchased at \$65 per ton $Ca(OH)_2$.

Lime costs about \$18 per dry ton of sludge treated.

10. STAFFORD, CONNECTICUT

(Lime Added to Vacuum Filter Conditioning Tank)

A. PLANT DATA

Plant Type: Secondary treatment by contact stabilization

Plant Flow: 2.0 mgd design
2.5-3.0 mgd present average

Quantity Limed: 1.4 dry ton tpd present average

B. WASTEWATER PROCESSING TRAIN

Pretreatment
- Bar screens
- Grit removal

Secondary Treatment
- Contact stabilization

Filtration

Chlorination

Discharge
- Willimantic River

Comments: Influent wastewater is 80 percent industrial flow, dyeing and printing wastes, and 20 percent domestic.

C. SLUDGE PROCESSING TRAIN

Secondary Sludge
- Gravity thickener (to 5.0 percent solids)
- Sludge conditioning/lime stabilization (ferric chloride also added)
- Vacuum filtration
- Landfill

Comments: Lime stabilization is practiced because it is too costly to operate the multiple-hearth furnace.

D. LIME USE

Type of Sludge: Gravity thickened secondary sludge

Solids Concentration of
Sludge Before Lime Added: 5.0 percent

Lime Dosage (as CaO per
weight of dry sludge solids): 16.0 percent

Quantity of Lime Used: 8.9 tons per month, $Ca(OH_2)$

pH Attained: 11.5

Other Chemicals: Ferric chloride added in sludge conditioning, 4 percent

E. DETAIL OF LIME SYSTEM

Lime Delivery/Storage

Type of Lime Purchased: 50-lb bags of high-calcium hydrated lime.

Delivery: 900 bags about 4 times a year. Pallets, with 50 bags stacked on a pallet are moved with a forklift.

Storage: The pallets are unloaded at the town garage where they are stored inside in a dry area. As the treatment plant needs lime, full pallets are mechanically loaded on a truck and brought to the plant where they are manually unloaded. The treatment plant has dry indoor storage for 150 bags.

Inventory: A minimum of 3 tons of lime is always kept on hand (6 days).

Preparation of Lime Slurry

Type and Number of Mixing Tanks: One 350-gallon steel tank

Type of Mixing: High-speed propeller mixer

Mixer Motor Size: 0.5 HP

Dust Control Equipment: No dust control in original design. Have installed a vent to the outdoors above the lime slurry tank to remove dusty air. Works quite well.

Method of Slurry Preparation: Operator adds 50 pounds of lime to 50 gallons of water.

Prepared Lime Slurry Concentration: 11.0 percent as $Ca(OH)_2$

Type of Water Used in Slurry Makeup: Plant water

Frequency of Slurry Makeup: Lime slurry is prepared continuously throughout the day while the filtering operation is in progress. Operator notices no problems with this method.

Lime Slurry Metering Pumps

Type and Number of Pumps: One plunger pump.

Type of Piping: One-inch diameter PVC pipe. Have also installed about one-foot of flexible hose just after pump to protect the PVC pipe from the shock of the positive displacement pump.

Valving: No special valving. Only one slurry tank, one pump, and one conditioning tank.

Lime Application to Sludge Conditioning Tank

Point of Application: Slurry is added to a vertical sludge conditioning tank equipped with paddle mixers and located beside the vacuum filter.

Dosage Control: Set metering pump stroke length. Pump located beside vacuum filter.

Dosage Setting: Operator sets dosage for good dewatering and knows from past experience that the pH is 11.5 when a good cake is attained.

pH Measurement: Sample taken from filter vat to laboratory, measured with pH meter.

pH Holding Time: Detention time in filter vat only.

Quantity of Slurry Used: 1000 gallons per filter day.

F. DOWNSTREAM PROCESS

Dewatering

Type: One vacuum filter (cloth medium)

Scheduling: Filter 4 days per week, 6 hours per day

Loading Rate: 3.5 lb/sq ft-hr

Cake Solids Concentration (includes weight of lime): 23 to 25 percent

Comments: There have been no major effects reported from the high lime dose. Some lime caking has been experienced in the vacuum filter grid and vacuum pump. This has been taken care of by washing the vacuum filter system with muriatic acid every 3 months.

Disposal

Method: Landfill

Procedure: The stabilized sludge cake is transported by conveyor to a dump truck located outdoors and hauled to a landfill. One trip takes about 30 minutes. At the landfill the cake is mixed with woodchips and stockpiled. Periodically sludge is taken from these piles and used as final cover at the site. No monitoring is done.

G. COST OF LIME STABILIZATION

Equipment

Lime handling equipment was originally installed for chemical conditioning prior to dewatering. The equipment is of sufficient size to handle the increase in lime dose required for stabilization. Thus, no additional capital expense incurred.

Operation and Maintenance

No increase in costs were noted, other than the increased use of lime. Lime is purchased at $80 per ton $Ca(OH)_2$.

Lime cost about $17 per dry ton of sludge treated.

11. STAMFORD, CONNECTICUT

(Lime Added to Belt-Filter Cake)

A. PLANT DATA

Plant Type: Conventional activated sludge

Plant Flow: 20.0 mgd design
20.0 mgd present average

Quantity Limed: 13 dry tpd present average

B. WASTEWATER PROCESSING TRAIN

Pretreatment
- Comminutor

Primary Treatment
- Sludge to cyclonic degritter

Secondary Treatment
- Conventional activated sludge

Chlorination

Discharge
- Ocean

Comments: Influent wastewater is 75 percent domestic and 25 percent industrial.

C. SLUDGE PROCESSING TRAIN

Primary Sludge
- Gravity thickener

Secondary Sludge
- Gravity thickener

Combined Sludge
- Combined in gravity thickener
- Aerated storage
- Polymer addition
- Belt filter
- Lime added to cake
- Landfill

Comments: New lime stabilization system is to be used only when the co-incineration system is inoperative.

D. LIME USE

Type of Sludge: Dewatered, mixture of gravity thickened primary and secondary sludge

Solids Concentration of Sludge Before Lime Added: 23 percent

Lime Dosage (as CaO per weight of dry sludge solids): 18 to 20 percent

Quantity of Lime Used: 90 tons per month, $Ca(OH)_2$, estimated

pH Attained: 12.1

Other Chemicals: Polymer added prior to dewatering, 6.5 percent dose.

E. DETAIL OF LIME SYSTEM

Lime Delivery/Storage

Type of Lime Purchased: 50-lb bags of high-calcium hydrated lime.

Delivery: Bags

Frequency of Delivery: Ordered as needed. Backup system.

Storage: Storage area will be improved to an indoor dry facility.

Inventory: No data.

Lime Application to Cake

Point of Application: To dewatered cake conveyor.

Type of Applicator/
Method of Application: This system is described in detail in the text.

Method of Mixing
Lime and Sludge: Screw conveyor specially fitted with "pug mill" type blades to actually push some sludge back and improve mixing. Operator reports these actually mix too well, they make the sludge gummy.

Lime Dose Control: Control of the sludge cake conveyor speed from a panel at the belt press.

pH Measurement: Take a cake sample to the lab every four hours, slurry it and measure pH with a pH meter.

pH Holding Time: Few minutes. Initial pH is high so that after two hours, the pH is still 11.8 or greater.

F. DOWNSTREAM PROCESS

Dewatering

Disposal

Method: Landfill

Procedure: The stabilized sludge cake is transported on the screw conveyor to a dump truck located outdoors. It is then hauled to a landfill. No monitoring is done.

G. COST OF LIME STABILIZATION

Operation and Maintenance

Lime purchased at $90 per ton $Ca(OH)_2$. One man needed full-time to keep lime hopper loaded.

Lime cost about $21 per dry ton of sludge treated.

H. SPECIAL STUDIES

Studies of pH versus time have shown that pH drops 0.2 to 0.3 pH units in one half hour in the summer and in one hour in the winter.

In one test, lime was added at a dose of 25 percent to a 5 percent sludge which has been stored in a lagoon. One year later, there is a dry cake with a pH of 11.5 or greater. No vegetation grows on cake, there is no sign of bacterial regrowth.

12. STRATFORD, CONNECTICUT

(Lime Added to Vacuum Filter Conditioning Tank)

A. PLANT DATA

Plant Type: Conventional activated sludge

Plant Flow: 11.5 mgd design
8.0 mgd present average

Quantity Limed: 8.9 dry tons per day

B. WASTEWATER PROCESSING TRAIN

Pretreatment
- Screens
- Comminution
- Aerated grit removal

Primary Treatment

Secondary Treatment
- Conventional activated sludge

Chlorination

Discharge
- Housatonic River

C. SLUDGE PROCESSING TRAIN

Primary Sludge
- Gravity thickener

Secondary Sludge
- Aerobic digester
- Recycled to primary clarifier

Combined Sludge
- Settled in primary clarifier
- Gravity thickener
- Sludge conditioning/lime stabilization (polymer added)
- Vacuum filtration
- Sand drying beds
- Stockpile/landfill

Comments: Lime stabilization is practiced because it is too costly to operate the multiple-hearth furnace. Lime stabilization is only an interim technique; will be going to composting. An effort is being made to improve the effectiveness of lime stabilization. Dewatered sludge is spread to further dry on sand beds before it is stockpiled.

D. LIME USE

Type of Sludge: Combination of aerobically digested and gravity thickened secondary sludge and gravity thickened primary sludge

Solids Concentration of Sludge Before Lime Added: 3.1 percent

Lime Dosage (as CaO per weight of dry sludge solids): 18 percent

Quantity of Lime Used: 64 tons per month, $Ca(OH)_2$

pH Attained: 11.8 - 12.0

Other Chemicals: Polymer added in sludge conditioning, 5 percent.

E. DETAIL OF LIME SYSTEM

Lime Delivery/Storage

Type of Lime Purchased: Lime slurry, waste product from acetylene production. This replaced the purchase of bagged hydrated lime. Operator notes that slurry concentration received varies greatly.

Delivery: Purchase a 4800 gallon truckload about once a week. Wash out truck after delivery to get out any settled lime. Plant supplies 3-inch line and centrigual pump to unload truck.

Storage: Two, 4500-gallon concrete storage tanks, equipped with high-speed propeller mixers.

Inventory: A minimum of one weeks inventory is kept. One delivery supplies the plant for a little more than one week.

Lime Slurry Transfer Pumps

Type and Number of Pumps: One progressive cavity pump.

Type of Piping: Two-inch diameter PVC pipe. A long (20-ft) vertical line clogs frequently. Pipes are flushed daily as preventive maintenance.

Valving: One pump and one pipeline.

Lime Day Tank Storage

Type and Number: Two, 500-gallon unlined steel tanks

Type of Mixing: High-speed propeller mixers.

Special Equipment: No dust collection equipment. Bagged lime use was stopped due to dusty conditions and availability of lime slurry.

Lime Metering Pumps

Type and Number of Pumps: Two plunger pumps

Type of Piping: One-inch rubber hose from pump to sludge conditioning tank.

Valving: One pump and one pipeline serve each vacuum filter.

Lime Application to Sludge Conditioning Tank

Point of Application: Slurry is added to a vertical conditioning tank that is mixed with a flocculator - paddle type mixer.

Dosage Control: Cperator sets the metering pump speed.

Dosage Setting: Dosage is set to attain required pH.

pH Measurement: Measured with litmus paper or a pH meter on a sample taken from the vacuum filter vat.

pH Holding Time: Detention time in filter vat only.

Quantity of Slurry Used: 800 gallons per filtering day

F. DOWNSTREAM PROCESS

Dewatering

Type: Two vacuum filters (cloth medium)

Scheduling: Filter 4 days per week, about 6 hours per day

Cake Solids Concentration (includes weight of lime): 18 to 22 percent

Comments: The effects of the high lime dose on the treatment plant operations are minmal. Extra vacuum filter maintenance has resulted from the high dose. The filter cloths have to be manually scrubbed nightly. The filters are thoroughly cleaned every 3 months to eliminate lime clogging and scaling problems.

Disposal

Method: Landfill

Procedure: The stabilized sludge cake is transported by conveyor to a dump truck and hauled to drying beds. It is spread 2 to 6 inches deep on the sand drying beds and allowed to dry for a week. Then it is scooped up and stockpiled until it is utilized as a cover material at the landfill.

Comments: The extra drying of the sludge has helped reduce odors. Before this extra drying was practiced, the stockpiled sludge piles would turn black, putrefy and emit offensive odors. Even with the extra drying some ammonia odors are reportedly given off from the cake.

G. COST OF LIME STABILIZATION

Equipment

No new equipment was required to implement lime stabilization at this plant.

Operation and Maintenance

Six loads of sludge are presently trucked per day versus one truckload when incineration was practiced. Lime is purchased at $61 per ton $Ca(OH)_2$. A study prepared to compare the costs of incineration in September of 1975 versus the cost of lime stabilization in September of 1976 showed the following results: the cost per ton of sludge handled was $73.21 for incineration and $14.60 for lime stabilization. 241 man-hours were spent during the one month of incineration versus 149 man-hours while practicing lime stabilization.

Lime costs about $14.50 per dry ton of sludge treated.

H. SPECIAL STUDIES

A number of bacterial studies have been performed at this facility. Data and discussion are presented in the text.

13. THOMPSON, CONNECTICUT

(Lime Added to Liquid Sludge Storage)

A. PLANT DATA

Plant Type: Secondary treatment by activated sludge

Plant Flow: 1.5 mgd design
0.15-0.20 mgd present average

Quantity Limed: 0.7 dry tpd present average

B. WASTEWATER PROCESSING TRAIN

Secondary Treatment
- Activated sludge

Chlorination

Discharge
- French River

Comments: Influent wastewater is essentially all domestic.

C. SLUDGE PROCESSING TRAIN

Secondary Sludge
- Aerobic digester (may add polymer)
- Aerobic digester (second stage, operated as a storage tank)
- Lime addition to second stage digester
- Land application

Comments: The sludge is aerobically digested. Periodically the digester is stopped and the sludge is allowed to settle for four hours. The decant liquid is returned to the influent channel and the settled sludge is pumped (with a portable, gas driven centrifugal pump) to the second stage aerobic digester which is operated as a storage tank. Lime stabilization occurs by lime addition to this holding tank.

The treatment facility is equipped with a vacuum filter which is not used. Lime stabilization of liquid sludge is less expensive and more convenient.

D. LIME USE

Type of Sludge: Aerobically digested secondary sludge

Solids Concentration of
Sludge Before Lime Added: 2 percent

Lime Dosage (as CaO per
weight of dry sludge solids): 16 percent

Quantity of Lime Used: Variation in frequency of lime stabilization. Total lime usage of approximately 11 tons per year.

Other Chemicals: Polymer

E. DETAIL OF LIME SYSTEM

Lime Delivery/Storage

Type of Lime Purchased: 50-lb bags of high-calcium hydrated lime

Delivery: 900 bags approximately every 2 years. The bags are unloaded manually (2 people, 4 hours).

Storage: Indoors, on a concrete floor. Bags are stacked about 5 feet high.

Inventory: A 20 bag minimum inventory is always kept on hand.

Preparation of Lime Slurry

Type and Number of Mixing Tanks: One 300-gallon steel tank

Type of Mixing: High-speed propeller mixer

Mixer Motor Size: 0.5 HP

Dust Control Equipment: Mix tank fitted with ventilation system to pull dusty air into lime loading hatch. Bag filter cleans the air. System not vented to outdoors.

Method of Slurry
Preparation: Operator adds 100 pounds of lime to 50 gallons of water.

Prepared Lime Slurry Concentration: 19 percent as $Ca(OH)_2$

Type of Water Used in Slurry Makeup: Plant water

Lime Slurry Transfer Pumps

Type and Number of Pumps: One, portable, gas driven centrifugal pump

Type of Piping: Portable 4-inch firehose.

Lime Application to Liquid Sludge Storage

Type, Size and Number of Storage Tanks: One 80,000-gallon capacity tank (an old aerobic digester) plus in the winter months an aeration basin, (250,000-gallon capacity) is also used.

Type of Mixing: Fine-bubble air diffusers.

Method of Operation: Settled aerobically digested sludge is pumped to the secondary digester/storage tank. This tank is kept mixed but occasionally the mixing is stopped and the sludge settles, allowing clear liquid to be decanted. When the tank is full of sludge, it is at 2.0 percent solids. When sludge is to be stabilized and removed from the site, lime slurry is pumped to the storage tank until the desired pH is attained.

Method of Lime Addition: Batch operation, lime slurry is pumped from mix tanks.

Lime Dosage Control: Lime is added until a pH of 12.0 is reached.

pH Measurement: Grab samples are tested in the lab with a pH meter.

pH Holding Time: At least one half hour. No pH decay has been observed after a 3-4 day holding time prior to land application.

Removal of Sludge: The tank truck is loaded using the portable pump and firehose to pump the stabilized liquid sludge.

F. DOWNSTREAM PROCESS

Disposal

Method: Land application.

Procedure: The stabilized liquid sludge is applied to sileage corn and hay fields with a tank truck. The tank truck is a dump truck with a 1200 gallon steel tank. The sludge is applied by gravity flow through a nozzle at a rate of about 1000 gallons per acre per year. Treatment plant personnel do all of the work. They average about 2-4 round trips per hour. It takes 5 minutes to load the truck and 3 minutes to empty it.

Comments: Operator estimates that it takes 100 gallons of fuel for the tank truck to empty the stabilized sludge in the holding tank.

G. COST OF LIME STABILIZATION

Equipment

The only new pieces of equipment required for lime stabilization were the portable lime slurry pump and the land application truck. The conversion of the dump truck to a land application truck cost $1500.

Operation and Maintenance

A rough study of vacuum filter versus liquid lime stabilization showed a supply cost (chemicals and fuel) reduction of 80 percent when using stabilization. A savings in utility expenses was noted but not quantified. An annual manpower reduction from 864 to 200 hours per year was reported.

Lime is purchased at $86 per ton $Ca(OH)_2$.

Lime cost about $18 per dry ton of sludge treated.

14. VERNON, CONNECTICUT

(Lime Added to Vacuum Filter Conditioning Tank)

A. PLANT DATA

Plant Type: Powdered activated carbon treatment in activated sludge process.

Plant Flow: 6.4 mgd design
3.5 mgd present average

Quantity Limed: 4 dry tpd present average (primary sludge only)

B. WASTEWATER PROCESSING TRAIN

Pretreatment
- Comminutor
- Grit removal

Primary Treatment
- Clariflocculator (no chemical addition at present)

Secondary Treatment
- Activated carbon added to activated sludge aeration tank
- Sludge to carbon regeneration

Rapid Sand Filtration

Chlorination

Discharge
- Hockanum River

Comments: Influent wastewater is 30 percent industrial, mostly plating, dyeing, and textile wastes.

C. SLUDGE PROCESSING TRAIN

Primary Sludge
- Gravity thickener
- Sludge conditioning/lime stabilization (ferric chloride also added)
- Vacuum filtration
- Landfill

Secondary Sludge
- Carbon regeneration by wet air oxidation of waste activated sludge
- Regenerated carbon returned to system

Comments: Lime stabilization is only expected to be used until existing incinerator is started.

D. LIME USE

Type of Sludge: Gravity thickened raw primary sludge

Solids Concentration of Sludge Before Lime Added: 9.0 percent

Lime Dosage (as CaO per weight of dry sludge solids): 22.0 percent

Quantity of Lime Used: 35.0 tons per month, $Ca(OH)_2$

pH Attained: 11.8 to 12.0

Other Chemicals: Ferric chloride added in sludge conditioning, 1-2 percent

E. DETAIL OF LIME SYSTEM

Lime Delivery/Storage

Type of Lime Purchased: Lime slurry, 35 percent concentration. It is a byproduct/waste material from acetylene production. Consistent slurry concentration is received.

Delivery: Purchase a 4,800-gallon truckload about once a week. Pumping to storage is by a self-priming centrifugal pump supplied by the treatment plant.

Storage: Outdoors in one 15,000-gallon steel tank, constantly mixed by a rotating paddle mixer. Loading pump is valved so that it too can mix the stored lime by recirculating the tank contents. Tank is baffled to cut down on vortexing within the tank while mixing.

Inventory: As soon as there is room in the storage tank for a delivery, an order is placed. A full tank will last for approximately 16 filter days.

Lime Slurry Transfer Pumps

Type and Number of Pumps: Two centrifugal pumps, with a fiberglass housing. Have operated quite well considering that a 35 percent slurry is pumped.

Type of Piping: Two-inch diameter PVC pipes are used. They have few bends and no cleanouts. Flushing with plant water is done at the end of every filtering day.

Valving: Can pump from the storage tank with any pump to any day tank.

Lime Day Tank Storage

Type and Number: Two, 700-gallon unlined fiberglass tanks.

Type of Mixing: Low-speed rotating paddle boards.

Mixer Motor Size: 0.75 hp.

Special Equipment: These tanks are also equipped to handle bagged hydrated lime. The tanks are ventilated for dust control and have slurry dilution/makeup water meters (dilution is not practiced at present).

Lime Metering Pumps

Type and Number of Pumps: Two plunger pumps (these pumps replaced diaphragm pumps that failed, likely due to the high concentration of lime slurry being pumped. The plunger pumps have sheared pins occasionally, but operator is satisfied with them).

Type of Piping: Two-inch flexible plastic hose with a 0.5-inch wall thickness. This hose was installed to replace a rigid PVC pipe. Replacement was required because original pipes were too small and because a flexible pipe was desired to absorb shocks from the positive displacement pump. This system is flushed daily.

Valving: Can pump from any day tank, with any pump, to any conditioning tank.

Comments: The day tanks are filled as needed by turning on the pumps from the storage tank while the filtering process is in progress.

Lime Application to Sludge Conditioning Tank

Point of Application: Slurry is added to a vertical, paddle mixed, sludge conditioning tank located beside the vacuum filters.

Dosage Control: Operator sets metering pump speed from a panel located at vacuum filters.

Dosage Setting: Operator sets lime dose to attain required pH.

pH Measurement: pH is measured twice weekly on the filter cake using litmus paper. Measurement occurs more frequently if sludge dewaterability changes.

pH Holding Time: Detention time in filter vat only.

Quantity of Slurry Used: 900-1100 gallons per filter day.

F. DOWNSTREAM PROCESS

Dewatering

Type: Two vacuum filters (cloth medium)

Scheduling: Filter 5 days per week, 6 hours per day, 1 filter.

Loading Rate: 5 lb/sq ft-hr

Cake Solids Concentration (includes weight of lime): 30 percent

Comments: The effects from the high lime dose on the treatment plant operations are negligible. Only normal maintenance is required.

DISPOSAL

Method: Landfill

Procedure: The stabilized sludge cake is transported by conveyor to a hopper which deposits it in a dump truck located outdoors. The hopper is designed for short term storage when the truck is not there. The sludge is hauled to a private landfill in the next town and used as fill. About 5-6 loads are hauled in a day with each round trip taking about 40 minutes. No monitoring is done.

G. COST OF LIME STABILIZATION

Equipment

Lime handling equipment was originally installed for chemical conditioning prior to dewatering. The equipment is of sufficient size to handle the increased dose required for stabilization. Thus, no additional capital expense was incurred.

Operation and Maintenance

No data are available to compare the dose and cost of lime stabilizing versus lime conditioning. Lime conditioning alone has not been used. Lime is purchased at $92 per ton $Ca(OH)_2$.

Lime cost about $27 per dry ton of sludge treated.

15. WILLIMANTIC, CONNECTICUT

(Lime Added to Vacuum Filter Conditioning Tank)

A. PLANT DATA

Plant Type: Conventional activated sludge

Plant Flow: 5.5 mgd design
2.4 mgd present average

Quantity Limed: 1.7 dry tpd present average

B. WASTEWATER PROCESSING TRAIN

Pretreatment
- Bar screen

Primary Treatment

Secondary Treatment
- Conventional activated sludge

Chlorination

Discharge
- Shetucket River

C. SLUDGE PROCESSING TRAIN

Primary Sludge: combined with secondary sludge in sludge conditioning tank.

Secondary Sludge: Flotation thickner (polymer added), combined with primary sludge in sludge conditioning tank.

Combined Sludge: Sludge conditioning/lime stabilization (ferric chloride also added, vaccum filtration, stockpile or landfill.

Comments: Lime stabilization is practiced because it is too costly to operate the multiple-hearth furnace.

D. LIME USE

Type of Sludge: Raw primary and flotation thickened secondary sludge.

Solids Concentration of
Sludge Before Lime Added: 3-4 percent

Lime Dosage (as CaO per
weight of dry sludge solids): 15 percent

Quantity of Lime Used: 10 tons per month, $Ca(OH)_2$

pH Attained: 10.5 to 11.0

Other Chemicals: Ferric chloride added just prior to conditioning, 7.0 percent.

E. DETAIL OF LIME SYSTEM

Lime Delivery/Storage

Type of Lime Purchased: Lime slurry, 13 to 30 percent (20 percent average), byproduct/waste material from acetylene production.

Delivery: Purchase a 4500 gallon truckload. Delivery by gravity to an underground concrete storage tank. Delivery port is fitted with a removable screen to take out any pebbles. A solids test and a specific gravity test is done on each load to determine the lime concentration of the batch.

Storage: Underground, outdoor concrete storage tank of 14,500 gallons. Tank is constantly mixed by a propeller type mixer with a 10-HP motor.

Inventory: Operator orders about 3 truckloads per month. Orders a shipment when inventory is down to 5000 gallons.

Lime Slurry Transfer

Description: Transfer is by gravity to the dilution/day tank. Flow controlled by a gate valve (manually operated).

Type of Piping: Transfer pipeline is iron, three feet long and large diameter. There is no provision for cleaning, none has been needed.

Lime Slurry Dilution

Type and Number of Dilution Tanks: One unlined steel tank, 960 gallons.

Type of Mixer: Low-speed rotating paddle boards.

Mixer Motor Size: 1.5 HP

Water Used for Dilution: Plant water

Diluted Slurry Concentration: About 10 percent $Ca(OH)_2$ by weight.

Special Equipment: Tank is only equipped to handle lime slurry. There is no provision for utilization of hydrated lime.

Lime Metering Pumps

Type and Number of Pumps: One hydraulic-diaphragm pump. Exit line outfitted with air cushion/surge control cylinder.

Type of Piping: Two-inch galvanized pipe to pump inlet (gate valves) and 2-inch PVC pipe at pump outlet (ball valves). Pipes outfitted for flushing by connecting a portable hose. Flushing done daily. Pipes also have unions so that they can be opened for cleaning, this has not been required, as flushing has been sufficient.

Lime Application to Sludge Conditioning Tank

Point of Application: Slurry is added to a conventional horizontal sludge conditioning tank located beside the vacuum filters.

Dosage Control: Operator sets metering pump speed from panel beside the vacuum filters.

Dosage Setting: Operator sets lime dose to get a good cake, does this by eye.

pH Measurement: Measured in lab on sludge cake by using a pH probe.

pH Holding Time: Detention time in filter vat only.

F. DOWNSTREAM PROCESS

Dewatering

Type: Two vacuum filters (coil medium)

Scheduling: Filter 2 to 3 days per week, 6 hours per day.

Loading Rate: 2.5 lb/sq ft-hr

Cake Solids Concentration: (Includes weight of lime) 17 percent

Comments: The effects from the lime dose on the treatment plant operations and equipment have not been determined because lower doses have not been used.

The operator regularly acid-cleans coils attacked by lime. He removes three coils at a time for cleaning.

Disposal

Method: Stockpile

Procedure: The stabilized sludge cake is transported by belt conveyor to a dumptruck, hauled to a gravel pit, and stockpiled. Some sludge is taken from the stockpile, mixed with loam, and used to grow grass.

Comments: Process has been in use for a few years and treatment plant personnel are satisfied with it.

G. COST OF LIME STABILIZATION

Equipment

Lime handling equipment was originally installed for chemical conditioning prior to dewatering. The equipment is of sufficient size to handle the increased dose required for stabilization. Thus, no additional capital expense was incurred.

Operation and Maintenance

Lime doses being used at present time are no greater than would be used if incineration were practiced. No change in operation and maintenance costs.

16. BATH, MAINE

(Lime Added to Vacuum Filter Conditioning Tank)

A. PLANT DATA

Plant Type: Secondary treatment by activated sludge

Plant Flow: 1.6 mgd design
2.6 mgd present average

Quantity Limed: 1.0 dry tpd present average

B. WASTEWATER PROCESSING TRAIN

Pretreatment
- Communitor
- Grit chamber

Secondary Treatment
- Activated sludge

Chlorination

Discharge
- Kennebec River

Comments: Influent wastewater is 90 percent domestic and 10 percent industrial.

C. SLUDGE PROCESSING TRAIN

Secondary Sludge
- Flotation thickener (polymer added).
- Aerated storage (periodically decanted, 7 percent solids).
- Sludge conditioning/lime stabilization (ferric chloride also added).
- Vacuum filtration
- Landfill or land application

D. LIME USE

Type of Sludge: Thickened and stored secondary sludge.

Solids Concentration of
Sludge Before Lime Added: 7.0 percent.

Lime Dosage (as CaO per weight of dry solids): 10.0 percent.

Quantity of Lime Used: 4.0 tons per month, $Ca(OH)_2$

pH Attained: 11.5 to 12.0

Other Chemicals: Ferric chloride added in sludge conditioning, 3.0 percent.

E. DETAIL OF LIME SYSTEM

Lime Delivery/Storage

Type of Lime Purchased: 50-lb bags of high-calcium hydrated lime.

Delivery: 200 bags every month and a half. The bags are unloaded and restacked manually. This takes 2 people less than an hour.

Storage: Bags are stacked 6-feet high on pallets. The storage area is dry, indoors, and located beside the slurry mixing tanks.

Inventory: A 25 bag (about 2.5 filtering days) minimum inventory is kept at all times. Maximum storage is about 250 bags.

Preparation of Lime Slurry

Type and Number of Mixing Tanks: Two 350-gallon fiberglass-lined steel tanks.

Type of Mixing: Low-speed paddle mixer.

Dust Control Equipment: Lime is added through a small hatch on the top of the tank. Forced ventilation pulls lime dust into the tank. Air is cleaned with bag filters and vented to the outdoors. System works well.

Method of Slurry Preparation: Operator manually adds 50 pounds of lime to 75 gallons of water.

Prepared Lime Slurry Concentration: 7.5 percent as $Ca(OH)_2$.

Type of Water Used in Slurry Makeup: Strained plant water.

Frequency of Slurry Makeup: Prepare lime slurry every 1.5 hours while filtering. Uses both tanks simultaneously during process.

Lime Metering Pumps

Type and Number of Pumps: Two plunger pumps. Pumps are calibrated to be metering pumps. Air cushion/standpipe type shock absorber on pumps.

Type of Piping: PVC pipes with breaks and unions for clean-outs. Had trouble with steel pipes clogging. Was using too strong a slurry (17 percent). Pipes are flushed every day with plant water for approximately 15 minutes.

Valving: Pumping is from both tanks simultaneously during the lime stabilization process.

Lime Application to Sludge Conditioning Tank

Point of Application: Slurry is added to a conventional horizontal sludge conditioning tank located beside each vacuum filter.

Dosage Control: Operator sets metering pump speed from control panel located at the vacuum filters.

Dosage Setting: Dosage is set by eye, estimating the pH by looking at dewaterability.

pH Measurement: Measured twice a day on the sludge cake with a pH probe.

pH Holding Time: Detention time in filter vat only.

Quantity of Slurry Used: 1,000 gallons per filter day.

F. DOWNSTREAM PROCESS

Dewatering

Type: Two vacuum filters (coil medium)

Scheduling: Filter 2-3 days per week, 6 hours per day.

Loading Rate: 6.0 - 7.0 lb/sq ft-hr

Cake Solids Concentration (includes weight of lime): 15.0 percent.

Comments: One result of the high lime dose is that the sludge cracks more quickly on the vacuum filter. No other major effects were reported. Normal operation does call for washing the coil filter with muriatic acid every 8 months to get rid of any lime scaling.

Disposal

Method: Landfill or land application

Procedure: The stabilized sludge cake is transported by conveyor to a 5 cubic yard dump truck parked indoors. In the summer the sludge is hauled to lands stripped of loam and applied as a soil amendment. It is applied at a rate of 33 cubic yards per acre per year. Monitoring of this procedure is done to make sure it is mixed in with the soil. The rest of the year, the sludge is hauled to a landfill, mixed one part sludge to one part dredge material, and used as fill.

G. COST OF LIME STABILIZATION

Equipment

Lime handling system was originally installed for chemical conditioning prior to dewatering. The equipment was of sufficient size to handle stabilization doses, thus, no capital expense was incurred for the lime system. A Rototiller is rented for $125 a week to aid in land application.

Operation and Maintenance

No available data to compare the dose and cost of lime with other alternatives. Lime is purchased at $80 per ton $Ca(OH)_2$.

Lime cost about $10.50 per dry ton of sludge treated.

H. SPECIAL STUDIES

One bacteriological study was done. It showed less than 100 colonies of fecal coliforms per 100 milliliters.

17. FALMOUTH, MAINE

(Lime Added to Liquid Sludge Storage)

A. PLANT DATA

Plant Type: Secondary treatment by extended aeration.

Plant Flow: 1.5 mgd design
0.5 mgd present average.

Quantity Limed: 0.35 dry tpd present average

B. WASTEWATER PROCESSING TRAIN

Pretreatment
- Bar rack

Secondary Treatment
- Extended aeration

Chlorination

Discharge
- Presumpscot River estuary

Comments: Influent wastewater is essentially all domestic.

C. SLUDGE PROCESSING TRAIN

Secondary Sludge
- Aerobic digester (settled, decanted)
- Aerated mixing tank for lime stabilization
- Land application

Comments: Original system called for using a gravity dewatering unit with the addition of polymer. System did not work well. Abandoned for economical and environmental reasons.

With the present operation, aerobically digested sludge is settled, decanted, remixed, and pumped to an aerated mixing tank. Lime slurry is added and pH is checked the next day prior to land application.

In the winter, the aerobic digester stores all sludge produced.

D. LIME USE

Type of Sludge: Aerobically digested secondary sludge

Solids Concentration of
Sludge Before Lime Added: 1.0 to 3.0 percent

Lime Dosage (as CaO per
weight of dry sludge solids): 5.0 percent

Quantity of Lime Used: 0.7 tons per month, $Ca(OH)_2$

pH Attained: 11.5 to 12.5

Other Chemicals: None

F. DETAIL OF LIME SYSTEM

Lime Delivery/Storage

Type of Lime Purchased: 50-lb bags of high-calcium hydrated lime

Delivery: 60-80 bags are picked up by the operator at the local supply store about once a month during the 6 months that land application takes place.

Storage: Bags are stacked in a dry outdoor shed.

Inventory: Always have at least 5 bags on hand. This lasts about half a week during the land application months.

Preparation of Lime Slurry

Type and Number of Mixing Tanks: One 500-gallon fiberglass tank, located outdoors.

Type of Mixing: Air mixing

Dust Control Equipment: None. Tank is located outdoors.

Method of Slurry Preparation: Operator adds 50 pounds of lime to about 50 gallons of water. All measurements are done by eye.

Frequency of Slurry Makeup: One batch is made up for each storage tank load.

Prepared Lime Slurry Concentration: About 11 percent, as $Ca(OH)_2$

Type of Water Used in Slurry Makeup: Plant water

Special Equipment: A platform is needed next to the tank so the operator can dump the lime into the top of the 8-ft high tank.

Lime Slurry Transfer

Type of Transfer: Lime flows by gravity from the mix tank to the sludge storage tank. A centrifugal pump is used to pump the conditioned sludge from the storage tank to the tank truck.

Type of Piping: PVC pipe (4-inch dia.) is used, about 5 ft long. No flushing system exists.

Valving: No special valving, direct flow by gravity from lime slurry tank to lime stabilization tank.

Lime Application to Liquid Sludge Storage

Type, Size and Number of Storage Tanks: One 16,000-gallon concrete storage tank. Entrance pipe fitted with a strainer to keep out rags.

Type of Mixing: Diffused air

Method of Operation: Settled, aerobically digested sludge is pumped to storage tank. Lime slurry is added to this tank, which is kept constantly mixed. pH is checked. The sludge is then mixed overnight. In the morning, pH is rechecked and sludge is land-applied.

Lime Dosage Control: Manually done by the operator using past experience. pH is checked after loading lime.

pH Measurement: pH is measured after an evening of mixing using a pH probe.

pH Holding Time: Overnight, average 12-14 hours.

Removal of Sludge: The sludge is pumped from the storage/holding tank with a centrifugal pump to the tank truck.

Comments: Slight ammonia odors exist at the sludge conditioning tank. Also, some ammonia odors are present for a while after the stabilized sludge has been land-applied.

F. DOWNSTREAM PROCESS

Disposal

Method: Land application

Procedure: The stabilized liquid sludge is applied to grass fields during the warm months (May through October). A 2,000-gallon tank truck, fabricated by the operator, is used to apply about 800 truckloads annually. There is no flow regulator on the truck to control the gravity flow application. pH is monitored for up to a year after the sludge is applied. If pH falls below 6.6 then lime is applied, but this has not been needed.

Comments: Sludge is applied at no charge to fields within the town. There is a waiting list for sludge. Application to lawns has been curtailed.

G. COST OF LIME STABILIZATION

Equipment

A land application truck was fabricated. The truck was donated, but conversion cost $2700.

Operation and Maintenance

Lime is purchased at $108 per ton $Ca(OH)_2$.

Lime costs about $7 per dry ton of sludge treated.

H. SPECIAL STUDIES

It was found that heavy metals were below state guidelines and that there were no detectable levels of coliforms, fecal streptococci or salmonella.

18. KENNEBEC (WATERVILLE), MAINE

(Lime Added to Vacuum Filter Conditioning Tank)

A. PLANT DATA

Plant Type: Secondary treatment by activated sludge.

Plant Flow: 12.7 mgd design
8.4 mgd present average

Quantity Limed: 6.0 dry tpd present average

B. WASTEWATER PROCESSING TRAIN

Pretreatment
- Bar screens

Primary Treatment

Secondary Treatment
- Activated sludge

Chlorination

Discharge
- Kennebec River

Comments: Influent wastewater is 40 percent industrial, mostly paper mill wastes, and 60 percent domestic.

C. SLUDGE PROCESSING TRAIN

Primary sludge: grit removal by cyclone, gravity thickener, combined with secondary sludge in blending box.

Secondary sludge: Flotation thickener (polymer addition), combined with primary sludge in blending box.

Combined sludge: blending box (3.5-4.0 percent solids), sludge conditioning/lime stabilization (ferric chloride also added), stockpile or land application.

Comments: Originally the plan was simply to dewater and landfill, now stabilization is required.

D. LIME USE

Type of Sludge: Gravity thickened primary and flotation thickened and stored secondary sludge.

Solids Concentration of Sludge Before Lime Added: 3.5 to 4.0 percent.

Lime Dosage (as CaO per weight of dry solids): 15.0 percent.

Quantity of Lime Used: 27.0 tons per month, CaO

pH Attained: 11.5

Other Chemicals: Ferric chloride added in sludge conditioning, 2.4 percent.

E. DETAIL OF LIME SYSTEM

Lime Delivery/Storage

Type of Lime Purchased: Quicklime, granular

Delivery: About 25 tons of lime once a month. Truck blows lime into storage silo.

Storage: One 40-ton capacity storage silo, outdoors. Silo is fitted with a vibrator and lime level probes. It is also equipped with a bag filter to clean the conveyor air.

Inventory: Operator orders a load of lime when the inventory is down to 10 tons (similar to 2 weeks).

Conveyance and Slaking

Conveyance System: The storage silo is set right over the slaker, lime falls by gravity to the feed system. A valve has been supplied to hold back flow from the silo.

Type, Size and Number of Slakers: One, 1000-lb/hr paste type slaker.

Prepared Lime Slurry: 11.0 percent as $Ca(OH)_2$

Type of Water Used in Slurry Makeup: Plant water.

Special Equipment: The slaker is fitted with a belt feeder. Lime dose is controlled by adjusting lime pile depth with gate.

Lime Slurry Transfer

Type of Piping: Lime slurry is transferred from the slakers to the lime slurry storage/day tanks by gravity. The slakers sit on a platform that covers the tanks so no piping is required.

Lime Day Tank Storage

Type and Number: Two, 6000-gallon, concrete, square tanks.

Type of Mixing: Low-speed rotating paddle mixers.

Mixer Motor Size: 3 HP.

Special Equipment: Day tanks may be used as dilution tanks, but this is not practiced.

Concrete tanks are completely covered except for an access manhole.

There is no provision for using hydrated lime, operator would like to have this option for back-up.

Lime Metering Pumps

Type and Number of Pumps: Two progressive cavity pumps. The operator reported that the pumps wear out quickly. This could be attributed to the high vertical lift (30 feet) and the abrasive nature of the lime slurry.

Type of Piping: The inlet line has a box installed in it to allow grit to settle out before it reaches the pump. Minimal effects have resulted because the slurry is too thick to allow any settlement of the grit. The outlet line from the pump is fitted with a one-foot piece of fire hose. This allows for easy disconnection so the pumps can be removed.

The vertical runs and short horizontal runs are iron pipe. The long horizontal runs are flexible hose. This hose sits in troughs that hang overhead. The hoses can be cleaned by manually shaking them.

A flushing system that uses plant water is used daily.

Valving: Lime slurry can be pumped from any day tank, with any pump, to any conditioning tank.

Lime Application to Sludge Conditioning Tank

Point of Application: Slurry is added to a conventional horizontal sludge conditioning tank located beside each vacuum filter. Just in front of this tank is a small (about 8 cubic foot) box in which primary and secondary sludges are mixed. No mixer is provided in the blending box, mixing is from turbulence only.

Dosage Control: Operator sets metering pump speed from vacuum filter operation panel in a room near the filters.

Dosage Setting: Operator, from past experience has a rough idea of what lime dose will be required to attain the required pH. The pH is checked after startup. If it is too low the lime dose is increased.

pH Measurement: Filtrate is checked for pH by taking a sample to the lab. This is done throughout the day using a pH meter.

pH Holding Time: Detention time in filter vat only. They have held sludge for an extra 1/2 hour and checked pH versus time and feel confident that there is no pH drop.

Quantity of Sludge Used: 3,400 gallons per filter day.

F. DOWNSTREAM PROCESS

Dewatering

Type: Two vacuum filters (coil medium)

Scheduling: Filter 5 days per week, 6 hours per day, one filter.

Loading Rate: 3.0 lb/sq ft-hr.

Cake Solids Concentration (includes weight of lime): 18 percent.

Comments: There has been a slight increase in plant effluent pH, but no major effects have been noticed in plant operations. The filtrate (pH 11.5) is returned to the influent. There has been no acid washing of equipment needed.

Disposal

Method: Land application or landfill

Procedure: The stabilized sludge cake is transported by conveyor to a hopper which deposits it in a 10 cubic yard dump truck. The hopper is designed for short-term storage but does not work well in this capacity.

The sludge is hauled to farm fields when they are available. A manure spreader is used to spread the sludge cake. It is plowed into corn fields and left sitting atop hay fields. Some odors have been reported during this process. The sludge is applied at 40-50 cubic yards per acre per year with a limit of 300-400 lb per acre per year. The fields are monitored for metals, metals uptake in crops and nitrogen.

When land is not available, the sludge is hauled to a landfill and mixed with gravel at a one to one ratio. More gravel is mixed in if heavy equipment is to be driven over the area.

Comments: Area farmers like to get the sludge and report improvements in their crops.

G. COST OF LIME STABILIZATION

Equipment

Lime handling equipment was originally installed for chemical conditioning prior to dewatering. The equipment is of sufficient size to handle doses required for stabilization. Thus, no additional capital expense was incurred for the lime system. A bulldozer which cost $19,000 did have to be bought for landfilling the sludge.

Operation and Maintenance

No increased operation and maintenance costs, versus the cost of simply lime conditioning sludge, were noted other than the cost of the lime. Lime is purchased at $67 per ton CaO.

Lime cost about $10 per dry ton of sludge treated.

H. SPECIAL STUDIES

Have compared lime stabilizing with polymer as a filtering aid instead of ferric chloride. Polymer use resulted in a small lime dose requirement, but the filter ran slower and the sludge was sloppier at the same solids concentration.

They have a little bacteriological data which shows that the sludge is effectively stabilized after lime addition. pH tests have shown that sludge pH dropped to 7.0 after 5 months in the landfill.

Data shows that the limed sludge has inhibited metals uptake in crops. They actually have seen a lower metals concentration in crops fertilized with lime stabilized sludge than in conventionally fertilized fields. They recognize that more intensive, long-term, studies are needed.

19. LEWISTON-AUBURN, MAINE

(Lime Added to Vacuum Filter Conditioning Tank)

A. PLANT DATA

Plant Type: Conventional activated sludge

Plant Flow: 14.2 mgd design
11.0 mgd present average

Quantity Limed: 7.0 dry tpd present average

B. WASTEWATER PROCESSING TRAIN

Pretreatment
- Bar screen

Primary Treatment

Secondary Treatment
- Conventional activated sludge

Chlorination

Discharge
- Androscoggin River

Comments: Influent wastewater is approximately 15 percent industrial, mostly textile wastes with some poultry and plastics wastes.

C. SLUDGE PROCESSING TRAIN

Primary Sludge
- Gravity thickener

Secondary Sludge
- Flotation thickener (polymer addition)

Combined Sludge
- Blending box
- Sludge conditioning/lime stabilization (ferric chloride also added)
- Vacuum filtration
- Landfill

Comments: Originally the plan was simply to dewater and landfill, now stabilization is required.

D. LIME USE

Type of Sludge: Gravity thickened primary and flotation thickened and stored secondary sludge.

Solids Concentration of Sludge Before Lime Added: 5 to 8 percent

Lime Dosage (as CaO per weight of dry sludge solids): 16 to 18 percent

Quantity of Lime Used: 36 tons per month, CaO

pH Attained: 11.5 to 12.0

Other Chemicals: Ferric chloride added in sludge conditioning (3.5 to 5.5 percent)

E. DETAIL OF LIME SYSTEM

Lime Delivery/Storage

Type of Lime Purchased: Quicklime, pebble

Delivery: About 30 tons of lime once a month. Truck blows lime into storage silo.

Storage: One 60 ton capacity storage silo, outdoors. Silo is fitted with a vibrator and a high/low level sensor. It also has a bag filter to clean conveyor air.

Inventory: Operator orders a load when he is down to a two week (20 ton) inventory.

Conveyance and Slaking

Conveyance System: Pneumatic conveyance system to day bin silo over slaker.

The air blower is located outdoors, below the storage silo. Lime is passed through an air lock feeder to the conveying line. The pebbled quicklime is blown through the line to a valve which diverts the lime into the day bin. The air continues to the slurry tanks, which are fitted with bag filters. These bag filters are vented to the outdoors for extra dust control.

Type, Size and Number of Slakers: One, 1000-lb/hr paste type slaker.

Prepared Lime Slurry: 5.0 percent $Ca(OH)_2$

Type of Water Used
in Slurry Makeup: City water

Lime Slurry Transfer Pumps

Type and Number of Pumps: Two mechanical diaphragm pumps. There is no shock absorption equipment on these pumps.

Type of Piping: Original installation had about 20-feet of 2-inch iron pipeline from each pump to the slurry day tanks. These lines had removable elbows with flanges to allow for cleaning pipes. In addition, a manual flushing system was included.

Despite these precautions, they have had clogging problems in the lines which caused diaphragms to pop. They have replaced one of the lime slurry lines with a 2-inch flexible hose. This seems to work well.

Valving: Lime slurry can be pumped with any pump to any day tank.

Lime Day Tank Storage

Type and Number: Two, 800-gallon steel tanks.

Type of Mixing: Low-speed rotating paddle mixers.

Mixer Motor Size: 1.5 HP

Special Equipment: The day tanks are fitted with dust control equipment and hatch which allows for the use of hydrated lime as a backup. About 30 bags of hydrated lime are kept on hand. Slurry would be made up at about 6 percent if needed.

Lime Metering Pumps

Type and Number of Pumps: Three mechanical diaphragm pumps. No shock absorption system in pipelines.

Type of Piping: Two-inch iron lines to sludge blending box. Manual flushing by hooking a hose up and running hot city water through the system is done daily. Also removable elbows are in the bends for cleaning the pipes.

Valving: Lime slurry can be pumped from any day tank, with any pump, to any conditioning tank.

Lime Application to Sludge Conditioning Tank

Point of Application: Slurry is added to a conventional horizontal sludge conditioning tank located beside each vacuum filter. Just prior to these tanks is a small (about 8 cubic feet) box in which primary and secondary sludges are mixed. No mixer is provided in the blending box; mixing is by turbulence only.

Dosage Control: Operator sets metering pump speed from vacuum filter control panel.

Dosage Setting: Operator sets lime dose by eye to get a good cake.

pH Measurement: Measured in lab on slurried cake, using a pH meter

pH Holding Time: Detention time in filter vat only.

Quantity of Slurry Used: 7300 gallons per filter day.

Comments: Some ammonia odors have been noticed during warm weather at the conditioning tanks.

F. DOWNSTREAM PROCESS

Dewatering

Type: Two vacuum filters (coil medium)

Scheduling: Filter 7 days per week, 10 hours per day, both filters.

Loading Rate: 2 lb/sq ft-hr

Cake Solids Concentration (includes weight of lime): 16 percent

Comments: The high lime dose has had minimal effects on treatment plant operations. Filtrate is returned back to the influent. Only normal maintenance has been required.

Disposal

Method: Landfill

Procedure: The stabilized sludge cake is transported by conveyor to a hopper which deposits the sludge in a 4.5 cubic yard dump truck. The hopper was designed for short term storage but does not work well in this capacity. The truck hauls about 14 loads of sludge a day to a landfill where it is mixed with sand at a one to one ratio and used as fill. The landfill has a clay lining. No monitoring is done.

Comments: The treatment plant has to pay an annual disposal fee of $2000.

G. COST OF LIME STABILIZATION

Equipment

Lime handling equipment was originally installed for chemical conditioning prior to dewatering. The equipment is of sufficient size to handle the increased dose required for stabilization. Thus, no additional capital expense was incurred.

Operation and Maintenance

No increased operation and maintenance costs, versus the cost of simply lime conditioning sludge, was noted other than the cost of the lime. Lime is purchased at $77 dollars per ton CaO.

Lime cost about $13 per dry ton of sludge treated.

Vacuum filter operation requires one person about five hours per filter day. One person is also needed for ten hours per filter day to haul the sludge away.

20. PORTLAND-WESTBROOK, MAINE

(Lime Added to Vacuum Filter Conditioning Tank)

A. PLANT DATA

Plant Type: Conventional activated sludge

Plant Flow: 4.5 mgd design
1.5-2.0 mgd present average

Quantity Limed: 1.9 dry tpd present average

B. WASTEWATER PROCESSING TRAIN

Pretreatment
- Aerated grit chamber

Secondary Treatment
- Conventional activated sludge

Chlorination

Discharge
- Presumscot River

Comments: Influent wastewater is 100 percent domestic.

C. SLUDGE PROCESSING TRAIN

Secondary Sludge
- Air flotation thickener
- Aerated storage tank
- Sludge conditioning/lime stabilization (ferric chloride also added)
- Vacuum filtration
- Landfill/land application

Comments: Original design was for lime conditioning and landfill. They hope to replace the lime system with a more efficient one, use lower lime doses, and compost.

D. LIME USE

Type of Sludge: Air flotation thickened secondary sludge

Solids Concentration of
Sludge Before Lime Added: 5.0 - 6.0 percent

Lime Dosage (as CaO per weight of dry sludge solids): 25.0 percent (irregular)

Quantity of Lime Used: 19.0 tons per months, $Ca(OH)_2$

pH Attained: 11.5 to 12.5

Other Chemicals: Ferric chloride added in sludge conditioning, 5 percent

E. DETAIL OF LIME SYSTEM

Lime Delivery/Storage

Type of Lime Purchased: 50-lb bags of high-calcium hydrated lime

Delivery: 300 bags approximately every two weeks.

Storage: Bags are stacked about 5 feet high on pallets. The storage area is dry, indoors, accessible to heavy equipment and located beside the lime silo feed/mix system.

Inventory: A minimum of 100 bags (4 days) is always kept on hand.

Preparation of Lime Slurry

Type and Number of Mixing Tanks: Two 120-lb/hr automatic lime feeders.

Method of Slurry Preparation: Two automatic slurry preparation systems are used. Each system has a hopper, on the upper level, to which bagged lime is manually added. In the basement each system has a day silo equipped with a vibrator, followed by a screw fed automatic slurry mixing machine. The silo has steep sides and is equipped with intermittent vibration to allow the lime to flow. The screw feeder does not feed a consistent quantity of lime, forcing the operator to use much more lime than is necessary.

Dust Control Equipment: None, fairly dusty at hopper.

Prepared Lime Slurry Concentration: 10 percent, average, as $Ca(OH)_2$

Type of Water Used in Slurry Makeup: City water

Comments: The operator plans to replace the automatic system with two conventional slurry mix tanks.

Lime Metering Pumps

Type and Number of Pumps: Two diaphragm metering pumps. No shock absorbing equipment exists.

Type of Piping: Two-inch diameter PVC pipe with unions for cleanouts. Plant water is pumped through the pipes to flush them out at the end of every filtering day.

Comments: Line clogging is a problem. Higher lime doses than needed are used (with a greater flow) to keep lines "flushed".

Lime Application to Sludge Conditioning Tank

Point of Application: Slurry is added to a conventional vertical conditioning tank located beside each vacuum filter.

Dosage Control: Operator adjusts feeder/pump speed.

Dosage Setting: Operator sets dosage to obtain an excess to allow for feeder equipment failure.

pH Measurement: Once a day filter cake is tested with a pH meter.

pH Holding Time: Detention time in filter vat only.

Comments: Some ammonia odors are present at the sludge conditioning tanks.

Quantity of Lime Used: 1100 gallons per filter day

F. DOWNSTREAM PROCESS

Dewatering

Type: Two vacuum filters (cloth medium)

Scheduling: Filter 7 days per week, 10 hours per day, both filters.

Loading Rate: 2.5 lb/sq ft-hr

Cake Solids Concentration (includes weight of lime): 20-22 percent

Comments: There have been no major effects reported from using the high lime dose. The filtrate is returned to the aerated grit chamber without any problem. Only normal maintenance required.

Disposal

Method: Landfill

Procedure: The stabilized sludge cake is transported by conveyor to a 14 cubic yard steel container. About 3 times a week 3 of these full containers are brought to a landfill with a container truck. At the landfill the sludge is mixed with sand and used as fill. No monitoring is done.

Comments: They have recently started their composting project and stopped landfilling the stabilized sludge.

G. COST OF LIME STABILIZATION

Equipment

Lime equipment was installed in original design, no extra equipment has been purchased.

Operation and Maintenance

No change when going from conditioning to stabilization and back to conditioning. Problems with lime feeder mask any lime dose changes. Lime is purchased at $108 per ton $Ca(OH)_2$.

Lime cost about $36 per dry ton of sludge treated.

21. SCARBOROUGH, MAINE

(Lime Added to Liquid Sludge)

A. PLANT DATA

Plant Type: Secondary treatment by extended aeration.

Plant Flow: 0.4 mgd design
0.3 mgd present average

Quantity Limed: 0.2 dry tpd present average

B. WASTEWATER PROCESSING TRAIN

Pretreatment
- Comminutor
- Bar screen
- Pre-chlorination

Secondary Treatment
- Extended aeration.

Chlorination

Discharge
- Nonesuch River

Comments: Influent wastewater is 10 percent industrial and the rest is domestic.

C. SLUDGE PROCESSING TRAIN

Secondary Sludge
- Aerobic digester (during warm months, in winter remove sludge to town septage handling facility).
- Lime stabilization.
- Land application.

D. LIME USE

Type of Sludge: Aerobically digested secondary sludge.

Solids Concentration of
Sludge Before Lime Added: 2.0 percent.

Lime Dosage (as CaO per
weight of dry solids): 4.0 percent.

Quantity of Lime Used: 0.3 tons per month, $Ca(OH)_2$

pH Attained: Estimated 11.5 to 12.0

Other Chemicals: None.

E. DETAIL OF LIME SYSTEM

Lime Delivery/Storage

Type of Lime Purchased: 50-lb bags of high-calcium hydrated lime

Delivery: 25-30 bags are picked up by the operator at the local supply store about once a month during the months land application takes place.

Storage: Bags are stored indoors, in a dry area on the floor.

Inventory: A minimum of 10 bags are kept on hand, this supplies the plant for 1.5 weeks during the land application months.

Lime Application to Liquid Sludge

Description of System: Detailed description appears in text.

F. DOWNSTREAM PROCESS

Disposal

Method: Land application in summer.

Procedure: A converted oil truck is used to land apply the stabilized sludge to hayfields, lawns, and land stripped of loam. The 2400-gallon capacity truck is equipped with internal mixing by recirculation pumping. The truck can be loaded or unloaded in 10 minutes. Sludge is applied using a splash plate or sprayed with a hose. No regular monitoring occurs.

Comments: Farmers will sometimes supply the lime in exchange for spraying their fields. Treatment plant personnel do the land application and usually receive $6 per truckload from the land owner. New regulations will decrease the number of acceptable disposal sites.

G. COST OF LIME STABILIZATION

Equipment

The only capital expense for conversion to lime stabilization was the cost of converting the truck for land applying the liquid sludge.

Operation and Maintenance

One man can run the operation, taking approximately one hour for one complete round trip. Only maintenance is on truck. Lime cost is minimal. Lime is purchased at $120 per ton $Ca(OH)_2$.

Lime cost about $6.50 per dry ton of sludge treated.

22. SOMERSWORTH, NEW HAMPSHIRE

(Lime Added to Vacuum Filter Conditioning Tank)

A. PLANT DATA

Plant Type: Conventional activated sludge

Plant Flow: 2.6 mgd design
1.6 mgd present average

Quantity Limed: 0.9 dry tpd present average

B. WASTEWATER PROCESSING TRAIN

Pretreatment
- Bar rack
- Comminitor

Secondary Treatment
- Conventional activated sludge (plug flow)

Chlorination

Discharge
- Salmon Falls River

Comments: Influent wastewater if 45 percent mixed industrial and 55 percent domestic.

C. SLUDGE PROCESSING TRAIN

Secondary Sludge
- Flotation thickener in summer (4-6% solids, add polymer, may also add hydrogen peroxide to control odors)
- Gravity thickener in winter (3-4% solids)
- Sludge conditioning/lime stabilization (ferric chloride or polymer also added)

Comments: When using polymer, a smaller lime dose is required than when using ferric chloride. Operator reported no savings in cost. Improved sidestream quality reported when using polymer with a trace of ferric chloride (85 percent capture versus 75 percent with ferric chloride alone).

D. LIME USE

Type of Sludge: Thickened secondary sludge

Solids Concentration of Sludge Before Lime Added: 3 to 4 percent

Lime Dosage (as CaO per weight of dry sludge solids): 23 to 25 percent with ferric chloride
18 to 20 percent with polymer and some ferric chloride

Quantity of Lime Used: 8.6 tons per month, $Ca(OH)_2$, with ferric
6.7 tons per month, $Ca(OH)_2$, with polymer

pH Attained: 11.0 to 12.0

Other Chemicals: ferric chloride, 6.0 percent or polymer 0.5 percent.

E. DETAIL OF LIME SYSTEM

Lime Delivery/Storage

Type of Lime Purchased: 50-lb bags of high-calcium hydrated lime

Delivery: 900 bags are delivered about every 2.5 months. The bags are manually unloaded, rolled down a conveyor to the basement and stacked. During the unloading process many bags are accidently broken and the storage area is quite dusty. The process requires 16 man-hours (8 people).

Storage: Bags are stored indoors on a wooden floor.

Inventory: A minimum of 200 bags (about 2.5 weeks) is always kept on hand.

Preparation of Lime Slurry

Type and Number of Mixing Tanks: Two 400-gallon unlined steel tanks covered and fitted with a hatch for lime addition.

Type of Mixing: Low-speed rotating paddle board.

Mixer Motor Size: 0.75 hp.

Dust Control Equipment: Lime is added through a small hatch on top of the tank. Forced ventilation pulls dust into the tank. Air cleaned by bag filters but not vented to outdoors. Area remains dusty.

Method of Slurry Preparation: Operator manually adds 50 pounds of lime to 80 gallons of water.

Prepared Lime Slurry Concentration: 7.0 percent as $Ca(OH)_2$

Type of Water Used in Slurry Makeup: City water

Special Equipment: The bags are stored on a platform which has the same elevation as the lime slurry makeup tank top. This allows the operator to lay the bag on the floor, and simply lift the bottom of the bag to pour the lime into the tank.

The operator replaced the original water lines (0.5-inch dia.) with lines (2-inch dia.) of a larger diameter to reduce the tank filling time.

Comments: Lime and water are added proportionally to the mix tanks throughout a filtering day. The operator reported no problems with this procedure.

Lime Metering Pumps

Type and Number of Pumps: Two plunger pumps. The outlet line has an air cushion chamber (surge control standpipe).

Type of Piping: Two-inch iron pipe. The pipes conveying the lime slurry from the pumps to the conditioning tank have numerous elbows. These are a source of frequent problems for the operator. As a result, a lower concentration of lime slurry than desired is pumped (one-half desired concentration). Operator also flushes the lines daily, attaching a hose to the lines.

Valving: Can pump from any mix tank, with any pump, to any conditioning tank.

Lime Application to Sludge Conditioning Tank

Point of Application: Slurry is added to a conventional horizontal sludge conditioning tank located beside each vacuum filter.

Dosage Control: Operator sets metering pump speed from control panel located beside each vacuum filter.

Dosage Setting: Operator sets lime dose to get optimal dewatering as determined by a buchner funnel test. When filtering, the pH of the cake is checked; if pH is not sufficient, the lime dose is increased.

pH Measurement: Measured daily on the filter cake with a pH meter.

ph Holding Time: Detention time in filter vat only.

Quantity of Slurry Used: 2600-3300 gallons per filter day

Comments: Some ammonia odors are present around the conditioning tank.

F. DOWNSTREAM PROCESS

Dewatering

Type: Two vacuum filter (coil medium)

Scheduling: Filter 2 days per week, 10 hours per day, both filters.

Loading Rate: 2.0 lb/sq ft-hr

Cake Solids Concentration (includes weight of lime): 12-14 percent

Comments: There have been no major effects reported from using the high lime dose. The filtrate (pH 10-11) is returned to the influent. Vacuum filter system receives an acid cleaning every 6 months.

Disposal

Method: Land application or stockpile

Procedure: The stabilized sludge cake is transported by conveyor to two, steel containers (3, 4 cubic yards) located indoors. About 12 times a day one of the sludge containers is trucked to a farm or stockpile site. At a farm the sludge is land applied with a manure spreader and harrowed into the ground. The farmer plows, supplies lime, seeds, and harvests. Various application rates (4-12 tons per acre per year) have been experimented with. The fields are monitored for heavy metals and nitrates. When the sludge is stockpiled, it is just left sitting in open pits. Some odors are reported if the piles are broken into. If this occurs lime is usually added. Stockpiles have been monitored for 30 days to check pH decay. pH was reported to be around 9-10 after that period.

Comments: Only 20 percent of the sludge is land applied and the rest is stockpiled. Finding suitable land is a problem.

G. COST OF LIME STABILIZATION

Equipment

Lime handling equipment was originally installed for chemical conditioning prior to dewatering. The equipment is of sufficient size to handle the increased dose for stabilization. Thus, no addition capital expense was incurred.

Operation and Maintenance

Operator notes that vacuum filter coils must be cleaned regularly. Conditioning drum had to be epoxy coated. Lime is purchased at $86 per ton $Ca(OH)_2$.

Lime cost about $24 per dry ton of sludge treated.

23. ROCHESTER (Northwest), NEW YORK

(Lime Added to Vacuum Filter Conditioning Tank)

A. PLANT DATA

Plant Type: Conventional activated sludge

Plant Flow: 15.0 mgd design
12.0 mgd present average

Quantity Limed: 10 to 12 dry tpd present average

B. WASTEWATER PROCESSING TRAIN

Pretreatment
- Aerated grit removal
- Mechanical bar screen

Primary Treatment
- Chemical addition for phosphorus removal, normally alum is added.

Secondary Treatment
- Conventional activated sludge

Chlorination

Discharge
- Lake Erie

Comments: Have two stage secondary clarification, originally designed for phosphorus removal.

C. SLUDGE PROCESSING TRAIN

Primary Sludge
- Gravity thickener

Secondary Sludge
- Wasted from mixed liquor
- Gravity thickener

Combined Sludge:

- Gravity thickener (to 5 percent).
- Unmixed storage tank, no decanting required.
- Sludge conditioning/lime stabilization (polymer added).
- Vacuum filtration.
- Land application.

Comments: Original design was to dewater primary sludge by vacuum filter and centrifuge the secondary sludge prior to incineration. Presently lime stabilize and vacuum filter combined sludges in summer and centrifuge and incinerate in winter.

D. LIME USE

Type of Sludge: Gravity thickened mix of primary and secondary sludge.

Solids Concentration of Sludge Before Lime Added: 5.0 percent.

Lime Dosage (as CaO per weight of dry solids): 30 to 40 percent, higher than desired, but sometimes sludge is backlogged and the lime demand of the sludge increases during storage.

Quantity of Lime Used: 120 tons per month, CaO

pH Attained: 12.2

Other Chemicals: Polymer added in sludge conditioning, 3 percent. No reported effect on lime dose.

E. DETAIL OF LIME SYSTEM

Lime Delivery/Storage

Type of Lime Purchased: Quicklime, pebble

Delivery: About 22 tons of lime twice a week. Truck blows lime into storage silo.

Storage: Three storage silos, one 20-ton capacity and two 80-ton capacity. Bag filters on storage silos' clean conveyance air.

Inventory: Purchase one to two loads per week, but as much as three loads per week at the end of the summer. An order is placed as soon as space is available.

Conveyance and Slaking

Conveyance System: Each silo is equipped with a vibrator to aid the movement of lime. One silo directly over each slaker. Screw feeders are used.

Type, Size and Number of Slakers: Three slurry type slakers.

Prepared Lime Slurry: Up to 45 percent (as high as possible) as $Ca(OH)_2$

Lime Slurry Transfer

Method: Gravity.

Piping: Fifteen feet of pipe from each slaker to slurry storage. Pipes flushed daily, rodded as required.

Lime Slurry Storage

Type and Number of Storage Tanks: Two 250-gallon steel storage tanks.

Type of Mixing: Medium-speed paddle mixers.

Mixer Motor Size: 0.5 HP.

Dilution: None practiced.

Lime Slurry Transfer Pumps

Type and Number of Pumps: Three progressive cavity pumps (use only one at a time).

Type of Piping: Four-inch reduced to 2-inch steel pipe, no cleanouts. Flush daily. Few clogging problems, high pressure system.

Valving: Valved so that two pumps serve one storage tank and one pump serves the other storage tank.

Lime Day Tank Storage

Type and Number: One, steel tank (estimated at 800-gallon capacity).

Type of Mixing: High-speed propeller mixer.

Comments: Have to occasionally clean grit out of tank.

Lime Metering Pumps

Type and Number of Pumps: Progressive cavity pump (this pump replaced a plunger pump, operator prefers the progressive cavity pump's ability to pump grit).

Type of Piping: Steel piping, 1.5-inch diameter reduced from 2-inch. No cleanouts or bends.

Lime Application to Sludge Conditioning Tank

Point of Application: Slurry is added to a sludge line about twenty feet before the conditioning tank. Vertical conditioning tank is beside vacuum filter.

Dosage Control: Operator sets metering pump speed from control panel located beside the vacuum filter.

Dosage Setting: Dosage is set to obtain required pH of 12.2.

pH Measurement: Measurement taken with a pH meter.

pH Holding Time: Detention time in filter vat only. Tests have shown pH to remain at 12.0 or greater after 3 hours.

Quantity of Slurry Used: 2800 gallons per filter day.

F. DOWNSTREAM PROCESS

Dewatering

Type: One vacuum filter (cloth medium).

Scheduling: Filter 5 days per week, 14 hours per day.

Cake Solids Concentration (includes weight of lime): 24 percent.

Comments: The sludge requires a pH of 12 to dewater well, therefore a high lime dose has always been useds. No major effects from the high dose were reported.

Sidestream quality is better when ferric chloride is used, but want to keep from adding metals. Polymer is also cheaper to use.

Disposal

Method: Land application

Procedure: The stabilized sludge cake is transported by conveyor to a 10 cubic yard hopper which drops sludge into a 4 cubic yard dump truck. The hopper is not used for long-term storage because sludge sticking results. The operation requires 3 trucks. They haul the sludge to town lands, farms and orchards. There it is applied at a rate of 20 to 30 tons per acre per year. It is applied by a tractor pulling a sled that deposits a 1.5-inch layer of cake to the land. Also attached to the tractor, behind the sled, is a set of blades and a harrow to plow the cake into the land.

Well points are installed on most of the sites to check for metals and coliforms. The Health Department monitors all operations closely.

Comments: Most of the sludge presently goes to town land. A farmer uses this land to grow corn for cattle feed.

The treatment plant personnel do all the spreading of the sludge cake.

G. COST OF LIME STABILIZATION

Equipment

Operation and Maintenance

No abnormal operation and maintenance costs. They did a cost study that showed lime stabilization to be cheaper than incinerating. The study reported incineration and disposal to cost $102 per ton dry solids versus $80 to $90 per ton dry solids for lime stabilization (these costs don't include maintenance). They are looking at the possibility of charging customers for the stabilized sludge in the future.

Lime is purchased at $50-60 per ton CaO.

Lime costs about $15-24 per dry ton of sludge treated.

H. SPECIAL STUDIES

A viral study showed that none were present just after lime stabilization. Fecal and total coliform were also absent.

Total and fecal coliform are monitored. Background samples (prior to any sludge addition) showed that there were very few fecal coliform and some total coliform present in the soil. There were essentially no coliform in the well water. Raw sludge was applied and there were significant quantities of total and fecal coliform in the soil, but only a slight coliform count in the well water. Coliform counts in soil and water decreased with the onset of lime stabilization.

24. BUCKNAM POINT, RHODE ISLAND

(Lime Added to Vacuum Filter Conditioning Tank)

A. PLANT DATA

Plant Type: Conventional activated sludge

Plant Flow: 31.0 mgd design
23.0 mgd present average

Quantity Limed: 8.5 dry tpd present average

B. WASTEWATER PROCESSING TRAIN

Pretreatment
- Bar rack
- Comminutor
- Grit channel
- Preaeration

Primary Treatment

Secondary Treatment
- Conventional activated sludge

Chlorination

Discharge
- Seekonk River

Comments: Influent wastewater is 50 percent mixed industrial flow and 50 percent domestic flow.

C. SLUDGE PROCESSING TRAIN

Primary Sludge
- Mixed with secondary sludge in primary clarifier

Secondary Sludge
- Sludge re-settled with primary sludge in primary clarifier

Combined Sludges
- Two stage anaerobic digestion
- Sludge conditioning/lime stabilization
- Vacuum filtration
- Landfill

D. LIME USE

Type of Sludge: Anaerobically digested primary and secondary sludge

Solids Concentration of
Sludge Before Lime Added: 3.0 percent

Lime Dosage (as CaO per
weight of dry sludge solids): 18-19 percent

Quantity of Lime Used: 47.0 tons per month, $Ca(OH)_2$

pH Attained: 11.0

Other Chemicals: Ferric chloride added in sludge conditioning. Operator reports using insufficient ferric chloride, and thus, using extra lime.

E. DETAIL OF LIME SYSTEM

Lime Delivery/Storage

Type of Lime
Purchased: Lime slurry (33 percent concentration) is purchased from a supplier who makes up the slurry from hydrated lime. A consistent concentration is received.

Delivery: Purchase a 5000 gallon truckload 1-2 times a week. The slurry is unloaded with a centrifugal pump; the same pump that is useds for transfering slurry to the day tanks. This process takes about one half hour.

Storage: Four, 1500-gallon, horizontal, steel storage tanks, equipped with high-speed propeller mixers. Two of these tanks are located in one room and serve that part of the lime system, while the other two tanks are located in another room and serve a duplicate system. Four 1500 gallon vertical day tanks can also be used for storage.

Inventory: A minimum of 3000 gallons is always kept on hand. This is about 2 filtering days.

Comments: The purchase of lime slurry replaced the original system of making up lime slurry from bagged, hydrated lime. The bagged system was difficult to handle, the system was dusty and not equipped with dust control. Also the system was very labor intensive. Bags were moved manually to the mixing area and batches had to be mixed frequently because only two 250 gallon mix tanks existed.

A chemical additive is added to the slurry to prevent lime scaling in pipes. It has worked well.

Lime Slurry Transfer Pumps

Type and Number of Pumps: Four centrifugal pumps, equipped for abrasive handling.

Type of Piping: Galvanized steel pipes (2-inch diameter). The system is equipped for flushing and this is done every filtering day.

Lime Day Tank Storage

Type and Number: Four 1500-gallon, vertical, steel tanks.

Type of Mixing: High-speed propeller mixer.

Mixer Motor Size: 5.0 HP

Lime Metering Pumps

Type and Number of Pumps: Four plunger pumps

Type of Piping: Two-inch galvanized steel pipe to pumps. One-and-a-quarter-inch PVC to conditioning tank. Pipes are equipped with an automatic flushing system and unions for cleaning. System flushed daily.

Lime Application to Sludge Conditioning Tank

Point of Application: Slurry is added to vertical, propeller mixed, sludge conditioning tanks located beside the vacuum filters.

Dosage Control: Operator sets metering pump speed from control panel located at day tanks (downstairs from filter).

Dosage Setting: Operator adds lime as required to obtain good dewatering.

pH Measurement: Measured on filter cake with a pH meter.

pH Holding Time: Detention time in filter vat only.

Quantity of Slurry Used: 1700 gallons per filter day.

F. DOWNSTREAM PROCESS

Dewatering

Type: Four vacuum filters (cloth medium)

Scheduling: Filter 5 days per week, 7 hours per day, 2 filters.

Loading Rate: 2-3 lb/sq ft-hr

Cake Solids Concentration (includes weight of lime): 20 percent

Comments: The effects from the high lime dose on the treatment plant operations are negligible. Only normal maintenance has been required.

Disposal

Method: Landfill

Procedure: The stabilized sludge cake is transported by conveyor to a dump truck and hauled to a landfill. There it is used as fill and covered with foundry slag that is obtained nearby for free. Some pH monitoring of the cake was reported.

G. COST OF LIME STABILIZATION

Equipment

Lime system was converted from a small bag system to a lime slurry system. It was cost effective.

Operation and Maintenance

Lime is purchased at $125 per ton $Ca(OH)_2$.

Lime cost about $30 per dry ton of sludge treated.

25. EAST PROVIDENCE, RHODE ISLAND

(Lime Added to Vacuum Filter Conditioning Tank)

A. PLANT DATA

Plant Type: Conventional activated sludge

Plant Flow: 10.4 mgd design
6.0 mgd present average

Quantity Limed: 3.2 dry tpd present average

B. WASTEWATER PROCESSING TRAIN

Pretreatment
- Bar rack
- Comminutor
- Aerated grit channel

Primary Treatment

Secondary Treatment
- Conventional activated sludge

Chlorination

Discharge
- Narragansett Bay

Comments: Influent wastewater is 60 percent industrial and 40 percent domestic. Also high infiltration.

C. SLUDGE PROCESSING TRAIN

Primary Sludge
- Holding tank

Secondary Sludge
- Centrifuge thickening (normally bypassed)
- Holding tank

Combined
- Holding tank
- Sludge conditioning/lime stabilization (ferric chloride also added)
- Vacuum filtration
- Landfill

Comments: Lime system originally designed as a backup to heat treatment system. Conditioning problems and cost of fuel resulted in heat treatment abandonment. Will compost in future.

D. LIME USE

Type of Sludge: Mixture of raw primary and thickened secondary sludge.

Solids Concentration of Sludge Before Lime Added: 4.5 percent

Lime Dosage (as CaO per weight of dry sludge solids): 20-22 percent

Quantity of Lime Used: 27.0 tons per month, $Ca(OH)_2$

pH Attained: 12.0

Other Chemicals: Ferric chloride added prior to sludge conditioning tanks, 6.0 percent.

E. DETAIL OF LIME SYSTEM

Lime Delivery/Storage

Type of Lime Purchased: 50-lb bags of high-calcium hydrated lime

Delivery: 200 bags approximately every 3 days. The bags are stacked 50 bags to a pallet and unloaded with heavy equipment.

Storage: Bags are stacked 4 feet high on a wooden platform, indoors, accessible to heavy equipment, and located beside the slurry mixing tank.

Inventory: Operator keeps a minimum of 200 bags of lime on hand (4 days).

Comments: Plans are being made to convert to a lime slurry (33 percent) system. This will be more cost effective and help solve the lack of lime storage problem.

Preparation of Lime Slurry

Type and Number of Mixing Tanks: One 200-gallon steel mixing tank

Type of Mixing: High-speed propeller mixer

Dust Control Equipment: None, area is dusty

Method of Slurry Preparation: Operator manually adds 50 pounds of lime to 25 gallons of water.

Prepared Lime Slurry Concentration: 19 percent as $Ca(OH)_2$

Type of Water Used in Slurry Makeup: City water

Frequency of Slurry Makeup: Approximately eight times a day. The day tanks are always kept full so batch mixes are made up in the mix tank and pumped to the day tank as needed throughout the day.

Lime Slurry Transfer Pumps

Type and Number of Pumps: One, progressive cavity pump. No vibration absorption equipment.

Type of Piping: Three-inch diameter PVC pipe with unions for cleanouts. Pipes are flushed with plant water every day after filtering is complete.

Valving: Only one tank and one pump.

Lime Day Tank Storage

Type and Number: Two 375-gallon fiberglass tanks. No dilution takes place in these tanks.

Type of Mixing: High-speed propeller mixer

Lime Metering Pumps

Type and Number of Pumps: Two positive displacement chemical feed pumps.

Type of Piping: One-inch diameter PVC pipe with unions for cleanouts. Pipes are flushed with plant water every day after filtering is complete.

Valving: Can pump from any day tank, with any pump, to any conditioning tank.

Lime Application to Sludge Conditioning Tank

Point of Application: Slurry is added to a vertical sludge conditioning tank equipped with a large impeller slow-speed mixer. A tank is located beside each vacuum filter.

Dosage Control: Operator sets the metering pump speed from a control panel located at the vacuum filters.

Dosage Setting: Dosage is set to obtain a good filter cake and to obtain the required pH.

pH Measurement: pH is checked every hour with a pH meter.

pH Holding Time: Detention time in filter vat only.

Quantity of Slurry Used: 1600 gallons per filter day.

F. DOWNSTREAM PROCESS

Dewatering

Type: Two vacuum filters (cloth medium)

Scheduling: Filter 5 days per week, 8 hours per day.

Loading Rate: 4.0 lb/sq ft-hr

Cake Solids Concentration (includes weight of lime): 20-25 percent

Comments: There have been no major effects reported from using the high lime dose. The filtrate is returned to the primary influent. Only normal maintenance required.

Disposal

Method: Landfill

Procedure: The stabilized sludge cake is transported by conveyor to a 6 cubic yard dump truck equipped with a water sealed gate. The truck hauls the sludge 15 miles to a landfill where it is used as fill and covered with gravel. No monitoring is done.

Comments: Disposal fee for dumping sludge is $5 per dry ton. Future plans call for composting.

G. COST OF LIME STABILIZATION

Equipment

The lime equipment was originally installed as a backup sludge conditioning system to heat treatment. Currently, no expense incurred in conversion to lime stabilization.

Operation and Maintenance

No unusual operation and maintenance effects noted. The costs are much lower than the heat treatment alternative. Lime is purchased at $119 per ton $Ca(OH)_2$.

Lime cost about $33 per dry ton of sludge treated.

H. SPECIAL STUDIES

A three week study of pH versus time was conducted. A sample limed to pH of 12.2 remained at 12.1 or greater for the entire period.

26. WOONSOCKET, RHODE ISLAND

(Lime Added to Vacuum Filter Conditioning Tank)

A. PLANT DATA

Plant Type: Conventional activated sludge.

Plant Flow: 16.0 mgd design
8.0 mgd present average

Quantity Limed: 6.0 dry tpd present average.

B. WASTEWATER PROCESSING TRAIN

Pretreatment
- Bar screen
- Comminutor
- Aerated grit removal

Primary Treatment

Secondary Treatment
- Conventional activated sludge

Chlorination

Discharge
- Blackstone River

Comments: Influent wastewater is 75 percent domestic and 25 percent industrial.

C. SLUDGE PROCESSING TRAIN

Primary Sludge
- Gravity thickener (with secondary sludge).

Secondary Sludge
- Gravity thickener (with primary sludge).

Combined Sludge
- Gravity thickener (to 5 percent solids).
- Storage
- Sludge conditioning/lime stabilization (ferric chloride also added)
- Vacuum filtration
- Landfill

Comments: Multiple-hearth furnace not in use because sludge production presently is not high enough to make it economical to use. If used in future, sludge will not be lime stabilized.

D. LIME USE

Type of Sludge: Gravity thickened primary and secondary sludges.

Solids Concentration of
Sludge Before Lime Added: 5 percent

Lime Dosage (as CaO per
weight of dry solids): 10 to 12 percent

pH Attained: 11.0, not checked regularly.

Other Chemicals: Ferric chloride added in sludge conditioning, 3 to 4 percent.

E. DETAIL OF LIME SYSTEM

Lime Delivery/Storage

Type of Lime Purchased: Quicklime, granular

Delivery: 25 tons delivery. Truck blows lime into storage silo.

Storage: One 60-ton capacity storage silo. The silo has a bin activator (live bin bottom) with a bridge breaker. There is no gate to hold lime back from the conveyance system.

Inventory: Order for more lime placed when silo gets down to about 25 tons of lime.

Conveyance and Slaking

Conveyance System: A single screw conveyor moves the lime to the two day bins located above the slakers. Conveyor works well with granular lime, but clogged when a pebble lime was used.

Type, Size and Number of Slakers: Two, 1000-lb/hr paste type slakers.

Prepared Lime Slurry: 12.0 percent as $Ca(OH)_2$

Type of Water Used in Slurry Makeup: City water.

Special Equipment: Frequently the operator overrides the gravimetric feeder and simply varies the belt speed.

The day bins have been fitted with vibrators (electromagnetic type) attached to a timer. These vibrators have worked well. Before they were installed, the operator had to watch to make sure lime wasn't clogging. The clogging had been partially attributed to a new lime supplier who is supplying a lime with more powder and grit.

Lime Slurry Transfer

Type of Piping: Lime slurry is transferred from the slaker to a small day tank by gravity. The transfer line is 2-inch galvanized pipe with no provision for flushing but with crosses at each bend to allow for cleaning with a rod. Cleaning has not been required.

Slurry can be pumped from a small day tank to two larger day tanks.

Type and Number of Pumps: Three double-diapragm pumps equipped with air cushion/surge control cylinders.

Valving: The piping system is interconnected between transfer pumps and day tanks. Any pump can pump lime slurry to any day tank.

Lime Day Tank Storage

Type and Number: Three steel tanks, (2) 800 gallons capacity and (1) 350 gallon capacity.

Type of Mixing: High-speed propeller mixer.

Mixer Motor Size: 0.5 HP

Special Equipment: Smaller day tank is fitted with a capacitance type level probe. A baffle surrounds the probe to reduce turbulence.

Tank is fitted with a 2-inch gravity drain/overflow line.

Lime Metering Pumps

Type and Number of Pumps: Two plunger pumps. Replaced diaphragm pumps which frequently clogged with lime grit (these pumps had smaller check valves than those in the plunger pumps). The pumps are equipped with air cushion/surge control cylinders.

Type of Piping: Installing PVC piping with a built-in flushing system. Flushing is done at the end of every shift.

Valving: Lime slurry can be pumped from any day tank, with any pump, to any conditioning tank.

Lime Application to Sludge Conditioning Tank

Point of Application: Slurry is added to a conventional horizontal sludge conditioning tank located beside each vacuum filter.

Dosage Control: Operator sets metering pump speed from control panel located at the vacuum filters.

Dosage Setting: Judge by eye to obtain good dewatering.

pH Measurement: Not regularly measured.

pH Holding Time: Detention time in filter vat only.

Quantity of Slurry Used: 4400 gallons per filter day.

F. DOWNSTREAM PROCESS

Dewatering

Type: Two vacuum filters, one cloth and one coil medium. The coil filter is being converted to cloth.

Scheduling: Filter 6 days per week, 6 hours per day, one filter.

Loading Rate: 4.5-5.0 lb/sq ft-hr

Cake Solids Concentration (includes weight of lime): 20 to 22 percent

Comments: No higher lime dose than required for dewatering has been used. There are no abnormal effects reported from the high dosage. System works well.

Disposal

Method: Landfill

Procedure: The stabilized sludge cake is transported by belt conveyor to a sludge hopper, dropped into a dump truck, and hauled to a landfill site. At the landfill the sludge is used for fill and covered with 6-12 inches of gravel daily.

Comments: No disposal fee.

G. COST OF LIME STABILIZATION

Equipment

No equipment needed other than that originally installed for lime conditioning of sludge.

Operation and Maintenance

No higher dose than needed for dewatering.

Lime is purchased at $76 per ton CaO.

Lime cost about $20 per dry ton of sludge treated.

27. BURLINGTON, VERMONT (Main Plant)

(Lime Added to Vacuum Filter Conditioning Tank)

A. PLANT DATA

Plant Type: Conventional activated sludge

Plant Flow: 5.0 mgd design
4.5 mgd present average

Quantity Limed: 1.0 dry tpd present average

B. WASTEWATER PROCESSING TRAIN

Pretreatment
- Bar rack
- Screening
- Grit removal

Primary Treatment

Secondary Treatment
- Conventional activated sludge

Chlorination

Discharge
- Lake Champlain

Comments: Influent wastewater is 50 percent industrial and 50 percent domestic.

C. SLUDGE PROCESSING TRAIN

Primary Sludge
- Two stage anaerobic digestion
- Vacuum filtration (in winter only)
- Landfill (in winter), Land Apply (warm months)

Secondary Sludge
- Flotation thickener (polymer added)
- Anaerobic digestion (optional, may be practiced in summer prior to land application)
- Sludge conditioning/lime stabilization
- Vacuum filtration (in winter only)
- Landfill (in winter)

Comments: In the winter, if waste activated sludge is not digested, it is stabilized prior to vacuum filtration. In one summer experiment, thickened waste activated sludge was lime stabilized by simultaneously pumping the sludge and lime slurry to a land application vehicle. Enough lime was added to reach a pH of 11.5. (There is no lime dose data from this test.) The lime and sludge were mixed in the truck by recirculation pumping.

D. LIME USE

Type of Sludge: Flotation thickened secondary sludge (a high lime dose to the anaerobically digested primary sludge is also reported)

Solids Concentration of Sludge Before Lime Added: 4.5 percent

Lime Dosage (as CaO per weight of dry sludge solids): 20 to 30 percent

pH Attained: 11.5

Other Chemicals: Ferric Chloride

E. DETAIL OF LIME SYSTEM

Lime Delivery/Storage

Type of Lime Purchased: 50-lb bags of high-calcium hydrated lime

Preparation of Lime Slurry and Lime Metering Pumps

Type and Number of Mixing Tanks: One steel tank, 400 gallons.

Method of Slurry Preparation: Batch mix prepared as needed.

Prepared Lime Slurry Concentration: 17 percent as $Ca(OH)_2$, estimate

Type of Water Used in Slurry Makeup: Plant water

Slurry Metering Pump Type: Diapragm

Lime Application to Sludge Conditioning Tank

Point of Application: Slurry is added to a conventional horizontal sludge conditioning tank located beside the vacuum filter.

Dosage Control: Operator sets metering pump speed.

pH Measurement: pH is occasionally checked with a pH meter.

F. DOWNSTREAM PROCESS

Dewatering

Type: One vaccum filter (coil medium). Vacuum filtration is used during the winter months when land application cannot be practiced. Lagooning is being considered as a possible alternative to this practice.

Disposal

Method: Land application (one week experiment) or landfill (normal)

Comments: Liquid digested sludge is land applied in the warm months. Sludge is dewatered and landfilled the rest of the year. The plant is reclaiming a town dump by landfilling.

G. COST OF LIME STABILIZATION

Equipment

Lime handling equipment was originally installed for chemical conditioning prior to vacuum filtration. No new equipment was needed.

Operation and Maintenance

Lime is purchased at $64 per ton $Ca(OH)_2$. Not cost effective to lime stabilize versus anaerobically digesting all of the sludge.

28. BURLINGTON, VERMONT (Riverside Plant)

(Lime Added to Vacuum Filter Conditioning Tank)

A. PLANT DATA

Plant Type: Conventional activated sludge

Plant Flow: 1.0 mgd design
0.7 mgd present average

Quantity Limed: 0.2 dry tpd present average

B. WASTEWATER PROCESSING TRAIN

Pretreatment
- Screening
- Communition
- Grit removal

Primary Treatment

Secondary Treatment
- Conventional activated sludge

Chlorination

Discharge
- Winooski River

Comments: Influent wastewater is 80 percent hospital and university wastes and 20 percent domestic.

C. SLUDGE PROCESSING TRAIN

Primary Sludge
- Two stage anaerobic digestion
- Vacuum filtration (in winter only)
- Landfill (in winter), land apply (warm months)

Secondary Sludge
- Flotation thickener (polymer added)
- Anaerobic digestion (optional, may be practiced in summer prior to land application)
- Sludge conditioning/lime stabilization
- Vacuum filtration (in winter only)
- Landfill (in winter)

Comments: In the winter, if waste activated sludge is not digested, it is lime-stabilized prior to vacuum filtration. In one summer experiment, thickened waste activated sludge was lime-stabilized by simultaneously pumping the sludge and lime slurry to a land application vehicle (there is no lime dose data from this test). The lime and sludge were mixed in the truck by recirculation pumping.

D. LIME USE

Type of Sludge: Flotation thickened secondary sludge (a high lime dose to the anaerobically digested primary sludge is also reported)

Solids Concentration of Sludge Before Lime Added: 4.5 percent

Lime Dosage (as CaO per weight of dry sludge solids): 20 to 30 percent

pH Attained: 11.5

Other Chemicals: Ferric Chloride

E. DETAIL OF LIME SYSTEM

Lime Delivery/Storage

Type of Lime Purchased: 50-lb bags of high-calcium hydrated lime

Preparation of Lime Slurry and Lime Metering Pumps

Type and Number of Mixing Tanks: One steel tank, 400 gallons.

Method of Slurry Preparation: Batch mix prepared as needed

Prepared Lime Slurry Concentration: 17 percent as $Ca(OH)_2$, estimate

Type of Water Used in Slurry Makeup:. Plant water

Slurry Metering Pump Type: Diaphragm

Lime Application to Sludge Conditioning Tank

Point of Application: Slurry is added to a conventional horizontal sludge conditioning tank located beside the vacuum filter.

Dosage Control: Operator sets metering pump speed.

pH Measurement: pH is occasionally checked with a pH meter.

F. DOWNSTREAM PROCESS

Dewatering

Type: One vacuum filter (coil medium). Vacuum filtration is used during the winter months when land application cannot be practiced. Lagooning is being considered as a possible alternative to this practice.

Disposal

Method: Land application (one week experiment) or landfill (normal)

Comments: Liquid digested sludge is land applied in the warm months. Sludge is dewatered and landfilled the rest of the year. The plant is reclaiming a town dump by landfilling.

G. COST OF LIME STABILIZATION

Equipment

Lime handling equipment was originally installed for chemical conditioning prior to vacuum filtration. No new equipment was needed.

Operation and Maintenance

Lime is purchased at $64 per ton $Ca(OH)_2$. Not cost effective to lime stabilize versus anaerobically digesting all of the sludge.

ENGLISH TO METRIC CONVERSION FACTORS

Multiply	by	To obtain
mgd	157	m^3/hr
^oF	^oF-32/1.8	^oC
ton	907	kg
lb	0.454	kg
ft	0.305	m
gallon	3.78	l
inch	.0254	m
Hp	746	watt
mile	1852	m
acre	4046	m^2
Kwh	3.6×10^6	joule
yd^3	0.764	m^3
lb/ft^2/hr	4.88	kg/m^2/hr
tons/day	907	kg/day
lb/hr	0.454	kg/hr

END
DATE
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6-22-81
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